

LA USABILIDAD EN BLOCKCHAIN: ANÁLISIS
EXPERIMENTAL DE LAS PLATAFORMAS PARA
ORGANIZACIONES AUTÓNOMAS
DESCENTRALIZADAS

USABILITY IN BLOCKCHAIN: EXPERIMENTAL
ANALYSIS OF PLATFORMS FOR DECENTRALIZED
AUTONOMOUS ORGANIZATIONS



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RESUMEN

La usabilidad en blockchain: análisis experimental de las plataformas para Organizaciones Autónomas Descentralizadas

Blockchain se ha convertido en una tecnología rompedora e innovadora en el campo de la gestión de datos y las transacciones digitales. Sin embargo, ya está mostrando su potencial para revolucionar la forma en que los usuarios interactúan no sólo con aplicaciones, sino también entre ellos. Su naturaleza descentralizada, que elimina cualquier control por parte de una autoridad central, pretende fomentar nuevas formas de gobernanza entre los usuarios. Este cambio de paradigma ha dado lugar al concepto de Organizaciones Autónomas Descentralizadas (“Decentralized Autonomous Organizations”, DAOs), que capacitan a las comunidades para tomar decisiones y gestionar recursos de forma colectiva, transparente y democrática. La creciente popularidad de las plataformas DAO, marcos que proporcionan una interfaz para permitir a los usuarios crear y desplegar DAOs, ha aumentado la necesidad de investigar su usabilidad y experiencia de usuario.

Este trabajo de fin de máster tiene como objetivo evaluar la usabilidad de dos destacadas plataformas DAO, concretamente Aragon y DAOhaus. Se ha diseñado un experimento de usabilidad en el que los participantes interactúan con las plataformas y rellenan un cuestionario de usabilidad estandarizado “System Usability Scale” (SUS). Los resultados proporcionan información sobre los puntos fuertes y débiles de la usabilidad de Aragon y DAOhaus, así como de la tecnología blockchain subyacente.

Palabras clave

Blockchain, Organizaciones Autónomas Descentralizadas, Aragon, DAOhaus, Evaluación de Usabilidad, Experimento de Usabilidad, Cuestionario SUS

ABSTRACT

Usability in Blockchain: Experimental Analysis of Platforms for Decentralized Autonomous Organizations

Blockchain has become in a groundbreaking and innovative technology in the field of data management and digital transactions. However, it is already showing its potential to revolutionize the way users interact not only with applications, but also with each other. Its decentralized nature, which removes any control by a central authority, aims to foster new forms of governance between users. This paradigm shift has given rise to the concept of Decentralized Autonomous Organizations (DAOs), which empower communities to collectively make decisions and manage resources in a transparent and democratic manner. The growing popularity of DAO platforms, frameworks that provide an interface to allow users to create and deploy DAOs, has increased the need to investigate their usability and user experience.

This master's thesis aims to evaluate the usability of two prominent DAO platforms, namely Aragon and DAOhaus. A usability experiment has been designed in which participants interact with the platforms and fill out a standardized System Usability Scale (SUS) usability questionnaire. The results provide insights into the usability strengths and weaknesses of Aragon and DAOhaus, as well as the underlying blockchain technology.

Keywords

Blockchain, Decentralized Autonomous Organization, Aragon, DAOhaus, Usability Evaluation, Usability Experiment, SUS Questionnaire

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Chapter 1 - Introduction

In recent years, blockchain has become one of the most innovative technologies in the field of data management. The blockchain concept was born in 2008 along with the creation of bitcoin [1] as a way to secure the critical data retrieved in token transactions, following a decentralized architecture, and storing them in an immutable and nested structure of blocks. Since then, many ideas and solutions have been developed relying on this technology and its applications. The wide adoption of this technology is due to the main characteristics that blockchain has: the immutability of the transactions, the replication of the data between all the nodes of the network ensuring transparency, the decentralized infrastructure, and the use of cryptographic methods to guarantee the correct validation and acceptance of the blocks that form a blockchain.

Depending on the nature of the blockchain, it can be classified into different types starting with permissionless, where all nodes can validate transactions, or permissioned, where only preregistered nodes can validate transactions. There is also a distinction between private, where only preregistered nodes can submit new transactions, and public blockchain, where transaction entry is available to all nodes [49]. Ethereum is the most widely used public permissionless blockchain project, it provides an interface where developers can write code that will be executed directly in the blockchain, called smart contracts [47]. These contracts have invariable definitions because they are stored in the chain, and also its response will also be stored there, turning it into a self-running technology. This is used to build decentralized applications. Anyone can use this infrastructure to build their own application over the Ethereum network and other similar ones.

The blockchain is being used in many different fields, one of them is the Decentralized Autonomous Organizations (DAOs). DAOs are user organizations that facilitate coordination between the members. The DAO governance is based on rules stored in the blockchain and executed as smart contracts [42][43]. The decisions taken in the DAOs are voted by the members reaching a consensus between them, as blockchain technology does. The main target of the DAOs is to organize the members following a fair and transparent decision model.

To create a DAO, a large infrastructure is needed to interact with blockchain functionalities, which makes them complex to develop. However, different DAO platforms have been created in order to help users. These platforms provide interfaces to handle the creation and management of DAOs via API or user interface with web applications.

Nowadays, DAO platforms are becoming a hot research topic due to the popularity they are earning. There are many studies about their performance, adoption, and functionalities, but the lack of studies about usability is remarkable. DAO platforms are oriented to be used by different people despite their experience with decentralized applications. They try to abstract the tough tasks involved in the use of blockchain applications, to improve their usability.

Decentralized applications based on blockchain can result difficult to understand even for users with computer studies [8]. The interaction with this type of applications is different than that of the ones that usually people use daily. There are new concepts and terminology that can make the experience frustrating at the beginning.

In order to look into how DAO platforms implement the usability to help the users to complete tasks, a usability experiment over two DAO platforms (Aragon and DAOhaus) has been designed, involving user participants performing tasks over the platforms and filling a usability questionnaire. This experiment follows a within-group design, because there is the only one group of participants who interact with both DAO platforms [25]. In order to achieve the goal of the experiment, the next research question is introduced:

What are the differences between Aragon and DAOhaus as DAO platforms for introducing users to the DAO environment?

Based on the research question, the next hypothesis is developed:

There will be differences in the usability of Aragon and DAOhaus when users interact with these platforms.

1.1 Motivation

This master's degree is designed to provide students with competence in Internet of Things (IoT), focusing on the integration of technologies, applications, services, and systems in very broad and multidisciplinary contexts. IoT technology aims to connect a wide range of devices and to change the way we interact with the physical world through smart devices designed to be autonomous. These devices are equipped with sensors, processors, and communication capabilities that enable them to collect data, process information, and perform actions based on predefined rules or algorithms, generating significant amounts of data. Many other technologies can be integrated into the IoT paradigm, but the decentralized nature of its ecosystem fits well with the integration of blockchain and its robust platform concept.

By leveraging on the distributed ledger technology of blockchain, IoT devices can establish trust, enhance security, and facilitate communication and data exchange. The transparency and immutability provided by blockchain offer significant benefits to IoT applications, including enhanced data integrity, secure identity management, and reliable device interactions.

One of the most recognized and notable implementations of the integration of blockchain and the IoT is the IOTA project [67]. IOTA is a cryptocurrency and distributed ledger technology designed specifically for the IoT ecosystem. Unlike "traditional" blockchain-based systems, IOTA uses a unique data structure called the Tangle. The Tangle is a directed acyclic graph (DAG) [68] that enables secure and trusted transactions between IoT devices. It works by requiring each new transaction to validate two previous ones, creating a network of interconnected transactions. This structure eliminates the need for miners, reduces transaction fees, and enables scalable and decentralized data transfer in IoT environments.

Also, this convergence of technologies presents opportunities to address critical challenges in the IoT ecosystem. For example, blockchain is providing innovative solutions for IoT cloud computing [63] in terms of decentralization, data privacy and network security, due to its decentralization it eliminates single point failure risks due to the disruption of central authority, saving operational costs and enhancing trustworthiness. It

is also being used for identity management in fog computing architectures [65] managing the relationships and interoperability between subjects and IoT devices.

Despite the fact that IoT devices create distributed architectures due to their diverse nature and location, traditional and common governance models in IoT networks are centralized. Moreover, as the number of devices joining in IoT networks grows, the current centralized models can run into bottleneck issues when authenticating, approving, and connecting new nodes within the networks [64]. To address these issues, new governance frameworks are emerging such as IoT-Gov [66], where authors implement a solution by using blockchain for processes of authorization, authorization revocation and access control.

An alternative approach to merging blockchain and IoT is to digitally integrate smart devices and digital assets into DAOs. As a reliable IoT service platform, DAOs can monitor the entire lifecycle of smart devices in a secure and trusted manner, implement automated trading among equipment, and use smart contracts to achieve interoperability between smart devices [43].

DAO offers a promising solution by providing decentralized and user-centric governance frameworks. By incorporating DAO principles, IoT device owners can actively participate in decision-making processes, propose, and vote on changes, and influence the direction of the IoT network. This participatory approach increases user empowerment, trust, and engagement in the governance of their IoT devices. An example of an implementation is AutomataDAO [69], a decentralized data marketplace designed specifically for robot and IoT systems, where a set of governance smart contracts allows both human and synthetic agents to participate in the DAO.

The concept of DAOs is experiencing rapid growth and increasing adoption, as DAOs offer a novel approach to organizational decision-making and resource management. As demonstrated by data from platforms such as DeepDAO (shown in Figure 1-1), the DAO ecosystem is expanding at a remarkable pace opening up new possibilities for decentralized governance.

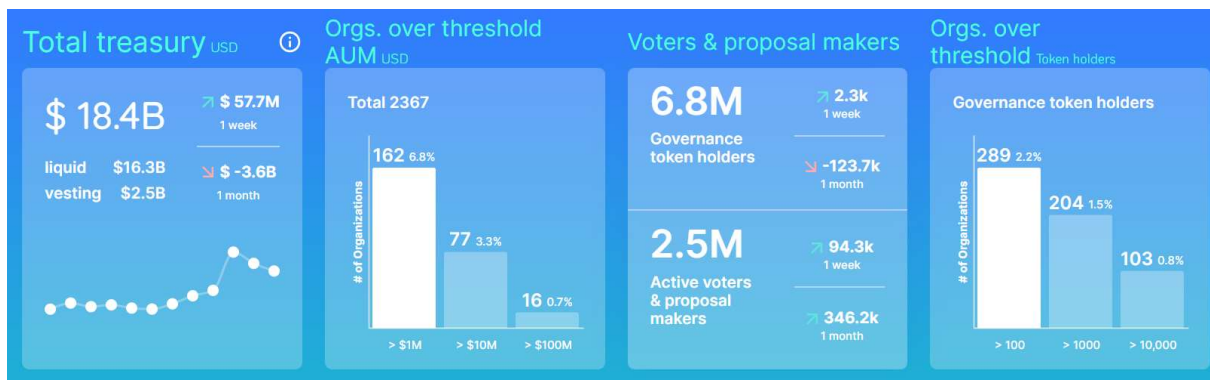


Figure 1-1 Aggregated data on 12,739 DAOs, extracted from the website <https://deepdao.io/>

However, usability in blockchain and DAOs presents a significant bottleneck that limits their widespread adoption and effectiveness, because the complexity and steep learning curve associated with their interfaces and processes pose usability challenges for users [8]. Interacting with blockchain-based applications often requires technical knowledge, familiarity with cryptographic operations, and an understanding of distributed technologies. Addressing these usability issues is critical to improving the accessibility and usability of blockchain and also of DAO platforms, as it will enable a broader range of individuals to actively participate in decentralized governance and realize the full potential of DAOs.

1.2 Objectives

The goal of this study is to analyze how well DAO platforms implement the usability in their web applications, in order to ease the introduction to this technology for users without experience.

This study also wants to concretely determine if the current usability evaluation methods are appropriate for new technologies such as blockchain, which introduces a new paradigm in the use of applications and software.

To achieve all this, this study has the objective of performing research about the state of the art of DAO platforms and about the current standardized usability evaluation methods, in order to design the most appropriate experiments that could accomplish these characteristics.

It is important to provide a clear rationale for the chosen approach showing a comprehensive understanding of the field, justifying it based on an informed decision and effectively demonstrating its benefits and limitations by presenting quantitative and qualitative results.

1.3 Work plan

The work plan for this thesis has been divided into phases, each with a different approach:

- The initial phase focused on conducting comprehensive research on DAO platforms, exploring potential lines of investigation. Two potential directions were considered: (a) conducting an analysis and comparison of DAO platforms using Open-Source Software (OSS) evaluation methods to identify the most suitable OSS solution based on specific criteria, and (b) conducting a usability study on DAO platforms due to the lack of existing research in this area.
- With the chosen scope of usability in DAO platforms, the second phase involved research into standardized usability measurement methods. This included investigating usability questionnaires, exploring different types of experiments, and understanding how to conduct experiments in the field of human-computer interaction.
- Once the research about usability methods was done, the usability experiment was designed by considering the goal of the study, determining appropriate participants, selecting the type of experiment, and defining the experimental procedure.
- The last part was to conduct the designed experiment involving real participants.

1.4 Memory organization

This master's thesis memory is structured as follows:

- **Chapter 1: Introduction**

This chapter provides an overview of the thesis, including the motivation for the study, the objectives, the planning followed, and how the document is structured.

- **Chapter 2: Blockchain and DAOs**

An introduction of blockchain, wallets, and DAOs is given, as well as the gap of usability studies about them found in the research. DAO platforms are explained, specifically mentioning Aragon and DAOhaus, highlighting their significance in the study.

- **Chapter 3: Measuring usability**

This chapter focuses on the research conducted to identify standardized usability questionnaires suitable for this study, and the selecting process followed to select the most appropriate one for this work.

- **Chapter 4: Experimentation**

In this chapter the usability experiment for the evaluation of DAO platforms is designed. It includes the criteria used to select user participants, how the usability questionnaire is applied, and a detailed description of the experiment procedure.

- **Chapter 5: Results**

The results of the experiment on DAO platforms are presented. Both qualitative and quantitative results are discussed, providing insights into the usability aspects of the evaluated platforms.

- **Chapter 6: Conclusions and future work applications**

This chapter concludes the thesis reasoning about future works and lines of investigation by the results obtained in this study.

Chapter 2 - Blockchain and DAOs

2.1 Introduction to Blockchain

Blockchain is a decentralized technology that serves as a transparent and immutable digital ledger. It operates through a computer network, known as nodes, that collectively maintain a synchronized copy of the entire blockchain. Each block in the chain contains a set of transactions that are recorded using cryptographic techniques, and stored them in a nested structure, where each block is validated using a unique cryptographic hash that depends on the data it contains and the hash of the previous block. This nested structure of blocks creates a chain, making it nearly impossible to modify past transactions without altering subsequent blocks [1].

To maintain the up-to-date copy of the blockchain along the network, new blocks are added through a consensus mechanism that ensures the integrity and security of the system. When a participant initiates a transaction, it is broadcasted to the network where validators, often called miners, compete to solve a complex mathematical puzzle and then reach a consensus through a predefined algorithm. Once the process is complete, the new block is added to the end of the chain. To incentivize miners and compensate them for their computational power consumed on the mining process, users who initiate transactions on the blockchain are required to pay a fee with cryptocurrencies.

Because of each node has a synchronized copy of the blockchain, all the transactions available in the blocks are accessible to all participants in the network. This transparency allows for a high level of visibility and trust, as any participant can view and verify the transactions and data on the blockchain [48].

The most popular public blockchain network is Ethereum [47][55]. Introduced in 2015, Ethereum goes beyond simple transactions by allowing developers to create self-executing programs, called smart contracts, with predefined conditions and business logic [46]. The smart contracts, as well as the results generated by their execution, are securely and immutably stored in the blockchain. This feature enables the creation of decentralized applications (dApps) that can autonomously execute smart contracts and interact with the blockchain.

These applications can range from decentralized finance (DeFi) protocols [58] and tokenized asset platforms to decentralized social networks [59] and gaming applications [60]. With the ability to execute code on the Ethereum Virtual Machine (EVM) [55], dApps enable new forms of economic models and peer-to-peer interactions. To develop smart contracts and dApps, developers use the native Ethereum programming language, Solidity. Designed specifically for this purpose, Solidity¹ allows developers to define the behavior and logic of smart contracts. It provides a high-level language with support for object-oriented programming, facilitating the creation of complex smart contracts with rich functionalities.

One of the reasons for Ethereum's widespread adoption is the acceptance of its technical standards, such as ERC20 [53] for fungible tokens (also called cryptocurrencies), where each token is interchangeable with another of the same value, and ERC721 [54] for non-fungible tokens (NFTs), which represent unique assets with different properties and characteristics. These standards are widely accepted in the crypto industry, ensuring interoperability and compatibility of tokens across multiple dApps and platforms.

An important aspect of the Ethereum ecosystem is the concept of "gas". Gas refers to the fee required to execute transactions or smart contracts on the Ethereum network. It serves as a measure of the computational effort required to perform certain operations [56]. The gas fee is paid in Ether (ETH), the native cryptocurrency of the Ethereum blockchain [47]. The amount of the gas fee is determined by market demand and computational complexity. Users can adjust the gas price they are willing to pay, balancing transaction speed with cost [57]. This fee model incentivizes miners, who secure the network, to include transactions with higher gas fees in the blocks they mine.

2.2 Authentication in blockchain: Wallets

Transactions on the blockchain are validated and authenticated by signing them with private keys, thereby verifying the identity of the user or source. However, manually

¹ Solidity programming language documentation: <https://docs.soliditylang.org/>

constructing and signing transactions requires extensive knowledge of blockchain protocols, cryptographic operations, and careful handling of private keys. To facilitate this process, cryptographic keys are securely stored in cryptocurrency wallets (crypto wallets or wallets). Crypto wallets provide a user interface that simplifies the creation of transactions, as well as identity management and authentication capabilities. They act as a bridge between users and blockchain networks, abstracting away complexities for users.

There are two types of crypto wallets: hot and cold [39]. Hot wallets are connected to the internet, making them more vulnerable to potential theft or loss. They include online wallets accessed through web browsers, mobile wallets, and desktop wallets. Cold wallets, on the other hand, are offline and offer a higher level of security. Hardware wallets, such as USB devices, offer strong protection, while paper wallets are the safest form, consisting on printed paper with QR codes representing public and private keys, where the only concern of the user should be to keep that piece of paper [37][38].

In addition to creating transactions, wallets are software applications that allow users to view cryptocurrency balances. Unlike traditional wallets, cryptocurrencies are not physically stored in crypto wallets. Instead, they exist as transaction data on the blockchain, without a single centralized location or physical form. Wallets help to access all transactions associated with a specific address on the blockchain and view the balance, facilitating the movement of funds as long as the user possesses ownership of the corresponding address [37].

The way to authenticate a wallet is by its address, a unique identifier generated through sophisticated cryptographic techniques [40]. This wallet address serves as the key to validating user interactions within the blockchain ecosystem, providing both anonymity and security. Unlike traditional authentication methods that rely on usernames and passwords, blockchain-based applications authenticate users through their wallet address [41]. This approach leverages the inherent cryptographic security of the blockchain to ensure tamper-proof authentication and eliminates the need for traditional login credentials.

In this study, a browser wallet was chosen as the preferred method of interacting with the blockchain. Specifically, MetaMask² was selected as the wallet of choice due to its user-friendly interface (as shown in Figure 2-1) and its easy installation as a web browser extension. MetaMask simplifies the management of digital assets and the execution of blockchain transactions, providing a secure storage solution for private keys. Its compatibility with dApps enhances the user experience by eliminating the need for manual address input and transaction signing. With support for multiple blockchain networks and features such as transaction history tracking and customizable gas fees, MetaMask offers a comprehensive solution for convenient and secure interaction with blockchain-based applications.

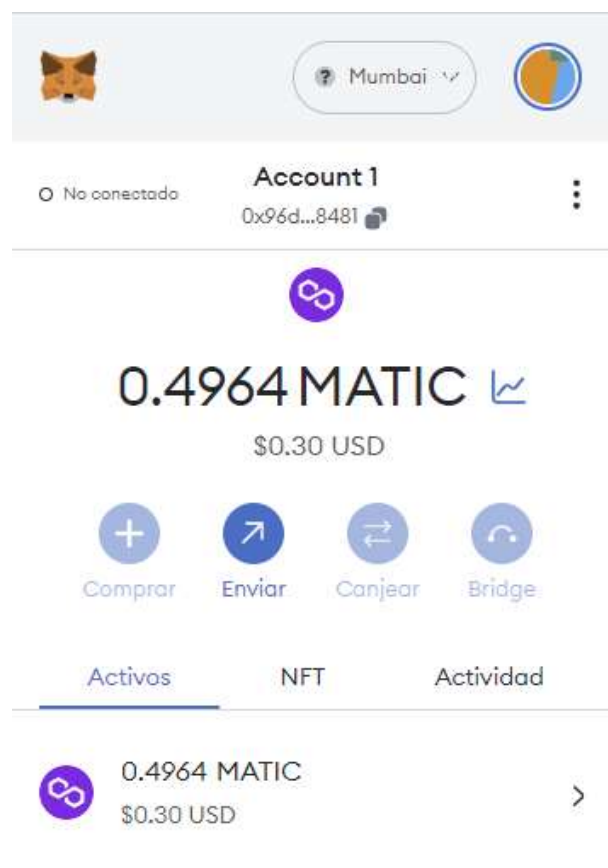


Figure 2-1 MetaMask user interface dashboard

² Metamask website: <https://metamask.io/>

2.3 Decentralized Autonomous Organizations

Decentralized Autonomous Organizations (DAOs) are a type of user organizations based on blockchain technology. The DAO term was defined by Buterin in 2014 as: "Decentralized Autonomous Organization is an entity that lives on the internet and exists autonomously, but also heavily relies on hiring individuals to perform certain tasks that the automaton itself cannot do" [2].

DAOs are designed to be self-governed and autonomous, with rules and regulations that are encoded into the blockchain. They operate without the need for any central authority or intermediaries and are entirely run by their members with decisions made through a decentralized system of voting, following the principles of equality, voluntariness, reciprocity and mutual benefit [44].

DAOs are able to run actions on their own, executing smart contracts, often triggered by the decisions made by the organization's members after voting on a proposal, and always following a governance model defined by the rules of the DAO (also stored as smart contracts in the blockchain) [43]. The fact that they are self-executing is the reason why they are considered autonomous. Because of the nature of the underlying blockchain technology, the rules, the smart contracts, and the transactions on a DAO are transparent and immutable, allowing members to verify their authenticity and validity.

As other organizations, DAOs can be used to manage funds and make decisions on the development of a project. However, it is important to understand that the concept of a DAO can be used to refer to a wide variety of things- i.e. it can be applied to any organization or community that seeks to operate in a decentralized and democratic manner [42].

Despite the fact that the DAO term is well established in the blockchain space, there are still some misconceptions and questions that need to be answered. The level of decentralization required, the level of autonomy allowed for human involvement, and if a higher level of involvement is required than merely interacting with a smart contract to be considered as an actual organization, are some of the issues that remain [42]. Although DAO yearns for "code is law" or "Regulation by Code," DAO rules and

regulations face challenges in practice. This is primarily due to a significant semantic gap between legal rules, which are often written at a high level of abstraction using ambiguous and flexible natural language to achieve versatility, and the rules encoded in smart contracts, which require strict and formal computer language to accurately describe the rules [45]. This results in potential ambiguity and errors during translation.

Most of the DAOs utilize Ethereum as their blockchain network due to several key factors [50]. Ethereum's robust smart contract functionality allows developers to create complex and customizable DAO structures. The native programming language, Solidity, provides a high level of flexibility and enables the implementation of self-executing contracts and decentralized governance within DAOs. Also, Ethereum community has contributed by the creation of a rich ecosystem of tools, frameworks, and libraries specifically tailored for building DAOs on this network. Additionally, the widespread adoption and the interoperability open possibilities for collaboration, integration, and access to a broader range of assets and functionalities that greatly benefits DAO developments.

Nevertheless, it is important to note that emerging blockchain networks are gaining prominence, presenting viable alternatives for constructing DAOs, consequently shaping a dynamic and evolving landscape.

Despite the potential benefits of DAOs, there have been some cases of DAOs being hacked or exploited, leading to losses for their members. As a result, the concept (and moreover the implementation) is still in its early stages, and there is ongoing research and development to improve their security and functionality.

One of these examples is "The DAO". "The DAO" was a big Decentralized Autonomous Organization that was built on the Ethereum blockchain in 2016. It was created to function as a decentralized investment fund, allowing members to invest in various projects using cryptocurrency. Unfortunately, "The DAO" was hacked in June 2016, and approximately one-third of its funds were stolen. Therefore, the Ethereum community has forced to make a decision and fork the blockchain creating a new chain where the theft would never have occurred [44].

This event led to the development of new DAO frameworks and protocols, such as Aragon and DAOhaus, which improve the security and functionality of DAOs. The Ethereum community also implemented more rigorous security auditing processes and guidelines for smart contract development.

2.3.1 DAO platforms

Following these developments, the concept of DAO platforms emerged as a means to provide the infrastructure and tools for creating, managing, and governing decentralized autonomous organizations (DAOs). A DAO platform can be formally defined as a software framework that enables the creation, deployment, and operation of DAOs on a specific blockchain network. These platforms offer a range of features and functionalities designed to enhance the security, governance, scalability, and user experience of DAOs.

DAO platforms, such as Aragon and DAOhaus mentioned earlier, provide pre-built modules, templates, and smart contract frameworks that simplify the process of creating DAOs. They offer customizable governance models, voting mechanisms, and token management, allowing DAO creators to adapt their rules and decision-making processes to their specific needs. Additionally, these platforms are often integrated with popular blockchain networks, like Ethereum and also with test networks providing a sandbox environment where developers and users can experiment and test the functionalities of DAO platforms without risking real assets or funds.

Moreover, DAO platforms focus on improving the user experience by offering user-friendly interfaces, dashboards, and collaboration tools for members to participate in DAO activities, vote on proposals, and manage their tokens. They also assist in resource allocation, token distribution, and treasury management, facilitating the efficient management of financial operations within DAOs.

2.3.2 Usability research on DAOs

Despite the increasing significance of DAOs, there seems to be a conspicuous absence of rigorous usability evaluation and testing conducted on these systems. Specifically, within the domain of blockchain technology, Schweiger [3] has recognized

the necessary improvement in user experience, stating that blockchain is still in a pretty early state in terms of user experience. Also, Gebron [4] empathized three usability challenges of blockchain-based applications: the abundance of new terminology and the lack of standardization, the necessity of giving valid feedback during the long wait time requiring for adding transactions and creating new blocks, and the protection of user's funds from hacks or user errors. In another article [7], authors reached the conclusion that blockchain concepts introduce a new paradigm that is different from user's established mental models. Specifically talking about the wallet management, even technical users with experience in different technologies, faced problems with the interaction of these systems, reaching the conclusion that these concepts are not explained well enough to end users, which leads to substantial problems that encumber the practical use and purpose of the technology.

The study in [8] presented a usability study of two groups of participants performing tasks over a blockchain based application, and the results revealed usability issues with blockchain applications, pinpointing opportunities for improving the user experience. The authors found that these issues are related to the need to adjust the mental models of the users, which are strongly influenced by Web 2.0, to the new paradigms and concepts emerging around the blockchain. Specially, they discovered two aspects of particular concern, namely a significant lack of knowledge related to several concepts of the blockchain ecosystem and also a lack of familiarity with financial concepts used in blockchain-based applications, which users found sometimes unnecessarily when using this type of vocabulary to carry out interactions on nonfinance-related applications. In another study [9], a blockchain-based game that uses the DAO concept as a central element coordinator between teams was created. In this study, researchers evaluated the integration of the DAO concept in a game achieving a decent usability score (70 points in the System Usability Scale (SUS)[14] questionnaire), and the participants stated that the collaborative decision-making approach had been the most exciting and fun aspect.

However, a comprehensive review about usability reveals a significant gap when it comes to DAO platforms. Empirical research has been conducted and some studies about DAO technologies have been found, but very little regarding usability. This lack of

user-centered research in the field emphasizes the importance and necessity of the present study, aiming to fill this critical research gap. In the article [5], researchers exposed problems and open issues of blockchain-based applications and specifically about DAOs, but their proposals were oriented to enhance security, governance systems and legal issues related to DAOs. Also, in the study of [6], they created a high value decision model for comparing DAO platforms based on the functionalities that they provide, but without considering usability or user experience.

2.3.3 DAO Platforms Evaluated

The two DAO platforms selected to be evaluated in this study are DAOhaus and Aragon: both are platforms that provide a framework for creating and managing DAOs on the Ethereum blockchain, as well as on other networks (including testnets).

Despite the fact that both platforms provide interfaces (including a web application) for creating and managing a DAO, they differ in their unique governance approaches and in the provided tools, so they can be considered as relevant representatives of two different classes of DAO platforms.

These platforms have been selected based on previous research that demonstrated their maturity and widespread adoption [29] [30] [31] [32]. These studies consistently identify both Aragon and DAOhaus as some of the most prominent and well-established platforms in the DAO environment.

There were other cases of DAO platforms studied, such as DAOstack³, Colony⁴, and Gardens⁵. DAOstack has been mentioned in some studies [30][32] as a notable DAO platform, although its launch application is no longer available at the time of this research. Gardens is a DAO platform based on the 1Hive model [61], which also uses the AragonOS smart contract framework as one of the building blocks for the DAO design. This DAO platform was not included in this study due to its relative novelty, limited existing

³ DAOstack website: <https://daostack.io/>

⁴ Colony website: <https://colony.io/>

⁵ Gardens website: <https://gardens.1hive.org/>

research, and its reliance on the Aragon framework. Finally, Colony was a strong candidate for be included in this thesis; it is mentioned in studies [29][32] and highly regarded in [6]. However, it was not covered in the study discussed in [30] due to the lack of available research at that time, but currently it is gaining prominence. Nevertheless, given the time, resource, and scope constraints of this study, an evaluation of the Colony DAO platform was not conducted as part of this research. The decision to focus solely on the usability and user experience of the Aragon and DAOhaus platforms was made in order to provide a more in-depth analysis of specific platforms within the DAO landscape.

As mentioned above, Aragon and DAOhaus are some of the most widely used DAO platforms nowadays, and their different approaches of governance and interaction could yield very interesting results in this study. Comparing these two platforms will provide valuable insights into how different design philosophies and feature sets may impact usability.

2.3.3.1 Aragon

Aragon⁶ is one of the largest DAO platforms nowadays. Aragon's approach aims to extend the use of DAOs as a free and open-source technology to allow the creation and management of decentralized organizations.

⁶ Aragon website: <https://aragon.org/>



Figure 2-2 Aragon tech stack, extracted from their website <https://aragon.org/>

As shown in Figure 2-2, the Aragon actual tech stack is formed by three layers.:

- Aragon OSx⁷ (low level): This is the lowest level of the Aragon stack. It defines the Aragon smart contract framework on the blockchain that provides the basic functionality required to run a DAO. The Aragon OSx protocol allows users to customize DAOs by managing contract permissions or developing their own plugins, ensuring at the low level system that only authorized accounts and contracts (together referred to as entities) have permissions to perform specific actions.
- Aragon SDK⁸ and Aragon ODS (mid level): The Software Development Kit (SDK) is a set of tools designed to help developers build applications that run on top

⁷ Aragon OSx documentation: <https://devs.aragon.org/docs/osx/>

⁸ Aragon SDK documentation: <https://devs.aragon.org/docs/sdk/>

of AragonOS. It includes command-line tools for creating, testing, and publishing Aragon apps, as well as JavaScript libraries for interacting with AragonOS contracts. Aragon ODS is at the same layer level than the SDK, in the Aragon website it is defined as new functionality to "Design a user-friendly, custom UI for your Aragon App with our Open Design System."

- Aragon App⁹ (high level): At the top of Aragon's actual tech stack is the Aragon App, "a home for your DAO". Aragon App serves as the primary interface for users to interact with their DAOs, providing a web application to create and manage DAOs with no coding required, and following a modular design. Within the Aragon App the users can perform tasks like mint and distribute tokens among DAO members, authorize wallets for voting, set governance models determining how decisions are made in the DAO. Finally, they can also easily make proposals to introduce new ideas or initiatives for the DAO to consider. With its extensive customization options, it can be appealing for users who require more flexibility and control over their DAO's structure and governance. In this study, when Aragon is mentioned, we refer to the entire technological stack, but the usability study will be conducted using its web application interface.

Aragon provides two voting models. The user who creates the DAO must select one of these models to define the control and management of the proposals, which determine the governance as well. These are the two models:

- Token holders: A token is set up in order to share between the members of the DAO giving to them voting value. The more tokens a member holds, the more weight their vote has. One token equals one vote. Members can mint tokens through proposals.
- Multisig members: Only the members included in a multisig list can vote. One wallet address equals one approval.

⁹ Aragon App website: <https://aragon.org/aragon-app>

Aragon team is also involved in the development of new functionalities, frameworks, and protocols. One example is the Vocdoni¹⁰ project, a digital and decentralized voting system that aims to create a secure, anonymous, and universally verifiable voting system. It leverages the use of distributed ledger technology to ensure that voting processes are transparent and resistant to tampering, thus allowing the creation of polls with different voting models, such as anonymous or weighted voting. The Mayor of Bellpuig, a town situated in Catalonia, Spain, reached out to Vocdoni with the intention of digitalizing the town's voting procedures, trying to realize direct involvement of the citizens in governance. This pioneering referendum is the first-ever 100% digital consultation held by a public institution in Spain, resulting in an exceptionally high turnout for a non-binding local referendum [34].

Figure 2-3, Figure 2-4, and Figure 2-5 show screenshots of Aragon website and web application interface (accessed June 2023).

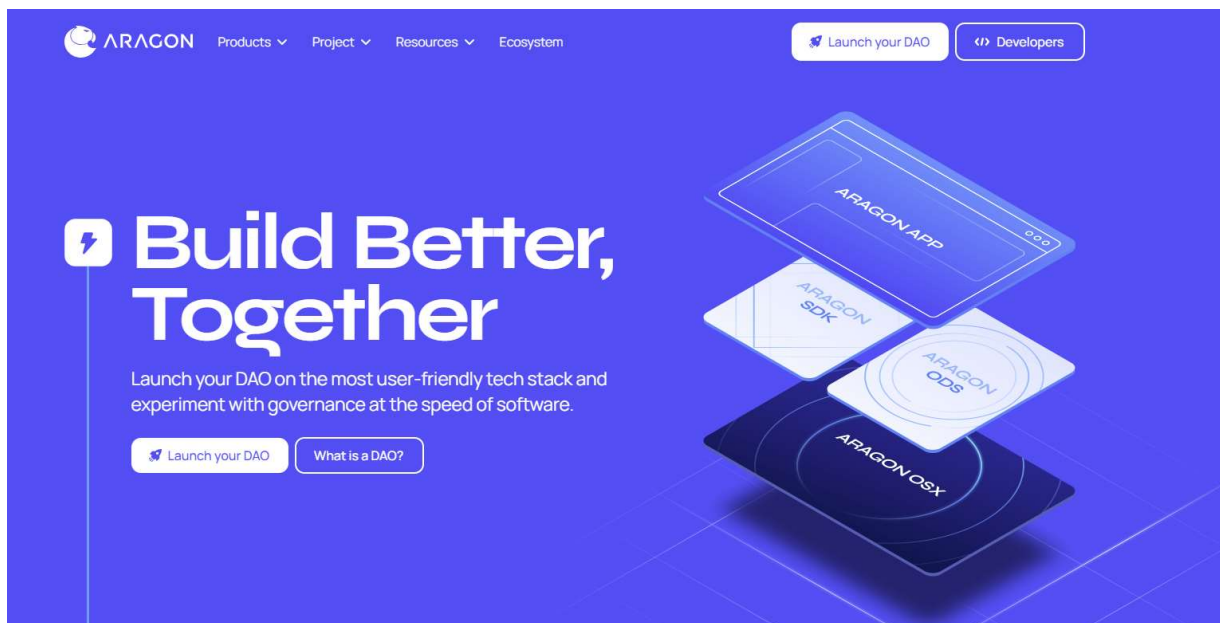


Figure 2-3 Aragon website home page

¹⁰ Vocdoni documentation: <https://developer.vocdoni.io/>

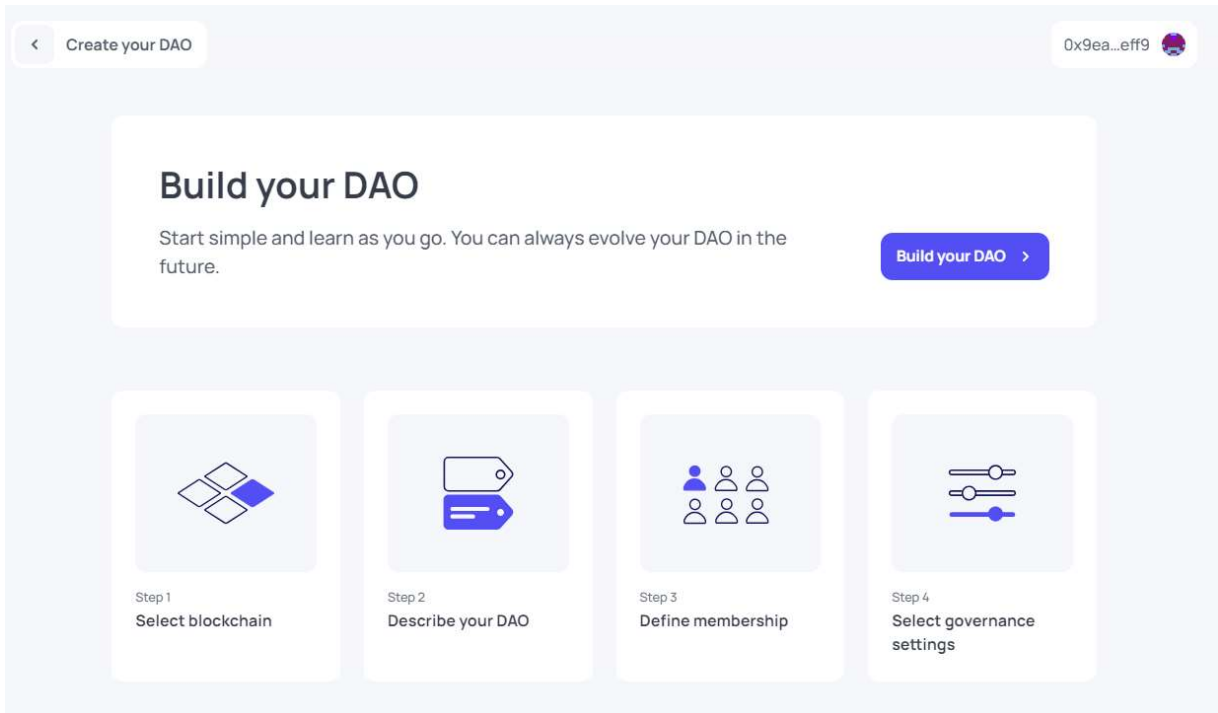


Figure 2-4 DAO process creation with Aragon App

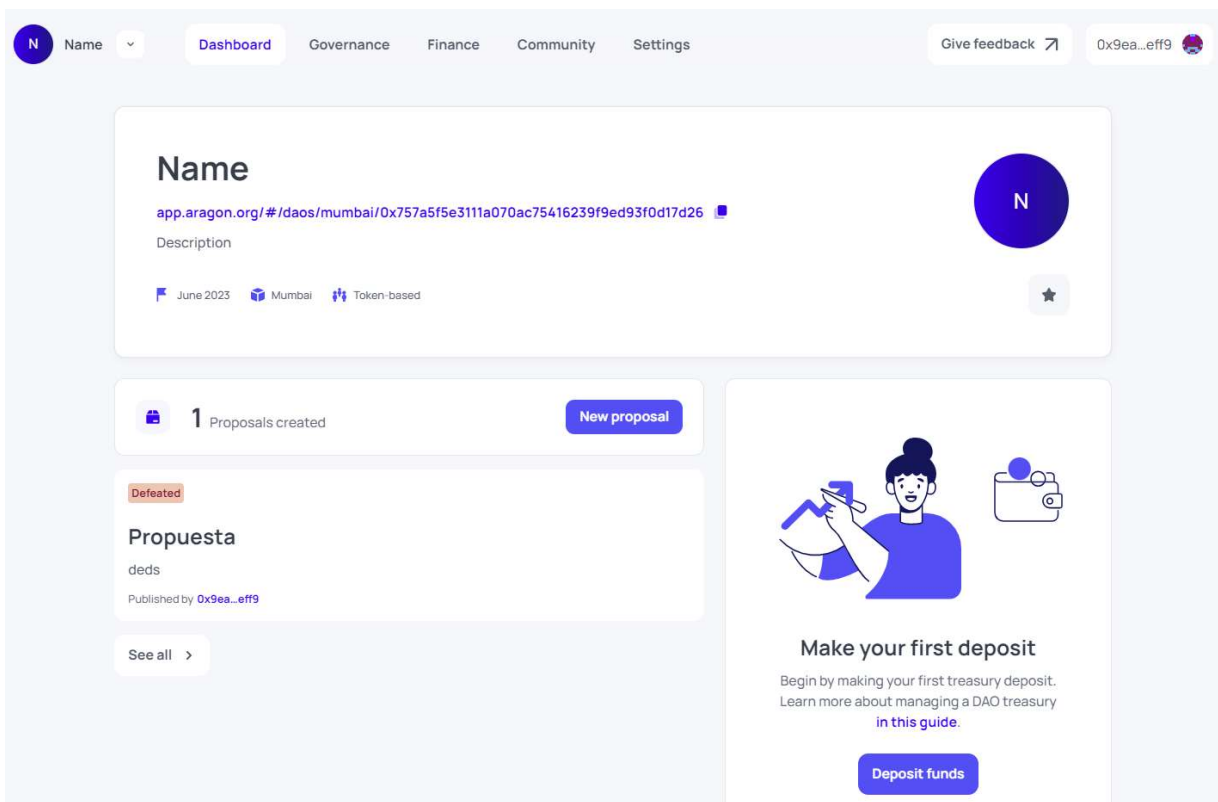


Figure 2-5 Aragon App DAO dashboard

2.3.3.2 DAOhaus

DAOhaus¹¹ is a DAO platform designed to facilitate the management of DAOs built using the Moloch DAO framework¹². This framework consists of a collection of smart contracts that serve as the basic infrastructure for DAOs operating on the DAOhaus platform. By leveraging the capabilities of Moloch, DAOhaus provides a robust and reliable environment for the efficient operation and administration of DAOs.

DAOhaus offers a web application interface to facilitate the creation and management of DAOs. Through the DAOhaus web application, individuals and communities can efficiently set up their own DAOs without requiring extensive technical expertise. With this interface, DAOhaus streamlines the setup process, allowing users to define governance structures, manage voting mechanisms, and handle operations within their DAOs. DAOhaus empowers users to leverage the power of decentralized decision-making and collective coordination through the features available in this user-centric web application interface.

The Moloch framework is mainly based on the idea of a DAO as a primitive solution to human coordination for testing real-world use-cases. Its contracts are simple, secure (audited), and battle-tested in the real-world. Finally, it is designed to be combined with many different currencies, functions, and extensions [35].

Some key functionalities that DAOhaus offers are a treasury management which allows members to collectively manage and monitor the organization's funds, a governance model with a share-based voting system that enables a variety of proposal types, and security features like grace periods and the exit fair share, most known as "rage quit" functionality. All these concepts are intrinsic with the use of Moloch [35]. The premise of rage quit is part of the "magic" of Moloch. If a member disagrees with a decision made by the DAO, they have the option to rage quit before the decision is executed. When a member rage quits, they can withdraw their proportion of funds of the DAO's treasury, effectively exiting the DAO and taking their share of resources with them. This ensures that

¹¹ DAOhaus website: <https://daohaus.club/>

¹² DAOhaus Moloch documentation: <https://moloch.daohaus.fun/>

the dissenting member is not financially tied to a decision they disagree with. This mechanism effectively protects the individual rights and interests of DAO members, preventing any enforced lock-in and allowing for exit options in case of disagreements. Furthermore, it encourages a mindful and considerate decision-making within the DAO, as members are aware that poorly received decisions could lead to a loss of membership and consequently, to a reduction in the DAO's funds.

Within a Moloch DAO, membership is represented by two different tokens distributed among the members of the organization: shares and loot [36]:

- Shares serve as a representation of a member's governance and voting power within the DAO. The number of shares held by an individual directly correlates to their influence and decision-making authority when it comes to creating and voting proposals.
- Loot represents economic claim against assets held in the DAO treasury, but not voting power. Loot holders have a financial stake in the DAO, giving them the potential to benefit from the success and growth of the organization. Loot does not grant any voting power to its holders; instead, it serves as a means to participate in the economic outcomes of the DAO without directly influencing on its governance.

This distinction between shares and loot enables a separation of governance authority and economic interests within the DAOs created with DAOhaus and the Moloch framework. It provides flexibility in the distribution of voting power while allowing members to have economic stakes in the DAO treasury. This structure promotes a balance between decision-making influence and economic participation, creating a dynamic and inclusive environment for members of the DAO. The complete governance structure is shown in Figure 2-6.

Figure 2-7, Figure 2-8, and Figure 2-9 show screenshots of DAOhaus website and web application interface (accessed June 2023).

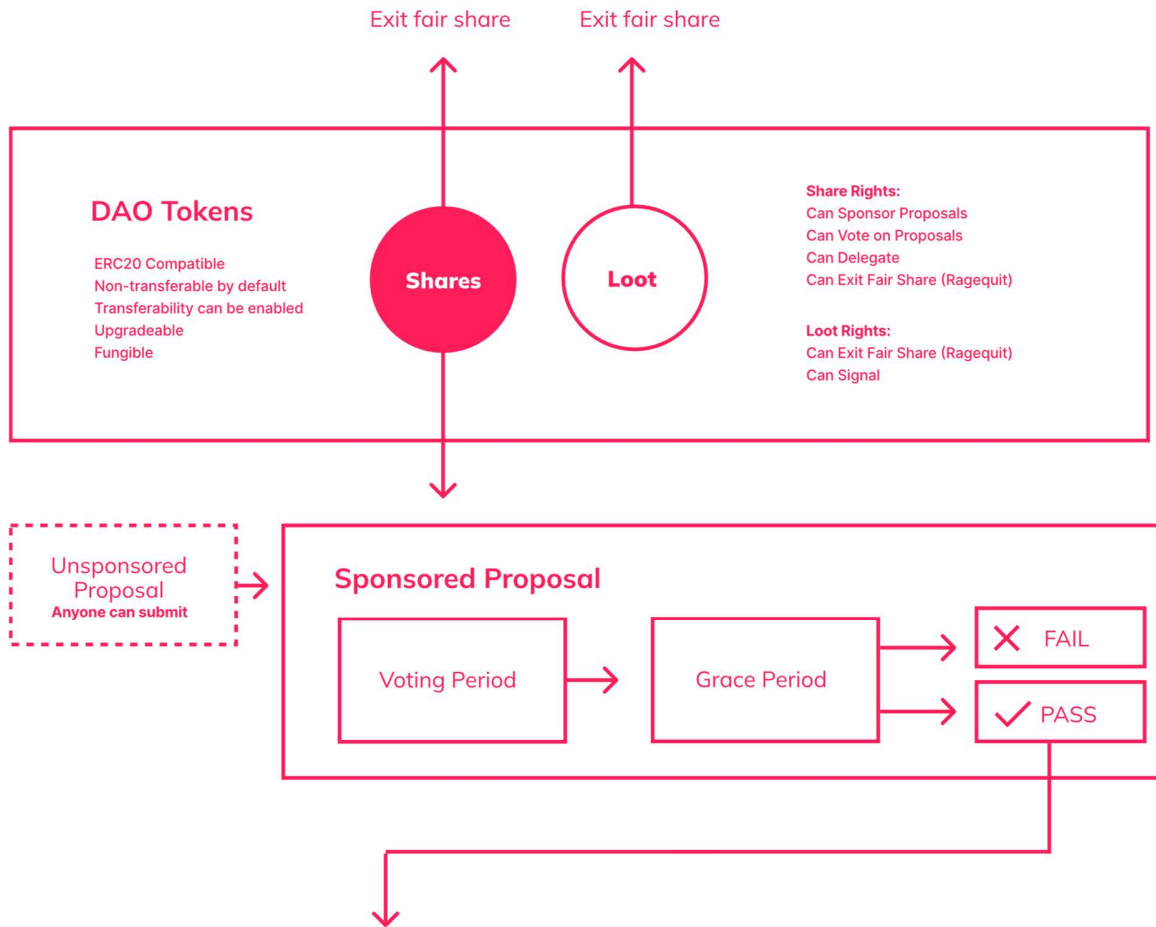


Figure 2-6 DAOhaus governance layer structure, extracted from their website <https://daohaus.club/>

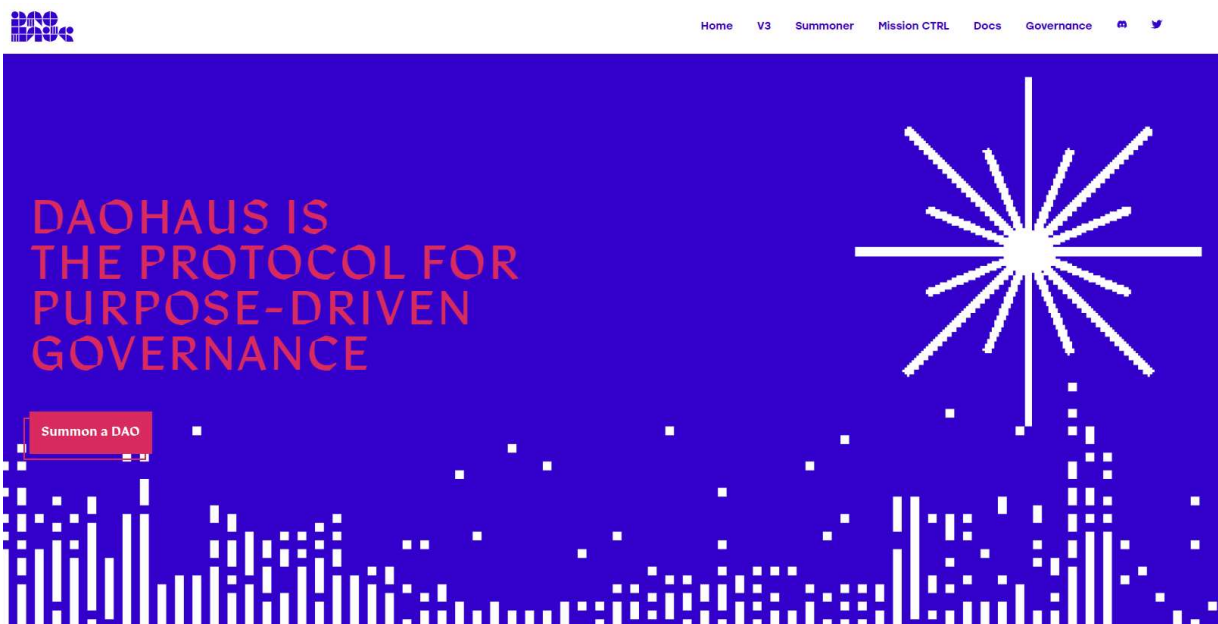


Figure 2-7 DAOhaus website home page

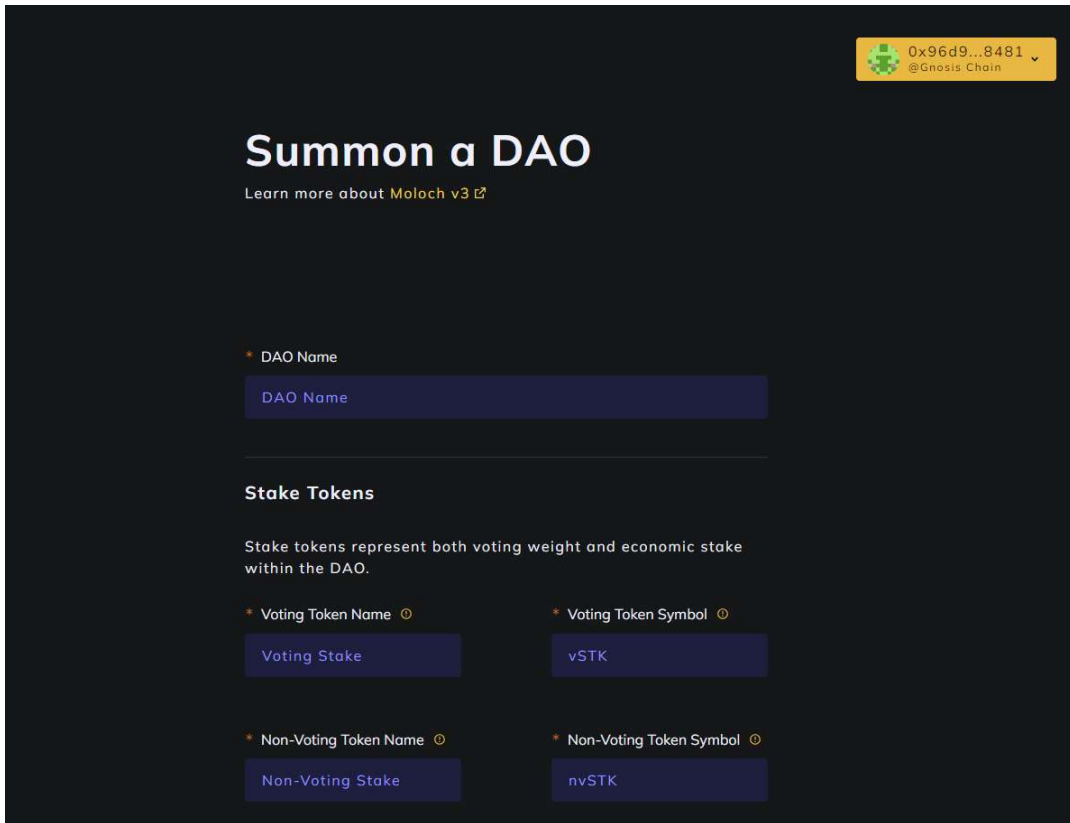


Figure 2-8 Form of DAO process creation with DAOhaus web application

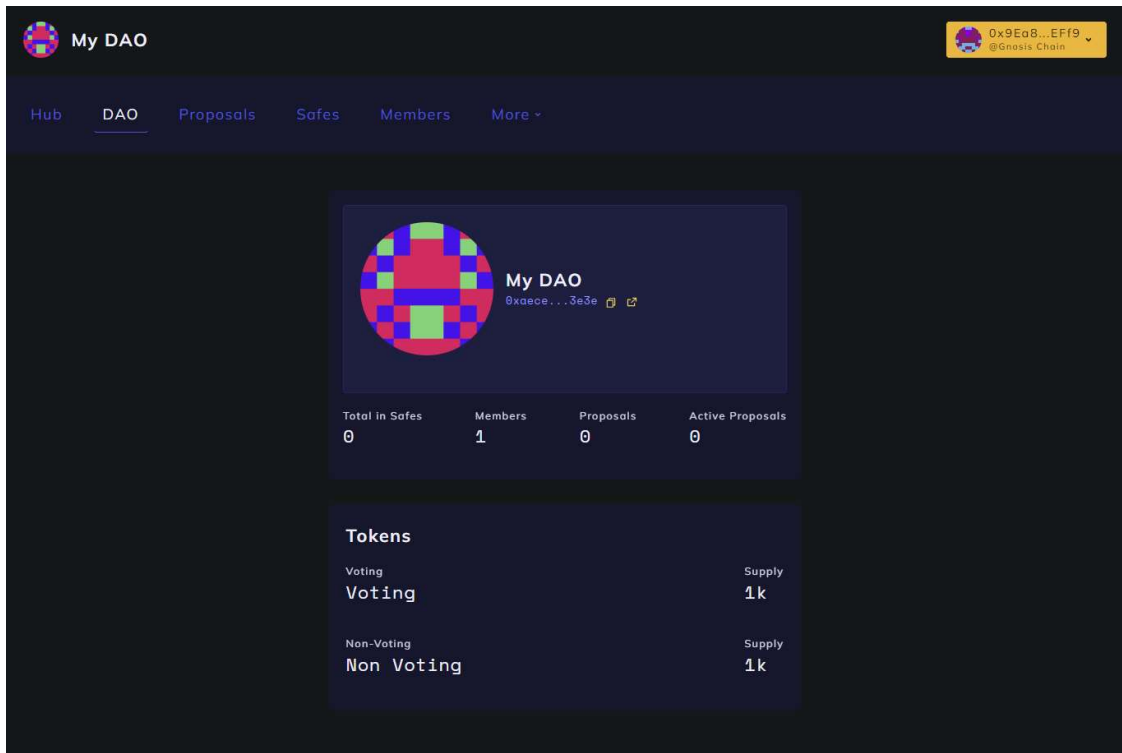


Figure 2-9 DAOhaus web application DAO dashboard

Chapter 3 - Measuring Usability

Usability has a wide range of definitions, and, at times, the concept can be misunderstood. The current definition of usability defines it as a human-computer interaction approach that measures how difficult is for users to complete tasks and learn how to use a web or application [10]. People often think that a high level of usability can be accomplished just by adding a simple and clear interface. However, usability is much deeper than the superficial features of the user interface. The way in which the information is presented, the organization and accessibility of the data, the responsiveness to user input, are also essential in ensuring a satisfactory user experience. An acceptable level of usability is reached when the design meets the user needs on a high level [11].

3.1 Usability Questionnaires

Understanding and evaluating the usability of web applications is crucial for delivering a positive user experience. Usability encompasses various aspects such as ease of use, efficiency, learnability, and user satisfaction. To assess these factors effectively, usability questionnaires serve as a valuable tool. There are standardized questionnaires which are designed for repeated use, typically with a specific set of questions presented in a specified order using a specified format, with specific rules for producing metrics based on the answers of respondents [13].

3.1.1 Standardized Questionnaires

The use of standardized measurements in usability research provides numerous benefits. They enable objectivity by allowing practitioners to independently verify measurements and they support replicability by facilitating the replication of studies. Standardization allows for quantification, reporting of results in finer detail, and the use of mathematical and statistical methods to better understand the results. They offer economy through the reuse of measurements, enhance communication among practitioners, and enable scientific generalization by assessing the generalizability of

results. Overall, standardized measurements play a crucial role in improving the rigor and effectiveness of usability research [13].

As Jeff Sauro declared [12], "most questionnaires was never meant to be diagnostic". The result does not indicate to the author what to fix in the interface. In general terms, what they provide is a measure of usability which could serve as a reference to be compared with other studies. There are questionnaires that also can give other measures such as the System Usability Scale (SUS) with the learnability, or the Post-Study System Usability Questionnaire (PSSUQ) with the System Quality, Information Quality, and Interface Quality.

3.1.2 Questionnaire Selection Process

There is a variety of standardized usability questionnaires oriented to different user groups or approaches. Depending on the characteristics of the evaluation to be done, it is essential to select the most appropriate one. For this reason, a research on current standardized usability questionnaires has been done to find the one that better accomplishes the requirements of this study.

The complete usability experiment is explained in the next section, including details regarding the user participant group. The experiment calls upon participants to perform a set of tasks in a DAO platform and then complete a post-study usability questionnaire about the system. The selected questionnaire should be concise and straightforward to ensure the engagement of the participants; it should be valid in a context with users without previous knowledge; the sample size of the participants is not so big (14 users) so it should give guarantees of be reliable enough even with little sample sizes; it should be widely used; and it should not require any license fee.

To further enhance the selection process of the most appropriate post-study usability questionnaire, other factors obtained in psychometric evaluations such as the reliability coefficient and various types of validity have also been utilized in this study. In particular, the Cronbach's alpha [15] is the most used metric to assess the internal consistency or reliability of a test or questionnaire. It measures how closely related a set of items are to each other as a group, and this is why it is considered a measure of scale reliability. A high Cronbach's alpha value suggests that the items in the questionnaire

measure the same underlying construct, indicating good internal consistency [16]. Cronbach's alpha is expressed as a value between 0 and 1. A value of 0 indicates that the test items are entirely uncorrelated, whereas an alpha of 1 implies that the test items are perfectly correlated. In the context of usability questionnaires, this metric is commonly used to assess the reliability of the questionnaire. Usability questionnaires typically consist of multiple items designed to measure different aspects of a system usability. Cronbach's alpha can be used to confirm that these items are measuring the same general concept, which is essential to ensure the validity of the questionnaire. If a usability questionnaire has a high Cronbach's alpha, researchers can be confident that the responses to the different items are consistent and therefore the questionnaire is reliable.

3.2 Questionnaires Evaluated

3.2.1 Post-Study System Usability Questionnaire (PSSUQ)

The first version of the Post-Study System Usability Questionnaire (PSSUQ) was created by Lewis [17] as an internal IBM project. It was designed to assess user satisfaction with computer systems or applications, by the evaluation of five usability characteristics: quick completion of work, ease of learning, high-quality documentation and online information, functional adequacy, and rapid acquisition of productivity [13]. It has evolved based on the results of the reliability that was getting after being tested, and the final and current version (the third) includes 16 items, evaluated in a scale between 1 and 7.

Apart from the overall measurement of usability, the PSSUQ produces three scores as subscales: System Quality, Information Quality, and Interface Quality. The initial iterations of the PSSUQ demonstrated exceptional scale and subscale reliability. For the third version the reliability values are:

- The overall reliability at 0.94
- System Quality (SysQual) at 0.90
- Information Quality (InfoQual) at 0.91
- Interface Quality (IntQual) at 0.83.

Each metric exceeds the 0.80 mark, meaning a sufficient level of reliability to be employed as standardized usability measurements [13].

3.2.2 Questionnaire for User Interaction Satisfaction (QUIS) and Software Usability Measurement Inventory (SUMI)

The Questionnaire for User Interaction Satisfaction (QUIS) and the Software Usability Measurement Inventory (SUMI) are two additional well-regarded usability questionnaires that have also been considered during the selection process. QUIS, developed by a team at the University of Maryland, evaluates satisfaction with specific aspects of the human-computer interface [19]. SUMI, on the other hand, provides a comprehensive assessment of software usability, producing scores on five dimensions: efficiency, affect, helpfulness, control, and learnability [18].

Both instruments have been shown to be reliable and valid in multiple contexts and could potentially provide valuable results in the evaluation of DAO platforms. However, the use of these questionnaires requires the purchase of a license, which is a barrier, given the requirements of this study. This, combined with the product-against-product orientation of SUMI, and their orientation towards users with experience in the evaluated system, ultimately led to the decision to exclude these options from the final selection. Instead, the focus was directed towards equally effective, but more accessible and pragmatic, usability assessment tools.

3.2.3 User Experience Questionnaire (UEQ)

The User Experience Questionnaire (UEQ) [20] [21] is designed to measure the user's experience with a product. Its strength lies in measuring six dimensions of user experience, divided into pragmatic quality and hedonic quality, and providing a detailed assessment. These dimensions are: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. The application of UEQ in some studies [21] [22] indicates acceptable consistency values in the Cronbach's alpha reliability metric. In addition, it is suitable for smaller sample sizes due to its quick completion time. Nevertheless, since the UEQ is a relatively new questionnaire, there is fewer comparative data available. Also,

interpreting the UEQ could be challenging as it involves more dimensions than most other usability scales.

3.2.4 Usability Metric for User Experience (UMUX)

The Usability Metric for User Experience (UMUX) is a shorter usability scale developed to get a measurement of perceived usability to be consistent with SUS questionnaire, but closely conformed to the ISO definition of usability (effective, efficient, satisfying) [24]. Due to its brevity and quick completion time, it is ideal for small sample sizes or when time is limited. Its correlation with the SUS allows it to be utilized for comparative studies. However, the UMUX covers fewer dimensions of usability than some other tools. Moreover, the original UMUX only comprises four items, and while a more extended version (UMUX-LITE) exists, it may still not provide as detailed information as other scales.

3.2.5 System Usability Scale (SUS)

The System Usability Scale (SUS) is a simple, ten-item scale that gives a global view of subjective assessments of usability. It consists of a series of statements to which users rate their level of agreement on a five-point scale [14]. Despite being a self-described “quick and dirty” usability scale, the SUS has become a popular questionnaire for end-of-test subjective assessments of usability [13].

The SUS questionnaire provides a reliable tool to evaluate a wide variety of products and services, including hardware, software, mobile devices, websites, and applications. Unlike other usability metrics, SUS is technology-agnostic and does not cater to a specific research design or methodology.

The SUS consists of 10 item statements to which a user rates their level of agreement on a five-point scale. Five of these statements are in positive tone, and five are in a negative one, to prevent the users from answering automatically. The SUS score is then calculated using a formula that converts the raw scores to a total score ranging from 0 to 100, obtaining the overall SUS usability score. This scale is simple and effective to use in a comparison between different systems. Some studies estimate that SUS has a high reliability, based by the Cronbach's coefficient alpha, being at or just over 0.9 [13].

Based on the content of the items, Lewis and Sauro [23] divided the overall usability value in two subscales, “Usable” and “Learnable”. Using the data given by Sauro and Lewis in this study, the subscale reliabilities, measured by coefficient alpha, were 0.91 for Usable and 0.70 for Learnable.

To provide a more fair grading assignment, Lewis and Sauro developed a curved grading scale interpretation of SUS scores using percentiles based on a set of individual SUS scores used in different studies [13]. With this grading scale, the SUS score can be converted to grades from F to A. The correlation is available in Table 3-1.

Grade	SUS	Percentile range
A+	84.1 – 100	96 – 100
A	80.8 – 84.0	90 – 95
A-	78.9 – 80.7	85 – 89
B+	77.2 – 78.8	80 – 84
B	74.1 – 77.1	70 – 79
B-	72.6 – 74.0	65 – 69
C+	71.1 – 72.5	60 – 64
C	65.0 – 71.0	41 – 59
C-	62.7 – 64.9	35 – 40
D	51.7 – 62.6	15 – 34
F	0 – 51.6	0 – 14

Table 3-1 SUS scores grading interpretation scale and percentile

3.3 Questionnaire Selected

The selection of an appropriate usability evaluation method is crucial to ensure a reliable and valid assessment of usability in the context of this study. After careful consideration, the SUS questionnaire was identified as the most appropriate method for several reasons.

First, the SUS questionnaire is a well-established and widely used tool for evaluating the usability of interactive systems and software applications [13]. Its popularity can be

attributed to its simplicity, efficiency, and ability to provide a standardized measure of usability. The concise and direct nature of the SUS makes it an efficient tool for gathering usability feedback from participants without causing survey fatigue.

It has been extensively validated and has demonstrated good reliability and validity across different domains [26]. Its adaptability to different technological contexts makes it particularly appropriate for its use in a novel technology such as blockchain.

Also, previous research studies have demonstrated that SUS remains a reliable tool even with smaller sample sizes [28], fitting with the requirements.

All of this, along with its accessibility and the absence of license fees, constitutes significant advantages in selecting the SUS questionnaire for this study.

Chapter 4 – Experimentation

This section presents the experimental design and methodology employed in this study to evaluate the usability of DAO platforms. The study will explore the usability aspects of two prominent platforms, Aragon and DAOhaus, from the perspective of users new to the domain of blockchain and DAOs, with the goal of identifying strengths and areas for improvement in their user interfaces and interactions.

The introduction to blockchain-based applications can be difficult. This technology introduces new and different concepts that differ from traditional software workflows and applications, and can be challenging even for people with a good technical background in software. Moreover, within the context of DAOs as part of the realm of blockchain applications, there are additional complexities with unique terminologies and functionalities that may be complicated at first for users with a lack of experience in this domain. The purpose of this study is to evaluate how well DAO platforms developed usability in their web applications.

To ensure a rigorous and well-structured experimental approach, this study draws upon the principles and guidelines outlined in the book "Research Methods in Human-Computer Interaction" [25]. This comprehensive resource serves as a guiding framework to design and execute the usability experiment, ensuring the reliability and validity of the findings.

To assess the core components of this study, the next research question is introduced:

What are the differences between Aragon and DAOhaus as DAO platforms for introducing users to the DAO environment?

Based on that research question, the next hypothesis has been developed:

There will be differences in the usability of Aragon and DAOhaus when users interact with these platforms.

4.1 Experiment Design

The research design for this study follows a controlled experiment approach. A controlled experiment allows for the systematic evaluation of the usability of DAO platforms providing a structured and controlled environment for participants to interact with the applications. This setup facilitates an accurate and fair evaluation, ensuring that any observed differences can be attributed to the platforms themselves and not to external factors. This design was selected to maintain uniformity and control over the experiment conditions, enhancing the validity and reliability of the results.

In this experiment, the independent variable is the DAO platform with which the participants interact: Aragon or DAOhaus. This is the primary variable that the experiment manipulates to observe its impact on the dependent variable, which is the overall measure of usability. This measure is gauged through a usability questionnaire that participants fill out after interacting with each platform. The dependent variable will allow us to quantitatively measure and compare the usability of Aragon and DAOhaus.

To ensure that the experiment conditions are identical for both platforms, the experiment involves a consistent set of tasks that participants will perform across the two DAO platforms. These tasks are designed to reproduce typical user actions on DAO platforms, such as creating a new DAO, or set up a proposal. By standardizing the tasks, we can ensure that any differences in the dependent variables are due to the platforms themselves and not to the nature of the tasks.

There is only one group of participants who interact with both DAO platforms, this is called a within-group design. There are a few considerations that are important to keep in mind to guarantee the validity of the results following this type of design. As the participants have no previous experience within the DAO environment, it is necessary to do a balanced distribution of the independent variable by counterbalancing the platform order among participants. Also, so as not to extend the test process too much, the tasks must not be excessively complicated. Finally, while a within-group design mitigates the impact of individual differences on the results, it does not eliminate them entirely. Consequently, it is important to select the sample participants carefully.

Furthermore, the order in which participants interact with the platforms is randomly determined to prevent any sequence effects, where the experience with the first platform influences the user's interaction with the second platform. This is done to prevent any order effects, such as learning or fatigue, from affecting the results. The platform order is the only thing that is randomized because is the only independent variable.

4.1.1 Applying SUS Questionnaire

After participants interact with and perform the tasks on each DAO platform, they complete the System Usability Scale (SUS) questionnaire defined by John Brooke [14]. This questionnaire has been selected due to its reliability, and validity, making it a widely accepted tool for measuring the usability of a variety of systems and interfaces [13] [26].

The SUS questionnaire is used to derive an overall usability metric for each DAO platform. It should be noted, however, that this is a subjective measure, as it is based on the individual perceptions and the context which is introduced. John Brooke already highlighted this [14]:

“Usability does not exist in any absolute sense; it can only be defined with reference to particular contexts. This, in turn, means that there are no absolute measures of usability, since, if the usability of an artefact is defined by the context in which that artefact is used, measures of usability must of necessity be defined by that context too. Despite this, there is a need for broad general measures which can be used to compare usability across a range of contexts.”

In addition to providing an overall usability score, the SUS questionnaire also gives a learnability metric, which provides valuable insights into how easily new users can understand and navigate the DAO platforms. This learnability score is particularly relevant given the relative novelty of DAO platforms and the participant's lack of experience with such technology.

Once completed, the SUS provides a score which can be compared to a standardized table of grades and percentiles, enabling a more nuanced interpretation of the results. The comparison allows us to understand how the usability of the DAO platforms compares to other systems, providing a benchmark for the interpretation of the results [13] [27].

One limitation in the study is the relatively small sample size of 14 participants. This reduced size might lead to decreased confidence in the findings and increase the margin of error. Furthermore, using the same participants to evaluate both DAO platforms also reduces variability, increasing the reliability of our results.

4.1.2 User Participants

The methodology for selecting participants was followed by ethical guidelines [51] [52], ensuring that informed consent was obtained from all individuals who took part in the study. Participants were informed of the purpose of the study, the tasks they would be asked to perform, and any potential risks associated with participation. They were made aware that their participation was voluntary and that they could withdraw from the study at any time without consequence. Privacy and confidentiality were strictly maintained throughout the study, and any identifying information was carefully removed from the data.

To prevent any factor apart of the defined variables that could influence in the results of the study and ensure the relevance and effectiveness of the study, the participant selection was based on a specific criterion.

Participants include individuals with a strong technical background such as developers, software engineers, and those with formal education or professional experience in computer studies. Including non-computer users would introduce challenges that may not be directly relevant to the evaluation of DAOs and blockchain technology. This criterion ensures that the participants have a solid foundation in computer programming, user interfaces, and software development principles. Their technical expertise will enable them to understand the functionalities of the DAO platforms evaluated. Furthermore, conducting this evaluation provides an opportunity to explore a new approach, as previous studies have not specifically focused on evaluating the usability of DAO platforms with computer users. Finally, by including only computer users, the goal is to determine whether having computer knowledge alone is sufficient for users to effectively and proficiently engage with these platforms.

One crucial aspect of the selected participants is that they should not have prior knowledge or experience with blockchain-based applications, specifically DAO

platforms. This criterion is particularly important in this study as it allows to explore the usability challenges faced by users who are unfamiliar with the DAO environment. By evaluating the interactions and feedback of these first-time users, the research aims to uncover usability challenges and issues that might not be apparent to users who are already familiar with blockchain and DAO platforms.

By selecting participants with computer science or related background and limited blockchain knowledge, the study aims to gather insights into the usability of DAO platforms simulating a real-world scenario from the viewpoint of technically inclined users encountering this technology for the first time. Their expertise in software, combined with their lack of prior blockchain experience, allows for a comprehensive evaluation of the usability challenges faced by novice users. The feedback provided by these participants will be instrumental in identifying areas for improvement and enhancing the overall user experience of DAO platforms.

Finally, 14 participants were selected based on the above criteria. Among the participants, 13 identified as male and one as female. The age distribution of the participants included the following ranges: two individuals were between the ages of 32 and 35, another two were between 45 and 50, and the majority, consisting on ten participants, were aged between 24 and 28.

4.2 Procedure

The participant will be asked to interact with two web applications of DAO platforms in order to perform a usability test. The participant will do some tasks in each platform and, after completing them, will fill a usability questionnaire that will reflect the general satisfaction with the platform as a result of the overall usability measure given in the questionnaire. The whole session should not be longer than 60 minutes.

1. [2 minutes] The participant is greeted, and their consent is requested to record part of the session on video. The participant is informed that at any time he/she can request to stop the recording, as well as that he/she can leave the session at any time. The participant is informed that during part of the session he/she will be asked to share his/her screen, so is required to hide all personal information that can be visible.

2. [5 minutes] The context of the test is introduced. A brief introduction about blockchain and DAOs is given to the participant, also that there are some platforms (SaaS) that offer a user interface to help in build and manage DAOs. The *wallet* concept is introduced to the user in the way of authentication in blockchain based applications.
3. [4 minutes] The test is explained to the participant. First, is necessary install the MetaMask extension in the browser. Then, after a random selection, the participant will complete a set of tasks in one DAO platform and will fill a usability questionnaire (SUS) without any intervention or suggestion. After the questionnaire, the user will complete the same tasks in the second platform and fill the usability questionnaire again. Finally, after both interactions, the participant will be asked about the main differences found between the applications.
4. [8 minutes] The participant is requested to install the MetaMask extension in the browser following the steps of the practitioner, also the participant is warned about that this step is not going to be included in the usability evaluation of the experiment. The credentials for the wallet are sent by email to the participant. Once this step is done, the recording will start.
5. [12 minutes] The participant will receive by email the information and the tasks of the first platform to evaluate. The conductor will try not to give direct answers or guide the participant in case of doubts or difficulties but will provide the minimum necessary help so that the participant can discover the solution of the problem on their own.
6. [4 minutes] After completing the tasks, the participant will complete the questionnaire received by email without any intervention or suggestion by the conductor. This means that in case of being online the participant and the conductor will turn off the microphone and the camera during the questionnaire time.
7. [12 minutes] The participant will receive by email the information and the tasks to perform in the second platform. The interaction between the conductor and the participant will be the same as with the previous platform (step 6).

8. [4 minutes] After completing the tasks, the participant will again complete the same questionnaire received by email in the same conditions as before (step 7), but regarding the second platform.
9. [5 minutes] Once everything is done, the conductor will ask the participant to point the main differences in usability or ease of use that the participant has noticed/found and also mark the biggest difficulties found. After that, the participant is thanked for their time, the recording is stopped, and the communication is terminated.

4.2.1 Tasks To Do

This study was designed to evaluate the usability of two DAO platforms, Aragon and DAOhaus, by asking users to complete a set of selected tasks within these applications. Bearing in mind that the participants of this study had no prior experience with blockchain-based applications and DAOs, and the fact that they were required to repeat the same tasks across two platforms, it was necessary to keep the tasks simple and not unnecessarily long in order to maintain participant engagement and focus.

These tasks were specifically chosen to provide a balanced exploration of the DAO platforms, introducing new concepts while also leveraging familiar ones. Creating a DAO and a proposal served to introduce new concepts and provided first-hand experience with the essential features of these blockchain platforms. Meanwhile, tasks such as visualizing the member list or settings represented familiar actions within a new context, easing the learning curve. The tasks are summarized in Table 4-1.

1.	Create a DAO
2.	Create a proposal
3.	Visualize the members list
4.	Check the settings
5.	See the details of the proposal created in step 2

Table 4-1 Tasks to do within the DAO platforms

The first pair of tasks focused on engaging participants in the process of creating a DAO and a proposal within it. This was considered essential for the next two reasons:

first, it allowed participants to gain experience with the key features of DAO platforms, and second, it gave them an opportunity to understand and appreciate the transactional nature inherent to these blockchain-based platforms. It was essentially a dive into the deep end of DAO interactions, helping them to understand how various operations translate into transactions on the blockchain, the need for confirmations, and how these processes can affect the user experience due to factors such as wait times and transaction fees.

On the other hand, the rest of the tasks were designed with a more exploratory objective. They were structured to encourage participants to navigate through different sections of the platform and explore its various features, while analyzing how easy it is to find these pages through the application. These tasks aimed to provide a balanced combination of essential platform functionality and interface design, ensuring that participants left the study with a well-rounded and nuanced understanding of DAO platforms.

Chapter 5 - Results

Before diving into the results of the SUS questionnaire, it is important to discuss the observations and user feedback that were gathered during the experiment. By observing user behavior in real time and recording their feedback, many usability issues were identified that may not have been adequately captured by the SUS questionnaire alone. This approach will provide a broader context for understanding the SUS results and provide a comprehensive picture of the user experience on both Aragon and DAOhaus platforms.

It is important to remember that usability is a broad concept that encompasses not only ease of use, but also user satisfaction, learnability, and efficiency. Through this combined method of observation, feedback collection, and formal usability testing, this study aims to present a comprehensive view of the usability on both platforms.

The experiment was conducted with 14 participants one by one. They had the option of doing it in presence or online with no difference in the evaluation, 6 participants chose online and the other 8 chose in person. The platform order was randomized half to half, 7 participants started with Aragon and 7 with DAOhaus. The average duration of each experimental session was about 55 minutes.

5.1 Aragon

The creation of a DAO on Aragon involves a series of well-explained steps, offering a good level of clarity that the participants found beneficial as it gave them a comprehensive understanding of the task at hand, making the users more comfortable with the process.

However, the user interface exhibited inconsistency, particularly with respect to some form selections. Certain options were displayed only upon the selection of a corresponding feature. An exception was the “Change vote” option, related to the “Early execution” feature, which remained visible but disabled, as shown in Figure 5-1. This is more confusing among users than hiding the option unless the parent option is checked.

The image shows a settings panel with two sections. The first section, 'Early execution', has a description: 'Allow proposal execution before the vote ends if the requirements are met and the vote outcome cannot be changed by more voters participating.' It features two radio buttons: 'No' (unselected) and 'Yes' (selected). The second section, 'Vote change', has a description: 'This setting allows voters to change their vote during the voting period. If you enabled early execution, this setting is automatically turned off.' It features two radio buttons: 'No' (selected) and 'Yes' (unselected). The 'Yes' button in the 'Vote change' section is disabled, indicated by a grey background and a grey radio button.

Figure 5-1 Vote change option disabled dependent of Early execution option

Aragon employs visual slider inputs for the selection of parameters like the minimum participation percentage in governance. Some participants reported that the sliders were not responsive. Although they were visually intuitive, their value could only be changed by modifying the text input, which contradicted user expectations.

Aragon's design includes a verification step at the end of the DAO creation process. This required participants to review and accept all values and attributes by means of checkboxes. Although some participants did not notice these checkboxes at first, they eventually found them valuable. This confirms the importance of user confirmation steps in complex processes, even though it may require additional effort from the user's side.

After the creation of the DAO, while its information is being added to the blockchain, a static image displays a message indicating that the DAO is being built, with a button that changes from "We're building your DAO" to "Open your DAO" when this process is complete. The rest of the interface remains unchanged, leading to some participants to wait for a more substantive change to indicate the completion of the process. While the main figure indicates that the creation is still in process, the button says that it is finished and you can open the DAO, as shown in Figure 5-2.

Despite the fact that the proposal creation process was not complicated for the participants, they were hesitant to add actions during this process, they tended to think that it would start another complex process or even another proposal. The few who attempted to add actions found the process informative and useful, indicating a possible

opportunity to educate and guide users on the importance and usefulness of adding actions in the DAO environment.

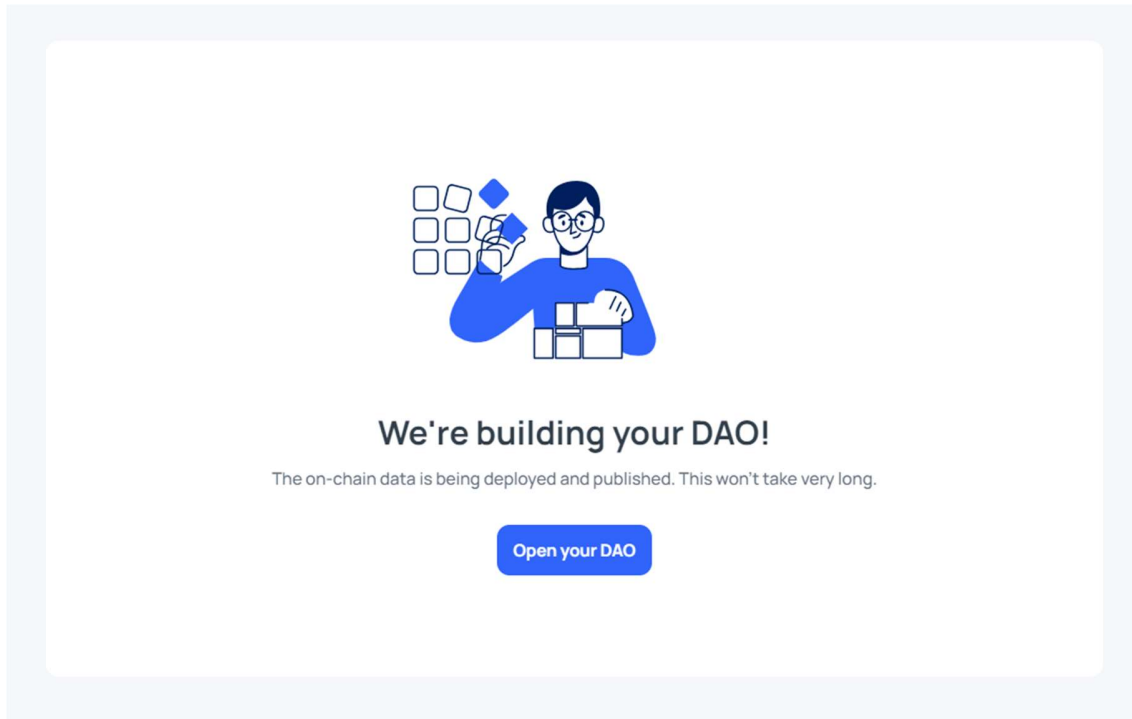


Figure 5-2 Inconsistent figure in Aragon DAO creation

All the participants found the upper navigation menu a bit confusing, being inconsistent across different pages. This menu gets sometimes hidden automatically and needs to be displayed with a button, causing participants to mistakenly use the DAO selector in the top left corner to exit the current page. In Figure 5-3 there is an example of how this menu is hidden when there is enough space to display all the options. In addition, the labelling of certain tabs in this menu led to some confusion and unexpected outcomes when users were searching for specific pages. For example, locating the member list and the proposals page was not intuitive due to the labels used for these sections. The member list was placed under the "Community" tab, which made participants think it was a link to a social media application, or a forum where people could talk and share opinions. The "Proposals" page was placed under the "Governance" tab, which led participants to expect to see in that page the governance information of the DAO, or some graphs with related statistics. Another inconsistent use of terms found during the DAO creation process was related to the "Launch" and "Deploy"

options, which were used interchangeably. This highlights the importance of consistent terminology in user interfaces to avoid confusion.

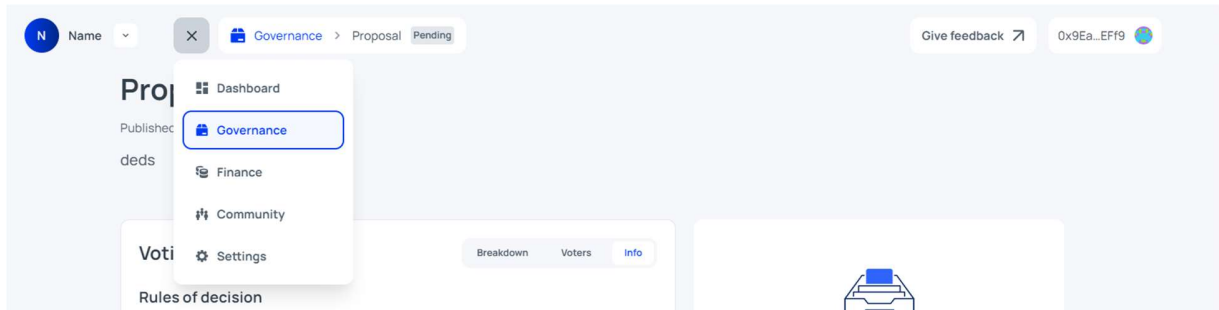


Figure 5-3 Hided Aragon upper menu navigation

Some participants did not change the network accordingly to the Mumbai test network when creating the DAO. They noticed this in the last step of the DAO creation when they could not click on the button. Throughout the creation process, a message was displayed at the top of the page indicating "Wrong network", which was easily overlooked due to its small size. Also, when they noticed it, they tended to think that what everything they had done was not valid and they had to start from the beginning. The DAO platform should give more information to the user about being in the wrong network.

Despite these issues, Aragon participants highlighted as positive aspects its clear interface, the use of descriptive images, the modular design, and the strategy of breaking down complex tasks into manageable steps. The modularity of the design follows the principle of high cohesion already seen in the organization's layered architecture, reflecting Aragon's commitment to clarity and simplicity, which is effectively communicated through the user interface design.

5.2 DAOhaus

In contrast to Aragon, DAOhaus uses a long, single form to collect information for DAO creation, which participants found less intuitive. The static nature of this form led to problems, especially when participants needed to backtrack and correct information. The scrolling required for the long form often caused users to miss fields or get lost, affecting the overall user experience.

Almost all the participants had problems with the format to introduce members into the organization during the DAO creation process, the input requires to add the address of the wallet, followed by two numbers, the amount of shares and loot to mint for each member. In Figure 5-4 there is an example of the input, the placeholder and the explanation given by the page. Since these are separate items, it might be better to add three different inputs for each member, one for the address and the other two for the tokens. Participants did not understand which was the correct format, and when they realized that they could not continue with the creation process, they started to change other options not related to the issue because they did not have enough feedback to know exactly which option was wrong.

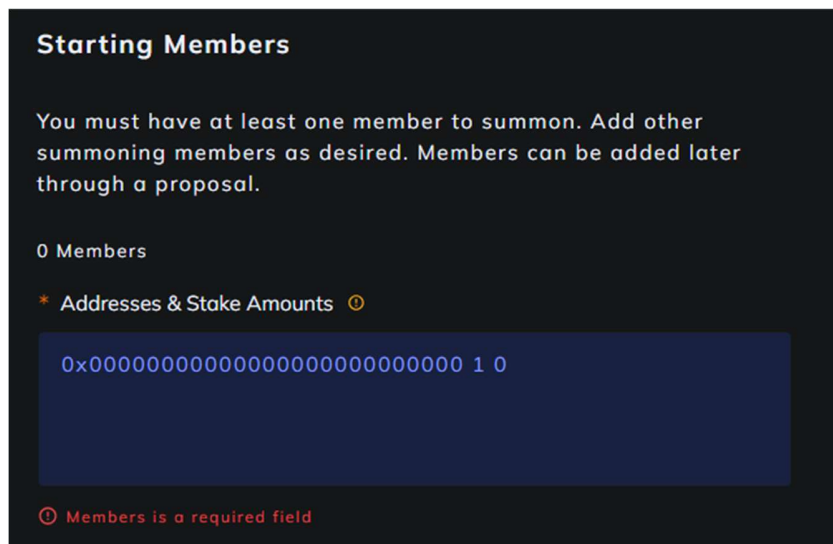


Figure 5-4 Member list input in DAOhaus during DAO creation

When it comes to creating proposals, DAOhaus shows a more advanced approach compared to Aragon by offering a larger variety of proposal types. Some of the participants appreciated this feature set, due to the enhanced flexibility and management possibilities that DAOhaus offers, while other users who preferred a simpler and more straightforward process, found it a bit overwhelming.

Navigating to the settings page was an issue for some users. The "Settings" button was hidden under a "More" button in the navbar menu, which made it less discoverable. Users questioned the necessity of this design decision, given the fact that there was enough space in the navbar to accommodate a dedicated "Settings" button and the rest of the links hidden under the "More" button as it can be shown in Figure 5-5.

Nevertheless, participants found the navigation in DAOhaus more intuitive than that of Aragon, and also stated that there was more information displayed on each page, which increased their perception of DAOhaus as a more complete DAO platform. The only exception was in the Settings page, where one of the first things displayed was the contract addresses of the tokens created. This was problematic because there was no prior explanation to users about the nature of a contract, or the correlation between tokens and contract creation. As a result, there was some confusion among participants.

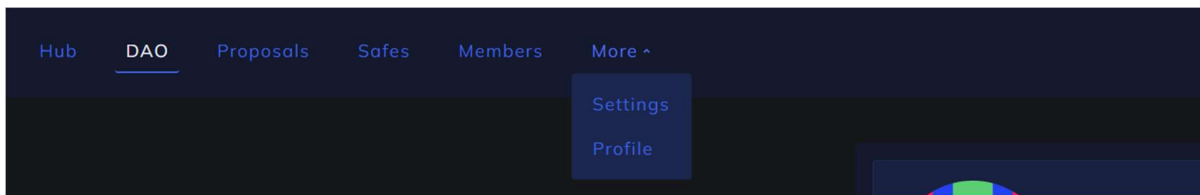


Figure 5-5 Hidden options in DAOhaus upper menu navigation

In this study, we observed that the governance structure of DAOhaus, resulting from the basis of its Moloch protocol, introduced certain complexities that were not completely understood by the users. These complexities revolve around the two different types of tokens - shares and loot - as well as the fundamental concept of "rage quit". While the tokens play a crucial role in DAOhaus operations, their true functionality remains obscure to many users. The platform provides limited explanation, mainly pointing out that shares serve as a voting token while loot means economic power. The lack of comprehensive background or contextual information about these tokens leaves the users with a fragmented understanding of their roles within the DAOhaus governance model, frequently making them wonder why both kind of tokens are necessary. The same happens with the "rage quit" concept, another core element of the DAOhaus and Moloch governance model [35]. This term is not explained while users are creating or managing the DAO. Given its importance, the users require thorough information to fully understand its impact on the DAO governance.

Some participants pointed and appreciated the implementation of computer-like language and design elements, as well as the integration of video game terminology, such as "summon" and "loot". This creative approach could create an unconscious emotional impact on some users, highlighting the potential influence of using familiar and appealing linguistic and visual elements on usability, increasing user interaction and engagement with the platform.

5.3 Usability Challenges of the Underlying Blockchain Technology

As participants interacted with the DAO platforms, they faced several inherent usability challenges that arise not from the DAO platforms themselves, but rather to the underlying blockchain technology they use. Issues such as significant waiting times, the need to pay fees for each transaction, and the use of digital wallets are not directly related to the DAO platforms, but are intrinsic to the blockchain technology. If users are not familiar with this concept and it is not well managed, it could result in a bad user experience.

Long waiting times for transactions resulted in a less than ideal user experience. Although Aragon had relatively shorter waiting times - leading to a seemingly improved user experience - this aspect was dependent on the test network used, an issue intrinsic to blockchain technology. There was also a noticeable lack of feedback to users about expected waiting times from DAO platforms, which should consider implementing mechanisms to inform users about potential delays in transaction processing. Otherwise, users may inaccurately assume they have made a mistake after waiting for some time, exacerbating usability issues. Some users noted that DAOhaus includes an attractive animation while the DAO is being created and registered on the blockchain. Incorporating such features is a recommendable practice that DAO platforms could adopt to improve the user experience, making transaction delays less noticeable and more tolerable. It is clear that small, user-focused design choices like this can play a significant role in mitigating the perceived drawbacks of transaction times.

For many participants, the concept of paying fees for each transaction was initially confusing. Participants found it unusual that each action required payment and also increased the number of interactions required to complete a single action. This departure from traditional free user interactions on the internet creates an unusual user experience that can impact user engagement and willingness to participate.

The wallet interaction feature was in general well received. Participants found the process of connecting their digital wallets to web applications, effectively bypassing traditional registration and login steps, to be straightforward and convenient. This type of

authentication fits well within the Web 3.0 framework and offers a positive perspective on this interaction model.

Participants often found the terminology and concepts introduced in DAO platforms confusing, leading to difficulties in understanding what exactly they were interacting with or doing. This level of conceptual complexity, combined with the unfamiliar interaction realm of blockchain applications, could be addressed by introducing optional interactive tutorials at the beginning of the DAO creation process. These tutorials could fill the knowledge gap and provide a more comfortable introduction to DAO and blockchain concepts for newcomers.

While it was initially difficult for participants to understand these blockchain concepts, they eventually agreed that it was inherent to the technology and accepted it. However, this does not necessarily mean that the perception of the usability will increase for some of these users. The same feeling appeared in certain aspects of DAO features, such as the need to create and approve a proposal even for minor changes, like changing the DAO settings. Once the participants understood that these steps were based on the principles of decentralization and the governance models adopted by DAOs, they agreed with their necessity.

5.4 SUS Questionnaire Results

The evaluation of both DAO platforms was supported by a SUS questionnaire that participants completed after interacting with each application, before going on with anything else. This questionnaire provides a standardized metric that measures the user's perception of the usability of the system.

The SUS questionnaire comprises 10 items on a scale from 0 (strongly disagree) to 4 (strongly agree). The interpretation of the results requires calculating each item's score contribution. For positively worded items (odd numbers), the score contribution is the scale position minus 1 ($x_i - 1$). For negatively worded items (even numbers), the score contribution is 5 minus the scale position ($5 - x_i$). The sum of these contributions, multiplied by 2.5, results in the overall SUS score, which ranges from 0 to 100 [14].

To better understand the SUS score results, in [13] was developed a curved grading scale interpretation of SUS scores that rank the scores from F to A following the Table 3-1.

In this study, the overall SUS scores of the two DAO platforms under study were as follows (graph in Figure 5-6):

- Aragon: 76.60 - Grade B
- DAOhaus: 66.25 - Grade C

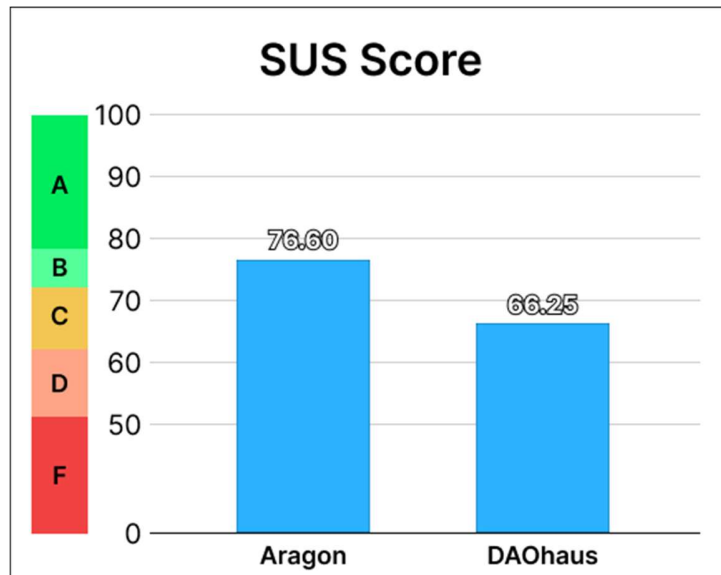


Figure 5-6 System Usability Score (SUS) results of Aragon and DAOhaus

In general, the participants found the Aragon platform more usable than the DAOhaus one, obtaining differences in the usability of both web applications. Analyzing the two subscales available in SUS, Usable and Learnable, the results obtained in Aragon are 83.92 for Usable (grade A) and 47.32 for Learnable (grade F). This is in line with the feedback and perception of the participants while interacting with the DAO platform: they highlighted the clear interface and the good design as positive aspects of the web application, but they also had problems with the navigation and the comprehensive understanding of DAO concepts. DAOhaus, on the other hand, showed more congruence between the Usable and Learnable subscales, scoring 67.41 (Grade C) and 61.60 (Grade D) respectively. These are not good results, and they spotlight usability issues, but their consistency shows a balanced evaluation.

The reliability of the answers given in this study is measured by the Cronbach's coefficient alpha, which was 0.89 for Aragon answers and 0.88 for DAOhaus. These results are high for both DAO platforms, indicating sufficient reliability of the responses.

An interesting aspect emerges when analyzing the SUS scores based on the order in which participants interacted with the DAO platforms. Half of the participants started the evaluation with Aragon, while the other half began with DAOhaus. These are the SUS scores depending on the order:

- Aragon:
 - Being the first platform evaluated: 76.78 - Grade B
 - Being the second platform evaluated: 76.42 - Grade B
- DAOhaus:
 - Being the first platform evaluated: 74.28 - Grade B
 - Being the second platform evaluated: 58.21 - Grade D

For the Aragon platform there are no differences depending on the order of evaluation, implying that the learnability of the platform does not significantly affect its perceived usability. The results for DAOhaus are different; participants who interacted with DAOhaus first, gave it the same usability score than Aragon (B), but DAOhaus experienced a significant drop in usability scores when evaluated secondly, after Aragon, even though participants were familiar with DAO concepts by then. Instead of feeling more comfortable with the concepts, terminology, and the entire domain of DAOs and blockchain, it seems that they were comparing it to their previous Aragon user experience at the time of filling out the questionnaire, perhaps unconsciously, resulting in a lower score.

Looking at the individual SUS scores for each platform, the DAOhaus score grades were distributed along the scale, with 4 participants scoring with an F, 2 scoring a D, 1 scoring a C, 3 scoring a B, and 4 scoring an A. The individual DAOhaus score graph is available in Figure 5-7.

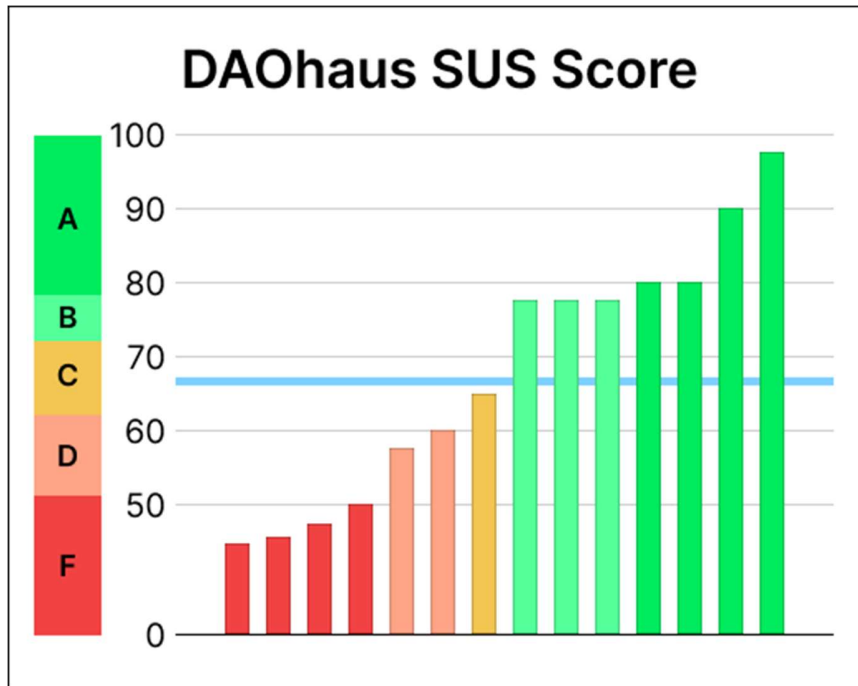


Figure 5-7 System Usability Scale (SUS) individual results of DAOhaus by participant

In contrast, Aragon's individual SUS scores did not group around the overall usability score of the platform. In most scenarios they tend to cluster around a certain score, being distributed as the percentile rank of the SUS table grading scale [13]. Specifically, 5 participants scored a D, just 1 scored a C, and the majority, 8 participants, scored an A. The Aragon score graph is available in Figure 5-8.

These disparity results indicate a high level of variance in the SUS scores, which is unusual. This suggests that some aspect of the DAO platforms or their context is causing a split in user perceptions. This might be due to the unique characteristics of blockchain based applications that are not fully captured by traditional usability measures such as SUS, or due to different user attitudes towards blockchain technology. Alternatively, it could simply be a conceptual error caused by the sample size of participants in this study.

It is important to note that while polarized SUS results are unusual, it does not automatically mean that they are invalid or useless. Rather, it calls for further investigation into why these polarizations occurred, which could provide valuable insights about the usability and user experience of blockchain applications. Such findings could be instrumental in driving the development of more suitable usability metrics for emerging technologies.

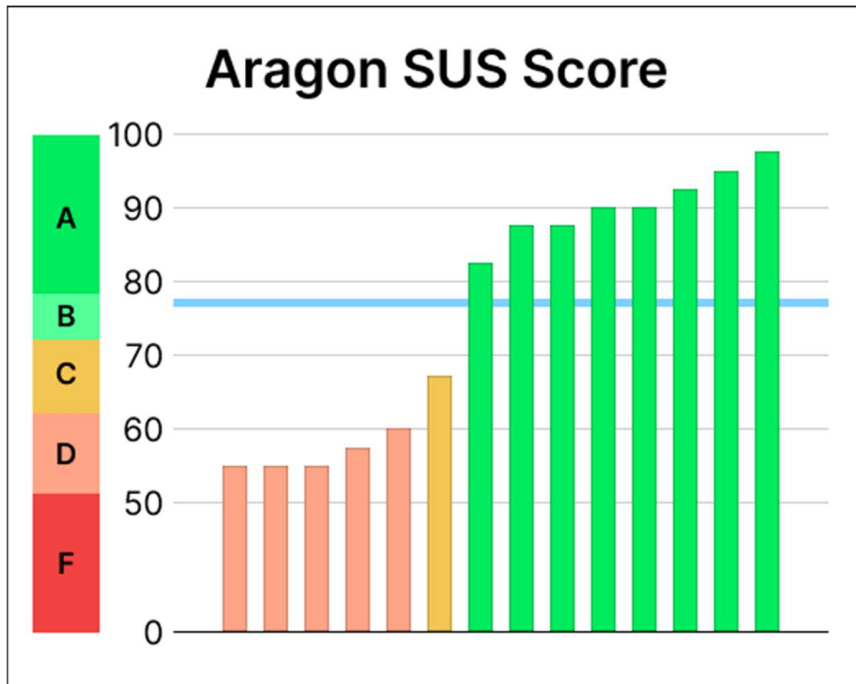


Figure 5-8 System Usability Scale (SUS) individual results of Aragon by participant

The complete SUS questionnaire results are available in Appendix 1.

5.5 Limitations

While this study provides insights about the usability of DAO platforms among a specific group of users, it has certain limitations that must be acknowledged for a complete understanding of the results.

First, the engagement of the participants with the DAO platforms was rather superficial. There were no restrictions given to the users at the time of creating the DAOs. This was done to give them freedom and not to overwhelm them with more prior information, thinking that they were going to simulate a real purpose DAO. The participants created DAOs and proposals labelled as "tests", without any real intention of practical use. This may have influenced their decision-making process during the interaction, making it less thoughtful than it would be in real-world scenarios. Ideally, participants should be encouraged to assume a more realistic role that mimics real users, which would lead to more meaningful interactions and thoughtful decisions on the platforms.

Second, a significant number of participants admitted that they did not fully understand what they were doing during the tasks, despite being able to continue with the process correctly. This was particularly evident when they were filling in DAO characteristics such as governance features, which require a strong understanding of their implications. This limitation may be in part caused by the relatively brief introduction provided by the practitioner, which may not have been adequate to establish a thorough understanding of blockchain technology and DAOs.

It is worth noting that the study was intentionally designed in this way, with the goal of providing just enough information about how blockchain and DAOs work, to observe if participants could effectively navigate and interact with the platforms. While this approach can be seen as a limitation, it was an essential part of the study design to evaluate the usability of the platforms from a newcomer's perspective. Future studies could consider providing a more detailed introduction, or including participants with different levels of prior knowledge about blockchain technology and DAOs to address this issue.

Chapter 6 - Conclusions and future applications

This master's thesis has evaluated the usability of two Decentralized Autonomous Organization (DAO) platforms, namely Aragon and DAOhaus. This was achieved through an experimental setup involving users with expertise in computer and software usage, but no prior experience with blockchain applications. By observing and analyzing their interactions and using the System Usability Scale (SUS) questionnaire, the study found that Aragon was perceived as more usable than DAOhaus. Nevertheless, both platforms faced with usability challenges due to the inherent characteristics of the blockchain technology they operate on, causing confusion and complications among the users due to their lack of knowledge and experience with this technology.

An interesting suggestion for future work would be to provide the results and usability feedback from this thesis to the developers of the Aragon and DAOhaus platforms. This would allow them to address any usability issues and enhance the user experience. Additionally, conducting a second iteration of the experiment after the implementations have been done would provide an opportunity to assess the impact of these improvements on the usability of the platforms.

System Usability Scale (SUS) was chosen among other questionnaires because of its widespread and recognized validity in evaluating user usability. Despite this, given the unusual results obtained in one of the evaluations, it may not to be the best choice for evaluating this type of technology, with different concepts and interactions than the normal web applications. Future research could consider using other modern usability tools like the User Experience Questionnaire (UEQ). It is possible that this modern questionnaire could capture additional nuances and dimensions of usability for these advanced platforms. Additionally, expanding the scope of the study to include a larger variety of DAO platforms and incorporating more complex tasks to cover more functionalities, can be useful to compare and discover how the different usability limitations are being addressed, providing new insights into usability challenges. Also, conducting heuristic evaluations with domain experts could provide a complementary perspective on usability, enriching the overall understanding of user experience within DAO platforms. All of this would further contribute to refining and adapting these

innovative technologies from different points of view and from different groups user groups.

An interesting line of future research about DAOs lies in exploring the intersection with the Internet of Things (IoT). As DAOs utilize blockchain technology to provide decentralized governance models, the potential for integration with other systems that tend to have the decentralization as a core part, such as the IoT domain, becomes a compelling area of study. DAO models could provide a way for IoT devices to make autonomous and collective decisions, increasing their efficiency and adaptability. Understanding how the governance protocols used in DAOs could be adapted to an IoT environment could revolutionize the way we interact with and manage our connected devices. This line of research has the potential to produce significant advances in both DAO and IoT fields.

BIBLIOGRAPHY

- [1] Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. Bitcoin. <https://bitcoin.org/bitcoin.pdf>
- [2] Buterin, V. (2014, May 6). Daos, dacs, Das and more: An incomplete terminology guide. Ethereum Foundation Blog. <https://blog.ethereum.org/2014/05/06/daos-dacs-das-and-more-an-incomplete-terminology-guide>
- [3] Schweiger, P. (2021). Improving Usability of Blockchain-Based Decentralized Applications. <https://doi.org/10.13140/RG.2.2.29383.62887>
- [4] Gebron, H. (2022). Why we need better blockchain content design. UX Content Collective. <https://uxcontent.com/better-blockchain-content-design/>
- [5] Liu, L., Zhou, S., Huang, H., & Zheng, Z. (2021). From technology to society: An overview of Blockchain-based dao. *IEEE Open Journal of the Computer Society*, 2, 204–215. <https://doi.org/10.1109/ojcs.2021.3072661>
- [6] Baninemeh, E., Farshidi, S., & Jansen, S. (2023). A decision model for Decentralized Autonomous Organization Platform Selection: Three industry case studies. *Blockchain: Research and Applications*, 100127. <https://doi.org/10.1016/j.bcra.2023.100127>
- [7] Khayretdinova, A., Kubach, M., Sellung, R., & Roßnagel, H. (2022). Conducting a usability evaluation of Decentralized Identity Management Solutions. *DuD-Fachbeiträge*, 389–406. https://doi.org/10.1007/978-3-658-33306-5_19
- [8] Saldivar, J., Martínez, E., Rozas, D., Valiente, M. C., & Hassan, S. (2022). Blockchain (not) for everyone: Assessing the user experience of blockchain-based applications. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4154040>
- [9] Karbach, L., Korte, M., Orbat, N., Muschiol, D., & Jansen, M. (2022). A usability analysis of the DAO concept based on the case study of a blockchain game.

Gamification - Analysis, Design, Development and Ludification.
<https://doi.org/10.5772/intechopen.105347>

- [10] Hustak, T., & Krejcar, O. (2015). Principles of usability in human-computer interaction. *Lecture Notes in Electrical Engineering*, 51–57. https://doi.org/10.1007/978-3-662-47895-0_7
- [11] Rotaru, O. A., Vert, S., Vasiu, R., & Andone, D. (2020). Standardised questionnaires in usability evaluation. applying standardised usability questionnaires in digital products evaluation. *Communications in Computer and Information Science*, 39–48. https://doi.org/10.1007/978-3-030-59506-7_4
- [12] Jeff Sauro, P. (2013, June 18). 10 things to know about the system usability scale (SUS). *MeasuringU*. <https://measuringu.com/10-things-sus/>
- [13] Sauro, J., & Lewis, J. R. (2016). Standardized usability questionnaires. *Quantifying the User Experience*, 185–248. <https://doi.org/10.1016/b978-0-12-802308-2.00008-4>
- [14] Brooke, J. (1996). Sus: A “quick and dirty” usability scale. *Usability Evaluation In Industry*, 207–212. <https://doi.org/10.1201/9781498710411-35>
- [15] Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297–334. <https://doi.org/10.1007/bf02310555>
- [16] Schrepp, M. S. (2020). On the usage of Cronbach's alpha to measure reliability of UX Scales. *Journal of Usability Studies*. <https://dl.acm.org/doi/abs/10.5555/3532713.3532717>
- [17] Lewis, J.R., 1992. Psychometric evaluation of the Post-Study System Usability Questionnaire: the PSSUQ. In: *Proceedings of the Human Factors Society 36th Annual Meeting*, Human Factors Society, Santa Monica, CA, pp. 1259–1263.
- [18] Kirakowski, J., & Corbett, M. (1993). Sumi: The software usability measurement inventory. *British Journal of Educational Technology*, 24(3), 210–212. <https://doi.org/10.1111/j.1467-8535.1993.tb00076.x>

- [19] Chin, J. P., Diehl, V. A., & Norman, K. L. (1988). Development of an instrument measuring user satisfaction of the human-computer interface. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '88. <https://doi.org/10.1145/57167.57203>
- [20] Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of A user experience questionnaire. Lecture Notes in Computer Science, 63–76. https://doi.org/10.1007/978-3-540-89350-9_6
- [21] Laugwitz, B., Schrepp, M., Held, T. (2006). Konstruktion eines Fragebogens zur Messung der User Experience von softwareprodukten [Construction of a questionnaire to measure the user experience of software products]. Mensch Und Computer 2006, 125–134. <https://doi.org/10.1524/9783486841749.125>
- [22] Rauschenberger, M., Schrepp, M., Perez-Cota, M., Olschner, S., Thomaschewski, J. (2013). Efficient measurement of the user experience of interactive products. how to use the user experience questionnaire (UEQ). Example: Spanish language version. International Journal of Interactive Multimedia and Artificial Intelligence, 2(1), 39. <https://doi.org/10.9781/ijimai.2013.215>
- [23] Lewis, J. R., Sauro, J. (2009). The factor structure of the system usability scale. Human Centered Design, 94–103. https://doi.org/10.1007/978-3-642-02806-9_12.
- [24] Finstad, K. (2010). The usability metric for user experience. Interacting with Computers, 22(5), 323–327. <https://doi.org/10.1016/j.intcom.2010.04.004>
- [25] Lazar, J., Feng, J. H., Hochheiser, H. (2017). Research methods in human-computer interaction. Elsevier.
- [26] Brooke, J. (2014, July 12). Sus: A retrospective - jux. JUX - The Journal of User Experience. <https://uxpajournal.org/sus-a-retrospective>
- [27] Lewis, J. R., & Sauro, J. (2018, May 1). Item benchmarks for the system usability scale. Journal of Usability Studies. <https://dl.acm.org/doi/10.5555/3294033.3294037>

- [28] Sauro, J., & Lewis, J. R. (2016). Quantifying the User Experience: Practical Statistics for User Research. Morgan Kaufmann.
- [29] Kronovet, D. (2019, June 16). Aragon, DAOstack, colony, moloch. <http://kronosapiens.github.io/blog/2019/06/16/aragon-daostack-colony-moloch.html>
- [30] El Faqir, Y., Arroyo, J., & Hassan, S. (2020). An overview of decentralized autonomous organizations on the blockchain. Proceedings of the 16th International Symposium on Open Collaboration. <https://doi.org/10.1145/3412569.3412579>
- [31] Mini, T., Ellinger, E., Gregory, R., & Widjaja, T. (2021). An Exploration of Governing via IT in Decentralized Autonomous Organizations.
- [32] Valiente Blázquez, M., Hassan, S. & Pavón Mestras, J. (2021). Evaluating the Software Frameworks for Developing Decentralized Autonomous Organizations. <https://hdl.handle.net/20.500.14352/8887>
- [33] Cuende, L. (2018, May 8) The Aragon Manifesto. <https://github.com/aragon/AGPs/blob/master/AGPs/AGP-0.md?ref=blog.aragon.org>
- [34] McCombie, C. (2022, August 9) - First Public Institution in Spain Holds Vocdoni Referendum | Bellpuig Council - <https://blog.aragon.org/first-public-institution-in-spain-holds-vocdoni-referendum-bellpuig-council/>
- [35] Gist, V. (2019, October 3). Moloch primer for humans. <https://medium.com/odyssy/moloch-primer-for-humans-9e6a4f258f78>
- [36] DAOhaus & spengraph (2023, March 22) DAOhaus V3: The Protocol for Purpose-Driven Governance. <https://daohaus.mirror.xyz/bcJCN2H7vow6xRE977A4pTWUNR0vqrgTscFLtu2ttn8>
- [37] Suratkar, S., Shirole, M., & Bhirud, S. (2020). Cryptocurrency wallet: A Review. 2020 4th International Conference on Computer, Communication and Signal Processing (ICCCSP). <https://doi.org/10.1109/icccsp49186.2020.9315193>

- [38] Jokić, S., Cvetković, A., Adamović, S., Ristić, N., & Spalević, P. (2019). Comparative analysis of cryptocurrency wallets vs traditional wallets. *Ekonomika*, 65(3), 65–75. <https://doi.org/10.5937/ekonomika1903065j>
- [39] COTI (2018, January 11) The difference between hot and cold wallets in the digital currency world. <https://medium.com/cotinetwork/the-difference-between-hot-and-cold-wallets-in-the-digital-currency-world-1aa6f957ddd1>
- [40] Baczuk, J. (2018, June 6) How to Generate a Bitcoin Address — Step by Step. <https://medium.com/coinmonks/how-to-generate-a-bitcoin-address-step-by-step-9d7fcbf1ad0b>
- [41] Petcu, A., Pahontu, B., Frunzete, M., & Stoichescu, D. A. (2023). A secure and decentralized authentication mechanism based on web 3.0 and Ethereum Blockchain Technology. *Applied Sciences*, 13(4), 2231. <https://doi.org/10.3390/app13042231>
- [42] Hassan, S., & De Filippi, P. (2021). Decentralized Autonomous Organization. *Internet Policy Review*, 10(2). <https://doi.org/10.14763/2021.2.1556>
- [43] Wang, S., Ding, W., Li, J., Yuan, Y., Ouyang, L., & Wang, F.-Y. (2019). Decentralized Autonomous Organizations: Concept, model, and applications. *IEEE Transactions on Computational Social Systems*, 6(5), 870–878. <https://doi.org/10.1109/tcss.2019.2938190>
- [44] Voshmgir, S. (2020) Tokenized Networks: What is a DAO?. <https://blockchainhub.net/dao-decentralized-autonomous-organization/>
- [45] Filippi, P. D., & Hassan, S. (2016). Blockchain technology as a regulatory technology: From code is law to law is code. *First Monday*. <https://doi.org/10.5210/fm.v21i12.7113>
- [46] Wang, S., Ouyang, L., Yuan, Y., Ni, X., Han, X., & Wang, F.-Y. (2019). Blockchain-enabled smart contracts: Architecture, applications, and future trends. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 49(11), 2266–2277. <https://doi.org/10.1109/tsmc.2019.2895123>

- [47] Ethereum Community (2023) Ethereum Whitepaper - A next-generation smart contract and decentralized application platform. <https://ethereum.org/en/whitepaper/>
- [48] Underwood, S. (2016). Blockchain beyond bitcoin. *Commun. ACM* 59, 11 (November 2016), 15–17. <https://doi.org/10.1145/2994581>
- [49] Beck, R. (2018). Beyond bitcoin: The rise of blockchain world. *Computer*, 51(2), 54–58. <https://doi.org/10.1109/mc.2018.1451660>.
- [50] Bellavitis, C., Fisch, C., & Momtaz, P. P. (2022). The rise of Decentralized Autonomous Organizations (daos): A first empirical glimpse. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4074833>
- [51] Yu, L. (2020). Ethical considerations in case studies. 2020 1st Workshop on Ethics in Requirements Engineering Research and Practice (REthics). <https://doi.org/10.1109/rethics51204.2020.00009>
- [52] American Psychological Association - Ethical Principles of Psychologists and Code of Conduct, <https://www.apa.org/ethics/code>
- [53] Vogelsteller, F. & Buterin, V. (2015, November 19) ERC-20 token standard. <https://eips.ethereum.org/EIPS/eip-20>
- [54] Entriken, W., Shirley, D., Evans, E., & Sachs, N. (2018, January 24) ERC-721 non-fungible token standard. <https://eips.ethereum.org/EIPS/eip-721>
- [55] Wood, G. (2022) Ethereum project yellow paper: Ethereum: A secure decentralised generalised transaction ledger. <https://ethereum.github.io/yellowpaper/paper.pdf>
- [56] Dannen, C. (2017). Introducing Ethereum and Solidity. <https://doi.org/10.1007/978-1-4842-2535-6>
- [57] Azevedo Sousa, J. E., Oliveira, V., Valadares, J., Dias Gonçalves, G., Moraes Villela, S., Soares Bernardino, H., & Borges Vieira, A. (2020). An analysis of the fees and pending time correlation in Ethereum. *International Journal of Network Management*, 31(3). <https://doi.org/10.1002/nem.2113>

- [58] Busayatananphon, C., & Boonchieng, E. (2022). Financial Technology Defi Protocol: A Review. 2022 Joint International Conference on Digital Arts, Media and Technology with ECTI Northern Section Conference on Electrical, Electronics, Computer and Telecommunications Engineering (ECTI DAMT & NCON). <https://doi.org/10.1109/ectidamtncon53731.2022.9720373>
- [59] Guidi, B. (2020). When blockchain meets online social networks. *Pervasive and Mobile Computing*, 62, 101131. <https://doi.org/10.1016/j.pmcj.2020.101131>
- [60] Min, T., Wang, H., Guo, Y., & Cai, W. (2019). Blockchain Games: A Survey. 2019 IEEE Conference on Games (CoG). <https://doi.org/10.1109/cig.2019.8848111>
- [61] Zargham, M., & Nabben, K. (2022). Aligning 'decentralized autonomous organization' to precedents in Cybernetics. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4077358>
- [62] 1Hive. (n.d) Welcome to 1Hive. <https://wiki.1hive.org/>
- [63] Nguyen, D. C., Pathirana, P. N., Ding, M., & Seneviratne, A. (2020). Integration of blockchain and cloud of things: Architecture, applications and challenges. *IEEE Communications Surveys & Tutorials*, 22(4), 2521–2549. <https://doi.org/10.1109/comst.2020.3020092>
- [64] Uddin, M. A., Stranieri, A., Gondal, I., & Balasubramanian, V. (2021). A survey on the adoption of Blockchain in IOT: Challenges and solutions. *Blockchain: Research and Applications*, 2(2), 100006. <https://doi.org/10.1016/j.bcra.2021.100006>
- [65] Zhu, X., & Badr, Y. (2018). Fog computing security architecture for the internet of things using blockchain-based social networks. 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData). https://doi.org/10.1109/cybermatics_2018.2018.00234

- [66] Sedrati, A., Ouaddah, A., Mezrioui, A., & Bellaj, B. (2022). IOT-Gov: An IOT governance framework using the blockchain. *Computing*, 104(10), 2307–2345. <https://doi.org/10.1007/s00607-022-01086-1>
- [67] Popov, S.Y. (2015). The Tangle.
- [68] Hazelcast (n.d.) Directed Acyclic Graph (DAG). <https://hazelcast.com/glossary/directed-acyclic-graph/>
- [69] Cardenas, I.S., May, J.B., Kim, JH. (2021). AutomataDAO: A Blockchain-Based Data Marketplace for Interactive Robot and IoT Data Exchanges Using Ethermint and State Channels. In: Lee, SW., Singh, I., Mohammadian, M. (eds) *Blockchain Technology for IoT Applications*. Blockchain Technologies. Springer, Singapore. https://doi.org/10.1007/978-981-33-4122-7_2

Appendix 1 – SUS questionnaire results

Aragon SUS results

	Participants														Variance
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
SUS – 1	3	4	3	3	3	3	4	5	4	4	4	3	5	4	0,52747253
SUS – 2	3	1	1	3	2	2	1	2	2	2	1	2	1	1	0,52564103
SUS - 3	3	5	3	2	3	3	5	4	5	4	5	4	5	5	1,07692308
SUS – 4	1	1	1	1	1	2	1	2	1	5	1	3	1	1	1,42307692
SUS – 5	3	5	4	4	3	3	4	5	5	4	5	4	5	4	0,59340659
SUS – 6	1	1	1	2	1	3	1	1	1	3	1	2	1	1	0,6025641
SUS – 7	2	5	4	1	4	3	4	4	3	3	5	2	4	5	1,5
SUS – 8	3	1	1	2	2	3	1	1	1	2	1	3	1	1	0,73076923
SUS – 9	3	5	4	3	2	4	4	5	5	4	4	3	5	3	0,9010989
SUS - 10	3	2	1	3	2	4	1	2	1	3	2	4	1	2	1,19230769
Sum	23	38	33	22	27	22	36	35	36	24	37	22	39	35	9,07326007
Result	57,5	95	82,5	55	67,5	55	90	87,5	90	60	92,5	55	97,5	87,5	
Score	D	A+	A	D	C	D	A+	A+	A+	D	A+	D	A+	A+	
Platform order	1	2	2	1	1	2	2	1	1	2	1	2	2	1	

DAOhaus SUS results

	Participants														Variance
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
SUS – 1	3	3	3	3	1	4	5	3	5	4	3	3	5	3	1,18681319
SUS – 2	4	2	1	4	2	2	2	3	1	2	3	4	4	2	1,25641026
SUS - 3	3	4	3	2	2	5	4	3	5	4	3	2	5	4	1,19230769
SUS – 4	3	2	1	2	4	2	1	4	1	3	2	3	1	2	1,19230769
SUS – 5	3	4	4	3	3	5	4	5	5	5	4	4	5	4	0,59340659
SUS – 6	3	1	1	3	2	1	1	1	1	1	1	2	1	1	0,6025641
SUS – 7	3	2	4	1	1	3	4	2	4	5	3	2	4	4	1,53846154
SUS – 8	3	3	1	4	2	2	1	3	1	1	3	3	1	1	1,14102564
SUS – 9	3	3	4	2	1	3	5	5	5	4	4	3	1	5	1,95604396
SUS - 10	5	2	2	3	4	2	1	4	1	3	4	2	2	3	1,56410256
Sum	17	26	32	15	14	31	36	23	39	32	24	20	31	31	12,2234432
Result	42,5	65	80	37,5	35	77,5	90	57,5	97,5	80	60	50	77,5	77,5	
Score	F	C	A-	F	F	B+	A+	D	A+	A-	D	F	B+	B+	
Platform order	2	1	1	2	2	1	1	2	2	1	2	1	1	2	