



CONCEPTUAL DESIGN PRINCIPLES FOR VISUALIZATION-ENHANCED DAO GOVERNANCE IN COOPERATIVES

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Abstract:

Cooperatives continuously faced governance challenges related to transparency, accountability, and member participation as decision-making processes became more complex. Hence, it was proposed that blockchain-based Decentralized Autonomous Organizations (DAOs) could serve as a governance mechanism. Despite this potential, DAO governance systems remained difficult for many cooperative members to trust, adopt, and interpret. This is even more so when the governance processes involve technically complex blockchain information. Therefore, this study aims to develop a set of conceptual design principles to explain how visualization can support trustworthy DAO governance in a cooperative. This study adopted a design-oriented conceptual approach. Focusing on Cognitive Fit Theory and Trust Theory, and current research on blockchain governance and cooperative decision-making, this paper depicts how visualization functions as a cognitive mechanism that drives members' understanding of governance processes and outcomes. The analysis identified six key principles, which included emphasized interpretability over technical completeness, cognitive load reduction, process visibility, inclusivity, and trust support in visualization-based DAO governance. These principles highlighted that transparency in blockchain was not achieved only through data availability, but via visual presentation of governance information in forms that align with users' cognitive processing capabilities. This paper contributed to the body of knowledge involving digital governance and blockchain adoption by offering theory-

informed design knowledge that extends beyond the technology acceptance model. The proposed design principles provide a foundation for future research and offer practical guidance for organizations and system developers in supporting inclusive, understandable, and trustworthy DAO-based governance in cooperatives.

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Blockchain Governance; Cognitive Fit Theory; Cooperatives; DAO Adoption; Data Visualization; Design Principles; Trust



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Introduction

Cooperatives is one of the main organizations that support the socio-economic development of a nation. It plays its role through a few principles, such as democratic participation, shared ownership, and collective accountability. As the cooperatives expand in size and their operations become more complex, it becomes more challenging to maintain effective governance. For example, a simple decision-making process that used to be manageable through physical interaction and manual reporting now becomes more demanding. The process became more difficult as there were irregular information, limited transparency, and members became disengaged with the decision-making process. These challenges have led to growing interest in potential digital governance mechanisms that can support transparency and accountability, while still preserving cooperative value (Silva et al., 2022; Saadan et al, 2024).

Meanwhile, blockchain technology has gained widespread attention and is viewed as a potential solution for transparent and tamperproof governance systems. Specifically, Decentralized Autonomous Organizations (DAOs) presented the possibility of having a model that can encode governance rules, voting procedures, and decision-making workflows in smart contracts, and the process can be performed automatically. According to Lustenberger et al. (2025), DAO-based governance aligned well with the cooperative values, where it fits the cooperatives' need for rule-based fairness, immutable records, and equal participation rights for members. However, despite this, the adoption of DAO governance within cooperatives remains low. A study by Polcumpally et al. (2024) also suggested that this situation is not solely based on technological readiness or infrastructure constraints. Instead, cooperatives often face difficulties understanding and interpreting blockchain-based governance processes, especially when information is presented in technical formats, such as transaction logs, cryptographic IDs, or automated execution records (Obidallah et al., 2024). For many non-technical users,

when the processes remain difficult to understand, it highly affects the confidence and trust among cooperative members.

In cooperative governance, trust is a crucial decisive factor, where it is very tightly linked to members' perception of fairness and shared control. Ghanmi, Ahmadjee, and Bahsoon (2025) highlighted that trustworthiness is not assessed based on cryptographic properties alone, but it relies on cues such as clarity, interpretability, and perceived fairness of procedures when evaluation is done in a governance system.

While blockchain ensures technical transparency, trust in cooperative governance is constructed through members' cognitive interpretation of governance processes. This study, therefore, conceptualizes visualization as a mediating mechanism between algorithmic execution and perceived legitimacy.

Based on this context, data visualization has emerged as a potentially important mechanism that is capable of providing the missing cues in complex digital systems. Previous research by Cabouat (2024) highlighted that visualization can reduce cognitive load and improve comprehension by aligning presented information with users' cognitive processing capabilities. Within DAO governance, visualization can depict voting processes, governance rules, and resource flows more effectively to cooperative members. However, existing research mostly treated visualization more towards technical or usability features, rather than as a governance-enabling mechanism that shaped trust and understanding.

Hence, this study proposed a set of conceptual design principles for visualization-enhanced DAO governance in cooperative, grounded in Cognitive Fit Theory and Trust Theory. The subsequent sections provide an overview of previous research within this context, detail the methodology, and elaborate more on the conceptual design principles as a foundation for an inclusive, trustworthy DAO-based governance system in cooperatives.

Literature Review

DAO had been frequently presented as a promising mechanism for automating governance rules, enhancing transparency, and reducing reliance on centralized authority. However, within a cooperative context, the literature review revealed persistent challenges related to interpretability, trust, and understanding. This section summarized previous works across four interrelated areas, which are DAO governance in cooperatives, trust in blockchain systems, the cognitive perspective in complex digital systems, and the role of visualization as a governance-enabling mechanism. Together, this review highlighted the need for visualization-based conceptual design principles.

Decentralized Autonomous Organization in Cooperative Governance

DAOs are commonly defined as blockchain-based governance arrangements in which an organization's rules and decision-making processes are encoded in smart contracts and executed automatically (Santana & Albareda, 2022). In recent years, research on DAOs has greatly expanded, especially in decentralized finance and digital-aware communities, where the participants are mostly technologically savvy and familiar with the blockchain concept (Lustenberger et al., 2025). For them, DAOs are efficient and transparent, unlike traditional governance structures. A different view is seen when DAO is applied in cooperative settings.

Concern related to member participation and governance transparency still persists (Saadan et al., 2024). To add, cooperative members were often diverse in demographics with different digital literacy capabilities. This further complicates engagement with a technical-based governance system such as a DAO. Moreover, existing studies did not prioritize how members actually experience and interpret DAO processes in the real world, accentuating the need for the conceptual guidance that focuses on the interpretability of the processes rather than focusing on governance structure alone.

Trust in Blockchain Systems

Trust remains at the main position in research on blockchain governance. This is consistent with a study by Polcumpally et al. (2024), which demonstrated that user trust remains important, especially during early stages of engagement. Meanwhile, Wallbach et al. (2020) highlighted that when governance outcomes are produced through poorly understood processes, users may question their fairness, even if the system is technically accurate. The literature also suggested that trust in blockchain governance is not an automatic result of decentralization. Rather, trust emerges from how governance processes are communicated, interpreted and cognitively processed by members. This indicates that trust is not embedded in technology itself but is shaped through members' understanding of procedural fairness and legitimacy. Consequently, the design of governance information presentation becomes central in shaping trust perceptions.

Cognitive Perspectives on Complex Digital Systems

Cognitive Fit Theory (CFT) claims that decision quality improves when information is presented in a way that aligns with the users' cognitive processing capabilities (Goodhue & Thompson, 1995). This is also supported by a recent study by Lindner et al. (2025). The study noted that cognitively dense information environments can overwhelm users and reduce effective participation in digital systems. For example, blockchain-based systems. To further explain, governance information is often presented in abstract or technical forms, such as transaction hashes, smart contract code, or automated execution logs. These are difficult and complicated for non-technical users to make sense of (Neri et al., 2025).

In cooperatives, this scenario increases cognitive burden, which can potentially discourage engagement and undermine members' ability to evaluate governance outcomes. From a trust perspective, when members experience cognitive overload or interpretive ambiguity, their ability to assess procedural fairness is weakened, which may subsequently reduce confidence in governance outcomes. Therefore, aligning information presentation with members' cognitive capabilities is not merely a usability concern, but a foundational requirement for sustaining trust in DAO-based governance. Due to this, there is a need to translate CFT into governance-relevant insights to explain how complex blockchain information can be made accessible to non-technical cooperative members.

Visualization as a Governance-Enabling Mechanism

Visualization has been widely studied as a channel to support sense-making and decision-making in many complex information environments. Previous research had demonstrated that visualization can reduce cognitive loads, highlight patterns, and improve comprehension by transforming abstract data into meaningful representations (Linder et al, 2025; Neri et al.,

2025). In traditional organization settings, visualization has shown its potential to enhance transparency and support informed decision-making, especially when users have various levels of expertise. Even within blockchain governance research, visualization is often used in practice through dashboards and monitoring tools. Unfortunately, until now, most research mainly viewed visualization from a technical or usability perspective, rather than as a governance-enabling mechanism. This led to the absence of a clear visualization of the role in supporting trust and understanding in DAO governance, which eventually highlighted the necessity of developing conceptual design principles in this study.

To summarize, this section revealed three gaps. The first gap is that DAO governance research in cooperatives has mostly focused on structural and technical considerations, with limited consideration to unveil the cooperative members' cognitive and interpretive challenges. The second gap highlighted that trust in blockchain governance is highly viewed as important but is insufficiently explained. Next, the third gap is that visualization's role as a conceptual design mechanism in DAO governance remains underexplored despite it being recognized as valuable in complex digital systems.

Taken together, the literature suggested that trust in DAO governance is mediated by cognitive interpretation rather than guaranteed by technological transparency. While blockchain provides immutability and automation, members' trust depends on their ability to comprehend how governance processes unfold. This conceptual gap highlighted the need for oriented principles that explain how visualization can translate complex blockchain operations into cognitively accessible and trust-supportive representations.

Methodology

This study involves a conceptual research design (Jaakkola, 2020) to develop theory-informed design principles for visualization-enhanced DAO governance in cooperatives.

Research Design

The research design followed a design-oriented conceptual approach that focuses on the development of explanatory and prescriptive knowledge without requiring the immediate implementation of a prototype (Gregor & Hevner, 2013). This study does not aim to design or assess a specific visualization interface but aims to demonstrate how visualization should function conceptually to support interpretability and trust in DAO-based cooperative governance.

To achieve this, this study focuses primarily on CFT and Trust Theory, complemented by the insights gained from recent literatures of blockchain governance and cooperative management. CFT provides a perspective to understand how information presentation influences users' ability to process complex governance data, while Trust Theory offers insight into how confidence can inform decisions. These theories, when treated together, provide complementary perspectives that allow governance understanding through the cognitive and affective dimensions.

Literature Selection Strategy

The literature selection process was performed to develop conceptual design principles. Major scholarly academic databases, such as Web of Science, Scopus, and Google Scholar, were used to identify peer-reviewed journal articles published between 2020 and 2024. Search terms included combinations of phrases such as “DAO governance,” “blockchain governance,” “cooperative governance,” “trust in technology,” and “data visualization.” This step prioritizes studies that offer strong theoretical insight into governance, cognition, trust, interpretability, and visualization. Technical-based studies without relevance to governance or human interpretation were excluded based on the papers’ abstracts. In line with Webster & Watson (2002), this selective strategy is consistent to synthesize relevant theoretical knowledge into design guidance rather than obtaining an overall view of existing systems or implementations.

Development of Conceptual Design Principles

The development of the conceptual design principles followed an iterative process. Firstly, frequently mentioned challenges in DAO-based governance were identified from the literature. This includes those related to information complexity, member understanding, and trust in automated decision-making. Secondly, these challenges were then examined through the lens of CFT to identify any mismatch between the way information is presented and how ordinary cooperative members think and process the information. Third, insights from Trust Theory were applied by reflecting on how, when people do not understand a process, naturally, the trust is less. Through this process, the resulting design principles were refined through repeated comparison between theoretical constructions and cooperative governance requirements, ensuring they are coherent and relevant. From here, general rules about what visualization should do, what it should prioritize, and what it should avoid will be clarified.

Iterative Development of Design Principles

The development of the conceptual design principles followed a structured and iterative synthesis process consistent with design-oriented conceptual research (Jaakkola, 2020; Gregor & Hevner, 2013). After identifying recurring governance challenges in DAO-based cooperative contexts, particularly those related to interpretability, complexity, and trust, these challenges were systematically mapped against constructs derived from CFT and Trust Theory.

Initial principles statements were drafted based on observed theoretical tensions observed between technological transparency and members’ interpretive limitations. These preliminary principles were then iteratively refined through repeated comparison between (i) relevant theoretical constructs, (ii) governance challenges documented in cooperatives literature, and (iii) the functional role of visualization in reducing cognitive burden and enhancing trust formation.

To mitigate potential researcher bias, principal formulation was anchored in cross-referencing multiple scholarly sources rather than relying on a single-study interpretation. Theoretical triangulation was applied by validating each proposed principle against both cognitive alignment mechanisms and trust formation constructs. A principle was retained only when it demonstrated coherence across theoretical perspectives and directly addressed governance challenges identified in prior research.

This structured refinement process ensured that the resulting principles were not intuitively derived but theoretically grounded, conceptually consistent and contextually relevant to cooperative DAO governance.

Conceptual Design Principles for Visualization-Enhanced DAO Governance

Grounded in Cognitive Fit Theory and Trust Theory, the following principles are derived from the premise that governance legitimacy in cooperatives depends not only on technological transparency but on members' interpretive clarity. Each principle therefore addresses specific cognitive and trust-related barriers identified in the literature.

This study proposed a set of conceptual design principles that depict how visualization should function to support trust and understanding in DAO-based cooperative governance. These principles are not intended as technical specifications or interface guidelines. Instead, they were insights translated from CFT and Trust Theory into governance-relevant guidance. In short, the principles were derived by reflecting on frequent governance challenges identified from the literature and shaped into solutions on how visualization can address the cognitive and trust-related barriers faced by cooperative members.

Principle 1: Prioritize Interpretability over Technical Specification Needs

Visualization in DAO governance should prioritize the interpretability of governance processes rather than showing technical or cryptographic details. Although blockchain systems are often known to offer extensive data transparency, previous studies indicated that access to raw data does not necessarily lead to understanding, especially among non-technical users (Polcumpally et al., 2024). In addition, CFT suggested that info should be presented in forms that fit the users' cognitive capabilities (Goodhue & Thompson, 1995). Thus, in cooperative governance, interpretability is important because members' acceptance of any decisions mainly depends on their ability to understand how outcomes are produced.

An illustrative implementation of this principle would involve translating technical blockchain artifacts, such as transaction hashes or smart contract execution logs, into summarized visual representations. For example, instead of exposing cryptographic records directly, a governance interface may present voting outcomes through percentage distribution accompanied by a plain language explanation of quorum fulfillment and decision thresholds. Such presentations prioritize interpretability while preserving procedural transparency.

Principle 2: Reduce Cognitive Load in Presenting Governance Information

Visualization should be designed to minimize cognitive load by simplifying complex governance information and highlighting the necessary relationships. Blockchain-based governance systems often present information in dense, abstract, and raw formats that can overwhelm users and discourage engagement (Neri et al., 2025).

With regard to cognitive load, previous research by Lindner et al. (2025) highlighted that minimizing cognitive burden improved understanding and, hence, the decision quality in many complex systems. Therefore, in cooperative contexts, where members have various capabilities of digital literacy, reducing cognitive load or effort is necessary in order to obtain meaningful participation in governance processes.

In practical terms, this principle may be operationalized through layered visualization structures. Members could first encounter simplified summaries of governance outcomes, with optional drill-down features for those who require deeper technical details. By structuring the information hierarchically, the system reduces cognitive burden while maintaining accessibility to comprehensive records.

Principle 3: Make Governance Processes Traceable and Visible

Visualization should support traceability by clearly showing how proposals, votes, and decisions are performed in the governance process. This agrees with Trust Theory, which states that confidence in complex systems increases when processes are predictable and understandable (Polites & Karahanna, 2012). Other than making processes visible, traceability is also of importance. In DAO governance, traceability can help members link inputs to outputs. For example, traceability will show the relationship between votes and decisions, hence demonstrating the fairness in procedures. Without visible process flows, governance outcomes may appear opaque or hidden, even when technically transparent.

For instance, visualization may incorporate a clear process timeline that visually links proposal submission, voting duration, and final execution stages. By clearly depicting procedural sequences and the relationships between votes and outcomes, members are better able to assess procedural fairness and governance legitimacy.

Principle 4: Support Trust through Clarity and Consistency

Visualization should function as a trust-support mechanism. This can be done by presenting government information in a consistent, structured, and clear manner. Previous studies by Wallbach et al (2020) and Merk (2024) showed that trust in blockchain systems is influenced not only by the system security but is highly linked to users' perception of clarity and stability in system behavior.

In contrast with usual cooperative governance, inconsistent representations of governance outcomes sometimes affect confidence and raise huge concerns about legitimacy. Thus, clear and stable visualization patterns will definitely help members develop reliable perspectives of how the governance system operates.

This principle may be reflected through the consistent use of visual cues across governance interfaces. For example, standardized color schemes representing approval, rejection and pending status as well as stable layout structures across proposals can reduce ambiguity and reinforce perceptions of procedural predictability, an essential condition for trust formation.

Principle 5: Emphasis Governance Meaning instead of System Operation

Visualization should focus on communicating the meaning and implications of governance outcomes rather than putting their attention on the system operation. Previous work on cooperative governance highlighted that members are mainly concerned with how decisions affect the interests collectively, more than how those decisions are technically executed (Silva et al., 2022). By emphasizing governance, visualization aligns the system's information with the expectations of members and then supports a shared understanding of the organization's direction.

Rather than foregrounding technical execution details such as gas fees or smart contract deployment codes, visualization may highlight the governance implications of decisions. For example, how a proposal affects dividends and distribution, capital allocation or cooperative resource planning. By focusing on collective impact rather than system mechanics, visualization aligns governance information with members' evaluative concerns.

Principle 6: Support Diverse Members' Cognitive and Digital Capabilities

Visualization should recognize and assist different members' cognitive and digital capabilities. This is important as cooperatives are often made up of diverse membership groups. According to Saadan et al. (2024), governance systems that assumed high technical proficiency among their members risked excluding part of the membership. Therefore, conceptual design principles should emphasize inclusivity and accessibility to ensure that visualization supports broad participation.

In practice, this principle may involve offering multiple representation formats, such as icon-based summaries, narrative explanations, and graphical dashboards. Providing alternative modes of engagement accommodates varying levels of digital literacy and cognitive preference, thereby promoting inclusive participation in DAO-based governance processes.

Figure 1 presented the six (6) conceptual design principles identified in this study. The diagram illustrates how principles related to interpretability, cognitive load reduction, process traceability, clarity, governance meaning, and inclusivity collectivity support trust in DAO-based cooperative governance.

Design Principles for Trustworthy Cooperative DAO Governance

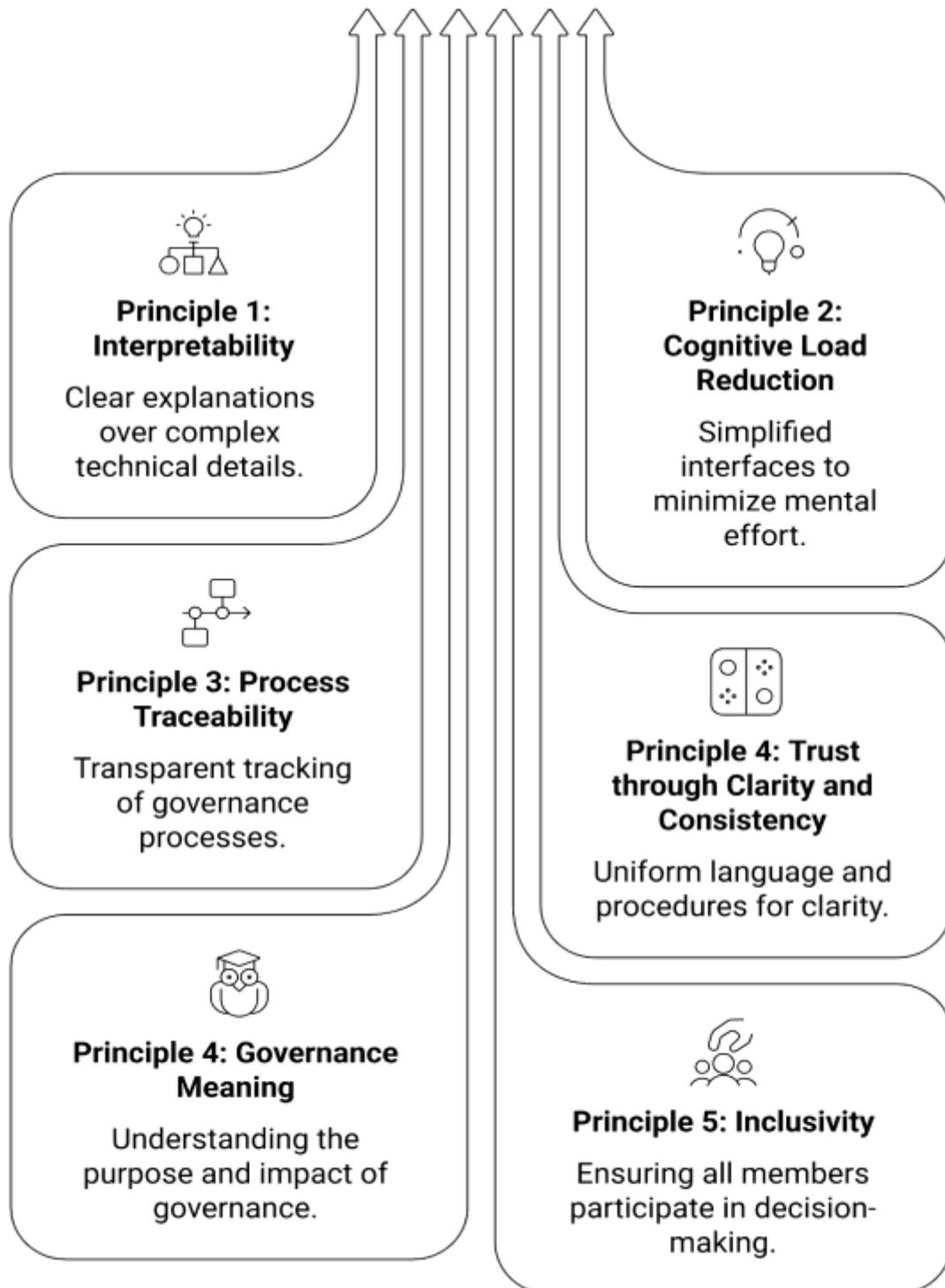


Figure 1: Conceptual Design Principles for Visualization-Enhanced DAO Governance

Table 1 summarizes the six conceptual design principles, their theoretical focus, governance function, and illustrative applications.

Table 1: Summary of Conceptual Design Principles for Visualization-Enhanced DAO Governance

| Principle | Theoretical Focus | Governance Function | Illustrative Application |
|--------------------------|--|---|--|
| Interpretability | Alignment with members' cognitive capabilities | Enhances cognitive fit and transparency | Replace raw smart contract logs with visual vote distribution and quorum explanation |
| Cognitive Load Reduction | Minimization of information complexity | Supports informed participation | Layered dashboard with summary and drill-down options |
| Process Traceability | Visibility of procedural flow | Reinforces procedural fairness | Timeline linking proposal submission, voting and execution |
| Trust Through Clarity | Consistency and stability in representation | Builds perceived legitimacy | Standardized color schemes and stable interface structures |
| Governance Meaning | Emphasis on collective impact | Aligns with member evaluative concerns | Highlight effects on dividends or resource allocation |
| Inclusivity | Accommodation of diverse capabilities | Broadens governance participation | Multiple representation formats (icons, narrative, graphs) |

Discussion

This study contributed to the growing interest in blockchain-enabled governance by highlighting visualization as a governance-enabling mechanism. The proposed conceptual design principles collectively suggested that the challenges faced by cooperative members in DAO-based governance are less about access to information and more about the ability to understand, interpret, and trust the governance process. From a theoretical lens, the principles advance CFT into the domain of digital governance. It showed how mismatches between information presentation and users' cognitive capabilities can weaken meaningful participation.

Previous research reported that complex digital systems are able to overwhelm users when information is difficult to understand, despite being technically accurate (Linder et al., 2025). Therefore, effective governance visualization should prioritize comprehension of the information over technical focus. This is similar to cooperative settings where the legitimacy of information depended on shared understanding among its members.

In addition, traceability and consistency further strengthen the role of visualization in supporting trust formation. When governance processes are visibly traceable through visualization, it will help members connect their participation to governance outcomes and reinforce the perception that fairness and accountability are present.

The principle emphasizing governance means over system operation highlighted a potential goal in blockchain governance. Despite the focus on technical competency and automation, cooperative members are still concerned with how decisions affect the collective goal and shared understanding (Silva et al., 2022). Hence, visualization is based on governance implications rather than operational mechanics aligns the system communication with members' expectations, supporting both needs for understanding and legitimacy.

The principles of inclusivity deepen the importance of visualization within a broader organization for social consideration. Cooperatives are mainly heterogeneous, and with a governance system that expects high level of technical literacy, this may risk excluding a portion of membership (Saadan et al., 2025). Taking into consideration heterogeneity as a design concern, the proposed principle necessitates the idea that visualization plays a role in mitigating informational ambiguities for a more inclusive approach towards digital transformation in member-based organizations. Overall, the proposed design principles suggested that visualization functions as a cognitive and trust-support mechanism that mediates a complex governance system with member participation. The principles provide general guidance that can inform future studies, system design efforts, and governance evaluation by showing how visualization should support interpretability, trust, and inclusivity.

By conceptualizing visualization as a mediating mechanism between algorithmic governance and perceived legitimacy, this study extends Trust Theory into the domain of blockchain-enabled cooperative governance.

While the proposed principles are articulated as generalizable as conceptual guidance, it is important to acknowledge the contextual variation across cooperative settings. Cooperatives differ substantially in sectoral focus (e.g., financial, agricultural, housing), regulatory environments, digital maturity, and cultural governance norms. These contextual factors may influence how governance transparency is interpreted and how members receive visualization mechanisms. Consequently, the applicability, prioritization, and operationalization of the principles may vary depending on institutional capacity, technological infrastructure, and sociocultural expectations surrounding participation and accountability.

Conclusion

The study addressed a recurring yet underexplored challenge in DAO-based cooperative governance in which cooperative members faced difficulties in understanding and trusting governance processes mediated by complex blockchain systems. Looking at this from a different lens, this study adopted a design-oriented conceptual approach to study how visualization can function as a governance-enabling mechanism. By grounding the study in Cognitive Fit Theory and Trust Theory, this paper shifted the attention from what governance systems were capable of doing to how governance processes are interpreted and experienced by members. The main contribution of this study lies in the proposed six (6) conceptual design principles. It describes how visualization should support interpretability, reduce cognitive burden, and reinforce trust in cooperative DAO governance. These principles emphasize that

transparency in governance is not achieved just through data availability or automation, but through meaningful presentation of governance information that align with the members' cognitive capabilities and expectations.

Beyond proposing conceptual guidance, this study contributes to digital governance by extending CFT into blockchain-enabled cooperative governance contexts. By conceptualizing visualization as a trust mediating mechanism between algorithmic execution and member interpretation, the study advances understanding of how technological transparency becomes perceived legitimacy. Furthermore, this research extends DAO adoption literature beyond the traditional technology acceptance perspectives by shifting attention from functional capability and system performance to interpretive governance experience and cognitive alignment. In doing so, it reframes visualization not as a supplementary usability feature, but also as a central mechanism in sustaining trust, inclusivity, and participatory legitimacy in cooperative DAO systems.

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Generative AI tools were used solely to assist with language refinement and clarity of expression during manuscript preparation. All study design, data collection, interpretation, and reference verification were conducted independently by the authors.

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