Decentralized Autonomous Organizations – Evolution, Challenges, and Opportunities

Bettina Schneider [1], Ruben Ballesteros [1], Pascal Moriggl [1] and Petra M. Asprion [1]

[1] *University of Applied Sciences and Arts Northwestern Switzerland, FHNW, Peter Merian-Str. 86, Basel, 4002, Switzerland*

Abstract

A decentralized autonomous organization (DAO) is an emerging entity facilitated through blockchain technology. It operates under the principle of a decentralized governance structure void of hierarchical leadership, and decisions are made based on community consensus. As DAO and its mechanisms are still in an early stage, its potential evolution and future influence on enterprises remain unclear. This work elaborates on this emerging type of organization through a literature review and case studies of DAOs to demonstrate the current state of the art. The findings presented include a brief discussion of the technology that facilitates these organizations. Additionally, advancements and the common characteristics of existing DAOs are presented. Examining current and defunct DAOs revealed the challenges these organizations should address to reach their full potential in future application areas. Finally, it is concluded which organizations and industries could most likely benefit from the DAO concept in future.

Keywords

Decentralized Autonomous Organization, DAO, Blockchain, Decentralized Governance

1. Introduction

Decentralized Autonomous Organizations (DAOs) today represent cutting-edge governance structures for organizations in the digital age. They can be described as non-hierarchical organizations managed and shared through a democratic consultation process and whose technical basis are blockchain and smart contracts managed within [1], [2]. For thousands of years, centralized governance structures have been refined through trial and error to their existing form [3] where a hierarchy of formal authority and human actors are responsible for decision-making within an organization. Technological advancements have paved way for a new form of governance structure known as decentralized organizations [4].

The ideology of decentralized governance structures directly conflicts with that of centralized organizations due to their dependence on flat hierarchies and lack of central authority. While the concept of decentralized governance structures has been a long-standing research topic for many years [4], the rise of blockchain technology has emerged as 'a new paradigm' to build a new type of decentralized system [5]. This emerging form of a decentralized system, which makes use of blockchain technology, is introduced as DAO. True to the ideology of decentralization, DAOs aim to operate without the need for traditional hierarchical management models as well as centralized control or authority. Instead, these types of organizations aim to rely on transparency and consensus-based decision- making built on distributed autonomy and facilitated through blockchain technology [1]. In other words, DAOs support the concept of decentralization by spreading the power of decision-making among its members rather than placing it solely in the hands of a specific authority figure [5].

PoEM'2022 Workshop and Models at Work Papers, November 23-25, 2022, London, UK EMAIL: bettina.schneider@fhnw.ch (A.1); ruben.ballesteros@student.fhnw.ch (A. 2); pascal.moriggl@fhnw.ch (A. 3); petra.asprion@fhnw.ch (A. 4)
ORCID: 0000-0001-8460-3658 (A. 1); 0000-0003-1774-3591 (A. 3); 0000-0001-6582-5087 (A. 4)

While the idea of decentralization is not new, DAOs are still in a relatively early stage of development. Among the many envisioned prospects for an ideal DAO are the ability to hire people autonomously, provide services, generate revenue, own smart property, and coordinate with other software [5]. However, as their inception was only recently facilitated by blockchain technology – with the first major DAO being introduced in 2016 [6] – DAO has not had sufficient time to evolve considerably, making it difficult to determine if its goals will be fully realized [5]. Consequently, emerging DAOs face many challenges, remain in active development, and are open to broader research [5]. Through the literature review of existing research, this work aims to provide insight into their evolution, the challenges they face, and the potential impact they could have on future organizations to raise interest and encourage further discussion. The following research questions are examined:

- What are the characteristics of a DAO, and how has the concept evolved?
- Which challenges do emerging DAOs face?
- How can the DAO concept provide opportunities for future organizations and specific industries?

This work sheds light on what DAOs are and how they may affect future enterprises. While the technology behind blockchain and DAOs will be briefly discussed, it is not the aim of this study to explain in detail how DAOs operate from a technological perspective.

A literature review to answer the proposed research questions was used as primary method and performed according to vom Brocke et al. [7]. The initial step was to define the goal of our study and then develop appropriate research questions. Subsequently, the search process was conducted iteratively using the research databases Google Scholar, IEEE Xplore, and Elsevier. Additionally, 'grey literature' pieces were found through the Google search engine to obtain a community perspective and help further explain some aspects of DAO. The related literature is limited to contributions published after 2015. Furthermore, keywords were used to produce relevant results ensuring the discovery of documents pertinent to the goal and questions posed by this work.

The remainder of this contribution is structured according to the research questions. First, an overview of DAO is provided by exploring what DAOs are, examining their evolution, and identifying their characteristics. Subsequently, the current challenges faced by these organizations are addressed. Finally, the applications of a DAO are discussed by listing some potential benefits and describing possible industries where it could grow.

2. Exploring DAOs

One of the significant drivers of DAOs is that they are grounded on the idea of decentralized decision-making and transparency [5]. The application of these ideas is primarily made possible in DAO using blockchain technology which also relies on principles of decentralization and auditability [8]. As a DAO should not rely on a central authority or power hierarchy, its management, and operational rules to facilitate collaboration are "encoded on tamper-resistant blockchains" [4]. As a result of this encoding of regulations and transactions, DAOs become more transparent than traditional centralized organizations. Additionally, blockchain technology's fast pace and rising popularity have allowed several types of DAOs and DAO building platforms to emerge [6]. As they all use blockchain technology and implement similar ideologies of transparency and democratic decision-making, most of the emerging DAOs share specific characteristics [4]. This section will first present a definition of a DAO, then list its core characteristics, and finally discuss current advancements by examining types of DAOs and platforms.

2.1. Definition and Characteristics

A DAO does not consist of managerial hierarchies, and decisions are made based on member consensus, meaning the community within the DAO governs itself [9], [1]. Members can create proposals, and the community then votes on said proposals to determine which activities the DAO will pursue. Additionally, due to the technology DAO is built upon, activities are handled through

automated processes once decisions have been made [10]. With these characteristics under consideration, DAO can be defined as the following: "A DAO is a blockchain-based system that enables people to coordinate and govern themselves mediated by a set of self-executing rules deployed on a public blockchain, and whose governance is decentralized" [11]. Specifically, the characteristics of DAOs can be described as (1) distributed and decentralized, (2) autonomous and automated, and (3) organized and ordered [4].

Traditional organization forms make decisions based on managerial hierarchies. DAOs lack this central authority and aim to run based on principles of cooperation and equality [4]. With this power distribution, the DAO can only act based on the consent of all of its participants, thereby creating a system void of a single authority or source of power and managerial hierarchies [10]

The autonomy and automation of blockchain technology are additional – yet equal – core characteristics of DAO. As 'code is law' within a DAO, the community can manage itself without need of traditional managerial positions. Moreover, efficiency is enabled through automated processes. When certain conditions are fulfilled, so-called 'smart contracts', with their predefined rules automatically carry out the necessary activities and transactions to facilitate cooperation [10]. In brief, smart contracts are computer programs consisting of rules that can execute autonomously, are trackable and irreversible [12]. The rules in smart contracts allow a DAO to self-manage without intervention of human actors by carrying out tasks once the encoded conditions have been fulfilled. The autonomy and automation provided by DAOs can also promote trust in organizations and reduce costs associated with communication and transactions [4]. Finally, DAOs can be characterized as organized and ordered. Blockchain technology and clearly defined rules in smart contracts provide transparency to the rights of community members and the actions carried out by a DAO [4]. As the blockchain ledger where a DAO's activities are saved is considered immutable and open for public viewing, all DAO members can audit the organization, potentially increasing the community's trust [13]. This transparency increases confidence within the organization, allowing members to operate more organized and coordinated to achieve the organization's goals.

2.2. Emerging Technology

DAOs are facilitated by blockchain technology which allows to integrate democratic decision-making and transparency. Characteristics of blockchain include decentralization (no central authority required for decision-making), persistency (transactions are recorded and challenging to tamper with), anonymity (users can use addresses to avoid identity exposure), and audibility (transactions are validated and can be easily verified). These characteristics are fundamental for creating DAOs [14]. One of the significant aspects of blockchain technology used in a DAO are smart contracts. They allow DAOs to perform activities based on the rules which have been established and coded into the smart contracts. Once these activities or transactions have occurred, they can be validated and recorded on the blockchain [12]. Consequently – as opposed to centralized organizations where transparency can vary – by implementing smart contracts, DAOs can provide a transparent and trustworthy environment where members can track decisions and transactions.

Additionally, DAOs implement transaction tokens that can represent voting or decision- making power. Tokens are a "kind of negotiable digital asset and the proof of rights and interests" [4] within a DAO. By implementing tokens, participants are provided with an incentive. They are – given the privileges to participate in voting processes – enabled to make decisions such as hiring individuals or companies, money-raising activities, or investing [15].

The principles of blockchain technology have been introduced as they allow DAOs to realize decentralization and transparency. Protocols and rules established in smart contracts are followed and autonomously executed, and consensus-based decision-making is achieved with tokens providing participants with voting authority.

2.3. Selected DAO Types

Multiple types and building platforms have emerged. The first major real-world example, known as 'The DAO', was in 2016. This DAO was short-lived as it was exploited within days after its launch. Despite its failings, proponents of DAOs have not been discouraged as new types of DAO are regularly being developed. Platforms such as Aragon, DAOstack, and Colony, have appeared [5]. While DAOs tend to follow general characteristics, there is no singular objective an organization operating as a DAO needs to fulfil. Multiple types of DAOs have evolved, each pursuing different goals.

These emerging types include protocol DAOs that govern a decentralized protocol, such as financial lending and borrowing [16]. A notable example of a protocol DAO is MakerDAO which uses smart contracts to allow users to lend and borrow cryptocurrencies. Two other types are Grant DAOs and Philanthropy DAOs [16]. Both have charitable goals in mind as they facilitate nonprofit donations and help members collaborate on causes that can positively impact them. Investment DAOs belong to some other type of DAOs that aim to pool capital/funds from members to be invested. In addition to those listed above, several other types of DAOs have materialized, and it is likely that as DAOs evolve, other areas of application and goals will continue to emerge.

2.4. DAO Platforms

While creating a new DAO from scratch requires technical know-how, several platforms that can assist with the development and implementation of DAOs have been established. These platforms allow users with limited knowledge of blockchain technology to create a DAO using customizable templates [5]. The broader access these platforms provide could potentially increase the rate at which DAOs expand.

Aragon, [8] the largest of these platforms built on the Ethereum blockchain, allows users to create different types of DAOs with varying goals and purposes and has been used to create over 500 new DAOs. Being the most powerful platform, Aragon offers multiple customization options, allowing users to come up with new variations of DAOs. The platform makes use of tokens that enable users to make decisions related to the DAO they are a member of.

Similarly, **DAOstack** [5] offers voting systems to allow decision-making. However, unlike Aragon, this platform does not offer significant customization options. DAOstack presents its limited number of choices as a positive aspect. First, significant customizations and a larger scope of a DAO increase the effort of qualified personnel for its maintenance. Second, extensive customizations can make DAOs more susceptible to attacks.

An additional noteworthy DAO development platform is **Colony** [5]. As opposed to the previously described DAO platforms, Colony tries to eliminate the need for voting systems through tokens and instead focuses on incentivizing members by increasing their influence when they perform tasks for the organization [5]. Tasks are created based on the goals of this DAO, and when a user completes a piece of work, they can gain more influence within the organization. As Liu et al. [6] state, Colony "focuses on mechanisms that enforce people to get their job done".

The three platforms presented above essentially act as building platforms for users with limited knowledge about the blockchain technology to create a new DAO. Consequently, they pave the way for the emergence of new organizations wanting to apply DAO concepts.

3. Challenges

While multiple DAOs have been created since 2016, it seems too early to concretely state if DAOs will ultimately fulfil the goals they set out to achieve and deliver on the promises of decentralization. This is because several challenges remain unaddressed. The first DAO revealed significant security shortcomings that were exploited shortly after the launch and led to the untimely collapse of the organization. This example, paired with the fact that DAOs have not had the proper amount of time to fully evolve, suggests that there are still challenges and limitations that must be addressed before considering future opportunities for DAOs.

3.1. 'The DAO' case

A brief overview of 'The DAO' case is presented to identify and analyze some of the issues that current and future DAOs may face. When it launched in 2016, 'The DAO' became the first of its kind. It was a new autonomous and decentralized organization made possible through blockchain technology. The organization, which was run on the Ethereum blockchain, was created to allow cryptocurrency investors to collectively fund and manage new enterprises with the promise of transparency, efficiency, fairness, and democratic interactions [3]. Quickly raising $250 million, it was evident that investors had high hopes for the goals and promises offered by the new type of organization. Shortly after the launch, however, an individual could exploit 'The DAO' by using "unintended behavior of the code's logic" which resulted in draining millions of dollars' worth of Ether tokens from the organization's funds [3]. Cryptocurrency exchanges and leaders of the Ethereum platform had to step in to stop the draining and find a solution to protect the investors' funds. This solution was a 'hard fork' of the blockchain ledger. Consequently, 'The DAO' was dissolved.

3.2. Governance Issues

While DAOs intend to operate as self- governing autonomous organizations, the reality is that at this point, they are still susceptible to being affected by external forces and, in some cases, even dependent on external actors [3]. In the case of 'The DAO', the lack of central authority within the organization likely made it difficult to react and attempt to quickly resolve the critical situation. This lack of authority has led to the need to bring in external parties to organize governance. DuPont [3] explains that themoment external actors stepped in to deal with the consequences of the draining of 'The DAO' funds, "the vision of the future governance structures" aspired by DAOs collapsed, as external intervention reflects the thinking of traditional organizations. In other words, while the activities carried out by DAOs are handled through self- governance principles, they remain dependent on external forces and can ultimately be influenced by them [8]. DuPont also states that conducting a 'hard fork' to fix the problem was perceived to be a form of centralized governance whereby an authoritative body decided to fix a problem. From this perspective, the decision of a hard fork appears to be in direct conflict with the idea of decentralized decision-making advocated by DAOs, suggesting that, at this time, such organizations are not truly free from centralized decision-making.

An additional governance issue deals with the voting mechanisms of DAOs [17]. While a DAO acts autonomously as it is governed solely by its community members, it may not necessarily be a fair system, as voting power within the organization may not be equal. While DAOs attempt to implement a democratic system with humans collaborating and acting as decision- makers through voting systems, users are often anonymous and work under pseudonyms, meaning that a single person can create multiple aliases and subsequently cast multiple votes [17]. In this scenario, a single individual casting multiple ballots results in a system that is not genuinely democratic, as one person can potentially have more substantial influence onthe DAO without the other community members. However, this situation is mitigated in DAOs operating under work-to-earn principles such as Colony [5] where members gain influence based on contributions. Nevertheless, as not all DAOs operate in this manner the issue remains a concern.

3.3. Security Risks

As made evident by the case of 'The DAO', DAOs and blockchain technologies in general remain susceptible to security threats which could ultimately result in severe consequences if they can be exploited. Smart contracts, a core aspect of DAOs, can be viewed as a vulnerability as they can be difficult to change after they are deployed to the blockchain [4]. Attackers can take advantage of loopholes in contracts, as was done in the case of 'The DAO' and would not be easy to reverse due to the tamper-resistant nature of blockchain [4].

In addition, Liu et al. derived that the blockchain technology still faces security risks, which makes DAOs susceptible to vulnerabilities. These risks include criminality, inaccuracy, and under-optimization in the contracts [6]. Moreover, blockchain technology as a whole could also be at risk of different types of attacks [14]. As DAO is built around blockchain technology, the risk of attacks on the blockchain could potentially make DAOs vulnerable.

3.4. Uncertain Legal Status

DAOs currently face unclear legal status because the concept emerged only recently and thus has not yet been regulated. As DAOs have not been defined at a legal level, existing laws have no definition or regulations which clearly outline the responsibilities and obligations that DAOs must fulfil [4]. Therefore, DAOs still face uncertainty regarding several legal issues, such as paying taxes and signing legal contracts. There could also be limitations in implementing future legal rules through code as these rules – known as 'wet code' – can often be ambiguous. Implementing such practices into smart contracts may prove challenging as the rules typically coded into a smart contract are clear and explicit, leaving little room for subjective interpretation.

DAOs may struggle even when the law has addressed their legal status. In the US state of Wyoming, DAOs are now allowed to register and obtain legal company status, providing them with legitimacy and accountability when conducting business transactions [10].

While being recognized as an official legal entity could be viewed positively, such status could undermine DAOs potential as it would either require organizations to implement some form of centralized human control or the modification of smart contracts, both of which are either incompatible with the principles of decentralization or the immutability of records on the blockchain [10]. As DAOs are in their infancy, their legal framework must be, at some point, clearly defined, as uncertainty and ambiguity may hamper the development and potential.

In conclusion, due mainly to being in the early stages of their evolution, DAOs still face several barriers which may limit their potential. As was the case in the failure of 'The DAO', these challenges can sometimes have significant consequences.

4. Opportunities

It is too early to predict how DAOs will evolve and if they will ultimately achieve their full potential. Wright, for example, outlines that the research community is faced with questions concerning the suitability of DAOs for existing organizational forms, blockchain-based governance structures, policy making, and (new) use-cases also for traditional industry sectors [18].

Looking at some of the current uses of DAO and examining its principles of decentralization, some suggestions can be made as to which industries may benefit. Recently, while they have not become fully decentralized, some companies have adopted models where employees are given more decision-making power and freedom to take on and manage tasks as they see fit [19]. Allowing employees with this freedom to self-organize without the need to involve top management suggests that some organizations are open to a more decentralized approach which may open the door for future opportunities for DAOs. Additionally, some of the features offered by DAOs could benefit specific industries.

Whereas previous DAOs were pertinent within the crypto-space [20], a shift has recently been observed to more traditional sectors [21]. In the following, potential advantages of those DAOs over traditional organizations are examined. Afterwards, industries where DAOs could have grounds for application are explored.

4.1. Potential Benefits

The technology and decentralized principles behind DAO can potentially change traditional modes of operation by offering future organizations several benefits [19]. One such advantage is directly tied to its decentralized nature. As a DAO is managed by its members, these organizations can forgo

aspects of traditional hierarchy models such as CEOs, boards of directors, and executives, allowing for funds that would typically go to salaries and bonuses for these positions to be used elsewhere in the organization [19]. Additionally, smart contracts could enable pre-programmed reactions to specific customer actions, resulting in improved time management and customer satisfaction, as customer requests could be handled timelier compared to traditional customer services. Tasks that are repetitive and considered rudimentary could also be automated, which would free up time for members or employees of the organization to focus on more critical, value- adding and fulfilling activities [22].

Finally, new compensation structures could be introduced where individuals contributing to a DAO could perform activities and receive compensation. An example is a DAO contributor creating a messaging app required for the organization. At completion, the contributor would receive compensation in form of tokens which represent ownership in the DAO and provide them with voting privileges [22]. In sum, the benefits offered by DAO are numerous, and if it continues to develop and fulfil its potential, the adoption of DAO may continue to expand.

4.2. Application Fields

Charities or other **nonprofit organizations** could potentially benefit by operating as a DAO. One of the critical issues associated with modern charitable organizations is a lack of transparency [16]. Due to this lack of transparency and oversight, donors are often unaware of where their money is going or if it fulfilled the intended purpose. As a result, some charities are sometimes accused of "financial mismanagement and opaque governance" [3]. These issues could then lead to a breakdown of trust between donors and the organizations resulting in a decrease in donations. As previously mentioned, one of the principal characteristics of DAO is transparency, as activities and transactions within the organization are stored on a blockchain, making it difficult to hide or alter them. This transparency means that the activities and fund allocations of a charity operating as a DAO would be publicly visible and could be readily audited by donors [13]. Working transparently would, in turn, increase the level of trust between donors and the charity as it would now be subjected to community oversight. However, it should be noted that some of the issues/challenges mentioned in section 3 still need to be addressed, including the uncertain legal status of DAOs and how tax benefits from charitable donations would be handled.

An additional area where future DAOs may find success is the **banking industry**. In a case study of MakerDAO, Brennecke et al. [23] propose that while some cryptocurrency finance applications are often subject to speculative behavior, DAOs could provide lower volatility. DAO-based currency systems could assist in solving some of the challenges of banking. As DAOs have global reach, they could potentially help connect the estimated 1.7 billion adults worldwide who are not members of a banking institution and enable these individuals to participate in investment or debt-incurring (borrowing) activities [23]. Though it is unlikely that financial DAOs will replace traditional financial institutions, they have the potential to offer a new way to invest and partake in financial activities such as lending or borrowing, as they can be designed to replicate the economic activities of traditional financial markets [24].

Due to the automated and transparent nature of DAOs, Diallo et al. [25] argue that **e-government** systems could potentially benefit from adopting DAO to handle certain government services. This is because many current government systems are built on complex and centralized IT infrastructure controlled by human actors and, therefore, susceptible to errors. In addition, these systems and government services often lack transparency and the processes necessary to carry out activities can often be lengthy and costly. Through a government-DAO, such operations could be automated to improve the overall efficiency and "provide transparency, accountability, immutability, and a better resource management for the service" [25]. Additionally, blockchain- based platforms can potentially be used to improve the quality and quantity of government services by providing citizens access to reliable and transparent government information that could strengthen government credibility [26]. While at the current time DAOs still face challenges, in the future, the promised benefits could provide more efficient ways for governments to handle services and other activities.

In the **health care industry**, DAO principles and the associated blockchain technology could alleviate transaction costs and data errors associated with health information exchange (HIE) [27]. A

blockchain-based HIE could facilitate information exchange by allowing health care providers to efficiently obtain and exchange a patient's medical history – without significant human input – and would also provide patients with control and independence in the sharing of their medical records [27], [28]. However, an existing challenge that should be considered for such a system is the incompatibility of right-to-erasure laws and the immutability of data on the blockchain. As health records are considered personal data, they are susceptible to existing privacy laws which provide individuals with the right to request personal data to be erased [28].

Insurance markets could also apply a decentralized and autonomous approach using smart contracts which could reduce information asymmetry, transaction costs, and transaction settlement times involved in the insurance policy transaction process [29]. Additionally, insurance business processes could be automated, security could be improved by making client data confidential and accessible only to authorized parties, reduce administrative and operation costs, and enable regulators to detect suspicious transaction patterns [30].

5. Conclusion and Outlook

DAO can be described as a blockchain-based organization that operates autonomously with principles of decentralization and where decisions are made based on the consensus of its members [6]. Since the launch of the first DAO, various types of new DAOs and DAO building platforms that facilitate the creation of these organizations have emerged [5]. However, despite the growing number of DAOs, as the architecture is still at an early stage of its evolution, these organizations face several challenges that need to be addressed. These challenges include issues with the governance aspects of DAO [6], security risks [4], and uncertain legal status [14]. It is possible that these challenges will be overcome, which may pave the way for broader adoption and acceptance of its governance structure as the advantages it can offer are numerous [19]. This includes the automation of repetitive tasks. and the lack of necessity for managerial hierarchies. These benefits could, in turn, result in opportunities for cost minimization and differentiation for an organization implementing DAO mechanics.

At the time of this study, there are more questions than answers regarding the future of DAO and its possible effects on future organizational and governance structures. The consensus of existing research used throughout this work is that DAO is still evolving, additional time is required for it to develop thoroughly [19]. As DAO continues to grow and organizations implementing its mechanisms emerge, it is possible that the challenges currently faced will be mitigated. DAO should be scrutinized, and further research should be conducted to determine if it can be a viable and sustainable business structure for the future.

In general, it is too early to determine the future of DAO. If the adoption of new business models exploiting decentralized governance and disintermediation increases, it is possible that the opportunities offered by DAO will gain traction. If existing challenges are resolved, new types of DAOs will continue to emerge, and they may play a more significant role in future enterprises. However, businesses must individually evaluate if the characteristics of DAOs will provide more advantages than traditional business structures in their respective field.

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