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## Research Article

## Governance of decentralized autonomous organizations that produce open source software

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## ABSTRACT

Decentralized autonomous organizations (DAOs) have found use in the governance of open source software (OSS) projects. However, the governance of an OSS producing DAO should match the particularities of OSS production while also overcoming the existing challenges of decentralized governance. The existing decentralized governance frameworks do not include all the governance activities of OSS projects. Therefore, this study presents a governance framework for DAOs that produce OSS. The framework is built upon a total of 34 articles on DAO and OSS governance. The framework was evaluated in three leading DAOs that produce OSS. The evaluation underscores the significance of the framework and proves the potential of the systematic categorization of governance mechanisms. Finally, we list emerging governance practices in various governance domains in this developing field.

## 1. Introduction

The widespread emergence of blockchain technology can be traced back to the year 2008, when Nakamoto introduced his Bitcoin whitepaper [1]. Bitcoin allows two parties to confirm an event or transaction without a middleman for the first time. Six years later, Buterin presented Ethereum, which adds Turing completeness and state awareness to blockchain networks [2]. Ethereum allows for code to be written, deployed, and executed on the decentralized network. This enabled the creation of a range of decentralized applications, including decentralized autonomous organizations (DAOs). A DAO, as defined by Hassan and De Filippi, is “a blockchain-based system. It enables people to coordinate and govern themselves mediated by a set of self-executing rules deployed on a public distributed ledger. Its governance is decentralized” [3].

Various types of DAOs have since been instantiated, including investment DAOs [4], protocol DAOs [5], common DAOs [6], and others. Another variant, open source software (OSS) producing DAOs, allows OSS project governance in a decentralized and transparent manner. OSS projects that are maintained by their community could be well supported by a DAO [7]. These OSS producing DAOs are the scope of this research.

We define an OSS producing DAO as *an organization that autonomously manages the production of OSS. It does not need a strong centralized actor because it operates on a public and transparent distributed ledger*<sup>1</sup>. Since DAOs run on public infrastructure, their reliance on algorithmic governance is greater than traditional forms of governance [8]. Algorithms provide flexibility regarding the level of decentralization (decentralization of governance or infrastructure) and level of autonomy (autonomous or automated). Hence, a DAO possesses the potential to deliver more flexibility and decentralization than conventional projects. Within DAOs, this radical decentralized infrastructure leads to the creation of liquid democracy [9], where voters have a flexible voting share depending on their participation. This flexibility has a downside. In algorithmic governance, when code is law [10], bugs in code become faults in governance. This has already happened in the failed TheDAO, where a bug in the smart contracts led to the drainage of project funds [4].

The failed project highlights both the wide use and importance of quality smart contracts. A smart contract is “a set of promises, specified in digital form, including protocols within which the parties perform on these promises” [11]. The smart contracts of an OSS producing DAO define the roles, relationships, and interactions of actors with each other and the organization. An OSS project scales to many types of stakehold-

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<sup>1</sup> This is a slight rewording of the definition given by Hassan and De Filippi [3], with a focus on OSS production.

ers, such as software engineers, maintainers, translators, and designers. An OSS producing DAO governs the development of the project, including the onboarding and participation of all the stakeholders. It defines their interactions with the project as well as their cooperation with each other.

The field of decentralized governance is continuously evolving. Valiente et al. [12] described how scholars and practitioners have tried to simplify and clarify the process of building DAOs to ultimately make them an accessible organizational form. However, due to its complexity, extreme flexibility, and low fault tolerance, it remains a daunting task to build a DAO that fully incorporates all aspects of governance.

Some scholars have outlined frameworks for blockchain governance, such as van Pelt et al. [13] and Beck et al. [14]. However, given the focus on blockchain governance, these frameworks do not encompass the complexity of the particular community, autonomous decision making, or organizational governance that DAOs face.

Comprehending the governance intricacies of OSS production within the decentralized community dynamics of a DAO necessitates the establishment of a comprehensive framework. This framework serves to harmonize OSS governance practices with effective solutions to address the social challenges encountered by DAOs. The primary objective of this article is to realize this overarching ambition. The research question is: How are OSS producing DAOs governed? The goal of this research is to build an OSS producing DAO governance framework to answer this research question. To build a framework that covers the governance aspects of OSS producing DAOs, we gather OSS governance elements from the literature and complement this with DAO governance elements from the academic and grey literature.

The objective of this research is to a) build a framework that integrates OSS governance practices with DAO governance practices, b) evaluate this framework through three case studies at leading DAOs, and c) assess how leading DAOs solve blockchain governance challenges.

We first investigate the contributions of others to the intersection of OSS and DAOs in Section 2. Afterwards, we describe the method for framework creation in Section 3. Section 4 contains the OSS producing DAO governance framework, which is validated in the case studies in Section 5. Our discussion on these findings is provided in Section 6. Finally, we conclude this research in Section 7, where we reflect on the growth of the number of DAOs and discuss the challenges of this novel field.

## 2. Theory: how the OSS literature can contribute to solving DAO governance challenges

In this section, we describe the contributions of other authors to the fields of OSS governance and DAO governance. We first list the leading governance frameworks for OSS and the types of governance present in OSS communities.

Afterwards, we turn to the DAO governance literature. We list the current DAO governance challenges and review the current frameworks that address them. After concluding that no framework fully encompasses the governance that OSS producing DAOs need, we describe how the envisioned framework will fulfill this.

### 2.1. OSS governance frameworks

Markus [15] defined OSS governance as “the means of achieving the direction, control, and coordination of wholly or partially autonomous individuals and organizations on behalf of an OSS development project to which they jointly contribute”. OSS governance is a multi-faceted challenge. Two authoritative scholars have created unified frameworks that describe OSS governance: Markus [15] and de Laat [16]. Here, we briefly compare them, as this will be an input for OSS governance for DAOs. Both authors divided the concept into multiple dimensions. de Laat recognized six dimensions of governance: modularization, division

of roles, delegation of decision making, training and indoctrination, formalization, and autocracy/democracy.

Markus used a different multidimensional model. She divided OSS governance into six dimensions: ownership of assets, project chartering, community management, software development processes, conflict resolution and rule changing, and use of information and tools.

Some of these dimensions overlap, and some are distinctive. For example, the “use of information and tools” of Markus’ framework matches the ‘formalization’ of de Laat’s framework. Both describe how and which tools are utilized to communicate information and manage repositories.

However, there are also discrepancies between the frameworks. One of the pillars of Markus’ framework is project chartering. This is the establishment of a mission and vision for the project, which also includes roadmap development [15]. This is not present in de Laat’s framework. Similarly, training is one of the main dimensions of de Laat’s framework, which is only implicitly present in the work of Markus. In this work, we integrate both frameworks following the method described in Section 3.

Aside from unified frameworks, other researchers have focused on specific aspects of OSS governance. To answer this research question, we need to know the OSS solution to two of the most complex problems within DAO communities: motivation and role structure.

OSS projects have to motivate their contributors. Motivation is more interesting because OSS projects use more and more diverse incentives than closed source projects. A project can provide contributors with a feeling of accomplishment, status in the developer community, or financial motivations [17,18]. Other incentives are intellectual stimulation and improvement of skills, a sense of moral obligation to the open source community, and the belief that software should be free [19]. However, matching incentives with the community is challenging. Nevertheless, it is essential for DAOs and other OSS projects to ensure alignment between community desires and the incentives used [20].

Role structure is another aspect of OSS governance that differs from traditional organizations and is of particular relevance in DAO governance. Within OSS projects, Crowston and Howison [21] observed that members gravitate towards central roles. At the project core, there are leading developers or project leaders, with fewer involved participants around them. The authors referred to this structure as an onion model. Over time, the active users in the outer layers become more important and gradually transition inwards. These movements are referred to as role migrations. Role migration in OSS is more fluid than in traditional organizations and can be highly based on meritocracy and reputation [17,22].

The standards of OSS role structure and migration are of particular relevance to DAO governance because they guide the management of DAO participants. Smart contracts allow extremely flexible roles that simultaneously require rigid and correct coding. By mimicking the characteristics of open source roles, DAOs can design effective roles and clarify their members.

### 2.2. Categorizing OSS governance types to find a niche for DAOs

Finding a framework and selection mechanisms is insufficient for successful OSS governance. It requires adaptation to the circumstances at hand and therefore needs a style of governance [23].

Multiple authors presented the case of bazaar vs. cathedral types of software development, which was originally presented by Raymond [24]. In a cathedral, a few master builders define a central plan that is executed by a large group of developers. A different development type is a bazaar. In a bazaar, there is no central control or basic building plan. Instead, like the many small shops in a bazaar that build and sell anything that fulfills their client needs, programmers autonomously offer different approaches to any problem they face.

Recent scholars have provided less appealing and more sophisticated categorizations of governance. Di Tullio and Staples [25] adapted the

framework of Markus [15] to find three types of governance configurations. First, *open communities* are bottom-up software projects with little overhead and few defined processes but clear tooling. Second, *defined communities* are also bottom-up projects, but they do have clear processes for decision making, conflict resolution, and software development. The rules of the project are clear, and the community enforces the use of specific tooling. Finally, *authoritarian communities* are guided top-down. A few central actors make decisions, and they do not provide conflict resolution. Tooling is unenforced, and the rules remain unclear.

Other authors created other community classifications. Germonprez et al. [26] divided open source project groups into four types according to their goals. The groups are divided into quadrants of adhocracy versus bureaucracy and family versus meritocracy. Adhocracy and family provide freedom and flexibility, while bureaucracy and meritocracy maintain control and reward structures. Combining bureaucracy and family focuses on inward reflection, while adhocracy combined with meritocracy generates outward achievements.

De Noni et al. [27] presented a final taxonomy. They discerned four clusters with their own characterizing configurations: open source-based, sponsor-based, tolerant dictator-based, and collective.

As described, the literature shows different governance categories. The authors named these governance structures, governance configurations, or community types. These classifications show similarities. The models differ on the same governance properties. Generally, we observe that the authors classified projects on (a) the level of formalized governance, which ranges from undefined/open to defined governance, and (b) the type of rule, which ranges from democratic to authoritarian governance.

Based on these OSS governance taxonomies, we identify three requirements for the OSS producing DAO framework. First, it should allow for formal and loose governance. Second, it has to be flexible in incorporating actors, actor groups, and various types of authority. Third, it should be relevant for projects with democratic governance and with authoritarian rule. The OSS producing DAO framework should accommodate all these types of OSS governance.

### 2.3. The challenges of DAO governance

A DAO is an organizational form that is jointly owned by its members, where each member directly exerts his influence on decision making. It is facilitated by the transparent, immutable, and auditable nature of blockchain [3]. Jentsch [28] described the first DAO, which started in 2016. It failed because one of its smart contracts was exploitable. That exploit allowed a malignant to steal parts of the treasury. The event had severe consequences for the Ethereum blockchain community [4].

In the aftermath, the advancements and adoption of DAOs were tempered, and their technology remained nascent [28]. Only recently have DAOs matured, and new tools have been developed to support DAOs. Currently, DAOs face many unsolved governance challenges. Rikken et al. [29] investigated these challenges. These authors recognized that DAOs, among other challenges, lack control over infrastructure, experience voter fatigue, fail to act in crises, and cannot handle immutability breaches.

Both practitioners and scholars have worked to solve these challenges that prevent DAOs from becoming a popular governance form. We briefly describe how three governance challenges are being solved by the introduction of new technology: on-chain versus off-chain governance, voting, and tokenomics.

- Within DAOs, governance can be executed in two ways: on-chain and off-chain decision making. Reijers et al. [30] defined on-chain governance as the rules and decision making processes that have been encoded directly into the underlying infrastructure of a blockchain-based system. Off-chain governance comprises all other rules and decision making processes that are not encoded on the blockchain.

The current governance of DAOs consists of a small part of on-chain governance at the project core, while most governance occurs off-chain. This is because of the limitations of the current early state of DAO technology. On-chain decision making was affected by gas costs, although the newer consensus algorithms minimized this [31]. The high gas cost did limit user activity, as Faqir-Rhazoui et al. [32] remarked. As the technology matures, Wang et al. [33] suspected an increase in on-chain governance. Despite the increasing availability of on-chain governance tooling, it remains a challenge to find adequate synergy between on- and off-chain governance.

- Practitioners built voting systems for DAOs, which have been described by Liu et al. [34]. In traditional organizations, decision making is concentrated at the top. This is different in DAOs. In a DAO cooperative, all shareholders can directly participate in decision making through decentralized voting [35]. The current approach for most DAOs is governance by proposals. Some or all members can submit proposals after which all DAO members vote [33,36]. The proposals and votes are recorded on the underlying blockchain [37]. The proposal outcome may be an action that is automatically executed by the DAO, such as promoting a member, accepting a new member, allocating funds, or performing a payment. Members can vote on these proposals by using tokens. To further complicate decision making, DAOs use several vote counting methods, including plutarchy [30], reputation scores [14,38], quadratic voting, liquid democracy, and conviction voting [8]. So far, it remains unclear which form contributes to the most effective governance.
- The governance of decentralized systems is further complicated by a wide variety of tokenomics. The tokens in DAOs have different properties and roles. In Bitcoin and most classic applications, it is a digital currency indicating value. However, crypto-tokens fulfill currently a wide variety of roles. Some tokens are similar to currencies, others are similar to securities, and others have properties that are entirely new [39]. Wang et al. [33] described three utilities that are generally embedded in crypto-tokens: equity, property, and currency. First, equity implies that the token is value adding and provides long-term income. Second, property means that tokens represent goods, services, or a right to use. Finally, currency properties facilitate circulation within a certain range. Currently, practitioners are experimenting with these three token properties, and we observe rapid development and diversification.

A fourth technical development that aids decentralized governance is the rise of platforms for developing DAOs. Several platforms integrate governance mechanisms into services. Aragon, DAOstack, and Colony are the most popular DAO platforms [34]. These platforms simplify building a DAO, while services aid in the operation and governance of the DAO. They offer tools for registering a DAO on-chain, creating tokens, registering proposals, voting on proposals, and managing funds. Aragon appears to offer the most complete platform for building DAOs [12,40]. To aid practitioners in selecting the right platform for their DAO, Baninemeh et al. [41] created a decision making model. Although these platforms offer tools to ease the creation and governance of DAOs, they do not help in building effective leadership.

### 2.4. Existing frameworks for supporting decentralized governance

Researchers have described the governance areas that come with managing a blockchain. Beck et al. [14] divided governance into decision rights, accountability, and incentives. Decision rights range from centralized to decentralized, while incentives range from aligned to unaligned. Accountability can be institutionally enacted or technically enacted.

van Pelt et al.'s blockchain governance framework has a different division. It contains three layers: an off-chain community, off-chain processes, and an on-chain protocol [13]. The framework has six dimen-

sions that stretch across the three layers. It complements the framework of Beck et al. with social elements, including membership, roles, and communication.

Liu et al. [42] created a framework that includes the ecosystem around it and thereby offers a wider perspective than blockchain governance itself. The authors suggested six principles that together foster the blockchain and the surrounding ecosystem. This view adds a layer of ecosystem-level governance. Furthermore, Liu et al. emphasized a consideration of the level of decentralization, thereby following Beck et al. Finally, the authors added legal and ethical considerations.

A final framework that describes decentralized governance comes from the field of economics. The work of Ostrom describes eight principles of successful commons governance [43]. Adherence to the principles helps communities create collective action without relying on a central authority. In other words, it is decentralized governance. Commons governance has several similar characteristics to DAO governance, and the comparison is made by Rozas et al. [44] and Cila et al. [45]. Both commons and DAOs require decentralized enforcement of rules, participatory decision making, and collective action. This work is used to provide conceptual guidance for the field of DAO research by van Vulpen and Jansen [46].

### 2.5. The envisioned role of the OSS producing DAO framework

OSS governance is complex and diverse in its demands of hierarchy, governance types, and formality. The governance structures should be advanced to handle both decentralized and centralized projects. At the same time, the current stage of DAOs is nascent and faces numerous governance challenges.

Nevertheless, several communities are trying to build an OSS producing DAO. To guide them in establishing the right form of governance, we are writing this paper.

These communities are helped by a framework that integrates the acquired practices of OSS into the DAO research field. The fields are similar, as are the frameworks. For example, both fields face questions of decentralization, accountability, and institutionalization [14–16].

Although several blockchain governance frameworks exist, none of these frameworks incorporate all the essential elements of OSS production. For example, the work of Markus mentions project chartering and the resolution of conflicts as essential elements of governance, but none of the blockchain governance frameworks has these dimensions. As we also observe from our method in Table 2, DAO governance research has very limited coverage for role structures, legal foundations, chartering, and software development processes, which are all well-defined in the OSS literature. Therefore, an integration of OSS elements into DAO governance would be a novel contribution to this field. Hence, we follow the words of Rikken et al., “[for DAO governance], we recommend learning from the lessons from the open source community” [29].

## 3. Research methods: designing the DAO governance framework

The OSS producing DAO governance framework was constructed in three steps. In this method, we first describe the literature collection process for OSS and DAO governance. Second, we describe the framework production steps. Finally, we list the procedure for the evaluative case studies conducted at well-known DAO projects.

### 3.1. Literature study for capturing OSS and DAO governance

We conducted a literature review to identify the relevant literature and extract governance practices from it. These practices were used in the creation of the OSS Producing DAO governance framework.

Two search engines were selected for identifying relevant OSS and DAO governance mechanisms. These are Google Scholar and Scopus. Google Scholar was selected because it possesses the largest academic

collection, and Scopus has the most advanced tooling [47]. For both the OSS and DAO framework types, we used both search engines. The results are shown in Table 1. We derived the queries from the research question, and they are also listed in the table.

Sufficient academic literature was available to build the OSS governance side of the framework. However, these queries provided too few results for the DAO governance side. To overcome this lack of articles, we added gray literature to the scientific results. We followed the guidelines of Garousi et al. [48] for a multivocal literature review.

After defining the search queries and running the engines, we selected relevant papers from the results. We first excluded all papers that were not publicly available or not in English. Afterwards, we conducted two rounds of exclusion. The first round was conducted after reading the title and abstract, and the second round was conducted after reading the full paper. Papers were excluded based on two criteria. Neither did they concern OSS or DAO governance, nor did they report concrete governance activities. This selection resulted in a total of 16 relevant articles on OSS governance and 18 papers on DAO governance, as shown in the second to last columns of Table 1. The list of articles used for the framework creation is shown in Table 2.

In combining these results in a single overview, we used a systematic approach based on the guidelines of Kitchenham and Charters [49]. The documents were first uploaded on Nvivo. Codes of OSS producing DAO governance were created in an exploratory manner: whenever a governance concept was encountered, it was created as a new code. To adhere to the standards of Kitchenham and Charters, the data extraction was conducted by the lead researcher and reviewed by the supervising researcher.

As a result of this process, 165 codes were created for OSS governance and 136 for DAO governance.<sup>2</sup> These codes were governance concepts, challenges, legal designs, and ideas related to governance.

After creating the codes, we synthesized the results. We conducted two qualitative syntheses in adherence to the guidelines of Kitchenham and Charters. One was for OSS governance, and the other was for DAO governance.

#### 3.1.1. OSS governance overview

The overview of the OSS governance mechanism in Appendix A is the result of clustering and classifying the 165 codes. During this process, the governance dimensions of Markus [15] provide a framework for classifying governance mechanisms. These governance mechanisms are 1) ownership of assets, 2) chartering the project, 3) community management, 4) software development processes, 5) conflict resolution and rule changing, and 6) use of information and tools. These are combined with the similar categorizations of governance of De Noni et al. [50] and Di Tullio and Staples [25]. Appendix A provides a summary description of what each mechanism entails and references to the literature that describes these governance mechanisms.

#### 3.1.2. DAO governance overview

The 136 created codes were combined into 21 governance mechanisms. For each of the identified mechanisms, we added a description from the literature. The DAO overview divides governance mechanisms into 1) decision making, 2) incentives, and 3) community. Additional governance mechanisms beyond this categorization can be imagined but have not been found in the literature. This process resulted in the DAO governance overview in Appendix B.

### 3.2. Creating the OSS producing DAO governance framework

The second part of creating the OSS producing DAO governance framework was integrating the OSS governance overview in Appendix A

<sup>2</sup> The full list of codes is available upon request.



**Table 1**

Selecting literature from OSS and DAO literature. Scopus and Google Scholar together generated enough relevant work for the creation of the framework.

Literature search method	Queries	Search engine hits	Excluded on title and abstract	Excluded on full read	Total relevant articles	Relevant articles/total hits	Articles after duplication removal	Number of codes
Scopus OSS governance	TITLE(((open source software) OR OSS OR OSSD) AND governance)	28	13	2	13	46%		
Google Scholar OSS governance	allintitle: open source software governance OR allintitle: OSS governance OR allintitle: OSSD governance	83	53	14	26	31%	16	165
Scopus DAO governance	TITLE((decentralized AND autonomous AND organization) OR (decentralized AND autonomous AND organizations) AND governance)	5	3	1	1	20%		
Google Scholar DAO governance	allintitle: decentralized autonomous organization OR allintitle: decentralized autonomous organizations	116	85	12	18	16%	19	136

and the DAO governance overview in Appendix B into a single framework. The three authors independently conducted the integration into the final framework and compared afterwards. Every identified governance aspect was analyzed and integrated, adapted, or excluded for the OSS producing DAO governance framework.<sup>3</sup>

The dimensions were formed by considering their relative importance to the entirety of DAO governance. Mechanisms such as the use of information and tools or conflict resolution fit into other dimensions. Some of the OSS dimensions were reworded to suit DAO specifics.

In Table 2, we map the analyzed studies across the seven governance mechanisms. As shown in the table, the DAO governance literature is primarily concerned with decision making systems and incentive design. Those columns are more filled than the others. We suspect that this stems from the novelty of DAO technology. In contrast, OSS governance has been well-researched and embedded in the academic literature. This is also visible in the table.

Table 2 shows that the OSS governance literature covers observably more of the framework than DAO governance. This can be explained by two factors. First, the framework was created using a governance classification that stems from the OSS literature. Other work in that field can cover the same subjects and therefore better match the framework. Second, the OSS governance literature is more mature than the DAO governance literature. The table indeed highlights that DAO research can learn from open source research. The empty bars for DAO research in Table 2 show that DAO governance frameworks lack guidance, particularly for legal foundation, chartering, and software development processes.

### 3.3. Selecting case studies and framework evaluation

The created framework is evaluated by case studies. A case study is an observational evaluation method that is used to study the designed artifact in-depth in its intended business environment. The objective of the case studies is to evaluate the completeness and usefulness of the framework. This study follows the holistic multiple-case study approach of Yin [68], which entails a design with multiple cases but one unit of analysis. We chose this design because it provides a better understanding of the differences and similarities between the cases [69].

Cases were selected based on the researchers' perceived ranking of the most mature OSS producing DAOs. Maturity criteria were the project age, governance maturity, and availability of information. This is a form of purposive sampling based on the case study classification of Campbell et al. [70]. Six DAOs were contacted, and three replied positively to each interview. These are dOrg, Aragon, and TEC. dOrg is

the first legally registered blockchain-based limited liability company (BLLC).<sup>4</sup>

Aragon is perceived as one of the oldest, largest, and most well-known organizations working on DAOs and is the largest DAO platform [5]. The final case study, token engineering commons (TEC), is relevant because of its remarkably mature governance system, founded upon the work of Ostrom.

We started the data collection for every case with an in-depth investigation of the DAO's communication channels, forums, handbooks, and other publications. This information was used to create an initial overview of the DAO's governance framework. The overview followed the governance mechanisms in Fig. 1. The data collection took approximately two months and ended with the interview. In the interviews, the findings were validated and extended.

The interviews were conducted between December 2021 and February 2022. For Aragon and TEC, we conducted the interview with two DAO participants. dOrg could only provide a single interviewee for the interview. Descriptive information about the interviews is available in Table 3.

A case-study protocol allowed the researchers to evaluate the framework through semi-structured interviews.<sup>5</sup> It contained the questions that guided the interviewee through the governance overview in a semi-structured manner. The case study protocol also informed the participants of the context and purpose of the case study and contained an informed consent form.

The completeness of the framework was assessed by modeling the complete governance of the DAOs in scope. After going through the framework dimension by dimension, we asked the interviewees if any governance aspects of their DAO were not covered by the framework. Finally, we evaluated the usefulness of the framework. We asked the interviewees how the case study gave them new insights, was useful to them, and may be useful to others.

## 4. Results: The OSS producing DAO governance framework

The OSS producing DAO governance framework is a governance blueprint for OSS producing DAOs. DAO builders and researchers can use it to design, improve, or evaluate DAO governance. A general overview is shown in Fig. 1. DAO creators may use the governance framework to assess the maturity of their DAO and its governance. Researchers may use the OSS producing DAO framework to identify DAO governance challenges and form new theories about OSS creation. For both practitioners and scholars, the framework aids in DAO governance by providing structure for understanding this complex phenomenon. In the following paragraphs, we outline the concepts that form the framework.

<sup>3</sup> To ensure a reproducible analysis, we documented the steps we conducted, and the created data were documented in a dataset. The overview of governance mechanisms, inclusion, and explanation is available at <https://data.mendeley.com/datasets/ptkygymvyj>.

<sup>4</sup> As discussed in <https://www.coindesk.com/markets/2019/06/11/dorg-founders-have-created-the-first-limited-liability-dao/>.

<sup>5</sup> The interview protocol and the transcripts are available upon request.

**Table 2**

The analyzed studies across the seven governance mechanisms. Two datasets of, in total, 34 articles fill the framework. The columns indicate the governance coverage of the article: ○ indicates no coverage, ⊙ indicates partial coverage of the mechanisms, and ● indicates coverage of all mechanisms.

Ref	Article	Dataset	Coverage						
			Lead & role structure	Decision making	Legal foundation	Chartering	Incentives	Community management	Software development processes
[16]	Governance of open source software: State of the art.	OSS	⊙	●	●	●	●	⊙	●
[51]	An empirical study on the relationship between software design quality, development effort and governance in open source projects.	OSS	○	●	○	●	○	○	●
[52]	Governance in open source software development projects: A comparative multi-level analysis.	OSS	●	●	○	●	○	●	●
[27]	The evolution of OSS: A dimensional comparative analysis.	OSS	●	●	●	●	⊙	●	●
[53]	The emergence of governance in an open source community.	OSS	●	●	○	○	⊙	⊙	⊙
[54]	Transition of governance in a mature open source software source community: Evidence from the Debian case.	OSS	●	●	○	○	○	⊙	⊙
[50]	The governance of open source software communities.	OSS	⊙	⊙	●	○	●	⊙	○
[25]	The governance and control of open source software projects.	OSS	●	⊙	●	○	○	⊙	○
[26]	Collectivism, creativity, competition, and control in open source software development: Reflections on the emergent governance of the SPDX® working group.	OSS	⊙	●	○	○	○	⊙	○
[15]	The governance of free/open source software projects: Monolithic, multidimensional, or configurational?	OSS	⊙	⊙	●	○	⊙	●	●
[55]	Code forking, governance, and sustainability in open source software.	OSS	○	⊙	●	○	○	⊙	○
[17]	Governance practices and software maintenance: A study of open source projects.	OSS	●	○	○	○	○	⊙	⊙
[56]	Role migration and advancement processes in OSSD projects: A comparative case study.	OSS	●	○	○	○	○	⊙	○
[57]	Motivation, governance, and the viability of hybrid forms in open source software development.	OSS	⊙	○	⊙	○	●	⊙	○
[58]	The influence of network governance factors on success in open source software development projects.	OSS	○	○	○	⊙	⊙	●	●
[59]	Governance strategies for open collaboration: Focusing on resource allocation in open source software development organizations.	OSS	⊙	⊙	○	○	⊙	●	⊙
[4]	Experiments in algorithmic governance: A history and ethnography of “The DAO,” a failed decentralized autonomous organization.	DAO	○	●	○	○	○	○	○
[60]	Bitcoin and the rise of decentralized autonomous organizations.	DAO	○	●	○	○	○	⊙	○
[61]	Governance of decentralized autonomous organizations.	DAO	⊙	●	○	○	○	○	○
[8]	A decentralized autonomous organization (DAO) of DAOs	DAO	○	●	○	○	●	●	○
[33]	Decentralized autonomous organizations: Concept, model, and applications.	DAO	○	⊙	○	○	●	○	○
[30]	Now the code runs itself: On-chain and off-chain governance of blockchain technologies.	DAO	○	●	○	○	○	○	○
[62]	Decentralized autonomous organizations as the new form of economic cooperation in digital world.	DAO	○	⊙	○	○	⊙	○	○
[63]	Decentralized autonomous organizations (DAOs) as subjects of law—the recognition of DAOs in the Swiss legal order.	DAO	⊙	⊙	○	○	○	○	○
[32]	Effect of the gas price surges on user activity in the daos of the Ethereum blockchain.	DAO	○	○	⊙	○	○	⊙	○
[2]	A next-generation smart contract and decentralized application platform.	DAO	○	⊙	⊙	○	⊙	○	○
[35]	Decentralized blockchain technology and the rise of lex cryptography.	DAO	○	⊙	○	○	○	○	○
[64]	Blockchain: Blueprint for a new economy.	DAO	○	⊙	○	○	○	○	○
[9]	Implement liquid democracy on Ethereum: A fast algorithm for realtime self-tally voting system.	DAO	○	⊙	○	○	○	○	○
[65]	Quadratic voting: How mechanism design can radicalize democracy.	DAO	○	⊙	○	○	○	○	○
[38]	Reputation.	DAO	○	⊙	○	○	⊙	○	○
[14]	Governance in the blockchain economy: A framework and research agenda.	DAO	○	⊙	○	○	●	⊙	○
[66]	Incentivization in decentralized autonomous organizations.	DAO	○	○	○	○	●	○	○
[67]	eGov-DAO: A better government using blockchain based decentralized autonomous organization.	DAO	○	○	○	○	○	○	⊙
<b>Proposed OSS producing DAO framework</b>		Both	●	●	●	●	●	●	●

**Table 3**

The framework of the three case studies analyzed. dOrg, Aragon, and TEC are leading DAOs.

	dOrg	Aragon	TEC
Interviewee role(s)	dOrg member	Executive sub-DAO members	Stewards working group members
Interview duration (minutes)	120	56	116
Interview date	02/02/2022	20/12/2021	10/01/2022
Information collection period	01/2022–02/2022	10/2021–12/2021	11/2021–01/2022



**Fig. 1.** The OSS producing DAO governance framework classifies governance mechanisms into seven areas. It combines the governance mechanisms of 34 articles on OSS and DAO governance research.

#### 4.1. The seven dimensions of the framework

The dimensions of the framework are based on the identified dimensions of OSS governance in Appendix A and the categorization of DAO governance concepts in Appendix B. We created the framework according to the aforementioned method.

The seven dimensions of the framework together cover all the observed governance practices in the articles regarding OSS development. They also integrate the solutions and governance practices of DAO governance. Together, they provide a complete integration of the governance practices that academia observes for both governing OSS communities and DAOs. It integrates the long-established practices of OSS communities into DAO governance, thereby providing richer governance practices for these decentralized communities. For instance, it offers more robust and detailed governance guidelines for software development processes than existing DAO governance frameworks such as DuPont's and van Pelt et al.'s [4,13].

Some of the governance mechanisms are rather abstract. We therefore added references throughout this section to the case study chapter.

The seven dimensions of the DAO for the OSS governance framework are as follows:

- 1 Leadership and role structure** (see Section 5.2 and Table 5) represents the decentralized and initially flat hierarchical structure of DAOs. It combines the leadership aspect of the *leadership and decision making* dimension while incorporating the role structure aspects that are included in the OSS *community management* dimension.

DAOs emerged as a response to overly structured centralized power. Therefore, the initial DAOs were fully decentralized, had no power hierarchy, and were fully democratically governed. However, democratic decision making does not need to remain essential in the development of this new organizational form. Neither does it mean that all the members in existing DAOs are equal. Roles ap-

pear in DAOs that characterize how individuals participate in the community. For example, in an OSS organization, developers or contributors play a role that naturally emerges.

Within this governance area, we list how leadership emerges within a DAO and how the other roles are acquired. There are four concepts for leadership and role structure:

(a) **Roles and responsibilities**

Within a DAO, there is a division of work into roles. Role types include traditional roles such as observer, developer, core developer, and project owner, but a DAO can come with new roles such as decentralized infrastructure developer or community manager. There should be a role that distributes and manages responsibilities [10]. The number of roles differs per project and maturity level [54].

(b) **Role structure**

The role structure describes the DAO's organizational structure. It ranges from fully democratic to single, absolute dictatorship, and everything in between. Commonly, OSS projects have a form of elected leadership, but this is not necessary. The flexibility of DAOs can create widely varying types of organizations [67].

(c) **Role advancement**

In formalized communities, members may be obliged to go through a process of vetting and quality control to advance through roles. Role migration ranges from fluid and informal to very formal [25]. Roles can be acquired by volunteering, earning appointments, or elections [52].

(d) **Establishment of leadership**

The leadership structure must be designed and established. It can be self-appointed or elected. Leadership may also rest with an organization outside the community [16,50].

2 **Decision making** includes the essential community governance mechanisms of proposals and votes, divided over the on-chain and off-chain channels (see Section 5.3 and Table 6). It incorporates the decision making aspect of the OSS *leadership and the decision making* dimension.

(a) **On-chain decision making**

On-chain decision making covers all DAO decisions that have been formally written to the blockchain. Despite the growth of on-chain governance solutions, not all governance decisions are currently possible on-chain [30,33]. It varies per DAO what decisions are made on-chain.

(b) **Off-chain decision making**

Any governance decisions that are made through channels other than the blockchain are off-chain decisions. Reaching an agreement is more practical off-chain [8]. Most decisions of a DAO are made off-chain, and various DAOs have various preferred methods of reaching an agreement.

(c) **Proposal management**

Proposal management is the process of organizing and coordinating the creation of proposals. Proposals are one of the two ways in which DAO members democratically interact with the DAO. Depending on the underlying smart contracts, proposals can be made for only operational decisions or fundamental and constitutional decisions. Proposals pass through several gates before execution. For most DAOs, these are submission, approval, voting, and execution. A proposal usually requires collateral to be submitted [60].

(d) **Voting management**

Voting is the other method by which members govern a DAO. They vote on the proposals of their own or other members. Votes can be distributed in several different manners, such as based on token possession or by a classic one-token-one-vote design [8]. Proposals can be voted for in several different manners, including quadratic voting [65], Futarchy [8], and reputation-based voting [32].

3 The **legal foundation** dimension (see Section 5.4 and Table 7) includes OSS *ownership of assets* and the legal aspects of DAOs. The legal foundation of a DAO is not well defined, as the concept of a DAO is relatively new, and the legal implications are still being explored. The legal foundation of a DAO may be based on the same principles that govern other forms of organization. Hence, a DAO has to consider its legal representation and ownership of both the software and the DAO itself.

Therefore, a legal foundation consists of three aspects for an OSS producing DAO:

(a) **Legal representation**

The legal entity that represents the DAO enables interaction with the rest of the world. Currently, only a few countries have suitable legal representation for DAOs [71]. In general, a DAO may be represented in legal matters by its members, by a specific individual, or by a group of individuals who have been appointed to act on behalf of the organization. One of the main concerns is that current legal frameworks leave a gray area regarding liabilities, putting DAO members at risk.

(b) **Software ownership**

DAOs, in principle, must be radically open for participants to trust and join them. For this reason, most, if not all, DAOs use open source licenses for their software. The software produced by the DAO may be released under various OSS licenses. The license is the fundamental legal mechanism that ensures that the software will be open source. Various licenses that generally range from permissive to restrictive designs on the use and redistribution of the software are available. Their main distinction is whether they incorporate the concept of the copyleft.

(c) **DAO ownership**

The specific ownership structure of a DAO will depend on its governance model and the rules and regulations that govern it. A DAO may be owned by a specific individual or group of individuals who have been appointed to manage its operations, while in other cases, it may be owned by its members collectively. Ownership concerns the DAO itself with all its funding, intellectual property, and assets. It may be arranged on-chain by linking ownership to the number of tokens held. The ownership can also be handed to a traditional organization or foundation.

4 **Project chartering** (see Section 5.5 and Table 8) is a renaming of the OSS *chartering the project* dimension for naming consistency. It consists of overarching decision making and project steering mechanisms.

DAO charters describe the purpose of a DAO and the underlying structure. Currently, charters vary widely in length and content, but most contain a mission and vision statement, values and norms, and roadmaps. As the field of DAOs matures, we may observe how DAO charters adopt elements of traditional governance. Given that governance is as old as mankind, the charters may inherit elements from the traditional foundations of communities, politics, or organizations, such as national constitutions.

(a) **Mission and vision**

Mission and vision statements are the core instructions for the way individuals and organizations interact with the community as a whole [52]. Mission statements are used to guide the day-to-day activities of the organization and to help employees understand their roles and responsibilities. Vision statements are used to guide long-term planning and decision making. These documents may be created by the founders of a project or by community democracy.

(b) **Values and norms**

Values are the beliefs and principles that guide the actions and decisions of the DAO. They are the fundamental ideas and principles that the community considers important and worth pursuing. Norms are the unwritten rules and expectations that



are shared by members of a group or society. They are the social standards that govern the behavior of individuals within a group. Values and norms can be either explicitly encoded in smart contracts [54] or laws or be present implicitly, such as in social customs and traditions. Values and norms can be used as a tool of social pressure that discourages opportunistic behavior and self-interest [25].

(c) **Roadmaps and release plans**

Roadmaps and release plans steer project development and provide a timeline. A roadmap is a high-level view of the organization's plans and priorities. It typically includes a timeline that outlines the major milestones and achievements that the organization hopes to achieve over a given period of time. A release plan is a more detailed view of the organization's development efforts. It typically includes a schedule of when specific features or capabilities will be delivered and who will be responsible for their development and deployment [51]. They gain importance in formally controlled OSS projects and commercial OSS DAOs [56].

5 **Incentives** (see Section 5.6 and Table 9) are essential to DAO governance, as there are many alternative ways to incentivize members. The lack of central authority and the anonymity of participants can make it difficult to provide traditional incentives. Additionally, the decentralized nature of a DAO can make it challenging to coordinate and align the efforts of the organization's members and stakeholders. In a traditional organization, this is often achieved through a hierarchy of leaders and managers who can provide direction and guidance. In a DAO, however, there is no central authority to provide this guidance, and participants may not have a shared understanding of the organization's goals and objectives.

In OSS producing DAOs, incentives are divided into development incentives and DAO participation incentives. Development incentives are remunerations for building software. DAO participation incentives refer to nondevelopment activities that are rewarded. Incentives are frequently aligned with the tokens in DAOs. These tokens can have many utilities but generally have two purposes. First, they have monetary value and therefore enable economic activity in the DAO. Second, they provide governance rights, for example, by representing reputation.

(a) **Development incentives**

A DAO must consider the incentives for development. Developers of OSS projects are either paid for their efforts or work voluntarily. The DAO could employ developers or offer rewards for specific work, allowing anyone to take on the work [62]. This can be done in cryptocurrency or standard fiat currency [33].

(b) **DAO participation incentives**

Rewarding social participation is an important way for a DAO to recognize and acknowledge the contributions of its members and to encourage them to remain active and engaged within the organization. By offering rewards and incentives for social participation, a DAO can help foster a sense of community and collaboration among its members and support the growth and development of the organization.

A DAO can reward social participation by offering reputation-based rewards, such as badges or rankings, that are tied to the contributions and achievements of individual members. This can be based on the reputation tokens that a participant possesses [8].

(c) **Token model**

A token model is a system for using tokens or digital assets to incentivize and coordinate the activities of the organization's members and stakeholders.

In a DAO token model, tokens are used to represent ownership, value, or voting power within the organization. They can

be earned or acquired by members who contribute their time, effort, and resources to the organization, and they can be exchanged for goods, services, or other forms of value within the organization.

The specific details of a DAO token model will depend on the goals and objectives of the organization, as well as the preferences of its members and stakeholders. A DAO needs to consider which tokens to use and what utility they provide. The utility gives the token its value and can therefore be used as an incentive for the DAO [8]. DAOs can consider using tokens for governance [66]. Designing the token model involves setting the issuance, circulation, distribution, and utility [33].

(d) **Reputation model**

Participants may be incentivized by earning a reputation that is non-transferable, unlike tokens. The reputation can provide a certain utility, adding additional incentive to earning a reputation. Without additional utility, the system can simply represent reputation, which can be used to indicate the standing of a DAO member or signal their trustworthiness [8]. A DAO must consider how reputation can be earned, whether reputation can be lost or depreciated, and the additional utilities for reputation [33].

6 **Community management** (see Section 5.7 and Table 10) inherits all remaining mechanisms of the OSS *community management* dimension.

An OSS project is traditionally surrounded by a community. As a project grows, it attracts and fosters a community that in return further expands the project. This joint growth of OSS projects is enhanced in a DAO. DAOs present new opportunities to directly involve the community in the development and governance of the project. It consists of four concepts:

(a) **Joining process**

A DAO grows by joining new members. DAOs structure this process in various ways to formalize joining. The formalization may consist of assigning a community role or an explicit application process [8].

(b) **Vetting of new members**

Candidate vetting refers to the process of reviewing and evaluating potential candidates for membership in the DAO. Potential DAO members may need to prove their knowledge, technical competence, or alignment with the values of the project [8].

(c) **Identity verification**

The anonymity of decentralized applications is at odds with the creation of communities. Therefore, DAOs consider adding formal identifications of DAO members [8]. Both on-chain and off-chain solutions can help in registering members [67]. Common methods of identity verification in a DAO include using digital signatures, blockchain-based identity systems, and other forms of secure and verifiable online identification.

(d) **Conflict resolution and sanctions**

Given the absence of a central punishing authority, a DAO must design a protocol to manage conflicts. Conflict resolution typically involves procedures and processes for addressing and resolving disputes between members of the DAO, while sanctions are penalties or other forms of punishment that can be imposed on members who violate the rules of the organization. Resolutions can be a formally defined process or a very loose process [16]. Formal guidelines and rules can help to prevent conflict and thereby ensure the quality of the project [58].

7 The **software development processes** dimension (see Section 5.8 and Table 11) is included in the OSS *software development processes*. The DAO governance literature does not mention additional governance mechanisms that belong to this dimension.

As OSS projects center around the development of a project, governance directly affects the software development process. It consists of three concepts:

(a) **Task responsibility distribution**

The allocation of responsibilities should be formally allocated within the DAO. The management of responsibility for tasks ranges from open (unmanaged) to delegated (managed) responsibility [17]. Tasks may be divided by the centralized institution or in a decentralized way per working group (WG).

(b) **Code acceptance procedures**

Code acceptance procedures are the processes and criteria used to evaluate and approve new or updated code for the DAO. This process should be defined for the acceptance of new code [58]. Additionally, a role or member should be given responsibility for making decisions about this acceptance [50].

(c) **Release procedures**

Release procedures refer to the processes and procedures used to deploy and release updated versions of the DAO software. These procedures involve several steps, including testing the code, soliciting feedback and input from other DAO members, and finally code deployment. Release procedures increase software quality [16].

A DAO should consider which steps need additional DAO involvement and the scale of involvement. A certain step can be approved by a single DAO member, a selected committee, or by a full community vote. Additionally, the DAO should consider which steps are registered on-chain.

## 5. Framework validation by case studies

In our search to understand how OSS producing DAOs should be governed, we must add practitioner insights. In this section, we validate the framework by applying it to three case studies. We first provide a description of the three DAOs and add descriptive statistics in Table 4. Afterwards, we describe the governance of the three DAOs by following the framework areas. Finally, we add summarizing remarks on the case studies.

### 5.1. Three leading DAOs in scope: dOrg, Aragon, and TEC

dOrg is a collective of Web3 engineers, designers, and project managers organized in a DAO. They collaborate on projects to advance the Web3 stack. Their mission is to become the best service provider, workplace, and example of what is possible to achieve with Web3 technology.<sup>6</sup> The members conduct DAO development, operations, and governance themselves. The DAO was formed in 2019 and was registered as a BLLC in Vermont. When the interview took place, the DAO had 55 active members.

The Aragon Network DAO was launched on October 20, 2021, and came out of the related Aragon Association. The association was founded in 2016 [72]. Aragon builds a platform for the standardized creation of DAOs. The Aragon Network DAO determines the spending of funding on software development. The DAO consists of the main DAO, the executive sub-DAO, the compliance sub-DAO, and the tech committee sub-DAO. Through an initial coin offering in 2017, they raised an equivalent of \$25 million in cryptocurrencies [73]. There were 12,000 addresses that held Aragon tokens (ANT tokens) at the time of the interview [74]. The DAO charter is the founding document of this community.<sup>7</sup>

TEC funds and builds OSS projects, research, and education that relate to token engineering. TEC's purpose is "to become a Schelling Point

for the token engineering community." TEC started in July 2020 with a cultural build. The cultural build is the social foundation of the DAO. TEC envisioned a community formed around the eight design principles of Elinor Ostrom's *Governing the Commons* [75]. The DAO commenced with a phase in which the DAO was formed and built, called the Hatch. A temporary Hatch DAO was instantiated to support the community as they were building the final DAO. In January 2022, after the Hatch, the DAO launched its TEC token.<sup>8</sup>

In the upcoming sections, we compare these DAOs in the seven governance areas. We add italicized quotes from the interviews. For every governance area, we follow the order of dOrg, Aragon, and TEC. After these, we add general summarizing remarks.

### 5.2. Leadership and role structure

The three DAOs differ in their procedures for electing leaders and assigning roles. dOrg has no formal leadership. Instead, the DAO possesses the signer role. These are "the top seven reputation holders in dOrg." They hold the keys to the treasury and therefore "are owners of the treasury. [...] They sign and propose or execute transactions from [the] treasury that result from governance decisions on Snapshot".

To acquire the signer role, a member must become one of the top seven reputation holders, which would lead to a change in the signer role and a transfer of ownership of the treasury. A hostile takeover would require four of the seven signers to conspire against the DAO.

All the members, even the seven signers, are given the builder role. They may also have other roles, such as marketing, accounting, legal talent, acquisition, builder experience, and client experience. For project management, there are tech lead (TL) and project manager (PM) roles. "The tech lead is ultimately responsible for the technical delivery, whereas the project manager is ultimately responsible for keeping the nontechnical aspects on track." Acquiring an internal role is a "governance decision" that is voted on.

Although there are multiple defined roles in the DAO, according to the interviewee, these are only loosely defined. They aim to adhere to the model of a collective. Although they do have "some specialists", they do not have "constricting roles for people". An overview of DAO leadership is provided in Table 5.

Within the Aragon DAO, three sub-DAOs have been created. They are the Executive sub-DAO, Compliance sub-DAO, and Tech committee. The members of the sub-DAOs are elected. However, the interviewee noted that only "0.1% voted on the members of the executive sub-DAO". Any person who has the backing of a person with many tokens could take control over such a decision and have themselves elected.

The Aragon DAO delegates various workstreams to different teams. According to the interviewee, this is "a direction the whole [DAO] space is going. [...] Various competent and experienced groups [are] taking up workstreams and have relative autonomy within". Work and power will be pushed toward teams that take ownership of the workstreams.

Workstreams solve voting fatigue, a problem that emerges when voters are confronted with voting for various irrelevant proposals. Instead, the DAO delegates operational decisions to autonomous teams. This delegation brings focus to important decisions in the main DAO.

In addition to the Aragon Network DAO, there is a committee in the Aragon Association that currently stewards the tangible assets treasury of the Aragon Network. The Aragon Association is "the operational unit, which does most of the productive work on the network". According to the interviewee, they are planning to transfer the treasury to the DAO over the course of the next three years. "Currently, the DAO only has a small portion of that budget".

The TEC DAO is organized into 11 WGs. The primary representatives and facilitators of the DAO are the stewards. The stewards are the

<sup>6</sup> as stated in the dOrg handbook, available at <https://docs.dorg.tech>.

<sup>7</sup> The Aragon Network DAO charter is available at <https://ipfs.io/ipfs/bafybeifbytiwuf6gvexqice7dbwkdmrwhg6vv5ohb64elvyqfnwhnchm/blob>.

<sup>8</sup> The TEC handbook is available at <https://token-engineering-commons.gitbook.io/tec-handbook/>.


**Table 4**

DAO descriptives. The three DAOs are of vastly different sizes and have very different governance structures, as shown in the upcoming pages.

Descriptive	dOrg	Aragon	TEC
Purpose	Become the best service provider, workplace and example of what is possible to achieve with Web3 technology	Use technology as a liberating tool	To become a Schelling Point for the token engineering community
Legal Entity start	2018	2016	2020
DAO launch	2018	2021	2021
Number of token holders	55	12000	271
Used blockchain	Ethereum	Ethereum	xDAI

**Table 5**

Governance Area 1, leadership and role structure. dOrg is governed by meritocratic leadership, token engineering commons (TEC) by democratic leadership. Aragon divides leadership across sub-DAOs and the association.

	dOrg	Aragon	TEC
Role structure	Leaderboard of seven. Other members may have internal or external roles.	Organized by participants in various DAOs. There are Main-DAO, Executive sub-DAO, Compliance sub-DAO, Tech committee sub-DAO, and work groups/guilds.	Members are divided into eleven working groups (WGs). The stewards' WG coordinates the other WGs.
Role and responsibility	Leaderboard executes the vote outcomes. Sourcing team is responsible for sales. Project manager and tech lead decide on project members. Project manager guides the project and project funds. Tech lead is responsible for code quality.	Executive sub-DAO members manage the treasury. Compliance sub-DAO has permission to veto proposals that breach the charter or are harmful. Tech committee approves releases. WGs execute a work stream.	The WGs are as follows: Stewards WG for overall governance, Softgov WG for governance of the commons, Legal WG for legal strategy, Transparency WG for mutual monitoring within the DAO, Omega WG for the ethos and ethics in the group, Gravity WG for maintaining equilibrium and conflict management, Communications WG for external communications, Labs WG for innovation, Communitas for community building, Rewards WG for the reward system, and Sampo WG for tokenomics.
Establishment of leadership	Top seven builders in reputation form the leadership.	Positions in sub-DAOs are established through voting/elections.	WG leads are established by stewards.
Role advancement	Positions are voted on through Snapshot.	Funding proposals ensure that certain work is funded. Members move with proposals.	Candidates can be nominated to become stewards by an existing steward.

informal leaders of the TEC. In addition to this role, there are WG coordination leads who support the coordination of the WGs. There are several WGs that facilitate internal DAO cooperation, while others advance projects of the DAO.

TEC leadership encourages the autonomy of DAO participants. One of the interviewees explained, “We actually do not want the stewards to be seen as the leaders that tell people what to do and what to work on.” This quote highlights the informality of the steward’s leadership.

### 5.3. Decision making

The three DAOs execute similar decisions on-chain, as shown in Table 6. For example, all three make on-chain decisions for funding and the creation of proposals. However, proposal management and voting management differ across DAOs. The differences will be discussed below.

Regarding the off-chain decision processes, dOrg’s builder covenant defines the expectations of off-chain behavior. There is even an escalation protocol to resolve conflicts in urgent situations. Many project-level decisions do not occur on-chain. As the interviewee states, “Those do not need to go on-chain. The team can work it out themselves. Usually, decisions go on-chain when we need more visibility through the DAO. Like meta governance, especially.” As Table 6 shows, most on-chain decisions concern important topics such as DAO governance, chartering, or community management. The interviewee explains, “That’s how we maintain our identity? If we make major decisions off-chain, then we might also be a traditional corporation.”

In Aragon, according to the interviewee, the “main DAO has free reign over the budget”. The main DAO holds control over the treasury, and “the other assets have not been transferred away from the association”.

Any token holder can create a proposal for funding from the treasury. To make a proposal, the token holder has to stake 50 ANT.<sup>9</sup> The proposal is first posted to the forum to give members the opportunity for deliberation and feedback. According to the interviewee, the forum is the stage for “off-chain negotiation and politics”. Everyone on the forum can disagree, but “if you have someone in your back pocket that has a lot of tokens, they can overrule that disagreement.” After the forum discussion, the proposal is uploaded to Aragon Voice. With that tool, members can vote on the proposal.

Before an approved proposal is executed, the compliance committee assesses it for alignment with the charter. If it conflicts, the committee has the power to cancel the proposal.


Voting power is represented by the ANT tokens. A DAO member can buy ANT tokens or receive them as compensation for doing “productive work for the network”. Currently, Aragon DAO uses a voting system where one token represents one vote, although the interviewee expressed Aragon’s interest in other voting systems such as conviction voting.

TEC makes a distinction between DAO governance and governance of the DAO and has distinct decision making processes. DAO governance entails the governance of all activities that fall under the DAO, such as approving proposals or deciding whether someone should become a member. Governance of the DAO is the design of the DAO itself. It includes decisions such as proposal design and setting admittance criteria. For both types of decision making, TEC uses self-designed tools within the 1Hive Gardens platform. We now explain how both tools work.

<sup>9</sup> As listed in the Aragon charter, point 5.5.

**Table 6**

Governance Area 2, decision making. dOrg's proposal management integration with its legal structure creates unique, legally binding proposals. Aragon's governance suffers from the value of its token. TEC is in the leading position in voting tooling.

	dOrg	Aragon	TEC
On-chain decision making	Changes to the DAO, proposal funding, new projects, new members, member removal, final stages of the escalation protocol.	Charter changes, proposal funding, electing sub-DAO members.	Changes to the DAO, proposal funding, community signals, large cultural change.
Off-chain decision making	Escalation protocol, project discussions, all other decisions.	New members, community advice, new projects, all other decisions.	New members, community advice, all other decisions.
Proposal management	Members make proposals at no cost on Snapshot. Proposals are not automatically executed.	Token holders make proposals at 50 ANT on Aragon Voice. Any member can execute proposals.	Covenant signers make proposals at 200 TEC on Garden. Funding proposals are automatically executed, others are not.
Voting management	Proposals cannot be challenged and are legally binding. REP. One REP is earned for every USD that a member earns. Additional REP is earned by donating time to dOrg.	The Compliance committee has veto power over proposals. ANT. Tokens can be bought or received for participation in the DAO.	Members judge proposals and can be challenged. TEC Token. TEC is bought at the augmented bonding curve, secondary markets, or earned by community participation.
Voting specification	Voting is free, no delegation, no quorum.	Voting is free, no delegation, 0.5% quorum.	Voting comes with minor xDai costs, delegation for TAO voting, 10% quorum for governance of the DAO, and 4% for DAO governance.

For the governance of the DAO, TEC uses a tool called TAO voting.<sup>10</sup> The tool is used for proposals that alter any fundamental parts of the on-chain DAO. It concerns any decisions impacting meta-governance, smart contracts, token contracts, or other economic parameters. As these decisions have a major impact on the DAO's performance, four measures should lead to better proposal outcomes. First, TAO voting has high voting requirements. It requires a 10% quorum and 85% support to pass. Second, it has lengthy decision periods, as members can vote for five days on a given proposal. Third, the voting system allows for delegation. Members can delegate their voting power to other members. Fourth, delegated votes can change after the results. After the voting period has passed, members who delegated their votes can change them. If this changes the proposal outcome, the voting period is extended by two days.

DAO governance in TEC mainly consists of funding proposals, and the DAO uses an unusual method of voting.<sup>11</sup> Votes are "counted" in a method called conviction voting, which follows the design of Zargham [76]. Conviction voting measures the conviction of its electorate toward a certain outcome. Instead of dichotomic yes-or-no voting, members support proposals by allocating tokens for a certain period. The weight of a vote increases over time, up to a limit. Currently, tokens gain half of their potential weight in seven days and reach 75% in 14 days. Funding proposals require 4% of the total potential weight to pass. The maximum funding for a single proposal is set to 11% of the total common pool.

#### 5.4. Legal foundation

A descriptive overview of the legal foundation of the three DAOs is shown in Table 7. dOrg is the first DAO to be legally registered as a BLLC in the state of Vermont [77]. Regarding the liability of the DAO and its members, the interviewee stated, "Being an LLC, everyone is a co-owner and contractor, and so we use the limited liability of US corporate law". Later, during the interview, the interviewee elaborated that the members are independent: "Since they're contractors, they have their own business ... Maybe it's specific to U.S. law, but every contractor

has their own LLC, their own business and so they contract with dOrg". This legal construction is the current best conceivable for the DAO and its members. The BLLC guarantees the DAO's legal existence and legal compliance. At the same time, the members' LLC protects them from liabilities while they interact with dOrg.

dOrg strives to produce software under an open source license: "For the stuff we build, we prefer to use open source. Usually, MIT, because if we build something, we want anyone to be able to use it for any reason, change it, or contribute to it. The things we build for our clients on our behalf are open source or closed source, depending on our clients' preferences."

dOrg ownership is formalized in its statutes. The dOrg DAO is owned by its members proportionate to the on-chain reputation of each member.<sup>12</sup>

The legal status of Aragon remained unclear in this case study. The charter of the Aragon Network DAO contains a section that explicitly states, "The Aragon Network is not intended to have legal personality" (section 2.2e). The interviewee brought some nuance to that statement, "[We are not] ideologically opposed to it. [...] When it makes sense, there could be a legal wrapper, [since] the space around legal wrappers is rapidly evolving."

To overcome Aragon's legal indistinctness, the Aragon DAO has chosen to transfer the liabilities to a committee. The charter states: "The Compliance Committee members assume full legal responsibility for the approval of any illegal, unlawful, criminal, or fraudulent proposal" (section 6.4e). However, the liability for individual voting members remains unclear.

According to the interviewee, the software is open source. However, the Aragon Association holds brand ownership and treasury access and has repository keys. According to the interviewee, the association "will [in the future] transition those assets into the DAO". For now, the Aragon DAO appears to be owned fully by the association.

The TEC DAO is not represented by a legal entity or legal wrapper. The Commons Stack, the organization that initiated the TEC, is represented by a Swiss foundation. Commons Stack also creates a codebase and cultural guidelines, but it is not involved in the creation of the DAO. Members of the Commons Stack Association who participate in the TEC Hatch DAO do so as individuals.<sup>13</sup> TEC releases its software under GPLv3.

<sup>10</sup> TAO voting is explained in the TEC handbook: <https://token-engineering-commons.gitbook.io/tec-handbook/governance/voting-tools-and-methods/tao-voting>. The established parameters are also listed here.

<sup>11</sup> Conviction voting is explained in the handbook and on Medium. The explanation and the parameters are available at: <https://token-engineering-commons.gitbook.io/tec-handbook/governance/voting-tools-and-methods/conviction-voting>.


<sup>12</sup> The ownership structure is explained in the dOrg handbook at <https://docs.dorg.tech/>.

<sup>13</sup> As stated in the Hatch terms, <https://token-engineering-commons.gitbook.io/tec-handbook/voting-templates-and-the-bonding-curve/hatch-proposal-template/full-hatch-terms>.



**Table 7**

Governance Area 3, legal foundation. dOrg is the first blockchain-based limited liability company (BLLC) in the world. Aragon's charter prevents its registration as a legal entity. TEC created a unique ownership in which the DAO owns itself.

	dOrg	Aragon	TEC
Legal structure	Registered as a BLLC in Vermont	No legal entity. Aragon Association takes on certain responsibilities	No legal entity. Commons Stack association provided funds for legal defense
OSS license	MIT for public projects, various licenses for client projects	GPL or AGPL	GPLv3 and MIT
Ownership and control	DAO ownership is proportional to tokens held	The Aragon Association holds trademarks, repository keys and funds	The DAO owns itself. TEC token holders have full decision power

TEC has created a remarkable ownership structure for itself. The purpose is to become as independent as possible. The TEC DAO is deployed and owned by the DAO itself, including all of its contents, functionalities, and elements. Holders of TEC tokens also govern the protocol that provides infrastructure and services. Since they govern both the DAO and the underlying infrastructure, the electorate can change all the elements that constitute the DAO. As a result, there is no ultimate owner besides the DAO and the community that governs it.

### 5.5. Project chartering

The summary of the project charters is given in Table 8. dOrg's charter is called the builder covenant and consists of a list of standards and a list of expectations of professionalism. The covenant did not exist until they encountered "internal challenges and disputes", and discovered that they had not laid out the expectations of behavior for their members. Therefore, the DAO drafted a builder covenant. It was approved through an on-chain vote. The covenant consists of a list of examples of expected behavior, a list of examples of unacceptable behavior, and a description of the situations when the covenant is in effect.

The Aragon Network DAO charter contains a manifesto titled *The Aragon Manifesto: A Pledge to Fight for Freedom*. The interviewee stated that specifying a structured mission and vision has been overlooked, which leaves Aragon without a formal DAO purpose. Adding a mission or vision to the charter would need on-chain proposal acceptance, which requires a 0.5% quorum (section 2.2f). However, according to the interviewee, the current charter was enacted while only receiving 0.2%. The interviewee states that "most people don't care enough to show up to vote".

In addition to the manifesto, the charter contains guidelines, provisions, agreements, and a description of the structure and responsibilities of the DAO. Finally, Aragon's roadmap and release plans are managed by the Aragon Association.

For TEC, the mission, vision, and values document were designed and approved by the community. The community held that it should be a collaboration of all members to form the mission, vision, and value statements, but it did not find a suitable design process. Therefore, they created a process in collaboration with Tokenlog.

The procedure consisted of two phases. First, community members could submit proposals for TEC's mission, vision, and values in Tokenlog. They could also fork submissions and submit a modified version. Afterwards, a community vote on the top submissions determined the final statements. Snapshot was used for this final selection. This process had three advantages for the community. First, it allowed the curation of the ideas of all community members. Second, it encouraged active community involvement. Third, community participation in the design process should lead to more support and adoption of these statements.

The created covenant contains three sections: 1) the pledge to which all members commit; 2) a set of standards for acceptable and unacceptable behavior; and 3) decision making process descriptions.<sup>14</sup> The covenant is a living document and is currently in its second iteration.

During the hatch phase, the TEC had a clearly defined and community-accepted roadmap to launch the DAO. However, since the hatch phase ended and the DAO was built, the TEC lacked an overarching roadmap. The vision for the project has been further decentralized as the WGs autonomously determine their own roadmaps. Nevertheless, the interviewee remarked that creating a new roadmap would give more support to their vision.

5.6. Incentive

Within dOrg, the primary incentive for software development is compensation based on an hourly rate. Members are paid in stablecoins. For governance, dOrg uses a non-transferable token that reflects the member's reputation. It is based on two work aspects. A member who generates revenue will receive a reputation for that. He or she also earns a reputation for internal work. These tokens grant voting rights, and possession can lead to election as a signer. An overview of the incentives and token models is provided in Table 9.

Within Aragon, development is mostly handled by the Aragon Association, which has employees and contractors. Some components are outsourced to teams outside of the association. These people are "incentivized through funding proposals".

Aragon has other incentives to participate. It tries to foster a culture of appreciation and recognition. According to the interviewee, people are also attracted to the Aragon brand. "Aragon has been one of the first projects in the DAO space". This attracts individuals who "want to make the world a better place".

Aragon's ANT token is a transferable token that can be freely bought and sold. It has two uses. First, it is a currency, as ANT is used to fund projects and reward community members. Second, it is a governance token, as possession of ANT gives voting rights.

Etherscan shows 43,029,810 tokens in circulation. The tokens are controlled by a meter contract. New tokens could be minted by the committee that controls the pool of assets. The interviewee remarked that this put immense power in the hands of some individuals. The only limit that prevents the committee from freely minting additional tokens would be the community and the market response.

Token holders have one more benefit from possessing ANT: they can become jurors on the forum of the arbitration system. "You have to stake ANT to be able to be part of that pool of jurors that gets elected to vote on things within the arbitration system". The interviewee stated that tokens are not burned or taken out of circulation, and there is no reputation system in place.


For TEC, the development incentives are funding to the WGs. The Commons Swarm is the main WG that develops the DAO. However, some of the other WGs also develop software.

TEC has a comprehensive set of participation incentives. It consists of proof of attendance protocols (POAPs), education, and two reward

<sup>14</sup> This community covenant can be found at <https://forum.tecommons.org/t/tec-community-covenant/572>.

**Table 8**

Governance Area 4, chartering. dOrg has a concise covenant to guide its small community. Aragon has a manifesto that appears weakly aligned with its community. TEC covenant is created by its community in a collaborative process.



	dOrg	Aragon	TEC
Mission and vision	dOrg's covenant includes a mission and vision statement and was approved by on-chain community vote	Aragon's charter contains a broad manifesto: A pledge for freedom. A concrete mission or vision has currently not been established	TEC has a mission and vision, built by its community
Value and norm	Covenant describes standards for behavior. Additionally, dOrg has a list of core values	The Charter describes a code of conduct with examples of behavior	A code of conduct describes behavior practices for members Organizational norms describe DAO practices
Roadmap	Decisions made at the project level	Determined by the Aragon Association	No overarching roadmap as DAO is no longer in build mode, but evolved to operational mode. Working groups may have their own roadmaps
Release plan	Decisions made at the project level	Determined by the Aragon Association	Working groups have autonomy to organize release plans

systems. We briefly discuss these four methods that encourage community building.

The two reward systems of the TEC are SourceCred and Praise. These systems collect community member contributions. SourceCred captures measurable contributions, such as the number of likes, forum posts, and time spent in meetings. Every contribution has a value based on previously defined parameters. The Praise system rewards hidden or invisible work. Members praise hard-to-measure work that is deemed eligible for remuneration.<sup>15</sup> The system stores all the praise in a list. Randomly selected DAO members discuss the entire praise list in a periodic quantification process. In this process, every praise receives a monetary value. SourceCred and Praise thereby create an overview of eligible rewards for all members. This is paid out periodically in TEC tokens.

TEC also has two non-monetary rewards: POAPs and education. TEC utilizes the POAP for community recognition. POAPs are NFTs that members receive as badges of accomplishment. These POAPs can be displayed in the community. In our research, we came across different achievements, including the 2021 TEC Steward and a Hatcher title.

Education is the final DAO participation incentive. The interviewees stated that education motivates people to contribute to the DAO. Working in the DAO prepares for cryptocurrency jobs. The TEC even offers internal training to its members.

Finally, people participate in TEC because of the open culture of the DAO. The culture is described as “welcoming, radically open, inclusive, and transparent”, which makes people eager to participate. Members feel that they are part of a community that they perceive as revolutionary and at the forefront.

The final remark about TEC's incentives is its currency design. Where other cryptocurrencies suffer from high-value fluctuations, the TEC DAO has a unique way of ensuring crypto stability. The price of TEC tokens is kept stable by an augmented bonding curve (ABC). The ABC is a set of smart contracts that create a local economic ecosystem. It will buy and sell tokens at a self-determined rate. When the ABC distributes many tokens, the exchange rate goes up, and vice versa. This leads to an economic system with three advantages: 1) Since the token can always be bought and sold, there is infinite liquidity. 2) The ABC will always buy and sell tokens and therefore create a stable exchange rate. 3) The ABC takes tribute when buying or selling TEC tokens. The tribute is added to the common pool treasury. The use of the ABC therefore generates additional community funding.

### 5.7. Community management

Unlike most OSS projects, where a community may form around the OSS product itself, dOrg is a closed organization. One cannot freely participate in dOrg. In fact, currently, it is “incredibly selective, in terms of who can join”. To join dOrg, a person can fill in the *builder interest form* to show his interest. The potential member is interviewed, and feedback of the interview is posted on the forum. The existing members deliberate over the potential new members. If the candidate passes the subsequent Snapshot proposal, they are on-boarded. The identity of every member is verified, as members are contractors from their own companies. dOrg verifies that their information is compliant with the law.

Regarding the management of conflicts, in dOrg, “Ultimately, things come down to the escalation protocol”. For instance, if members fundamentally disagree with project managers, the matter would be handled according to the escalation protocol. In the most severe cases, an on-chain vote determines the conflict outcome.

Within Aragon, individuals do not become DAO participants by following a joining process, as there is none. Instead, buying tokens is the method for DAO affiliation. Token holders are not vetted or required to show alignment with the project. When a token holder applies for funding, the funding proposal should provide justification for the strategic alignment of their proposal. In the words of the interviewee, “We don't want the association to be the single chokehold of power. You can do something different, but you need to explain why you are doing it”. Currently, there are no protocols other than the arbitration system to handle conflicts. The community management overview is shown in Table 10.

TEC has the most extensive community management. There is an extensive onboarding process and conflict resolution.<sup>16</sup> At the same time, there is no formal definition of the community or stakeholders. One interviewee suggested that the DAO and the active community are two different things. A person can be a token holder without participating in the DAO, while others may be active without holding any tokens. There is no formal process for a new member to join the DAO. The DAO is open to anyone, and all “meetings are open to anyone”. Anyone can buy tokens. The other interviewee suggested that anyone who received praise could be considered a member. So far, TEC has not formalized the definition of community.


Despite the absence of a formal joining process, the DAO has the *Communitas WG*, tasked with facilitating the community and onboarding new members. As one interviewee explained, “Their main objective

<sup>15</sup> For example, the interviewees praised the researcher with a discord message: “!praise [researcher] for the long 2-hour discussion with [name of interviewee].”.

<sup>16</sup> These processes are described in the TEC handbook: <https://token-engineering-commons.gitbook.io/tec-handbook/processes/how-do-we-work-together>.


**Table 9**

Governance Area 5, incentives. dOrg's reputation token creates meritocratic leadership. Aragon's token is controlled by its committee. TEC has an elaborate model to reward all DAO participation.

	dOrg	Aragon	TEC
Development Incentive	Builders are paid in stablecoins, and have occasionally a reputation-weighted bonus	Aragon Association develops the software	Working groups receive funding from funding pool
DAO participation incentive	None	Monetary rewarding of tech support guild	Token engineering education, SourceCred, and Praise systems give rewards for social building, event participation POAPs
Token model	No fungible token model	ANT token grants governance rights and has monetary value	TEC token grants governance rights and has monetary value
Reputation model	Reputation as a token	No reputation model	Praise, SourceCred, NFTs

**Table 10**

Governance Area 6, community management. dOrg is a selective collective that eases its community management. Aragon uses token acquisition as a joining process. TEC's Gravity working group is a solution to community conflicts.

	dOrg	Aragon	TEC
Joining Process	Joining by referral or suitable builders are selected from the list of applicants when needed. Candidate builders are then interviewed by existing builders. Interviewer creates a proposal to accept the new builder. After acceptance, the new builder is on-boarded	No formal joining process. There's a growing list of ways to participate. Work streams are proactively being pushed towards the community and offloaded from the Aragon Association. This is done by providing funding and actively including community members	Communitas working group facilitates onboarding experience by proactive engagements and personal guidance
Vetting of new members	Candidates are evaluated on the forum and through a proposal	Contributors are not vetted. When applying for funding, arguments for (strategic) alignment with the project must be given	Participating in TAO voting and conviction voting requires on-chain signing of the covenant
Identify verification method	The identity of builders is verified by their legal agreement	Commercial solution	No identity verification
Conflict resolution	Escalation protocol manages conflicts	Funding contracts can be ceased. Members in a formalized position of power can be removed. Arbitration system: Aragon Court	Gravity working group educates mediators and creates processes for conflict mediation, conflict resolution, and graduated sanctions

is to create social cohesion in the existing community". Communitas consists of guides who welcome new members.<sup>17</sup>

For participation in TEC voting, a formal affiliation is required. Token holders who want to vote have to sign the covenant through an on-chain transaction.<sup>18</sup> In this way, members show their awareness, understanding, and agreement with the values of the DAO. The identity of the members is, according to the interviewees, intentionally not verified.

The DAO has a specific WG assigned for conflict resolution. The Gravity WG offers conflict mediation and provides mediation training. The training courses are 8 to 10 weeks each and cover topics such as nonviolent communication, mediation, role-playing, and leadership. After completing training, participants receive a POAP for training completion.

While many DAOs experience conflicts, TEC has experienced few fights in its community, as stated by the interviewee. Therefore, the interviewee held that Gravity's approach was successful in managing conflicts.

### 5.8. Software development processes

The essence of an OSS producing DAO is the production of software. Even though all three DAOs have software production as their goal, they

define only a few software development guidelines at the DAO level. The DAO strategies for software development are shown in Table 11.

dOrg is not working on a single OSS project but is involved in many (client) projects. Therefore, it did not create overarching software development processes. Instead, the tech lead defines the code acceptance procedures at the project level. As the interviewee said, the "tech lead is responsible for the technical delivery of a project, and so ultimately the technical side".

Regarding the release procedures, the interviewee states, "The release process is appropriate to a project. It depends on the needs of the team, [and] the needs of the client." Since the needs, requirements, team members, and stakeholders differ per project, these governance aspects will also differ per project. Even though dOrg and the interviewee insist on tailor-making processes for projects, it also created a quality assurance worksheet. The worksheet sets a software development baseline for project managers and tech leads. The interviewee explains, "We started with this QA worksheet guide. These are our best practices. We want our project managers and tech leads to make sure these are getting covered." We observe that this is an initial DAO-level formalization of the software development processes within dOrg.

Currently, within Aragon, software development is mainly handled by the association. The association oversees task responsibility distribution and code acceptance procedures. The tech committee sub-DAO approves releases and deploys accepted proposals that contain new code (section 5.1c). The tech committee also has the authority to remove proposals that do not meet technical quality standards.


TEC does not define DAO-wide software development processes. Instead, software producing WGs have a high level of autonomy. The WGs use GitHub projects to allocate work to people. According to one interviewee, the WGs follow standard procedures in software development,

<sup>17</sup> The communitas role is described in the handbook: <https://token-engineering-commons.gitbook.io/tec-handbook/cultural-components/working-groups/communitas>. Its group manifesto is maintained by the group itself at: <https://tinyurl.com/mvn5ry3v>.

<sup>18</sup> The covenant is available in the TEC forums at: <https://forum.tecommons.org/t/tec-community-covenant/572>.

**Table 11**

Governance Area 7, software development processes. All three DAOs have little overarching processes defined.

			dOrg	Aragon	TEC
	Task	responsibility	distribution		
	Code Acceptance procedure		Depends on project and expertise	Handled by the association	Tasks are divided over working groups. Working groups further partition these tasks themselves
	Release procedure		QA worksheet defines development and code acceptance procedures	Handled by the association	Working groups have highly autonomous procedures but follow industry practices
			Procedures differ per project and depend on the needs and requirements	Releases are approved by the Technical committee	No overall defined processes for release procedures

such as having a code reviewer and a merging process. As the interviewee explained, “I’ve seen a few different groups who use what you would expect”.

### 5.9. The effectiveness of governance in the three DAOs

In this framework, we divided DAO governance into seven governance areas, but it remains an entangled phenomenon. Therefore, we use this section to reflect on the overall governance of the three DAOs.

The dOrg interviewee concluded, “I feel like we’re covering [dOrg] pretty well. This is an insight, because sometimes being in a collective, things are messy. But we are hitting our base well.”

dOrg is registered as a BLLC in Vermont and is therefore legally registered. Their incentive designs compensate for their builders in stablecoins and separate the governance utility from the monetary incentive. This ensures that governance power cannot be gained in a simple manner by simply buying tokens. Instead, it encourages long-term commitment to the DAO.

dOrg moved away from the DAOstack, its original on-chain DAO framework infrastructure. Instead, it votes on Snapshot, and its treasury is on Gnosis Safe. This reduces its gas fees. Every project has its own treasury. Project-level finances and decisions have thereby been separated from DAO-wide decisions.

dOrg has created an effective governance design and solved its problem of high gas fees. Its governance strategy consists of electing highly skilled individuals. The most committed of these are selected for leadership. This creates a DAO that is competitive and more structured than the other two. It remains relevant to the question of whether the dOrg model can be copied for other collectives and to what degree it can be scaled.

The Aragon interviewee acknowledges that “there are a lot of things [governance mechanisms] that we are not currently doing, but that we are thinking of. You [the interviewer] are touching upon those things”.

The Aragon token holds a significant value and is divided across 12,000 token holders. At the same time, Aragon faces difficulty in attracting voters with turnouts of 0.2% or lower. The development of the DAO is actually hindered by the high value of ANT. The value of the token may attract investors who are less or not at all interested in governance.

Even though Aragon is built around a DAO, the decoupled proposal execution, the influence of large token holders, and the fact that most work is performed by the association indicate centralization. The DAO appears to be very dependent on the association. At the same time, the push of workstreams and the transfer of treasury funds to the DAO indicate a move toward a further decentralized governance structure.

The TEC DAO built its governance and the tools needed to support it. Instead of investigating the technological possibilities that a DAO offers, they started from a social foundation through their cultural build.

TEC’s culture, grounded in Ostrows 8 principles, is at the foundation of many aspects of the DAO. The principles were encountered in many of the governance dimensions that were discussed in the interview.

Noticeably, the DAO possesses an arbitration mechanism to overrule proposals that are not in line with the charter of the DAO. This is a human control mechanism that limits the autonomy of the DAO.

The development of TEC DAO can be characterized as ad-hoc. Often, its members built tools that they needed, as the tools did not exist. One of the interviewees remarked that he experienced DAO development as if they were “building the airplane as you jump off a cliff”.

## 6. Discussion

Now that the framework is defined and we have displayed how dOrg, Aragon, and TEC govern themselves, we turn to the discussion of our research. In this research, we addressed the following research question: *How are OSS producing DAOs governed?* We have provided a two-fold answer to this question. The first answer is an academic framework that categorizes governance mechanisms for OSS producing DAOs. Afterwards, we used this framework to analyze the governance of three leading DAOs. The second answer is the governance practice of those DAOs. In this section, we first address the viability and reliability concerns of this research. Afterwards, we discuss the relevance of the framework and link it to the literature. As a concluding part of this discussion, we list opportunities for further research.

### 6.1. Addressing validity and reliability concerns

The method that created the results must be assessed for validity and reliability concerns. Here, we note the threats to framework validity, external validity, framework reliability, and case study reliability.

We assessed the **framework validity** together with the interviewees. It was the final part of the interview. In general, the interviewees made three positive remarks. First, the framework was able to map the DAO’s governance structures well. Second, the framework provided clarity and structure to the various aspects of DAO governance. Finally, the framework reminded them of the importance of some of the governance aspects. Sometimes, a lively discussion in the interviews arose regarding how the framework could help structure the existing governance processes.

We asked the interviewees whether they noticed irrelevant mechanisms or if any were missing. There were no mechanisms that were irrelevant for practitioners. We observed that the DAOs had few software development practices in place. However, the interviewees remarked that it is important for the DAOs to create these practices and that they are part of their roadmap. Therefore, we did not remove any governance mechanisms from the framework.

The case studies did reveal missing elements from the framework. We found two elements in the case studies that were absent. There were arbitration mechanisms and a financial layer. Aragon and TEC have an arbitration mechanism that allows members to challenge proposals against the DAO charter. The TEC case study also revealed the absence of financial governance in the framework. The interviewee remarked that the framework could be extended to fund governance or compensation decision making. Although financial decisions are an aspect of governance, we did not observe them in the DAO governance literature. Therefore, for this current work, we considered it out of scope. In future work, we would like to extend the framework with these two mechanisms.



The **external validity** of the framework was tested in the case studies. To evaluate whether the framework is valid for many OSS producing DAOs requires diverse case studies. The DAOs that agreed to an interview had a significant variation in purpose and governance maturity. Our framework was valid for these three varied DAOs. Therefore, we suspect that our findings can be applied to other OSS producing DAOs.

This study mitigates threats to **framework reliability** by utilizing a structured approach and by employing standardized research methods. Sourcing the literature was performed through a predefined search string with strict inclusion and exclusion criteria. This mitigated inclusion and exclusion biases. We tried to mitigate research bias by using tools in the framework creation. NVivo was used to extract, codify, and group OSS and DAO governance concepts. To further increase the transparency of our framework creation, we also published our datasets online.

Two aspects of the method contributed to this research's **case study reliability**: The availability of information and the use of an interview protocol. First, the DAOs published many internal documents online for open access. Therefore, we could create rather complete overviews of their governance before the interview started. This complete overview of DAO governance led to an effective interview, as it was a mere validation of earlier observations. Because of the large availability of information, the initial description was often correct. We selected interview candidates who belonged to the inner core of the DAOs. Because of their intense participation, they were able to adequately cover all our observations. If there was any uncertainty about the observations, we would have conducted another interview round.

Second, the strict interview protocol helped to create a reliable case study. Since we structured the interview along the governance areas, the findings followed the framework. In the transcription, we could easily map the findings across the governance mechanisms. Making the protocol out of the framework had another advantage. The protocol ensured that every governance mechanism would be discussed. We ended the interview by asking open-ended questions about governance mechanisms outside of the framework. This was another way to ensure that we published a complete overview of the governance of the DAOs.

## 6.2. Contrasting OSS producing DAOs with OSS communities and DAOs

The context of this work can be visualized in a Venn diagram. One circle contains OSS communities, and the other contains DAOs. The small intersection contains DAOs that produce OSS. DAOs and OSS projects are two different forms of organizations that have different origins. The OSS producing DAOs inherit characteristics from both other organizational types. If a practitioner were to ask which of those three forms of organization he needs for his project, we would give him a many-fold answer.

To allow for comparison, we list the characteristics of these organizational types according to the organizational value model of Jones [78]. The model abstracts the value creation of organizations in three stages: input, conversion, and output. Each stage is affected by the environment in which the organizations operate. We have added a governance layer to the model, as it aids in clarifying the differences between the three types. The overview is shown in Table 12.

OSS producing DAOs inherit features from both OSS communities and DAOs, although these features are not equally distributed across the stages. With respect to organization inputs, there are few differences at the organizational type level. We recognized the same workforce roles in OSS producing DAOs as in OSS communities and DAOs, although the role of community builders is important in OSS producing DAOs. OSS producing DAOs are similar to DAOs regarding funding. The big tech firms that provide major funding to OSS projects [79] were not observed in the case studies.

Regarding the operation in the conversion process, OSS producing DAOs follow both the pull and approval requests of OSS projects and

the on-chain proposal structure of DAOs. Section 5.3 shows how the off-chain and on-chain decisions complement each other in OSS producing DAO production.

The outputs of OSS producing DAOs are similar to those of OSS communities. Both develop software. The software comes with additional services such as education or funding for OSS producing DAOs, which is not always the case in OSS communities. OSS producing DAOs provide their members with recognition and financial tokens, and the observed case studies also used the tokenized rewards that DAOs provide.

The environment of OSS producing DAOs is more similar to that of the DAO organizational type. Both suffer from legal ambiguity and have limited tooling available. OSS producing DAOs are aimed at lead users in technical domains, whereas the two larger organizational types have a wider aim. OSS producing DAOs are unique in their lack of competition compared to the other two organizational types. The case studies did not show competition between OSS producing DAOs.

Foundations are common legal representations for all three organizational types. At the same time, many DAOs do not have any kind of legal representation. With regard to governance formality, OSS producing DAOs combine the off-chain formal roles of OSS communities with the on-chain smart contract-defined roles of DAOs. This combination is maturing, and we see that the case studies take different stances on the integration of governance formalities. Finally, in terms of ownership, there is a wide variety of ownership models in all three organizational types. DAOs add flexibility to ownership structures, facilitating experimentation with new ownership models [80].

An OSS project that is willing to accept the regulatory ambiguity and lacks mature tooling can benefit from a DAO. Its advantages include flexibility in rewarding and governance structures, a field with few competitors, and the opportunity to experiment with operations, funding sources, and ownership models. While the added value of using a DAO may not be realized in all cases, it allows organizations to achieve their intended goal in particular situations. For example, dOrg's desire for radical decentralization and flexible governance is realized by their use of a DAO.

## 6.3. Framework positioning within the research field

This research is the first attempt to create an overview of the governance mechanisms that OSS producing DAOs use. We provide a foundation for establishing shared understanding and discussion on the topic of DAO governance. The framework serves as a foundational basis, providing the concepts and terminology necessary to categorize and delineate the frequently intertwined governance facets inherent in a DAO.

This research complements blockchain governance research by adding more sophisticated community mechanisms. We follow the example that Liu et al. [42] set. These authors simplified blockchain governance by breaking down its governance into concrete principles. Their emphasis on community governance gives a deeper understanding of why some DAOs fail to govern their funding and community, and others succeed.

This research touched upon two other DAO governance aspects that we address here: The intertwinement between social and technical governance and the combination of on-chain and off-chain decision making.

The OSS producing DAO governance framework combines social and technical governance aspects. However, the practice of DAO governance shows that these aspects are inseparable. This is also seen in the final version of the framework, as every governance area contains both technical and social mechanisms. This intertwinement is also visible in other authors. Markus [15] insisted on understanding the social requirements of producing OSS. Another study by van Pelt et al. [13] called the community one of the three pillars of blockchain governance [13]. A correct alignment of community governance with the on-chain protocol is crucial.

**Table 12**

Comparison of OSS communities, OSS producing DAOs, and DAOs in general. The blue column is the object of this study. Italicized text parts are empirical observations, whereas normal text is the researcher's observations of the entire field.

Stage	Factors (Jones [78])	OSS communities	OSS Producing DAOs	DAOs
	Workforce	Software developers, designers, and enthusiasts	<i>The case study DAOs had Software developers, enthusiasts, community builders, and domain experts</i>	Software developers, legal experts, community builders, and domain experts
Organization's Input	Funding source	Big Tech, independent individuals, and foundations	Variety and experimentation lead by venture capital. <i>Case studies display venture capital (Aragon), independent foundation (TEC) collaboration of independent individuals (dOrg)</i>	Venture capital, foundations, and companies
Organization's Conversion Process	Operation	Pull requests make changes, approved by product owners	<i>Both OSS and DAO practices were observed</i>	Changes proposed on-chain, approved by whole community
Organization's Output	Delivered goods	Open source software and related propositions	<i>Open source software, but the case studies also provided education, funding, and other resources</i>	Various outputs including financial assets, tokens, and software.
Organization's Environment	Membership incentives	Organizational membership and recognition	<i>Both recognition and financial tokens</i>	Cash money, tokens, and recognition
	Regulation	Transparent and clear OSS licenses	<i>OSS DAOs face legal ambiguity just as DAOs</i>	Legal ambiguity and complexity
	Tooling availability	Many mature OSS tooling available	<i>OSS DAOs are hindered by a lack of tooling</i>	Governance is frequently hindered by tooling immaturity
Organization's governance	Clients	Wide variety of all types of clients	<i>The case studies aimed to attract lead users in technical domains</i>	DAOs are mostly oriented to clients with technical or financial expertise
	Competitors	Competition between OSS projects and with commercial software	<i>The Nascence of the field so far limits competition. Even Aragon has no real competition</i>	Intense competition because of low switching costs. Participants are not committed to DAOs and follow the highest return
	Legal representation	Foundation as typical organization	<i>The case studies all had foundations</i>	Foundation or only smart contracts
	Governance formality	Adoption of formal roles and structures	<i>A combination of smart contract defined roles and formal roles. dOrg had only smart contract-defined roles and responsibilities. The others had mostly non smart contract defined roles</i>	Smart contract defined roles and responsibilities
	Ownership	Different types of ownership: a foundation, directors, or a benevolent dictator	<i>Either foundations or token holder governance. Ownership by tokens was observed in dOrg. A foundation was used in the other cases. One of the DAOs was in legal possession of itself</i>	Foundation or stakeholder governance by tokenholders

This research integrates these findings and makes three contributions to combining social and technical governance. First, the framework provides concrete governance mechanisms that a DAO community can consider for bridging the sociotechnical gap. These mechanisms aid in creating the sociotechnical integration of leadership and decision making. Second, the case studies, analyzed through the lens of the framework, reveal three attempts at aligning the social and technical aspects of DAOs. These results provide guidance on successful and unsuccessful governance strategies.

Second, the framework allows DAOs to reflect on their governance structure and find opportunities to improve. For DAOs with a nascent governance structure, the framework can be used as a blueprint and can help the DAO sketch its governance. When we discussed the framework with the SecureSECO DAO,<sup>19</sup> a DAO with nascent governance, the participant remarked that it can help the DAO mature by providing clear steps to nurture governance. For mature DAOs, the framework can be used to critically reflect on the existing governance structure. TEC, which may possess the most mature DAO governance structure to date, remarked that “The framework provides clarity and structure to the governance aspects. The framework may be used by DAOs to track the maturation of their governance as they continue to build the DAO.

The final governance aspect we mention here is the combination of off-chain and on-chain decision making. The framework contains both processes, and we observe a beneficial complementarity between off-chain and on-chain governance. It can be good, necessary, and effective to conduct the majority of decisions off-chain, especially for decisions

that do not affect the majority of a DAO. In our view, this does not affect the decentralization of a DAO. We therefore disagree with the view of Rikken et al. [80] that the lack of automatic execution of decisions always affects decentralization. Sometimes it might be necessary to put decision making power in the hands of an individual. Emergencies might require this. However, this decision to trust an individual should not be taken lightly. It would create a kill-switch or emergency dictator. Only with powerful checks and balances can it be used well. These rules should be grounded in the DAO charter. This is in line with Rijers et al. [30]. These authors proposed a similar role for the Ethereum foundation in the Ethereum blockchain.

#### 6.4. Future work

This research integrates findings from OSS governance research and observes how DAOs present new opportunities for OSS project organization, incentive models, and further decentralization of OSS development. DAOs, as a form of advanced decentralized governance, could create approaches to solving societal challenges that were previously not possible. However, the novelty of DAOs makes it challenging to understand the full extent of this new technology. Therefore, the field has many opportunities for research.

Here, we propose future work in OSS producing DAO governance and mention larger opportunities in the field.

There are two research opportunities in governance frameworks for OSS producing DAOs. First, research can enhance the completeness of DAO governance frameworks by adding two governance aspects that were not present in the literature: the aforementioned financial dimension and the arbitration mechanism. To make this possible, we recommend further exploration and research on these aspects. Second,

<sup>19</sup> A DAO to secure the worldwide software ecosystem. <https://dao.secureseco.org/>.

further research can deepen the governance aspects of this framework. It can define health metrics, maturity levels, and stages for the existing governance mechanisms.

A second area for future work is the investigation of financial governance in DAOs. None of the DAO governance articles in the literature investigated financial governance. At the same time, understanding financial stability in DAOs is becoming increasingly important. There are two reasons that add a certain urgency to this research. First, DAOs have more financial resources than most traditional OSS projects. Second, we have already witnessed several financially mismanaged DAOs. This indicates an increasing need for effective financial governance.

A final area for further research is extending the DAO governance field to other domains. DAO governance is a multidisciplinary field consisting of technology, law, sociology, economics, etc. These other disciplines can help us create a better understanding of DAO governance. When rightly configured, a DAO may even be able to contribute to community building, local economies, and grassroots democracy. However, making a DAO socially relevant would require a synergy between the technical configuration and these other research fields. Building this bridge helps us understand the societal change that DAOs could bring. We consider several scholars from other fields relevant for extending DAO research. These are Ostrom for commons management [43], Schumacher [81] for distributive economies, and Hayek [82] for understanding liberty, decentralization, and society.

## 7. Conclusion

In the aftermath of the 2008 financial crisis, an anonymous researcher created Bitcoin. In a period dominated by the systematic failure of large centralized institutions, blockchains gave hope to an alternative financial system. Since then, researchers and practitioners have created blockchains, smart contracts, and financial investment DAOs. Alternative forms of finance have sparked so much interest that other fields are also investigating similar community collaborations. In this paper, we investigated the governance of one type of new community, OSS producing DAOs.

We contribute to the governance framework for OSS producing DAOs. It describes the seven required mechanisms for successful governance. First, a community that desires to build OSS in a DAO should design a role structure and establish leadership. Second, decision making processes must be established. Third, it organizes legal representation, DAO ownership, and software ownership. Fourth, the community requires the management and steering of members. Fifth, its incentives need to be worked out. Sixth, the DAO establishes effective community management. Finally, the overall direction in which the project should move has to be anchored in software development processes. For these governance mechanisms, the case studies show three practical translations.

In the near future, we do not expect large communities to transfer to the DAO model. Nevertheless, the number of DAOs is growing, and DAOs may well become an adopted organizational form in our society, financial systems, and regulations. One determining factor for this adoption is the establishment of successful DAO governance. It remains paramount for DAO developers and researchers to understand the governance of DAOs, to improve the governance designs of DAOs, and to anticipate attack vectors.<sup>20</sup> In the rapidly developing DAO governance field, this research contributes a foundational high-level overview of the various governance aspects of an OSS producing DAO.

<sup>20</sup> Recently, the Build Finance DAO has been taken over and had its funds drained because of failed governance. An attacker exploited the governance mechanisms of the DAO by creating a proposal that remained unnoticed <https://decrypt.co/92970/build-finance-dao-falls-to-governance-takeover>.

## CRedit authorship contribution statement

**Paul van Vulpen:** Conceptualization, Formal analysis, Validation, Visualization, Writing—original draft. **Jozef Siu:** Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing—original draft. **Slinger Jansen:** Conceptualization, Investigation, Supervision, Validation, Writing—review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix. Supplementary material

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.bcra.2023.100166>.

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