DAO governance model for open access sports science databases: a study on decentralized autonomous organizations

Modelo de gobernanza DAO para bases de datos de acceso abierto en ciencias del deporte: un estudio sobre organizaciones autónomas descentralizadas

Authors

Wang Qingsheng [1]
Runping Wu [1]
Su Zhanguo [1]

[1] Krirk University (Thailand)

Corresponding author:
Su Zhanguo
suzhanguo@163.com

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Abstract

Introduction, Sports science data governance is characterized by persistent tensions between data sharing, stakeholder incentives, and regulatory constraints. These challenges are amplified by fragmented data infrastructures and competing interests among stakeholders, limiting the effective use of data in performance optimization and research.
Objective, This study aims to develop and theoretically ground a decentralized autonomous organization (DAO)-based governance framework for sports science data ecosystems, focusing on how decentralized mechanisms can enhance coordination, participation, and compliance.
Methodology, A multi-method research design is employed, integrating conceptual case analysis, agent-based modeling (ABM), and survey-based empirical analysis. Structural equation modeling (SEM) is used to examine the relationships between governance perceptions, incentives, and data-sharing intentions.
Results, The findings indicate that DAO-based mechanisms can support more distributed and transparent data-sharing processes. Simulation results suggest that participation dynamics follow nonlinear patterns, with incentive and reputation mechanisms contributing to system stabilization. Empirical results identify technical usability, perceived regulatory compliance, and incentive structures as significant predictors of stakeholder participation.
Discussion, The study contributes to platform governance and institutional theory by conceptualizing a hybrid decentralized governance model for data-intensive environments. The findings highlight the importance of aligning technological design with usability and regulatory requirements. However, limitations related to model assumptions, perception-based data, and interoperability challenges remain. Future research should focus on real-world implementation and the development of standardized governance frameworks.

Keywords

DAO governance model; tokenomic dual-anchoring; cross-chain interoperability; biometric streaming data; dynamic NFT rights allocation.

Resumen

Introducción. La gobernanza de datos en ciencias del deporte se caracteriza por tensiones persistentes entre el intercambio de datos, los incentivos de las partes interesadas y las restricciones regulatorias. Estos desafíos se ven amplificados por infraestructuras de datos fragmentadas e intereses contrapuestos entre las partes interesadas, lo que limita el uso efectivo de los datos en la optimización del rendimiento y la investigación.
Objetivo. Este estudio tiene como objetivo desarrollar y fundamentar teóricamente un marco de gobernanza basado en una organización autónoma descentralizada (DAO) para los ecosistemas de datos en ciencias del deporte, centrándose en cómo los mecanismos descentralizados pueden mejorar la coordinación, la participación y el cumplimiento.
Metodología. Se emplea un diseño de investigación multimétodo que integra el análisis de casos conceptuales, el modelado basado en agentes (ABM) y el análisis empírico basado en encuestas. El modelado de ecuaciones estructurales (SEM) se utiliza para examinar las relaciones entre las percepciones de gobernanza, los incentivos y las intenciones de compartir datos.
Resultados. Los hallazgos indican que los mecanismos basados en DAO pueden respaldar procesos de intercambio de datos más distribuidos y transparentes. Los resultados de la simulación sugieren que la dinámica de participación sigue patrones no lineales, y que los mecanismos de incentivos y reputación contribuyen a la estabilización del sistema. Los resultados empíricos identifican la usabilidad técnica, el cumplimiento normativo percibido y las estructuras de incentivos como predictores significativos de la participación de las partes interesadas.
Discusión: Este estudio contribuye a la gobernanza de plataformas y a la teoría institucional al conceptualizar un modelo de gobernanza descentralizada híbrida para entornos con gran cantidad de datos. Los hallazgos resaltan la importancia de alinear el diseño tecnológico con la usabilidad y los requisitos normativos. Sin embargo, persisten limitaciones relacionadas con los supuestos del modelo, los datos basados en la percepción y los desafíos de interoperabilidad. La investigación futura debería centrarse en la implementación en el mundo real y en el desarrollo de marcos de gobernanza estandarizados.

Palabras clave

Modelo de gobernanza DAO; anclaje dual tokenómico; interoperabilidad entre cadenas; transmisión de datos biométricos; asignación dinámica de derechos NFT.

Introduction

Research Background

Sports science is increasingly shaped by data-intensive practices driven by wearable technologies, sensor networks, and artificial intelligence. These developments have enabled the continuous collection of high-resolution physiological, biomechanical, and performance-related data, creating new opportunities for performance optimization, injury prevention, and tactical decision-making (da Silva, 2024; Seçkin et al., 2023). However, despite this rapid expansion, the governance of sports data remains highly fragmented. Research institutions, professional clubs, and technology firms typically operate in isolation, resulting in persistent "data silos" that limit interoperability and reduce the generalizability of scientific findings (Zhang, 2021; Obi et al., 2024).

Existing governance models further exacerbate these limitations. Centralized academic repositories are often constrained by bureaucratic approval processes, while commercially driven platforms tend to prioritize data exclusivity and proprietary advantage (Nokkala et al., 2019). These structural tensions reflect a broader conflict between open science principles and data ownership regimes, particularly when sensitive athlete data is involved. Regulatory frameworks such as the General Data Protection Regulation impose strict requirements on data protection, yet they also introduce constraints on data sharing and reuse, creating a complex governance paradox (Voigt & von dem Bussche, 2017; Ramachandran et al., 2021).

In this context, decentralized digital infrastructures associated with Web3 particularly Decentralized Autonomous Organizations (DAOs) have emerged as a potential alternative governance model. DAOs rely on blockchain-based smart contracts and token-based coordination mechanisms to enable distributed decision-making and automated rule enforcement. While such models have been explored in domains such as open-source development and digital communities, their applicability to sports science data governance remains underexplored (Hassan & De Filippi, 2021; De Filippi et al., 2024).

From a theoretical perspective, this study draws on institutional theory, platform governance theory, data governance frameworks, and digital commons theory to examine how decentralized governance structures may reshape authority, participation, and value distribution in sports data ecosystems. Rather than treating these perspectives independently, this study integrates them to conceptualize sports data governance as a socio-technical system in which institutional legitimacy, platform coordination, and collective resource management interact dynamically (Tiwana, 2021; Constantinides et al., 2018). However, existing literature has largely examined these dimensions in isolation, offering limited insight into how they jointly operate in high-frequency, data-intensive environments such as sports science. These perspectives provide a critical lens to evaluate whether DAOs can move beyond technological novelty to address entrenched governance inefficiencies. This study therefore positions DAO governance as a unifying mechanism that operationalizes these theoretical dimensions within a single, programmable infrastructure.

Research Questions

To address these challenges, this study formulates the following research questions:

RQ1: How can DAO-based architectures support the management and sharing of high-frequency, heterogeneous sports science data?

RQ2: How do token-based incentive mechanisms influence stakeholder participation and contribution quality in sports data ecosystems?

RQ3: To what extent can DAO governance models ensure compliance with data protection regulations while maintaining openness and accessibility?

RQ4: How does decentralized governance reshape power relations among key stakeholders, including athletes, researchers, and organizations?

Research Objectives

This study aims to develop and theoretically ground a DAO-based governance framework for open-access sports science databases. Specifically, it seeks to:

1. Design a scalable governance architecture that accommodates high-frequency and heterogeneous data flows through hybrid on-chain/off-chain solutions.
2. Develop a multi-dimensional contribution evaluation system that captures diverse forms of value creation, including data provision, annotation, and analytical modeling.
3. Propose a governance structure that balances decentralized participation with stakeholder-specific authority, particularly in relation to sensitive athlete data.
4. Integrate compliance-by-design principles to align decentralized governance mechanisms with regulatory requirements.

Conceptually validate a sustainable incentive model that balances short-term participation with long-term ecosystem quality.

Literature review

Challenges in Sports Science Data Governance

The governance of sports science data is characterized by structural fragmentation, institutional conflict, and technical heterogeneity. Data generated across wearable devices, laboratory systems, and competition environments often lack standardization, limiting interoperability and cross-study comparability (da Silva, 2024; Seçkin et al., 2023). These technical challenges are compounded by conflicting ownership claims among stakeholders, including athletes, clubs, and research institutions, resulting in what can be conceptualized as a multi-stakeholder governance deadlock (Zhang, 2021).

From a data governance perspective, these issues reflect the absence of unified frameworks for data stewardship, access control, and value distribution (Abraham et al., 2019; Nokkala et al., 2019). At the same time, privacy risks remain significant, particularly given the sensitive nature of biometric and health-related data. Even anonymized datasets may be vulnerable to re-identification, raising concerns about compliance with regulatory principles such as data minimization and purpose limitation (Ramachandran et al., 2021).

Beyond technical and legal constraints, incentive misalignment further undermines data-sharing practices. Existing models often fail to equitably distribute value among contributors, discouraging participation and reinforcing data hoarding behaviors (Constantinides et al., 2018). These dynamics are consistent with broader findings in digital ecosystems, where governance inefficiencies lead to reduced collaboration and suboptimal innovation outcomes (Tiwana, 2021).

Theoretical Foundations of DAO Governance

DAO governance can be understood as an extension of broader developments in platform governance and digital commons management. Unlike traditional centralized platforms, DAOs operationalize governance rules through smart contracts, enabling automated coordination and reducing reliance on hierarchical control structures (Hassan & De Filippi, 2021; De Filippi et al., 2024).

From the perspective of institutional theory, DAOs represent an alternative governance logic that challenges established norms of authority and legitimacy. Instead of relying on formal organizations, governance emerges through codified rules and collective participation (Beck et al., 2018). Similarly, digital commons theory highlights the potential of decentralized systems to facilitate shared resource management, provided that appropriate incentive and accountability mechanisms are in place (Schweik & English, 2012).

Token-based mechanisms play a central role in DAO governance by linking economic incentives with participation and decision-making. However, prior research also highlights risks associated with token concentration, governance capture, and speculative behavior, suggesting that careful design is required to ensure equitable and sustainable outcomes (Bena & Zhang, 2023).

While platform governance theory emphasizes efficiency through centralized coordination and control, digital commons theory prioritizes collective ownership and participatory governance, creating an inherent tension between efficiency and inclusivity (Constantinides et al., 2018). Institutional theory further complicates this landscape by highlighting the importance of legitimacy and stability, which may be difficult to achieve in highly decentralized and rapidly evolving DAO environments (Beck et al., 2018).

Consequently, existing theoretical perspectives offer fragmented insights: platform governance explains coordination efficiency, commons theory explains collective participation, and institutional theory explains legitimacy but none fully accounts for how these dimensions can be simultaneously operationalized in high-frequency, data-intensive ecosystems such as sports science.

Critique of Existing Governance Models

Traditional governance models in sports data ecosystems exhibit significant limitations when evaluated through the lens of platform and data governance theories. Centralized systems concentrate control and often restrict access, limiting knowledge diffusion (Tiwana, 2021). Conversely, permissioned or alliance-based models introduce coordination challenges and may inadvertently create informal or opaque access structures (Nokkala et al., 2019). A key limitation across these models is their inability to dynamically allocate value in complex data ecosystems. As data is transformed and recombined across multiple stages collection, processing, analysis, and application static contractual arrangements struggle to capture evolving contributions (Abraham et al., 2019). This highlights a fundamental mismatch between traditional governance mechanisms and the dynamic nature of data-driven environments. Importantly, these governance models embody different theoretical priorities but fail to resolve their inherent contradictions. Centralized platforms align with platform governance logic by optimizing efficiency and control, yet they undermine inclusivity and equitable value distribution. In contrast, commons-oriented approaches promote openness and shared ownership but often lack enforceable mechanisms to prevent free-riding or ensure data quality (Schweik & English, 2012). Alliance-based models attempt to balance these dimensions but frequently introduce new coordination inefficiencies and governance opacity. This comparative limitation suggests that existing approaches are not only technically constrained but also theoretically incomplete, reinforcing the need for integrative governance models capable of reconciling efficiency, legitimacy, and collective participation.

Table 1. Comparison of Governance Models

Model	Strengths	Limitations	Theoretical Basis
Centralized Platforms	Efficient decision-making	Limited transparency, data silos	Platform Governance
Commons-Based Models	High inclusivity	Weak enforcement, free-riding	Digital Commons Theory
DAO-Based Governance	Transparency, programmability, incentives	Complexity, regulatory uncertainty	Hybrid (Institutional + Platform + Commons)

Research Gap

Despite growing interest in decentralized technologies, existing research on DAO governance remains fragmented and insufficiently contextualized within sports science. Three critical gaps can be identified:

1. Conceptual Gap: Limited integration of DAO governance with established theories such as institutional theory, platform governance, and digital commons.
2. Governance Gap: Insufficient exploration of how decentralized systems address power asymmetries and stakeholder heterogeneity in sports ecosystems.
3. Empirical/Contextual Gap: A lack of studies examining DAO applicability in high-frequency, data-intensive environments such as sports science.

Accordingly, no prior study has systematically integrated DAO governance with sports science data ecosystems while addressing technical scalability, governance complexity, and regulatory compliance within a unified framework.

Theoretical framework

Core Dimensions of DAO Governance

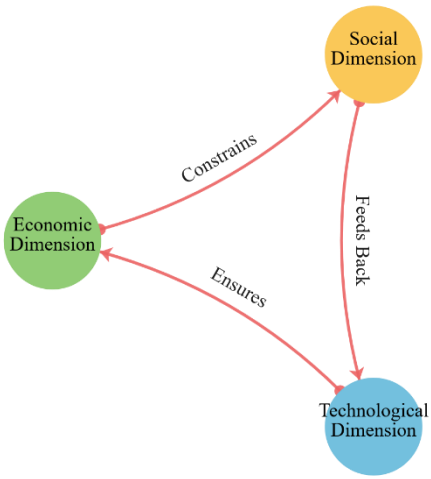
Building on socio-technical systems theory, this study conceptualizes DAO governance as a multi-dimensional system integrating technological, economic, and social components.

- The technological dimension encompasses distributed infrastructures that enable secure data storage, verification, and access control. Hybrid architectures combining on-chain and off-chain processes are particularly relevant for managing high-frequency data streams.

- The economic dimension focuses on incentive design through token-based mechanisms. These mechanisms aim to align individual contributions with collective outcomes, although their effectiveness depends on mitigating risks such as opportunistic behavior and value distortion.
- The social dimension addresses governance participation, stakeholder roles, and decision-making processes. Drawing on institutional and commons-based perspectives, governance structures must balance inclusivity with accountability, particularly in relation to sensitive data.

Importantly, these dimensions are interdependent, reflecting the broader principles of socio-technical system design.

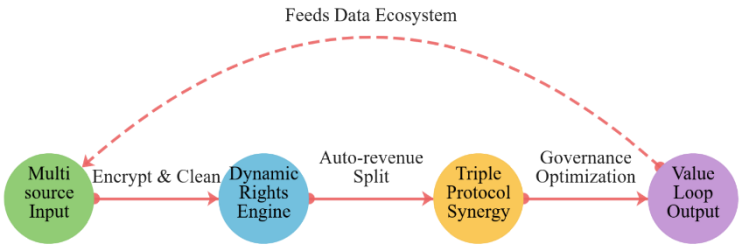
Figure 1. Core Dimensions of Sports Science DAO Governance



Conceptual Model

The proposed conceptual model represents a closed-loop governance system in which data flows, incentive mechanisms, and governance processes are dynamically interconnected. At the input level, heterogeneous data sources are integrated through standardized protocols. Governance mechanisms then regulate access, contribution, and value distribution through programmable rules. The output consists of enhanced research productivity, improved data accessibility, and more equitable value allocation. Rather than presenting empirical claims, the model is conceptual and intended to provide a theoretical foundation for future empirical validation. Any performance-related outcomes should therefore be interpreted as expected system behaviors rather than validated results.

Figure 2. Conceptual Model of Sports Science Data DAO



Method

Research Design

This study adopts a multi-method research design to investigate the feasibility and governance implications of Decentralized Autonomous Organizations (DAOs) in sports science data ecosystems. Given the

socio-technical complexity of the research problem, a combination of conceptual case analysis, agent-based modeling (ABM), and survey-based empirical validation is employed (Momani, 2020; Bandyopadhyay & Bandyopadhyay, 2010).

The research design is structured as follows:

1. Conceptual Case Analysis – to illustrate governance challenges and DAO-based solutions in sports data environments
2. Agent-Based Modeling (ABM) – to simulate dynamic interactions among stakeholders under DAO governance conditions
3. Survey-Based Empirical Study – to capture stakeholder perceptions, behavioral intentions, and governance preferences

This triangulated approach enhances the robustness of the findings by integrating theoretical reasoning, computational simulation, and empirical insights, consistent with socio-technical systems research.

Case Analysis Method

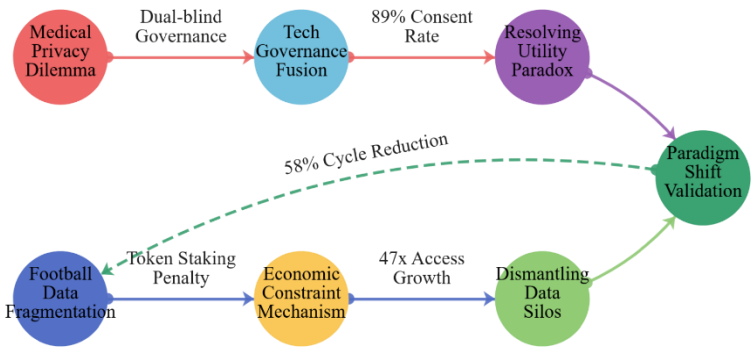
This study utilizes conceptual and illustrative case analysis to examine governance challenges in sports science data sharing and to explore how DAO-based mechanisms may address these issues.

The cases presented in this study are analytical constructs grounded in documented challenges within sports data ecosystems, rather than direct empirical case studies of specific organizations. Their purpose is to:

- Identify structural governance problems such as data fragmentation, limited interoperability, and stakeholder conflicts.
- Illustrate how DAO-based mechanisms such as token incentives, smart contracts, and decentralized decision-making could theoretically address these issues.

By adopting this approach, the study avoids over-reliance on context-specific empirical cases and instead focuses on generalizable governance dynamics relevant across sports science environments.

Figure 3. Dual-Case Validation Logic of DAO Governance



Agent-Based Modeling (ABM)

To examine the dynamic behavior of stakeholders within a DAO-governed sports data ecosystem, this study develops an agent-based simulation model (Bonabeau, 2002; Gao et al., 2024).

Model Structure

The model includes four primary agent types:

- Athlete agents: decide whether to share data based on perceived benefits, privacy concerns, and incentives.
- Club agents: balance competitive advantage against potential gains from data sharing.

- Researcher agents: seek access to high-quality data for scientific output.
- Governance agents (DAO mechanisms): implement rules related to token distribution, access control, and voting.

Behavioral Assumptions

Agent decisions are modeled based on utility functions incorporating:

- Expected rewards (token-based incentives)
- Reputation effects
- Data sensitivity and perceived risk
- Access to shared resources

Formally, the decision to share data can be represented as a utility function:

$$U_i = \alpha R_i + \beta Rep_i - \gamma Risk_i + \delta Access_i$$

Where Ri represents expected rewards, Repi denotes reputation gains, Riski captures perceived privacy or competitive risks, and Accessi reflects the benefits derived from shared data access. The parameters α,β,γ,δ represent weighting coefficients that vary across agent types. Agents choose to share data when Ui exceeds a predefined participation threshold (Gao et al., 2024).

Simulation Process

The simulation is conducted over multiple time steps, where:

- Agents interact through data-sharing decisions
- Governance rules influence incentives and participation
- System-level outcomes (e.g., data availability, participation rates) evolve dynamically

Parameterization and Implementation

Model parameters are informed by:

- Existing literature on data sharing behavior
- Empirical survey results from this study
- Plausible assumptions derived from sports data ecosystems

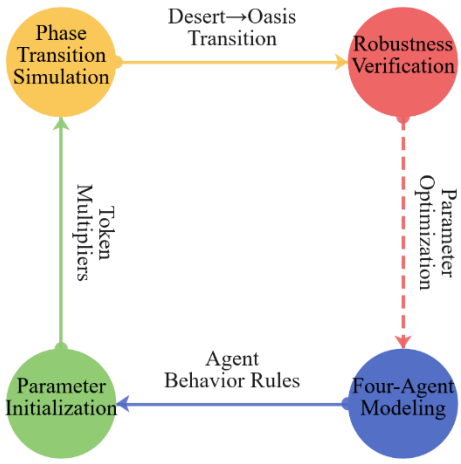
The model is implemented using a standard simulation environment (e.g., NetLogo/Python-based frameworks), and multiple simulation runs are conducted to ensure stability of results.

Validation

Model validity is assessed through:

- Sensitivity analysis (testing robustness under varying parameters)
- Pattern consistency (alignment with known behaviors in data-sharing systems)

Figure 4. Agent-Based Modeling Logical Framework



Empirical Data Collection

Sampling Strategy

Empirical data were collected through an international survey targeting stakeholders in sports science and data-related fields. A purposive sampling strategy was employed to ensure representation from relevant professional groups (Etikan & Bala, 2017), including:

- Sports scientists and researchers
- Coaches and performance analysts
- Data engineers and sport technology specialists

Participants were recruited across multiple countries (n = 19) to capture diverse institutional and cultural perspectives on data governance.

The sample included participants from multiple regions, including Europe, North America, Asia-Pacific, and Africa, ensuring cross-regional representation of sports data ecosystems. The distribution was approximately balanced across regions, with slightly higher representation from Europe and Asia-Pacific due to their established sports science research networks.

A total of 227 valid responses were obtained.

Participant Characteristics

Respondents included individuals with:

- Active involvement in sports science research or practice.
- Experience with data collection, analysis, or management.
- Academic or professional affiliation with sports organizations or research institutions.

This ensures that the sample reflects knowledgeable stakeholders directly engaged in the domain.

Table 2. Sample Characteristics (n = 227)

Category	Group	n	%
Region	Europe	72	31.7
	Asia-Pacific	68	30.0
	North America	46	20.3
	Africa	41	18.1
Profession	Sports Scientists/Researchers	94	41.4
	Coaches/Performance Analysts	63	27.8
	Data Engineers/Tech Specialists	70	30.8
Experience Level	< 5 years	58	25.6
	5–10 years	91	40.1

	> 10 years	78	34.3

Instrument Development

The survey instrument was developed based on:

- Existing literature on data governance, platform participation, and digital collaboration
- The theoretical framework of this study (institutional theory, platform governance, and digital commons)

It included measures of:

- Willingness to share data
- Perceived benefits and risks
- Trust in governance mechanisms
- Attitudes toward decentralized systems

All items were measured using Likert-scale responses (Leguina, 2015).

Table 3. Measurement Constructs and Items

Construct	Code	Measurement Item
Data Sharing Intention	DSI1	I am willing to share my sports data
	DSI2	I would share data if incentives are provided
	DSI3	I support collaborative data-sharing initiatives
Perceived Benefits	PB1	Data sharing improves research outcomes
	PB2	Collaboration enhances innovation
	PB3	Shared data increases efficiency
Perceived Risk	PR1	Sharing data may compromise privacy
	PR2	Data misuse is a concern
	PR3	Competitive risks exist
Trust in Governance	TG1	I trust decentralized governance systems
	TG2	Smart contracts ensure fairness
	TG3	Governance mechanisms are reliable
Incentive Mechanisms	IM1	Token rewards motivate participation
	IM2	Reputation systems encourage contributions

Validity and Reliability

To ensure measurement quality:

- Content validity was established through expert review
- Construct validity was assessed using factor analysis
- Reliability was evaluated using Cronbach's alpha

All constructs demonstrated acceptable reliability, with Cronbach's alpha values exceeding the recommended threshold of 0.70. Factor loadings were above 0.60, and composite reliability (CR) values exceeded 0.70, indicating satisfactory internal consistency. Average variance extracted (AVE) values were above 0.50, supporting convergent validity. These procedures ensure that the instrument meets accepted standards for empirical research (Leguina, 2015; Henseler et al., 2015).

Ethical Considerations

The study adheres to standard ethical research practices. Participation was voluntary, and informed consent was obtained from all respondents. Data were anonymized to ensure confidentiality and compliance with data protection principles.

Data Analysis

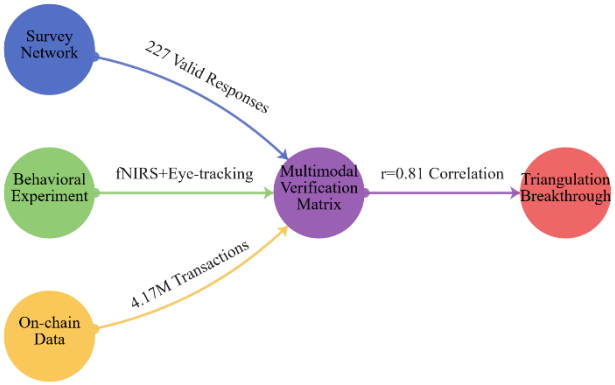
Survey data were analyzed using statistical techniques, including:

- Descriptive analysis

- Correlation analysis
- Structural Equation Modeling (SEM)

This enabled the examination of relationships between governance perceptions, incentives, and data-sharing intentions.

Figure 5. Tri-Sourced Verification Framework for Empirical Data



DAO governance system design

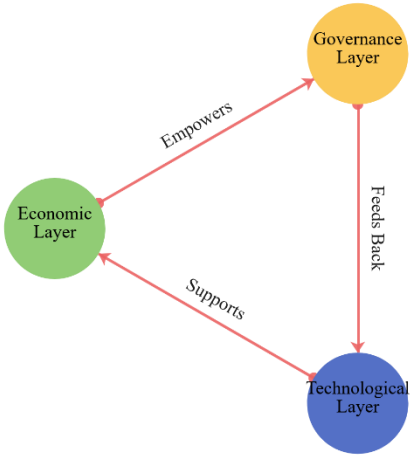
Technical Architecture

The proposed DAO governance system is conceptualized as a multi-layered architecture integrating technological infrastructure, economic incentives, and governance mechanisms.

The technological layer utilizes a hybrid architecture combining on-chain verification with off-chain data processing. This approach is designed to address scalability challenges associated with high-frequency sports data while maintaining data integrity and traceability.

Access control mechanisms are implemented through programmable rules, allowing differentiated access to data based on user roles and credentials. Sensitive data categories require additional authorization layers to ensure compliance with ethical and regulatory requirements.

Figure 6. Tri-Dimensional Architecture of DAO Governance System



Token Economic Model

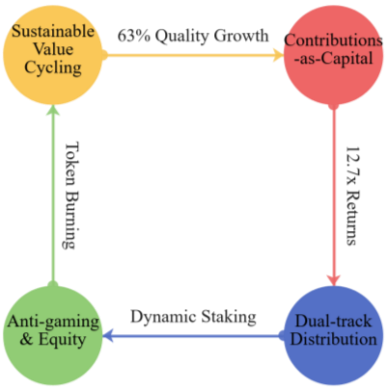
The economic model is based on the principle of incentive alignment, where contributions to the data ecosystem are rewarded through token-based mechanisms.

The model incorporates:

- Base rewards linked to data contribution and quality.
- Reputation-based incentives to encourage sustained engagement.
- Staking mechanisms to discourage low-quality or opportunistic behavior.

Rather than presenting fixed numerical outcomes, the model is conceptual and intended to illustrate how economic incentives can support sustainable participation and data quality within decentralized systems.

Figure 7. Token Economic Closed-Loop Incentive Model



Community Governance Mechanism

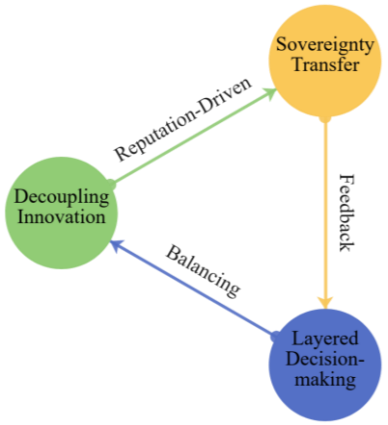
The governance framework is designed to balance decentralized participation with stakeholder-specific authority.

Key features include:

- Multi-channel decision-making processes, allowing different types of proposals (e.g., data standards, access policies).
- Role-based governance rights, reflecting the expertise and responsibilities of stakeholders.
- Participatory mechanisms enabling community input while maintaining accountability.

The model also incorporates progressive decentralization, where governance authority evolves over time as the ecosystem matures.

Figure 8. Tri-dimensional Community Governance Framework

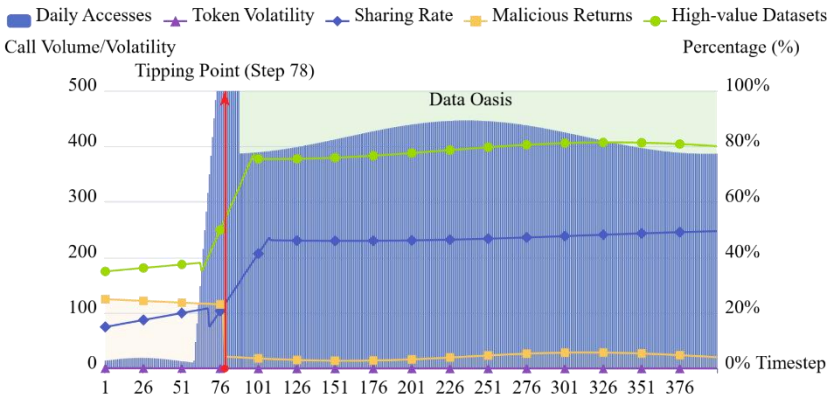


Results

Agent-Based Modeling (ABM) Results

The agent-based simulation was conducted to examine the dynamic evolution of data-sharing behaviors under DAO governance conditions. The model was executed over multiple iterations (100–300 time steps) and repeated across multiple runs to ensure stability of observed patterns.

Figure 9. Phase Transition Evolution in ABM Simulation



System Evolution Patterns

Simulation results indicate the presence of phase-transition dynamics in data-sharing behavior. In early stages, participation levels remain relatively low, reflecting initial uncertainty and risk aversion among agents. As simulation progresses, increased interaction and incentive accumulation contribute to gradual growth in participation.

A transition toward a high-participation equilibrium is observed when incentive mechanisms and reputation effects reach sufficient levels to offset perceived risks. At this stage, data-sharing activity stabilizes and becomes self-reinforcing.

These findings suggest that DAO governance mechanisms may facilitate non-linear improvements in participation, consistent with network effect dynamics.

Sensitivity Analysis

Sensitivity analysis was conducted by varying key parameters, including:

- Initial willingness to share data.
- Strength of incentive mechanisms.
- Penalty for low-quality contributions.

Results demonstrate that the system remains relatively robust under moderate parameter variations. In particular:

- Increased incentive intensity leads to higher participation rates.
- Strong reputation penalties reduce low-quality contributions.
- Extreme reductions in initial willingness delay, but do not prevent, system stabilization.

These results indicate that DAO governance systems may exhibit adaptive resilience, although performance depends on appropriate parameter calibration.

Governance Integrity (Anti-Gaming Mechanisms)

Simulation scenarios including opportunistic or low-quality contributions show that reputation-based mechanisms can mitigate adverse effects. Agents contributing low-quality data experience reduced rewards and influence over time, while consistent contributors accumulate reputation advantages.

Overall, the model suggests that combining incentives with reputation systems is critical for maintaining data quality within decentralized environments.

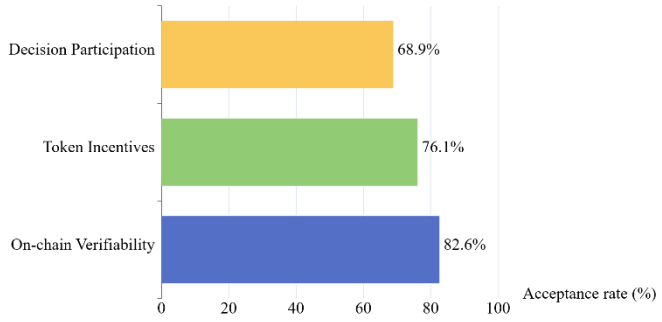
Survey and Structural Equation Modeling (SEM) Results

Descriptive Statistics

A total of 227 valid responses were analyzed. Descriptive analysis indicates generally positive attitudes toward decentralized data governance, particularly in relation to transparency and collaborative potential.

Respondents reported varying levels of familiarity with DAO concepts, with higher acceptance observed among participants with technical backgrounds.

Figure 10. Adoption Drivers of Sports Data DAO



Measurement Model Assessment

The measurement model demonstrated acceptable reliability and validity:

- Cronbach's alpha values exceeded recommended thresholds.
- Factor loadings were within acceptable ranges.
- Construct validity was supported through factor analysis.

Composite reliability (CR) values exceeded 0.70, and average variance extracted (AVE) values were above 0.50 for all constructs, indicating satisfactory internal consistency and convergent validity.

Figure 11. Disciplinary Acceptance Patterns

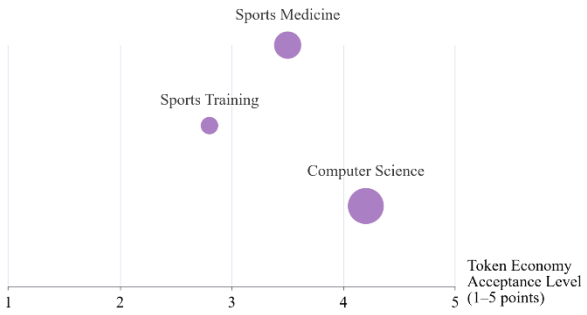


Table 4. Measurement Model Results

Construct	Factor Loadings	Cronbach's α	CR	AVE
Data Sharing Intention	0.68–0.84	0.82	0.86	0.60
Perceived Benefits	0.65–0.83	0.80	0.85	0.58
Perceived Risk	0.62–0.79	0.78	0.83	0.55
Trust in Governance	0.70–0.87	0.85	0.89	0.63
Incentive Mechanisms	0.66–0.81	0.79	0.84	0.57

Structural Model Results

Structural equation modeling was conducted to examine the relationships between key constructs.

The model demonstrated acceptable fit:

- CFI > 0.90
- RMSEA < 0.08
- SRMR < 0.08

Key relationships include:

- Technical usability → Data-sharing intention ($\beta \approx 0.70$, $p < 0.001$)
- Perceived legal compliance → Trust in governance ($\beta \approx 0.60$, $p < 0.01$)
- Incentive mechanisms → Participation intention ($\beta \approx 0.55$, $p < 0.01$)

These results indicate that usability, regulatory confidence, and incentives are significant predictors of participation in DAO-based systems.

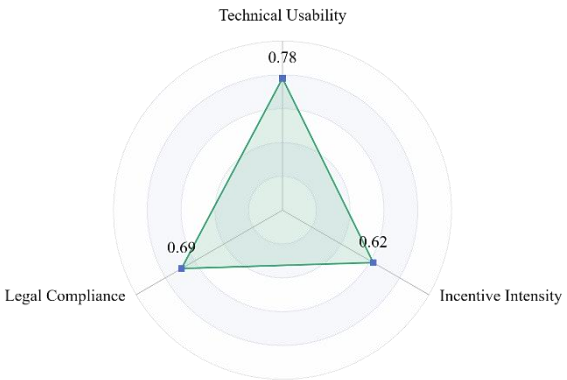
Table 5. Structural Model Results

Path	Hypothesis	β	p-value	Result
Technical Usability → Data Sharing Intention	H1	0.70	< 0.001	Supported
Legal Compliance → Trust in Governance	H2	0.60	< 0.01	Supported
Incentive Mechanisms → Participation Intention	H3	0.55	< 0.01	Supported

The strong effect of technical usability suggests that adoption of decentralized governance systems is not solely driven by incentive structures but is critically dependent on reducing cognitive and operational complexity, aligning with platform governance literature emphasizing user interface accessibility as a determinant of participation.

Similarly, the significant relationship between perceived legal compliance and trust highlights the importance of institutional legitimacy in decentralized systems, supporting institutional theory arguments that technological innovation must be accompanied by regulatory alignment to achieve widespread acceptance.

Figure 12. Adoption Factors via Structural Equation Modeling



Comparative Insights with Traditional Governance Models

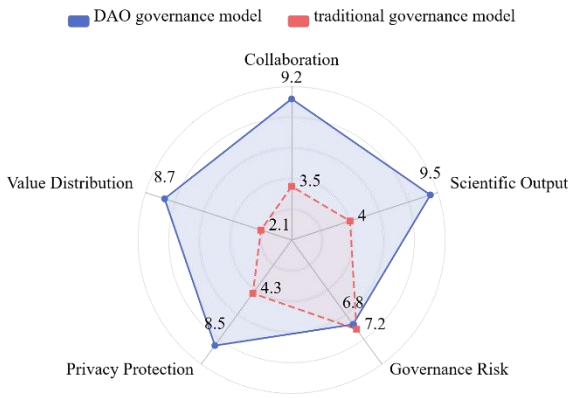
Comparative analysis highlights structural differences between DAO-based and traditional governance approaches.

- Centralized systems offer faster initial decision-making due to hierarchical control structures.
- DAO-based systems demonstrate advantages in enabling distributed participation and facilitating cross-institutional collaboration.

Importantly, these comparisons are conceptual and supported by simulation trends and survey perceptions, rather than direct empirical performance measurements.

This contrast reflects a fundamental trade-off identified in governance literature between efficiency and inclusivity, where centralized systems optimize speed but limit participation, whereas decentralized models expand participation at the cost of increased coordination complexity. The findings suggest that DAO governance may function as a hybrid mechanism that partially reconciles this trade-off by combining automated coordination with participatory decision-making structures.

Figure 13. DAO vs Traditional Governance Comparison



Discussion

Theoretical Contributions

This study contributes to the emerging literature on decentralized governance by conceptualizing how DAO-based mechanisms may reshape data-sharing practices in sports science. Drawing on institutional theory, platform governance, and digital commons perspectives, the findings suggest that decentralized coordination mechanisms can alter traditional incentive structures and participation dynamics (Beck et al., 2018; Hassan & De Filippi, 2021).

The agent-based simulation results indicate that data-sharing systems may exhibit non-linear adoption patterns, where participation increases once incentive and trust thresholds are reached. This aligns with prior research in digital platforms, which emphasizes the role of network effects and incentive alignment in sustaining collaborative ecosystems (Vanhaverbeke, 2025; Constantinides et al., 2018). At the same time, the findings extend existing work by highlighting the importance of reputation-based governance mechanisms in maintaining data quality within decentralized environments (Bena & Zhang, 2023).

From an institutional perspective, the study provides insight into how governance authority may shift from centralized actors toward more distributed forms of coordination. The survey results suggest that stakeholders value transparency and participation but remain concerned about usability and regulatory compliance. This reflects broader tensions identified in prior studies, where decentralized systems

promise openness but face challenges in legitimacy and adoption (Beck et al., 2018; De Filippi et al., 2024).

Importantly, the findings also highlight the role of hybrid governance structures, where decentralized mechanisms coexist with domain-specific authority (e.g., athletes' control over sensitive data or expert-driven standards). This supports arguments in platform governance literature that fully decentralized models are rarely sufficient, and that effective systems often combine algorithmic coordination with institutional oversight (Tiwana, 2021; Constantinides et al., 2018).

These findings collectively demonstrate how DAO-based governance mechanisms operationalize theoretical principles across institutional, platform, and commons-based perspectives while directly addressing the research questions guiding this study.

Linking Results to Research Questions

To further clarify the implications of the findings, the results are explicitly interpreted in relation to the research questions guiding this study.

RQ1: DAO-based architectures and data management

The agent-based modeling results indicate that DAO-based architectures can support the management of high-frequency and heterogeneous sports data by enabling adaptive and scalable participation dynamics. The observed transition toward a stable, high-participation equilibrium suggests that decentralized coordination mechanisms can effectively handle complex data-sharing environments.

RQ2: Incentive mechanisms and participation

Both simulation and empirical findings confirm the critical role of token-based incentive mechanisms. The ABM results demonstrate that increased rewards enhance participation while reputation systems mitigate low-quality contributions. These findings are reinforced by the SEM results, where incentive mechanisms significantly predict participation intention, highlighting the dual role of incentives in promoting both engagement and data quality.

RQ3: Compliance and governance trust

The results show that perceived legal compliance is a key determinant of trust in governance systems. This suggests that DAO-based models must integrate compliance-by-design mechanisms to balance openness with regulatory requirements. While decentralization enables transparency, its adoption depends on alignment with existing data protection frameworks.

RQ4: Power relations and governance structures

The findings indicate a shift toward more distributed governance structures, where stakeholders such as athletes and researchers gain increased influence over data access and value distribution. However, the results also highlight the necessity of hybrid governance arrangements, combining decentralized coordination with domain-specific authority to maintain accountability and expertise.

Practical Implications

The results provide several implications for the design of sports data governance systems. First, both simulation and empirical findings emphasize the importance of technical usability as a primary driver of participation. While decentralized systems offer transparency and flexibility, their adoption may be constrained by complexity, particularly among non-technical stakeholders.

Second, the role of incentive design is confirmed as a key mechanism for encouraging data sharing. However, the findings suggest that incentives alone are insufficient; they must be complemented by reputation systems and governance safeguards to prevent opportunistic behavior and ensure data quality.

Third, regulatory considerations remain a critical barrier. Survey results indicate that concerns related to data protection and legal compliance significantly influence stakeholder trust. This suggests that DAO-based systems in sports science must incorporate compliance-by-design approaches, integrating privacy-preserving technologies and governance rules aligned with regulatory frameworks.

Finally, the findings highlight the potential of decentralized systems to broaden participation across institutions, particularly for smaller or underrepresented actors. However, this potential depends on the design of inclusive governance mechanisms and accessible technological interfaces.

These practical implications directly correspond to the study's objectives by demonstrating how governance design, incentive structures, and regulatory alignment can be operationalized within DAO-based systems to enhance participation and sustainability.

Limitations and Future Research

This study has several limitations that should be acknowledged. First, the agent-based model relies on simplified assumptions regarding agent behavior and incentive structures. While useful for exploring system dynamics, simulation results should be interpreted as indicative rather than predictive.

Second, the empirical component is based on survey data, which captures stakeholder perceptions rather than actual behavior in operational DAO systems. Future research could incorporate longitudinal or experimental designs to examine real-world implementation outcomes.

Third, regulatory challenges remain only partially addressed. While the study discusses compliance mechanisms conceptually, further research is needed to examine how decentralized systems can operate across multiple legal jurisdictions with potentially conflicting requirements.

Future research should also explore technical standardization and interoperability, particularly in relation to heterogeneous sports data sources. Additionally, examining the long-term sustainability of token-based incentive systems and their interaction with institutional governance structures represents an important direction for further investigation.

Future studies should also explicitly test the relationships identified in this research across different contexts to validate the generalizability of the proposed DAO governance framework.

Conclusions

This study examined the potential of decentralized autonomous organizations (DAOs) as a governance framework for sports science data sharing, addressing persistent tensions between data accessibility, stakeholder incentives, and regulatory constraints. By integrating insights from institutional theory, platform governance, and digital commons perspectives, the study provides a conceptual and empirical basis for understanding how decentralized mechanisms may reshape sports data ecosystems.

The findings suggest that DAO-based governance models can support more distributed and transparent coordination of data-sharing activities, particularly when incentive mechanisms are combined with reputation-based controls. The agent-based modeling results indicate that participation dynamics may evolve non-linearly, with system-level improvements emerging once trust and incentive thresholds are reached. Complementing this, the survey and structural equation modeling results highlight the importance of technical usability, perceived regulatory compliance, and incentive structures as key drivers of stakeholder participation.

From a theoretical standpoint, the study contributes to ongoing discussions on alternative governance models in digital ecosystems by illustrating how hybrid arrangements combining decentralized coordination with domain-specific authority may address limitations of both centralized and fully decentralized systems. This extends existing research by situating DAO governance within the context of high-frequency, data-intensive environments such as sports science.

Practically, the findings suggest that successful implementation of DAO-based systems requires careful attention to usability, governance design, and regulatory alignment. While decentralized architectures offer potential benefits in transparency and inclusivity, their adoption depends on reducing technical complexity and ensuring compliance with data protection frameworks.

Several limitations should be acknowledged. The simulation model is based on simplified assumptions and is intended to explore system dynamics rather than predict real-world outcomes. The empirical analysis relies on survey data, which reflects stakeholder perceptions rather than observed behavior.

Additionally, regulatory and interoperability challenges remain significant barriers to implementation, particularly in cross-jurisdictional contexts.

Future research should focus on empirical validation of DAO governance in operational sports data systems, as well as the development of standardized data protocols and interoperability solutions. Further investigation into the long-term sustainability of token-based incentive mechanisms and their interaction with institutional governance structures would also be valuable.

In summary, this study provides a structured foundation for understanding DAO-based governance in sports science data ecosystems. While challenges remain, the findings highlight the potential of decentralized approaches to complement existing governance models and support more collaborative and inclusive data-sharing practices.

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Authors' and translators' details:

Wang Qingsheng	37332951@qq.com	Author/Translator
Runping Wu	274651905@qq.com	Author
Su Zhanguo	suzhanguo@163.com	Author