Governance of Decentralized Autonomous Organizations

How business objectives, internal governance and external infrastructural elements influence the long-term viability of DAOs

Rikken, O.K.

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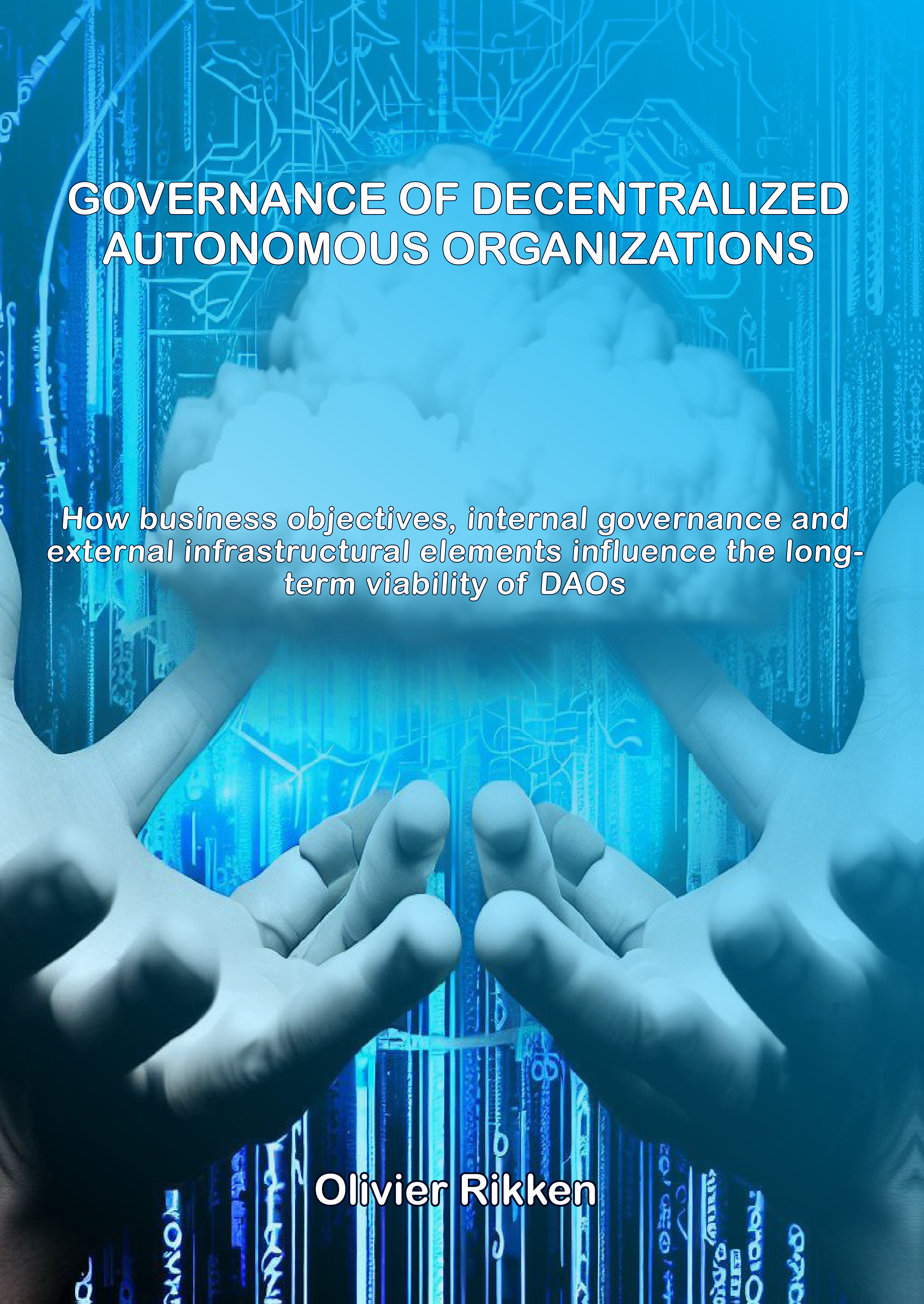
GOVERNANCE OF DECENTRALIZED AUTONOMOUS ORGANIZATIONS
How business objectives, internal governance and external infrastructural elements influence the long-term viability of DAOs
Olivier Rikken

Governance of Decentralized Autonomous Organizations

How business objectives, internal governance elements and external infrastructure elements influence the long-term viability of DAOs

Dissertation

For the purpose of obtaining the degree of doctor
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By Olivier Karel RIKKEN
Master of Science in Systems Engineering, Policy Analysis and Management, Delft University of Technology, the Netherlands
Master of Business Administration, Nyenrode Business University, the Netherlands
born in Curaçao

This dissertation has been approved by the promotors.

Composition of the doctoral committee:

Rector Magnificus	chairperson
Prof.dr.ir. M.F.W.H.A. Janssen	Delft University of Technology, promotor
Dr.ir. Z. Kwee	Delft University of Technology, copromotor

Independent members:

Prof.dr.ir. N. Bharosa	Delft University of Technology
Prof.dr. M.J. van den Hoven	Delft University of Technology
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Dr. R.L. Jansen	Utrecht University
Prof.dr. M.P. Rodríguez Bolívar	University of Granada, Spain

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The front cover image was generated by the artificial intelligence text-to-image software DALL-E

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Summary

Decentralized Autonomous Organizations (DAOs) are a fast-growing group of blockchain and smart contract-based applications. DAOs aim to serve new decentralized governance and organizational needs for various business purposes, ranging from decentralized exchanges such as UniSwap and theDAO, to R&D like VitADAO, managing infrastructures like Arbitrum, to charity funds like PactDAO. DAO projects have experienced an exponential growth over the past years. Although strongly rising in number, there is no clear consensus on what a DAO exactly entails. Additionally, despite this exponential growth, various DAO projects tend to pivot away from this form of governance or organization. They either experience a mismatch in the governance setup or the business objective, threatening their viability in the long-term. Also, as DAOs are built on blockchain infrastructure, this poses new governance challenges.

The goal of this thesis is to analyze how governance elements, business objectives and infrastructural choices can influence the long-term viability of DAOs. The main research objective of this PhD thesis is to:

"Develop a theory to explain how governance and infrastructure elements influence the long-term viability of decentralized autonomous organizations on public permissionless blockchains."

The research approach taken to achieve the research objective consists of structural literature reviews, interviews, empirical and statistical analyses. The literature used comprises both scientific literature and grey literature. Data for the statistical analysis were gathered from public sources and monitored over three years.

This thesis consists of four papers that follow in a logical order. The first paper addresses challenges within blockchain and DAOs. The second paper aims to establish a DAO definition, unravel general DAO characteristics and examine the effect of certain characteristics on long-term viability. Subsequently, the third paper extends this analysis by investigating governance elements in direct relation to long-term viability. Finally, the fourth paper introduces business objectives and external infrastructure elements as direct and moderating variables within our theoretical framework.

Specifically, the first paper focuses on identifying the governance challenges of blockchain and DAOs in general. By performing literature studies, interviews and empirical analysis, we contribute to explicating blockchain governance challenges and finding a unique governance entanglement between application and infrastructure in blockchain-based applications. DAOs often (partially) consist of blockchain-based smart contract code for executing on-chain business rules. Once deployed, these smart contract functions are stored on a blockchain, and the execution of these functions is performed on that same blockchain. This results in the fact that part of the governance of the application is entangled with elements that are under control by the governance of the infrastructure instead of the application itself. This should be considered when creating a theory of DAO long-term viability influencing factors.

The second paper first focuses on unraveling a clear DAO definition and characteristics using literature study as well as empirical analysis of DAOs. The first contribution of this paper is creating a comprehensive DAO definition:

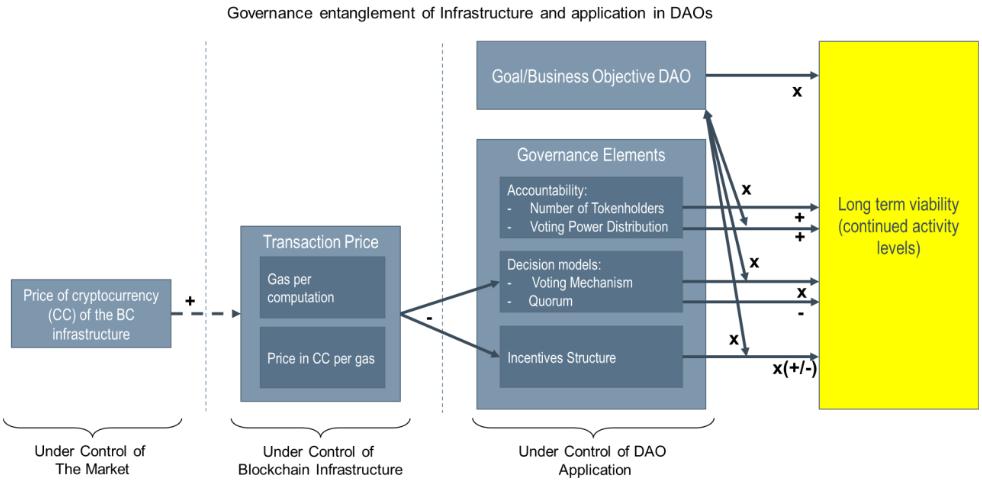
"DAOs are a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way" (Rikken, Janssen, & Kwee, 2023b, pp. 7-8).

Furthermore, the second paper studies the effect of decentralization on long-term viability and finds a positive relation between the level of decentralization and long-term viability. The findings are derived using empirical study and statistical analysis. Finally, we use empirical analysis to identify a trend of off-chain governance within DAOs. We conclude that off-chain governance DAOs give in to the autonomous elements of DAOs by lack of automatic execution of decisions, which in itself can pose a risk and thus better be classified as decentralized organizations instead of DAOs.

Using a literature review and empirical and statistical analysis, governance elements are classified in the third paper, and their effects on long-term viability are analyzed. The governance elements for the research were derived from the definitions of Ross and Weill and included the elements of accountability, incentives, and decision models. In the third paper (and in the fourth paper), a taxonomy for DAO governance elements and dimensions and a classification for DAO business objectives were created and used for empirical analysis of DAOs. In the third paper (as with the second), we found that a higher number of tokenholders and a democratic voting power distribution positively affect the long-term viability of DAOs. The third paper concludes that variations in governance elements of incentives and decision models affect long-term viability. Also, non-weighted decision models contribute positively to DAO long-term viability. Finally, differences in incentive structure also have an effect, where no incentive positively contributes to long-term viability. Based on our findings, the first version of a preliminary theory of governance elements and long-term viability was proposed. We conclude that for further analysis, the business objectives should be considered as a moderating variable in the governance elements.

The fourth paper builds upon the first three papers and analyzes business objectives and governance elements differentiation on long-term viability and the influence of infrastructure elements on DAO governance elements. In this paper, we derive a theory outlining governance elements of voting power distribution, voting mechanisms, incentive structure, and their relationship with long-term viability, moderated by business objectives. Also, the influence of external infrastructural elements on internal DAO governance elements is taken into account in this theory. The key conclusion is that DAOs with a non-economic purpose have a higher long-term viability than DAOs with an economic purpose. This could be explained by the inherent nature of DAOs focusing on more common or social goals and an altruistic community surrounding these initiatives, although this should be further analyzed. In this paper, we further conclude that, especially in non-economic DAOs, a democratic voting power distribution has a positive correlation with long-term viability. Furthermore, in non-economic DAOs, membership models have a better long-term viability then reputation models. Share-like models seem to have a positive effect on long-term viability in general. Reputation models have a significantly lower long-term viability. Also, our analysis reveals that in non-economic DAOs, the lack of incentives has a more positive effect on long-term viability than in economic DAOs. The analysis shows that the number of economic DAOs is higher on Ethereum than on other infrastructures. This could be explained by various factors. A high user base and the fact that Ethereum is one of the most prolonged-running protocols suitable for DAO deployment could play a role. The influence of infrastructural elements on DAO governance elements must be taken into account when selecting an infrastructure for DAO deployment. Gas costs for transactions, under the control of the infrastructure's governance, influence DAO applications. The rise of gas cost results in lower DAO deployments and vice versa. This can also influence the cost of transactions for governance actions (proposal voting) and, thus, governance of the DAO application.

Finally, in the conclusion of this dissertation, we present a theory of all the combined findings of the four papers of this PhD research, as shown in the figure below.



Summary Figure 1: Theory on explaining influencing factors for DAO long-term viability

In essence, as new organizational or governance forms, DAOs offer many opportunities; however, they do not seem viable for all long-term business purposes. To potentially improve the long-term viability, elements of accountability, decision models, and incentives must be considered alongside the business objective. Additionally, the choice of infrastructure should be taken into account beyond the user base and ecosystem, as this can influence the governance of a DAO, thereby impacting its long-term viability without the DAO being able to control this. Mitigations for these infrastructure elements, like off-chain governance solutions, give in to decentralization or autonomy, which poses various proven risks.

Future research can focus on the following key areas. First, given the fast proliferation of DAOs, our theory can be tested with an increased dataset over time to verify the theory as the numbers and lifetime of DAOs currently rapidly increase. Second, business purpose, governance elements, and combinations were tested directly for long-term viability. The full model of the interrelationship between infrastructure (gas pricing), governance elements amongst themselves, and business purposes' influence on the long-term viability was not yet researched and can be addressed in further research. Third, off-chain governance DAOs, although giving in on decentralization or autonomy, should be researched to see if they show similar behavior as on-chain DAOs. Fourth, a future iteration of the theory can include emerging governance models like quadratic voting mechanisms. Fifth, future research can explore the growing complexity of DAO governance models that involve multiple governance models and layers. Sixth, the effect of infrastructure elements, like gas pricing, and the effect on application governance behavior can be researched more thoroughly to measure any possible differences between infrastructures. Finally, with the emergence of new infrastructures, these new infrastructures should also be included in future research.

Samenvatting

Decentrale Autonome Organisaties (DAOs) zijn een snelgroeiende groep van op blockchain en smart contract gebaseerde toepassingen. DAOs ondersteunen nieuwe, gedecentraliseerde governance en organisatorische behoeften voor verschillende bedrijfsdoelstellingen variërend van gedecentraliseerde beurzen zoals UniSwap en theDAO, R&D zoals VitADAO, het managen van infrastructuren zoals Arbitrum tot aan charitatieve projecten zoals PactDAO. De afgelopen jaren laten een explosieve groei laten zien van het aantal DAO-projecten. Alhoewel het aantal snel groeit is er geen duidelijke consensus over wat precies een DAO is. Ondanks deze sterke groei ziet men dat meerdere DAO-projecten niet verder gaan als DOA. De projecten ervaren een mis-match in de governance inrichting van hun DAO of ervaren dat doel wat men najaagt niet geschikt is voor governance met behulp van een DAO, wat de levensvatbaarheid op lange termijn bedreigt. Ook komen er nieuwe governance uitdagingen naar voren doordat DAOs gebouwd zijn op een blockchain infrastructuur. Het doel van dit proefschrift is om te analyseren hoe governance elementen, bedrijfsdoelen, en infrastructurele keuzes de lange termijn levensvatbaarheid van DAOs beïnvloeden. Het hoofd onderzoeksdoel van dit proefschrift is:

"Ontwikkel een theorie die uitlegt hoe governance en infrastructuur elementen de lange termijn levensvatbaarheid van gedecentraliseerde autonome organisaties op basis van publieke permissionless blockchains beïnvloeden"

De onderzoek aanpak om tot het onderzoeksdoel te komen bestaat uit gestructureerde literatuurstudies, interviews, empirische en statistische analyses. De gebruikte literatuur bestaat uit zowel wetenschappelijke als grijze literatuur. Data voor de statistische analyse is verzameld vanuit openbare bronnen en is gemonitord gedurende drie jaar.

Dit proefschrift bestaat uit vier wetenschappelijke artikelen welke in logische volgorde zijn gepresenteerd. In het eerst artikel adresseert blockchain en DAO gerelateerde uitdagingen. Het tweede artikel heeft als doel de creatie van een algemene DAO-definitie, het ontrafelen van algemene DAO-karakteristieken en onderzoeken van het effect van enkele van deze karakteristieken op de lange termijn levensvatbaarheid van DAOs. Het derde artikel borduurt hierop voort door de relatie tussen DAO governance elementen en de lange termijn levensvatbaarheid te bekijken. Als laatste introduceren we bedrijfsdoelen en externe infrastructuur elementen als directe en modererende variabelen in ons theoretisch raamwerk in het vierde artikel.

Het eerste artikel focust zich specifiek op het identificeren van governance uitdagingen binnen blockchain en DAOs in het algemeen. Middels het uitvoeren van literatuurstudies, interviews en empirische analyse, dragen we bij door het expliciteren van blockchain governance uitdagingen en vinden een unieke governance verstrengeling tussen toepassen en infrastructuur binnen blockchain gebaseerde applicaties. DAOs bestaan vaak (gedeeltelijk) uit blockchain gebaseerde smart contract code verantwoordelijk voor het on-chain executeren van bedrijfsregels van die applicatie. Eénmaal geïnstalleerd zijn de smart contract functies opgeslagen op een blockchain en de uitvoering van deze functies wordt gedaan door dezelfde blockchain. Dit resulteert in het feit dat een deel van de governance van de applicatie verweven is met elementen die onder controle staan van de degene die de governance van de infrastructuur doet en buiten de governance van de applicatie vallen. Dit is een belangrijk element welke meegenomen dient te worden bij een theorie rond de DAO lange termijn levensvatbaarheid beïnvloedende factoren.

Het tweede artikel focust op het ontrafelen van een duidelijke DAO-definitie en karakteristieken gebruikmakend van literatuur en empirische studie. De eerste bijdrage van dit artikel is de creatie van een uitgebreide DAO-definitie:

"DAOs zijn een systeem waarbinnen opslag en overdracht van waarde en notaris (stemmingen) functies kunnen worden ontworpen, georganiseerd, opgeslagen en gearchiveerd en waar data en acties worden opgeslagen en autonoom worden geëxecuteerd op een decentrale wijze" (Rikken, Janssen, et al., 2023b, pp. 7-8).

Verder bestudeert het tweede artikel het effect van decentralisatie op lange termijn levensvatbaarheid en ontdekt een positieve relatie tussen de mate van decentralisatie en lange termijn levensvatbaarheid. Deze conclusies komen voort uit empirische en statistische analyses. Tenslotte, gebruikmakend van empirische analyse, identificeren we een trend van off-chain governance binnen DAOs. We concluderen dat off-chain governance DAOs inboeten aan het autonome element van DAOs. Dit komt door een gebrek aan automatische executie van besluiten wat kan leiden tot risico's. Deze off-chain governance DAOs kunnen beter geclassificeerd worden als decentrale organisaties in plaats van DAOs.

Door middel van literatuurstudie, empirische en statistische analyse, in het derde artikel, worden governance elementen geclassificeerd en hun effect op lange termijn levensvatbaarheid geanalyseerd. De governance elementen voor het onderzoek waren afgeleid van de definities van Ross en Weill en omvatten de elementen aansprakelijkheid, stimulansen en beslismodellen. In het derde (en het vierde) artikel zijn een taxonomie voor DAO governance elementen en dimensies, en een classificatie voor DAO-bedrijfsdoelen gecreëerd en gebruikt voor empirische analyse van DAOs.

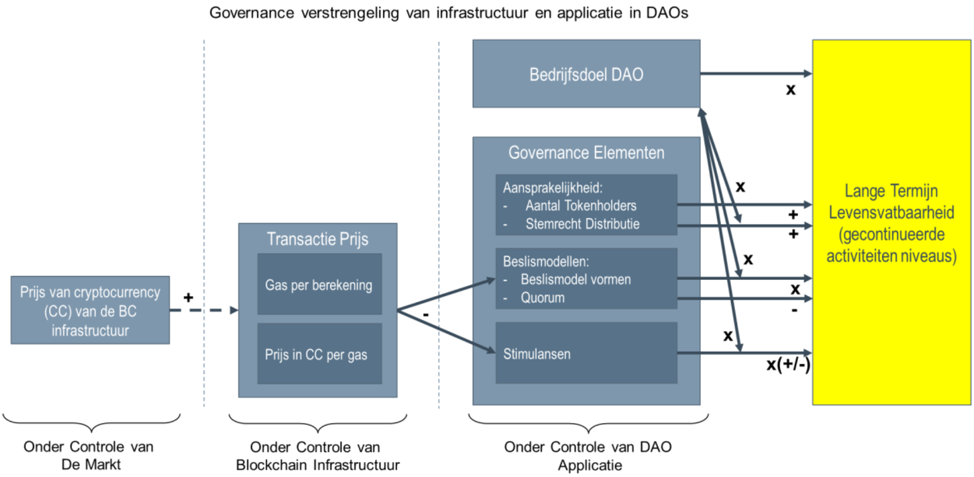
In het derde (en het tweede) artikel vinden we uit dat een hoger aantal token-houders en een meer democratische stemrecht distributie een positief effect hebben op de lange termijn levensvatbaarheid van DAOs. Het derde artikel concludeert dat variaties in de governance elementen stimulansen en beslismodellen invloed hebben op de lange termijn levensvatbaarheid. Niet-gewogen beslismodellen hebben een positieve bijdrage aan DAO lange termijn levensvatbaarheid. Tenslotte, verschillen in stimulans structuren hebben ook een effect, waarbij het ontbreken van een stimulans structuur positief bijdraagt aan de lange termijn levensvatbaarheid. Gebaseerd op onze bevinden stellen we in het derde artikel een eerste versie van een inleidende theorie van governance elementen en lange termijn levensvatbaarheid voor. We concluderen dat voor het bedrijfsdoel meegenomen moet worden als modererende variabele in de governance elementen.

Het vierde artikel borduurt voort op de eerste drie en analyseert de bedrijfsdoelen en governance element differentiaties op lange termijn levensvatbaarheid en de invloed van infrastructuur elementen op DAO governance elementen. In dit artikel leiden we een theorie af rond governance elementen, stemrechtverhoudingen, beslismodellen en stimulansstructuren en hun invloed op lange termijn levensvatbaarheid van DAOs waarbij bedrijfsdoel meegenomen is als modererende variabele. Ook de invloed van externe infrastructurele elementen op interne DAO governance elementen is meegenomen in deze theorie. De hoofdconclusie is dat een DAO met een niet-economisch bedrijfsdoel een betere lange termijn levensvatbaarheid heeft dan DAOs met een economisch bedrijfsdoel. Dit kan verklaard worden door de inherente aard van DAOs waarbij meer focus is op gemeenschappelijke of sociale doelen en een daarbij behorende meer altruïstische community, maar die moet nader onderzocht worden.

In dit artikel concluderen we dat, vooral in niet-economische DAOs met een democratische stemverhouding een positieve correlatie heeft met lange termijn levensvatbaarheid. Binnen niet-economische DAOs hebben ledenmodellen een betere lange termijn levensvatbaarheid dan reputatie gebaseerde governance modellen. Op aandeel gelijkende governance modellen lijken een positieve relatie te hebben op de lange termijn levensvatbaarheid van DAOs in het algemeen. Reputatiemodellen hebben significant lagere lange termijn levensvatbaarheid. Ook laat onze analyse zien dan binnen niet-economische DAOs, het ontbreken van een stimulansstructuur een positiever effect heeft op de lange termijn levensvatbaarheid van binnen economische DAOs.

De analyse laat zien dat het aantal economische DAOs groter is op Ethereum dan op andere infrastructuren. Dit kan worden verklaard door meerdere factoren. Een grote gebruikersgroep en het feit dat Ethereum één van de langst draaiende protocollen is welke geschikt is voor DAO implementaties zouden een rol kunnen spelen. De invloed van infrastructurele elementen op DAO governance elementen moeten in beschouwing worden genomen wanneer een infrastructuur wordt geselecteerd voor installatie van een DAO. "Gas"-kosten voor transacties, onder controle van de governance van de infrastructuur, beïnvloeden DAO-applicaties. Toename van "gas"-kosten resulteert in lagere DAO installaties en vice versa hogere. Dit kan ook de kosten van transacties aangaande governance acties (stemmen op voorstellen) beïnvloeden en daarmee de governance van de DAO-applicatie.

In de conclusie van dit proefschrift presenteren we een theorie waarin alle bevindingen uit de vier artikelen van dit promotieonderzoek worden gecombineerd, zie onderstaand figuur.



Samenvatting Figuur 1: Theorie aangaande DAO lange termijn levensvatbaarheid beïnvloedende factoren

In essentie, als nieuwe organisatie of governance vorm bieden DAOs bieden veel kansen, maar lijken niet geschikt voor de governance van alle soorten bedrijfsdoelen op lange termijn. Om de lange termijn levensvatbaarheid mogelijk te verbeteren moeten de elementen aansprakelijkheid, beslismodellen en stimulans meegenomen worden in combinatie met het bedrijfsdoel. Ook moet rekening gehouden worden met de keuze van infrastructuur voorbij gebruikersgroep en ecosysteem aangezien dit de governance van de DAO, en daarmee de lange termijn levensvatbaarheid, kan beïnvloeden zonder dat de DAO daar direct controle over heeft. Mitigerende maatregelen voor de invloed van deze infrastructurele elementen, zoals off-chain governance oplossingen, leiden tot afname van decentralisatie of autonomie, wat bewezen risico's met zich meebrengt.

Toekomstig onderzoek kan zich richten op volgende belangrijke elementen. Ten eerste, gezien de snelle groei van het aantal DAOs, kan de theorie worden getest met een grotere dataset welke over een langere periode gemonitord zijn om het effect van de nieuwste ontwikkelingen te bepalen. Ten tweede, de bedrijfsdoelen, governance elementen en combinaties zijn getest ten aanzien van lange termijn levensvatbaarheid. De volledige onderlinge relatie tussen infrastructuur ("gas"-prijs), governance elementen onderling en bedrijfsdoelen in relatie tot lange termijn levensvatbaarheid is nog niet onderzocht en kan worden onderzocht in toekomst onderzoek. Ten derde, off-chain governance gebaseerde DAOs hebben we buiten de scope gehouden. Ondanks dat deze inboeten aan decentralisatie en autonomie kunnen deze onderzocht worden om te kijken of dit type gelijk gedrag vertonen als on-chain DAOs. Ten vierde, een toekomstige iteratie van de theorie zou nieuwe governance modellen zoals kwadratisch stemmen erin kunnen betrekken. Ten vijfde, toekomstig onderzoek kan de toenemende complexiteit van DAOs met meerdere governance lagen en modellen binnen DAOs verder verkennen. Ten zesde, het effect van infrastructuur elementen, zoals "gas"-prijs, en het effect op governance gedrag binnen de applicatie kan meer diepgaand onderzocht worden om mogelijke verschillen tussen infrastructuren te meten. Als laatste, aangezien er meer nieuwe infrastructuren verschijnen om DAOs op te implementeren, kunnen deze infrastructuren en de eigenschappen van deze nieuwe infrastructuren ook worden geïncorporeerd in toekomstig onderzoek.

Glossary of Terms

Blockchain – A technology that provides an electronic transaction record of integrity (Nakamoto, 2008) for peer-to-peer transactions of information and/or value without the need for trusted third parties. Blockchain is a specialized subcategory of Distributed Ledger Technology (DLT) where integrity and immutability are assured by linking the various blocks of transactions through hashing mechanisms.

Block – A batch of transactions in a blockchain. The history of a blockchain database consists of all blocks, which are typically numbered in ascending order and are produced by the miners or other block producers.

Consensus Protocol, Algorithm or Mechanism – The mechanism of "reaching and maintaining consensus among distributed nodes" (Cachin & Vukolic, 2017, p. 4). Within blockchain, frequently used protocols or mechanisms are Proof of Work, Proof of Stake, Paxos and Byzantine Fault Tolerance or variances thereof. There are more than 50 different kinds of consensus protocols (A. Singh et al., 2022).

Consortium – A collaboration of multiple actors to achieve a common goal. A consortium can have a legal form but does not necessarily need so.

Cryptocurrency – Also referred to as a virtual currency or a crypto. In the Money and Terrorist Financing Act (Dutch: Wwft) a cryptocurrency or virtual currency is defined as value in a digital form that can be used for payments or means of exchange (DutchParliament, 2020). A cryptocurrency is not backed nor issued by a governmental organization like a central bank or another public authority. The legal status is often unclear (DutchNationalBank, 2023). The legal status can differ per country and per cryptocurrency. Cryptocurrencies are governed by the blockchain infrastructure protocol. Well-known examples are bitcoin and ether.

Decentralized Application (dApp) - In the context of this thesis an application (partially) built on top of and/or making use of a decentralized infrastructure like blockchain. Often, this is done by coding and executing (part of) the application's logic through smart contracts and/or storing (part of) the data used in the application on a decentralized infrastructure like blockchain.

Decentralized Autonomous Organization (DAO) – A DAO is a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way (Rikken, Janssen, et al., 2023b, pp. 7-8).

DAO deployment platform – a platform that facilitates the easy deployment of smart contracts for treasury, notary and other functions of DAOs. These platforms, e.g. Aragon and DAOHaus, also facilitate the instant creation of a front end / interface for DAO participants to interacts with these DAO functions.

Distributed Ledger (Technology) (DLT) – "A type of database that is spread across multiple sites, countries or institutions" (Walport, 2016, p. 17). The ledger is not stored on a single server or hard drive but divided over various (virtual) servers or hard drives. The various parts on the various servers do not necessarily have the same content. Blockchain is a form of DLT.

Gas – Unit of account that is being used to calculate an amount that needs to be paid for computations in executing smart contract code or processing of a transaction. E.g., computation A costs 3 gas, computation B cost 6 gas, standard transaction of a cryptocurrency costs 12 gas.

Gasfee – (also referred to as transaction fee) The fee that must be paid for the computation and handling of a transaction request. Calculated by multiplying the amount of gas times the gas price.

Gasprice – Price one has to pay for 1 unit of gas calculated in the local cryptocurrency. For example, 1 gas costs X Gwei (a denomination of Ether). Sometimes, for practical purposes, it is also calculated to fiat currency prices like Dollar or Euro but always paid in cryptocurrency as part of the transaction fee.

IT-Governance – "the decision rights and accountability framework to encourage desirable behavior in the use of IT" (Peter Weill & Woodham, 2002, p. 1) where incentives should be aligned (Peter Weill & Ross, 2005a).

Hash – The outcome of a cryptographic hash function where an arbitrary length input is converted into a fixed-length output.

Fork – A fork is an update in a blockchain protocol (software of the infrastructure). A soft fork is backward compatible, meaning that if the nodes did not update their software, they still can accept blocks generated by updated nodes. A hard fork is not backward compatible, meaning that non-updated nodes can no longer process blocks produced by an updated node. This leads to a split in the network. Where there was a previous one chain, now two appear with a common history until the time of the software update. Examples are Bitcoin and Bitcoin Cash and Ethereum and Ethereum Classic.

Merkle Tree (or Hash Tree) – "Structure that allows for the efficient and secure verification of content for a large body of data" (Ray, 2017). First described and patented by Ralph Merkle in 1979 (Merkle, 1989).

Miner – A miner is a node in the network (the infrastructure) that plays a crucial role in the creating of new blocks of transactions. Depending on the consensus mechanism, they either perform a large number of calculations (in proof of work) or they stake a certain amount of value (proof of stake) or another action.

Node – A computer or server that holds a full copy of the database and protocol. Nodes play a part in the consensus mechanism by validating and approving new blocks of transactions created by the miners and agreeing on the common history of a blockchain. Besides that, they can vote on protocol upgrades and thus are part of the governance mechanism.

Permissioned Blockchain – A blockchain type in which running a node needs to be approved by the existing group of nodes, companies, or other parties that run and or own that blockchain.

Permissionless Blockchain – A blockchain type in which the running of a node does not require permission but is open to anyone who wants to.

Peer-to-peer (P2P) – Directly connecting or transacting from one peer to another without the need of a party or server in the middle.

Private Blockchain – A blockchain type that is not publicly accessible.

Public Blockchain – A blockchain type that is publicly accessible.

Public-Private Key Cryptography – Cryptographic system. Using key pair, where the public key can be shared freely and the private key, which needs to be kept safe, can be used for signing or decrypting. In blockchain it is used for the digital signing of transactions. Any message that is signed with a private key, can be verified by holders of public key.

Smart Contract – A programmable piece of logic or code that can be deployed on a blockchain infrastructure. In various blockchains, smart contracts are accounts that can also hold on, receive and send value based on the code deployed. Some blockchain protocols use other terms for smart contracts. On Hyperledger, smart contracts are referred to as Chain code.

Transaction – Information that is sent from a wallet by a person of application to a blockchain, for e.g., transfer of value, update of an information element, or trigger for smart contract code.

Transaction fee – see Gasfee.

Trusted Third Party – Any party that fulfills the role of trustee to all actors in a certain process or chain on behalf or for the benefit of other parties in that process or chain.

Wallet – Communication software between a blockchain and the outside for transactions.

Web3 – Term for the new iteration after web 1.0 and 2.0 where decentralized technologies and decentralized applications are seen as some of the building blocks.

List of abbreviations

BC – Blockchain
CC – Cryptocurrency
dApp – Decentralized Application
DAO – Decentralized Autonomous Organization
DLT – Distributed Ledger Technology
P2P – Peer-to-peer
SC – Smart Contract
SHA – Secure Hash Algorithm
TTP – Trusted Third Party

1. Introducing Blockchain, Decentralized Autonomous Organizations (DAOs) and Governance

The birth of blockchain technology has created a freely publicly accessible decentralized infrastructure where anyone can record data and create applications with key characteristics like immutability and transparency. (Li, 2019; Nakamoto, 2008; A. Singh et al., 2022) This infrastructure promises to be community-owned, where no Trusted Third Party (TTP) acts as a central authority as governance of this infrastructure organized by continuous consensus (Cachin & Vukolic, 2017; A. Singh et al., 2022). On this infrastructure, besides native applications like cryptocurrencies, new applications are built that even go so far as to create new organizational forms, *decentralized autonomous organizations* (DAOs) (Al-Megren et al., 2018; Li, 2019; Mohanta, Panda, & Jena, 2018; Rikken, Janssen, & Kwee, 2019). These DAOs create a possibility for collaboration where no humans are needed for the operation and/or governance of this organization (Buterin, 2014).

DAOs were initially initiated by idealistic motives. Within DAOs, decisions are made through the voting of the participants creating the promise of transparent, democratic, decentralized organizations on a decentralized infrastructure (Jentzsch, 2016; R. Morrison, N. Mazey, & S. Wingreen, 2020). The business rules are guarded by application code, often through so-called smart contracts, deployed on a blockchain infrastructure and are (almost) immutable because of the inherent immutability of the blockchain data structure. DAOs are designed as a way to include public values. Public values like openness and user democracy (Janssen & van den Hoven, 2015; Jørgensen & Bozeman, 2007) are by nature characteristics of DAOs.

DAOs are seen as organizations that use advanced applications built on a decentralized infrastructure. Figure 1 shows several important layers for DAOs, 1) being the infrastructure layer the DAO application/organization is built upon, 2) the application layer that guards and executes the business rules and decisions of DAOs and 3) the participants in the DAO.

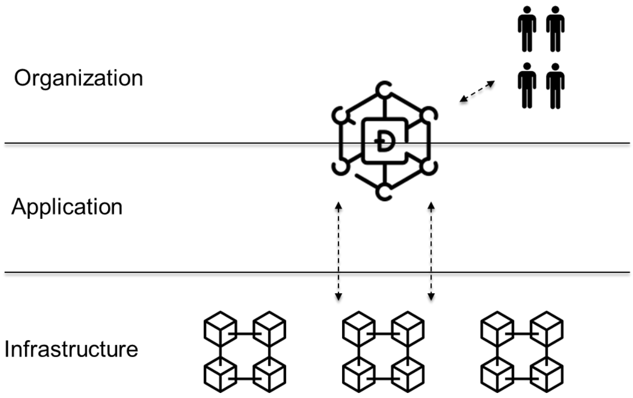


Figure 1: decentralization of organization/application and infrastructure on different layers

As shown in Figure 1, the decentralized set-up of both infrastructure and application and/or organization, in combination with the immutability of the data on a blockchain creates an entanglement of application and infrastructure. DAOs, governance of DAOs and the entanglement further leads to governance challenges, especially regarding DAO applications, were little researched. This entanglement which led to real live governance issues, the multi-actor complexity as well as the little empirical scientific towards the impact of business objectives and governance of DAOs which will be further discussed in these first two chapters led to the start of this research.

The overall overview of the chapters of this thesis are shown in figure 2. In this first chapter, we give an overview of key constructs. Furthermore, based on key literature review, the concept of blockchain in general, blockchain applications and blockchain and blockchain application challenges, a research gap is described at the start of this PhD research. Also, a general introduction and conclusion are described in this first chapter. Chapter 2 describes the challenge resulting in the problem statement and research objective. We discuss what a theory is in our view, present the research questions and methods, and provide an overview of the papers that constitute this PhD research. Chapters 3 to 6 contain the four papers underlying this PhD research project. Chapter 7 contains the overall conclusion, the final visualization of the theory, and the discussion and recommendations for future research. The epilogue is presented in chapter 8, and finally, in the appendices, my curriculum vitae, a list of publications, and the reference list are presented.

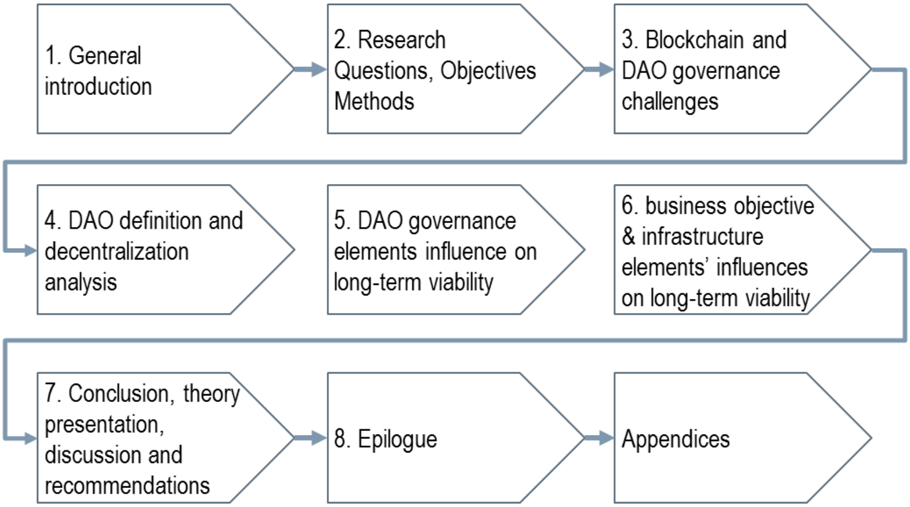


Figure 2: Dissertation structure based on the chapters

1.1 Introducing blockchain

Blockchain technology was first described by Satoshi Nakamoto in the whitepaper on Bitcoin, a peer-to-peer electronic cash system (Nakamoto, 2008), although some claim that blockchain technology was already described in the early 1990s by Haber and Stornetta (1991). The first blockchain was introduced in production in January 2009 by means of the Bitcoin blockchain. The technology provides a shared database or record of integrity without the need for a TTP to centrally guard the integrity of the shared database. At the moment, TTPs are needed to ensure that shared data is authentic and of integrity in a value chain or ecosystem where there is inherent mistrust among the actors involved when they need to do transactions of value or information. Examples of these TTPs are banks and insurers in transactions of money, custodian banks and exchanges in transactions of securities, governmental institutions for identity, and universities for diploma credentials. The elimination of these TTPs can lead to high efficiency across value chains and, in this way, to faster and cheaper processes.

The possibility of eliminating these TTPs and creating a shared database of integrity is achieved by a combination of the characteristics of decentralization, transparency and use of cryptography.

Firstly, through the decentralization of the network and database (Gencer, Basu, Eyal, Van Renesse, & Sirer, 2018). *Decentralization* in blockchain means there is no central server nor one single point where the data and the protocol are stored and processed, which means a trusted centralized third party becomes obsolete. Instead, the processing and handling are done through multiple parties called nodes in the network, where all nodes have an identical copy of the protocol and database. All incoming transactions are distributed to all nodes in the network and collected in draft batches (so-called blocks), to be processed and added to the database history. Through a consensus mechanism, it is determined what the new batch (block) looks like that is added to the history of all the nodes. The database, or record of integrity, thus consists of an ever-growing number of blocks containing transactions. All the nodes have an identical copy of this data. In blockchain, these are often open networks where the nodes are run by many unknown participants, meaning they don't necessarily have to identify who they are before they start running a node.

Secondly, TTP can be dismissed due to the *transparency* of information. The information in the network, like the protocol, incoming transactions, and transaction history, is transparent for all equal user and or nodes. Due to this transparency, nodes can continuously compare information, especially protocol versions and transaction history per node, to make sure that all parties have an identical copy of the historical data and new incoming information and transactions (Sas & Khairuddin, 2017). By ensuring that all nodes run compatible versions of the protocol and have and identical copy of the underlying data, decisions on the validity of incoming transactions can be made in a decentralized way. Cryptography plays a crucial role in this.

Thirdly, integrity guarding of the content of the data on the nodes is done by the use of *cryptography,* which, combined with transparency and decentralization, allows TTP to be eliminated. Because it is a decentralized database, one runs the risk of information inequality as not all transactions will reach all the nodes at the same time. Besides that, as no central authority monitors the integrity of all the individual copies of the databases, an individual node could alter the content of their copy to their benefit. Public-private key cryptography and cryptographic protocols like security hash algorithm (SHA) are used in order to guarantee that; 1) incoming transactions are valid and 2) that the content of all individual databased at the various nodes is equal before and after updating the database history with a new block of transactions, (Fernández-Caramès & Fraga-Lamas, 2020). The idea is that to reach consensus, there is no need to compare the full databased, but by the use of cryptography, only top hashes need to be compared as a result of Merkle trees (Merkle, 1989) to make sure the underlying content is identical. There is no central authority to check if all hashes over the various nodes are equal. To minimize the risk of fraud or other strategic behavior, consensus mechanisms are used to reach consensus amongst the nodes on what new block of transactions to accept. Some examples are the notorious, high energy-consuming Proof-of-Work (PoW) consensus mechanism, used, e.g., in the bitcoin protocol, or the currently widely used Proof-of-Stake consensus mechanism, which uses significantly less energy (Nguyen et al., 2019; A. Singh et al., 2022; Wendl, Doan, & Sassen, 2023; R. Zhang & Chan, 2020), used in e.g., the Ethereum protocol.

Figure 3 shows how the data in a blockchain is built up. The information in the form of incoming transactions is built up in an ever-growing series of blocks of information that are added to the previous blocks. After a predefined amount of time or effort, the block is closed for new transactions. The block with the transactions is now added to the previous blocks. All blocks are numbered and sequential in order. The hash of the just created block is added to the new block, hence in turn contributing to the hash of the new to be created block of transactions. This way, the information of the previous block becomes an integrated part of the hash of the next block and thus creates a chain of cryptographically linked.

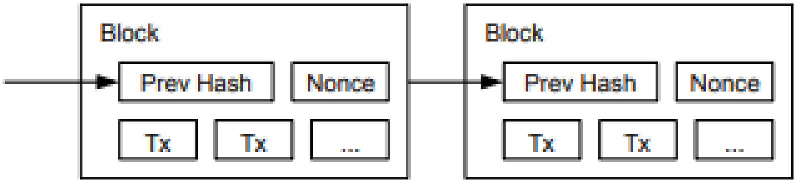


Figure 3: Visualization of cryptographically linked blocks from Bitcoin Whitepaper (Nakamoto, 2008, p. 3)

Nodes continuously compare the latest hash with each other to be certain that all nodes contain the exact same historical data. In a decentralized network, in this way, the historical data becomes extremely hard to manipulate one-sided, leading to the characteristics of immutability and permanence of a blockchain. Only if the majority of nodes agree can the content of a blockchain be altered. Transparency assures all nodes can continuously compare hashes and will only accept new blocks if the top hash of the previous block is alike. Plus, the nodes check if this hash, combined with the new block's hash, results in a valid new top hash. If any node would alter any piece of information in one of the lower blocks, this would immediately trickle up, and top hashes will not match, indicating differences in the underlying information (Di Pierro, 2017). Such a node can then be excluded in reaching a consensus with the rest of the network.

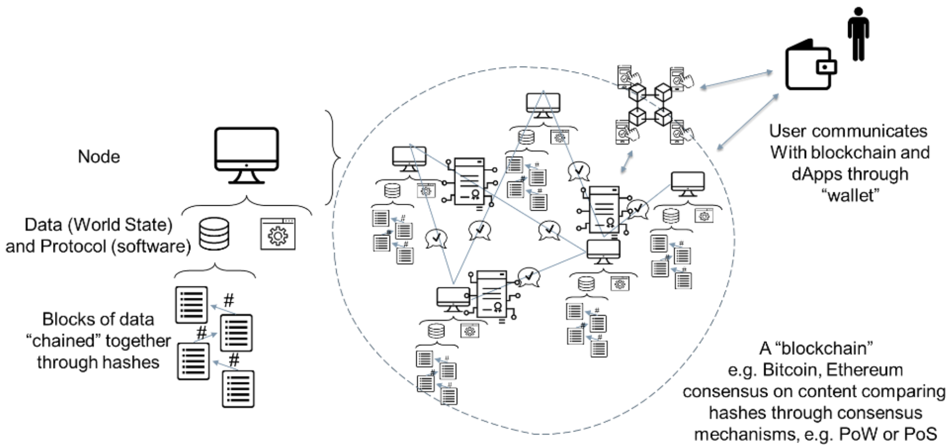


Figure 4: Schematic overview of blockchain network - nodes - data - protocol - chain of blocks – hashes – consensus mechanism - wallets

As visualized in Figure 4, the blocks of transaction data are chained together using cryptographic protocols (hashing). The data, together with the blockchain protocol of that network (e.g., bitcoin, Ethereum, Litecoin, etc.), constitutes a node. The nodes together form that specific blockchain network. Consensus on data update in the network (acceptance of a new block with transactions) is reached by means of the consensus mechanism of that protocol (e.g., PoW or PoS). Users can send new transaction requests in the network using so-called "wallet software". The nodes will check the public-private key signing of this transaction, the rules in the blockchain protocol, and the transaction history to accept or reject the incoming transaction request and add it to the transaction list in a block. There is no TTP in the network that coordinates this all. As stated, this can lead to higher efficiency and thus, potentially faster and cheaper processes (Rikken, Janssen, & Kwee, 2020). Also, the risk of malicious actions by or at a TTP potentially compromising the data in a network or single point of failure vulnerability is strongly reduced. Furthermore, networks are said to be very robust as a result of multiple real-time copies. If one node goes down, the network keeps on running. As long as one node is still reachable, the data is still available for the end user. Also, the combination of transparency, immutability, and permanence leads to "perfect provenance" or audit trail (Abu-Elezz, Hassan, Nazeemudeen, Househ, & Abd-Alrazaq, 2020; Ali, Jaradat, Kulakli, & Abuhalimeh, 2021; Habib et al., 2022).

However, the lack of a TTP also poses various challenges, such as slower transaction performance (Peck, 2017), since consensus needs to be reached in a distributed manner instead of in a single instance. From a governance perspective, if a change or update needs to be performed, this needs to be done in consensus with various stakeholders, at least the nodes in the network, instead of a single instance that can make the decision and perform actions (Ehrsam, 2017), which makes fast decisions and actions relatively hard (Rikken et al., 2019). If consensus on protocol update of the infrastructure or network cannot be reached, there is no overlaying party to make a final decision, but this will lead to a split or a fork in the system (Qureshi, 2018). The processes of consensus between data (block) adding and protocol updates differ, as explained in 1.3.

1.2 Blockchain Types

Although blockchain is often associated with fully open blockchains, like Bitcoin and Ethereum, two main axes of blockchain typologies can be used to differentiate between types (see Table 1). The first axis is public versus private, and the second one is permissioned vs. permissionless (Beck, Muller-Bloch, & King, 2018; Peters & Panayi, 2015).

Table 1: Public-Private vs. Permissioned-Permissionless blockchain quadrant

Axis	**Permissionless**	**Permissioned**
Public	• **Open** in use for any user. • Becoming a node in the network (run the network and become part of the governance) is in principle **unrestricted.** • Examples are Bitcoin, Ethereum	• **Open** in use for any user. • Becoming a node in the network (run the network and become part of the governance) is in principle **restricted.** • Example: Ripple, Diem
Private	• **Restricted** in view and or use. • Becoming a node in the network (run the network and become part of the governance) is in principle **unrestricted.** • No clear examples available	• **Restricted** in view and or use. • Becoming a node in the network (run the network and become part of the governance) is in principle **restricted.** • Examples: Hyperledger and Corda implementations

The axis of private versus public is related to the access and visibility of individual users. In a public blockchain, the blockchain is freely accessible for any end-user to connect their wallet, create an account, and send in transaction requests. The transaction history is visible to all. In contrast, in a private blockchain, the accessibility and visibility can be restricted for end-users. To access the system, an end-user might need to get permission from the party or parties that run the blockchain, and in this way, visibility can also be restricted.

The permissioned versus the permissionless axis is related to whether a user (person or organization) can freely enter as a (full) node and thus become part of the formal governance structure or whether the user's access to become a node is restricted.

In a permissioned setting, to become a node in the network, a new participant who wishes to run a node needs to get permission from the existing governance structure, in practice often the other node holders, to become part of the network (Vukolic, 2017). Once a user has a node in the network, it can participate in the consensus mechanism in which the user's node can validate transactions and vote on upgrades in the system according to the rules set by the consortium of users in that particular network. Development and upgrade management is under the control of that consortium. In permissioned networks, the user nodes are thus identified and approved by the consortium prior to participation in the governance thereof.

In a permissionless network, becoming a node in the network is unrestricted (Cachin & Vukolic, 2017). The network is thus governed by a flexible community. Anyone can enter without any restrictions by downloading the protocol software from an online repository (e.g., GitHub) and deploying the software and leave without restriction by just turning the node off. There is no need to identify oneself and get approval from the other nodes to become a node in the network, thus, this can be done relatively anonymously. Once a node is set up, this user can participate in the network's governance, participate in the consensus model, validate transactions, and vote on upgrades in the system. As there is no central authority to coordinate, development and upgrade proposals can be done by anyone who wants to contribute to the system. In these permissionless networks, where the nodes and participants can enter freely and can be relatively anonymous for the other nodes, cryptocurrency was introduced as native application of the core protocol to create an economic incentive to run the network.

Both permissionless as well as permissioned protocols are blockchain systems as they are in basic decentralized in set-up (governance and data storage), they have a batch-by-batch (blocks) buildup of their database, and they use consensus mechanisms and cryptographical linking between the blocks to guard the integrity of the content of the database.

The original blockchain set-up like Bitcoin and Ethereum are examples of public permissionless blockchain. Hyperledger is a clear example of a permissioned blockchain (Voshmgir, 2019) that can be set up as a public or private blockchain. Private permissionless blockchains are considered non-existent (WG5, 2020) as this would imply that visibility is restricted, but being part of the governance (which includes transaction verification and thus visibility) would be open.

Although all are called blockchain systems, due to the different types of blockchain, challenges in blockchain-related projects and systems cannot be generalized. Challenges can differ per blockchain type as a result of the open or closed character of the various types, resulting in various levels of identifiability of actors on infrastructure. Within DAOs, this could even complicate further due to the potential fuzziness and decentralization of governance and accountability on application level (Rikken et al., 2019).

The main difference between the various types is related to the identifiability and control of the parties in the network, which, in turn, control the governance of the network. Although both work with certain consensus mechanisms and can be technically alike, this difference poses potential new challenges in governance. In a permissioned set-up, the nodes in the network are known, limited and fairly stable. In a permissionless network, the nodes can be unknown, the number is potentially unlimited, and can be highly fluid (Voell, 2020), which complicates the coordination of the governance of such networks.

1.3 Blockchain Governance

Governance is a broad term used in many ways in the scientific literature. The governance referred to in this research is related to IT governance. This can be described as the "**decision** rights and **accountability** framework to encourage desirable behavior" (Peter Weill & Woodham, 2002, p. 1), where **incentives** should be aligned (Peter Weill & Ross, 2005a). Within blockchain governance, we need to distinguish between blockchain protocol or infrastructure governance and blockchain application governance, as two different groups of actors generally manage these.

1.3.1 Blockchain protocol or infrastructure governance

Although blockchain protocol or infrastructure governance is too often approached as one process and believed to be fully automated by the consensus mechanism, within a blockchain infrastructure, one can distinguish two main types of governance: (1) governance by or through the infrastructure and (2) governance of the infrastructure (P. De Filippi & McMullen, 2018). Table 2 summarizes the key differences between these two types.

Table 2: Comparing governance of and by the infrastructure

	Governance by the infrastructure	**Governance of the infrastructure**
Definition	Governance of the transactions, execution of smart contract code and update of the data history and world state	Governance of the core software of the protocol.
Consensus reached	Automated through the consensus mechanism of that blockchain protocol (e.g., PoW, PoS etc.).	Varies per blockchain, often a largely non-automated process which for a large part takes place outside the blockchain protocol.
Actors involved	Nodes/miners	Various – nodes, miners, core developers, users. Varies per blockchain

The first type of governance by or through the infrastructure refers to the management and continuous update of the data layer. The data layer needs to be updated as a result of incoming transactions where the various nodes in the network, through a consensus mechanism, determine if a transaction is allowed. In the case of smart contract applications, the code can be executed according to the protocol of that particular blockchain. This is a fully automated process where no human interference is needed. This is also referred to as operational governance of a blockchain. Widely used consensus protocols are Proof of Work, Proof of Stake, Proof of Authority and Byzantine Fault Tolerance, but many more exist (A. Singh et al., 2022; W. Wang et al., 2018). The fact that no human is needed for the operational governance of a blockchain gives it the added value of eliminating TTPs in the transfer of value or evidence trail use cases.

The second type, governance of the infrastructure, is related to updating the protocol or core software of the infrastructure instead of the content on the blockchain. This process is not run by the consensus mechanism as in governance by the infrastructure. In governance of the infrastructure, multiple parties play a role. For instance, new software needs to be accepted by the nodes, but the software is developed by core developers who are not necessarily tied to the nodes. In permissionless blockchains, like Bitcoin and Ethereum, anyone can propose a new software proposal (Ethereum.org, 2020). The nodes vote on this proposal and if accepted by the large majority, plan to be deployed as of a certain block number (Genesisblockhk, 2020). If (group of) nodes decide not to go along in the update, this could lead to a hard fork in the network, meaning that a part of the network is no longer compatible with the part that performed the update, thus splitting the original blockchain into two new chains. This can affect two other stakeholders in the network, the economic nodes and users, and as such any update needs to reach a vast majority for an update to prevent hard forks and split of the network (Rikken et al., 2019).

Additionally, within the governance of the infrastructure, two main forms can be distinguished, on-chain and off-chain governance (Chinyem, 2018). On-*chain governance* is the concept that all entitled to vote on an update will do so via a smart contract on that particular blockchain and once a certain quorum is met, the update is automatically pushed to the nodes. There are few to no real live examples of fully effective on-chain governance mechanisms yet, and there is much debate on whether this would be feasible (Qureshi, 2018). Most governance is off-chain, where the debate on update proposals takes place in online fora (often on Discord) and even in physical meetings and conferences and where continuous polls amongst the nodes are held to measure the support for a certain update. If a quorum is met, all nodes will have to update to the new version of the protocol individually and make sure they are compatible with the new version at a certain point in time to prevent a fork.

Whereas the governance by the infrastructure is very transparent and ruled by code, governance of the infrastructure tends to be less transparent. There are already examples of new infrastructure code being pushed through in the network without the general audience knowing about it, thus being less decentralized than expected (Walch, 2019).

Although the governance of the infrastructure does the execution of code in blockchain-based applications, the actors in charge of the governance of the application are, in most applications, largely independent of the actors involved in the governance of the infrastructure. But a unique challenge with blockchain-based application governance is the potential entanglement of application and infrastructure. Parts of the application are integrated into and executed by the infrastructure. Due to the immutability of the data on a blockchain infrastructure, including deployed smart contract code, the application can become dependent on the governance structure of the blockchain infrastructure itself (Rikken et al., 2019).

1.3.2 Blockchain functional applications and application governance types

Blockchain is often associated with cryptocurrencies. For many people, these are the main implementations of blockchain applications. However, the types of applications are spreading far more widely than cryptocurrencies, like tokenization, self-sovereign identities, document hashing solutions and new organizational forms like DAOs.

Although there are many uses for blockchain and its applications, we can identify two main functional use case categories, transfer of value and evidence trail use cases. Besides the functional categorization, we can also identify two main governance categories for blockchain-based applications. These differences in application types also lead to various application governance types.

Blockchain functional application types

As stated, in general, two main functional usage categories for blockchain applications can be identified: transfer of value applications and evidence trail applications. These two types of functional uses for blockchain applications can use the inherent characteristics of blockchains and logic built on top of the infrastructure in the form of smart contract applications.

Transfer of value in its basic form can be done by means of cryptocurrencies, or native coins used for the transfer of value. Cryptocurrencies, like bitcoin and ether, are native to the system. This functionality is part of the core protocol software, thus managed by the infrastructure. Any changes to that system would require an update from the core protocol. Another way to transfer value is through the use of so-called tokens. These can be created on a blockchain with smart contracts and are basically applications built upon a blockchain infrastructure. The functionality is arranged through a smart contract instead of the core protocol (Rhodes, 2018).

Also, evidence trail use cases make use of the primary characteristics of the blockchain, being the practical immutability of data stored in a blockchain. Once a data point is entered into a blockchain, it cannot be deleted nor altered and is thus immutable (Aste, Tasca, & Di Matteo, 2017), although there are exceptions. When all the nodes jointly agree to change a data point, they can. The data can be updated, but the old data is not replaced, like in most databases. The old data point is still stored and traceable.

Supporting automated and conditional transactions through Smart contracts

Blockchain-based applications are in most cases triggered by an incoming transaction request from an external application or user containing certain input.

The initial blockchain protocols like Bitcoin could only facilitate the transactions of these applications in a non-conditional manner. This means that the blockchain would perform a transaction from account A to account B containing value, information, or both. Any conditional logic or code related for that application (other than the direct transfer of value on-chain) would be stored, guarded and executed off-chain. The blockchain itself is then only used for non-conditional data storage.

Next-generation blockchain protocols, like Hyperledger and Ethereum, facilitated the inclusion of built-in logic through smart contracts, leading to smart contract applications. In general, these types of applications only make partial use of the core protocol for their characteristics, as smart contracts are decentralized pieces of code that can be programmed to will and deployed for execution on a blockchain (Rikken et al., 2019). In practice, these smart contracts are accounts that, if the particular blockchain allows them, can receive, hold on to, and transfer value. Also, a wide range and large numbers of variables can be stored in these smart contracts. But most importantly, coding logic can be stored in smart contracts (Antonopoulos & Wood, 2018) and executed by the blockchain infrastructure when called upon. This results in virtually any type of application with conditional logic being built on top of these blockchain protocols. Here, the logic is also immutably stored, thus partially incorporated in the database itself once deployed. Smart contracts are triggered if a message or transaction is sent to the smart contract address.

Governance types of blockchain applications

Blockchain is often used for executing and processing information exchange and transactions but is equally relevant for organizational governance. Responsibilities, decision-making rights, access to voting, the voting process, and resulting decisions can be supported by blockchain technology (Ayed, 2017; Lafarre & Van der Elst, 2018). This leads to a variation of governance application types based on blockchain. From a governance perspective, one can identify two main types of applications: 1) direct transactional, and 2) conditional transactional with a specialized subtype, decentralized autonomous organizations (DAO) (Rikken et al., 2019). Figure 5 illustrates these main application types. This will be further explained in the paper "Governance challenges of blockchain and decentralized autonomous organizations" presented in chapter 3.

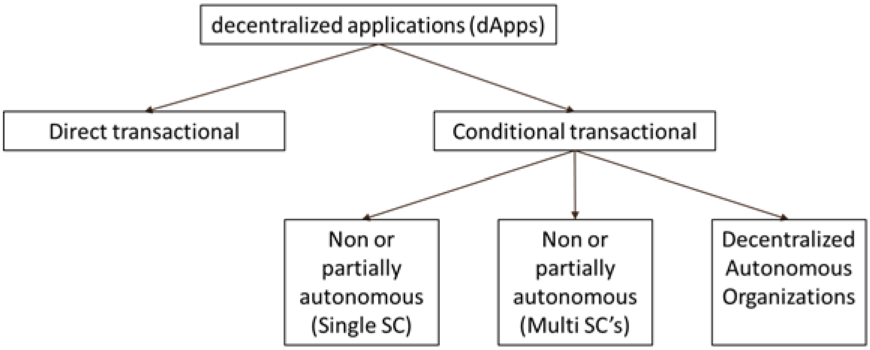


Figure 5: Governance types of blockchain applications (Rikken et al., 2019)

In both the direct and conditional transactional applications, there are usually clear (groups of) individuals or companies behind them in charge of development, deployment, and operation. This is where Decentralizes Autonomous Organizations (DAOs) can differ from the first two types.

Decentralized Autonomous Organizations (DAOs)

DAOs are a range of applications that represent virtual collaborations for organizational forms, mainly existing in computer code deployed on a blockchain infrastructure. First described by Daniel Latimer in 2013 as Decentralized Organized Company (Larimer, 2013). Although there are various descriptions of DAOs and their characteristics, there is no clear accepted definition yet of what a DAO is (P. De Filippi & Hassan, 2020). Parthasarathi and Kaushal (2020) describe a DAO in terms of a transparent computer-coded organization. This organization is not controlled by a central government but by its shareholders. Semyonova (2017) points out that a blockchain is used to maintain the program rules and the transactions of a DAO. Chohan (2017) describes DAOs as an organization that is run through rules encoded in smart contracts. Part of this PhD research entailed the formulation of a general DAO definition and is presented in the paper "The ins and outs of decentralized autonomous organizations (DAOs) unraveling the definitions, characteristics, and emerging developments of DAOs" in chapter 4. Technically DAOs are conditional transactional applications, but as they are controlled by shareholders, who can be anonymous, fluid, and non-responsive; this can pose various challenges from a governance perspective. As of 2018, we witnessed a sharp increase in the number of DAOs deployed on various blockchain infrastructures (see chapter 5, figure 24), although many DAOs seem to show a short life span, which could be explained by challenges around governance challenges or lack of a relevant business objective (Ivanov, 2022; McMahon, 2023).

There are multiple business objectives for DAOs (Buterin, 2014). They can replace family trust funds, grant funds, make peer-to-peer charity possible, the first mutual insurance is built via DAO already (Mutual, 2020), investment companies, create possibilities for citizen participation (Rikken, Janssen, & Kwee, 2022), all kind of membership organizations and many more possibilities. The first traditional foundations are already transforming into DAOs at the moment (Garg, 2020). The paper "The influence of and interplay between business objectives, governance elements, and infrastructure on the long-term DAO viability: Empirical insights" presents an overview of DAO business objectives in chapter 6.

All these organizations do not need a dedicated human administrative organization to organize, run, monitor, and archive votes, nor to manage incoming and outgoing financial streams. They can hold on to various forms of value on internal accounts without the need for a traditional financial institution. Such situations make traditional, human-driven, and semi-automated banks, notary, trust funds, grant or subsidy administration and execution organizations potentially obsolete (Samman & Freuden, 2020) from a technical perspective.

The above change can lead to efficiency in many processes. First, estimations go up to 60% more efficiency in prior highly bureaucratic processes due to elements such as automated decision-making and execution (Rikken et al., 2020). Second, besides the efficiency in faster processes, as these organizations are fully coded and running on open infrastructures, they can operate at a fraction of the costs. A DAO that can perform the same actions as the operational department of a family trust fund can be set up in minutes for cents to a dollar. Operating costs for decision organizing, making, monitoring and execution can be as low as a few dollars a month. Finally, another benefit is the enhanced democratization of processes. As the participants in DAOs can initiate and vote directly on various proposals (ranging from payment decisions to general polls), this could lead to more direct democratic processes. For example, grants and government processes could lead to higher citizen participation and, thus, more widely supported spending of community funds (Rikken et al., 2022).

The fact that DAOs run on blockchain infrastructures means that they also inherit various blockchain characteristics, e.g., transparency, audit trails, decentralization, and immutability (Samman & Freuden, 2020). As a result of the fact that in conditional transactional applications, part of the executable code of the application is embedded in an immutable way in the blockchain data layer, this automatically leads to an entanglement of application and infrastructure from a governance perspective. The governance of the application and the governance of the infrastructure are often owned by different groups.

1.4 Governance challenges in blockchain applications

As stated before, due to the immutability of a blockchain and the entanglement of applications and infrastructures, especially with conditional transactional applications where part of the code is stored in a blockchain, this leads to potential new governance challenges and risks (Rikken et al., 2019). If the application is not coded properly and something goes wrong, the governance structure of the application might not be sufficient to take action (Ellul, Galea, Ganado, Mccarthy, & Pace, 2020). If action needs to be taken, this might need to be performed by the governance mechanism of the infrastructure, which, especially in permissionless blockchains, consists of different groups, as illustrated in Figure 6.

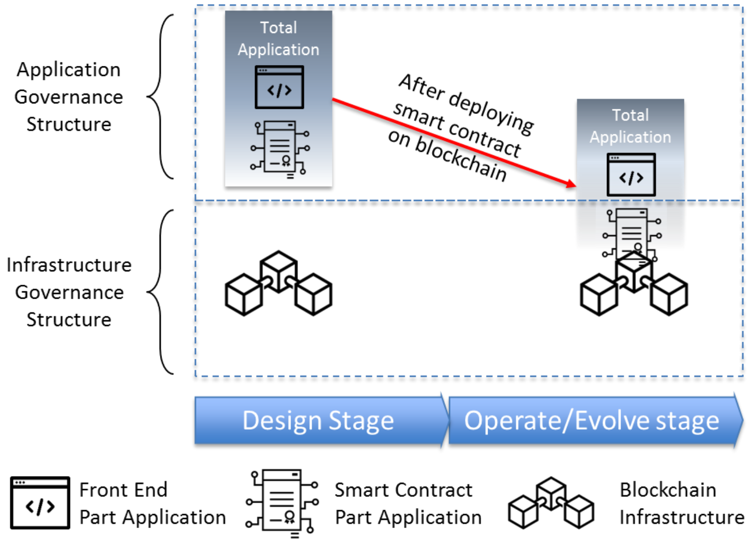


Figure 6: Visualization of entanglement of application and infrastructure

A clear early example of this happening was with the DAO hack of 2016. Here, the application contained an error. The smart contract code made it possible to get value out of the smart contracts in a way that was not intended. As the smart contracts were deployed already, the functions could not be altered anymore. Due to the immutability of the blockchain infrastructure, the transaction that triggered the hack could not be reversed. The governance of application, "theDAO", could not take corrective actions. In order to restore the hack, theDAO had to turn to the parties behind the governance structure of the infrastructure (Ethereum) and request a protocol update (hard fork) in which the corrective action was performed. Despite being different groups, it was decided to perform the hard fork and thus the corrective action (Falkon, 2017; Pelt, Jansen, Baars, & Overbeek, 2021; Slacknation, 2016). This is also the last time that the governance structure of a permissionless blockchain has performed such a corrective action on behalf of an application.

These inabilities to act in pressing situations are showcased many times in various forms. In July 2017, a vulnerability in a smart contract application, a multisig wallet, led to a loss of around $30 million (Palladino, 2017; Parity, 2017). In another incident involving a smart contract application, almost $300 million in value was destroyed (Akentiev, 2017; de Jesus, 2017). In these later hacks, although with larger cryptocurrency volumes and lost value, which led to new attempts for intervention by the governance structure of the infrastructure (Harper, 2018), the governance of the infrastructure did not act anymore (Schoedon, 2018). These vulnerabilities in blockchain and smart contract applications still exist and continue to surface (Robinson & Konstantopoulos, 2020). But not only the immutability of code, also other external infrastructural factors can influence the governance of the application, as explained in chapter 6.

With DAOs the ownership becomes fuzzier and poses a challenge as a DAO is directly steered by its shareholders who might join and leave at any point, and there is no clear board of management or ownership and can act pseudonymously (Samman & Freuden, 2020). Morris, Mazey, and Wingreen (2020) explain that the governance of DAOs can be seen as an unanticipated exception of IT governance theory from Ross & Weill as they did not anticipate a situation in an organization where decision-makers did not work together or where they do not need to trust the other decision makers and where it might be no longer feasible to separate corporate governance and IT governance. As ownership is fuzzy, decision-makers have no individual accountability. This accountability is crucial for IT governance theory (Peter Weill & Ross, 2005a).

1.5 Previous research blockchain and DAO governance - research gaps

Previous scientific research on blockchain governance focused on the governance of the blockchain system as a whole or on a more holistic level (P. De Filippi & McMullen, 2018; Reijers, 2015; Zamfir, 2018b). When this PhD research was started, blockchain governance research predominately focused on governance by the infrastructure (consensus mechanisms) (Cachin & Vukolic, 2017; Ellervee, Matulevicius, & Mayer, 2017; Milutinovic, He, Wu, & Kanwal, 2016) and hardly on the governance systems of the infrastructure in various blockchains and the multi-actor complexity other than Bitcoin (Walch, 2019) or other than in blogposts or other non-scientific articles (Bosankic; Buterin, 2017; Chinyem, 2018; Sclavounis, 2017; A van Wirdum, 2016; Zamfir, 2018a).

Research focuses on whether blockchain could be used as a governance mechanism in various use cases, being the technical enabler of new governance systems (Atzori, 2017; Batubara, Ubacht, & Janssen, 2018; Voshmgir, 2017; Yermack, 2017). Blockchain applications' governance mainly focuses on cryptocurrencies or smart contracts (Antonopoulos & Wood, 2018; Atzei, Bartoletti, & Cimoli, 2016; Hacker, 2019). Some initial explorative research was done for more complex applications like DAOs, and visions were formed (Beck et al., 2018; Choi, Row, & Laul, 2019). Taking into account the governance structures of underlying blockchain infrastructure in combination with the governance structure of the application as a result of the described entanglement is acknowledged as important in the light of auditing, regulatory certification, or future research for financial services (Ellul et al., 2020; Schreurs, 2018; Zachariadis, Hileman, & Scott, 2019). Finally, current common IT governance and corporate governance theory (of (Peter Weill & Ross, 2005a)) could be insufficient for the design of governance of DAOs on permissionless blockchain infrastructures due to the fuzziness of accountability as a result of an unknown and a fluid group of actors behind DAOs (R Morrison et al., 2020; Rikken et al., 2019).

We identified various research gaps to which this PhD research aimed to contribute. At the time of commencing this research, there was a clear gap in identifying governance challenges in blockchain-based applications and DAOs in particular. This is partially due to the fact that when starting this research, there is no comprehensive definition of what a DAO entails. Furthermore, there is a gap in what is meant by decentralization in DAOs and how this affects the viability of DAOs in the long-term. There is a lack of available research on emerging trends in DAOs in general, their governance, and the potential implications of these trends on definition and characteristics.

With regard to the governance and business objectives of DAOs, there is a need for clear taxonomies and categorizations that can be used in empirical analysis. Also, little research has been done on the viable business objectives of DAOs. When looking at empirical analysis, there is little empirical research on the effect of internal governance element variations and their effect on long-term viability of DAOs, a gap that this research addresses as well.

Finally, to the best of our knowledge, there is no previous in-depth scientific research performed on infrastructural and DAO application governance entanglement and developing this into a model or theory that can be used to design a proper fit of the DAO governance elements and blockchain infrastructure governance element on the one hand. On the other hand, the business objective of the DAO should be taken into account. These gaps, 1) governance challenges in blockchain and DAOs, 2) definition of DAOs, 3) the influence of different configurations of governance elements on DAO's long-term viability, 4) the business objectives of DAOs and the effect on DAO's long-term viability in relation with governance element configuration and 5) the effect of the entanglement of infrastructure governance elements on the governance of the DAO applications are addressed in this PhD research.

1.6 Conclusion

Blockchain creates many opportunities for efficiency and new business models but may also introduce many new challenges. Many DAOs show a short life span and thus fail to show long-term viability. The lack of long-term viability could be explained as a result of governance issues, but also the question if DAOs are suitable for all business objectives.

As there is no standard in DAO governance, variations in governance elements of accountability, decision-making, and incentives could explain why certain DAOs show better long-term viability than others. The complicating factor of the entanglement of infrastructure governance and application governance in DAOs could also be an explaining factor, especially in permissionless blockchain infrastructures. It could also very well be that certain business objectives suit certain governance element configurations better than others. Therefore, DAO governance should be further investigated considering all these elements.

2. Research Objective, Methods and Questions

2.1 Challenges and problem statement

DAOs are used for an ever-growing number of business objectives like investment funds, managing blockchain infrastructure protocols or social or club like DAOs. Certain DAO initiatives and industry players are becoming more critical of whether DAOs are the right organizational form for the business objective of their DAO in the first place or if the right governance setup of their DAO for its purpose is chosen. The core of the challenges is that we are now building applications on top of an infrastructure maintained and run by many parties with no formal ownership. Nobody is formally in charge of the governance as this is scattered amongst various actors in the system, with various of them even being pseudonymous (Zachariadis et al., 2019). Especially in permissionless blockchains, this leads to unclear accountabilities and responsibilities. As an individual you have little to no influence on the governance of the system, both from an operational as from a maintenance and other update perspective. Recorded data and performed actions, in general, are immutable and permanent. In permissioned blockchains, this is much less the case as the number of nodes is relatively low, the node owners are known, and responsibilities can relatively easily be appointed and action taken (Kadiyala, 2018).

Due to the entanglement of application and infrastructure, the governance of the application becomes dependent on each other. If the governance of the application contains an error and is setup wrongly, for corrective action the governance of the application can become dependent on the governance of the infrastructure for corrective actions. This challenge actually increases with the type of application. With *direct* transactional applications, the application logic is stored outside the blockchain. Only the result of actions in the application is stored in the blockchain itself, or it even just reads data stored on a blockchain. The governance of the application has little to no ties to the governance of the blockchain infrastructure. This becomes increasingly complex with conditional transactional applications where the code of the applications is (partially) embedded in the blockchain. In case of a flaw in the software code of the application, particularly the smart contract code, one could become completely dependent on the infrastructure's governance structure.

With regard to DAOs, there is the complicating factor that they exist out of code, where humans are positioned at the edges (Buterin, 2014) in the operational processes of the DAO. Once a certain decision is made, human interference in the process is no longer possible, because DAO's smart contracts code is embedded in a blockchain and autonomously executes the outcome of the decision. Reversal of the action is often impossible (unless separate governance processes are introduced). Acting if needed in case something goes wrong is hard and as the shareholders of a DAO are pseudonymous and volatile, accountability can also be hard to pinpoint.

The strong entanglement of infrastructure and application, without direct control by single or small groups of persons or entities, and in the case of DAOs even on both levels, poses new governance challenges of fuzzy accountability due to unknown and fluid actors as result of low entry and exit barriers and the "pseudonymity" of actors and lack of controls and actual possibilities to act. The governance of the application could not act by itself and becomes dependent on the governance of the infrastructure for corrective actions. This has already emerged in practice with the "theDAO"-hack incident (Akentiev, 2017; Falkon, 2017; Slacknation, 2016).

An additional challenge is the fact that there is no one blockchain infrastructure and thus not one governance structure. Blockchains infrastructures have their own governance structures that are not necessarily alike. So, what could work as a solution on one blockchain, does not necessarily work for the other protocols. No clear solutions have been shown in practice. The same goes for various DAOs. There is no single DAO governance model. All DAO implementations can choose their own governance configuration. DAOs are set up for a whole range of business objectives and may use many different combinations of governance elements. An extra complication is that there was no clear definition of when an application is a DAO. Some projects claim to be a DAO but, for example the lack of autonomy can have crucial consequences for governance and accountability. Chapter 4 elaborates further on this topic.

Due to the entanglement of application and infrastructure, the different governance structures of the various blockchain protocols, and the different governance structures of DAOs, there is a need for an explanatory theory to understand how governance of DAOs on permissionless blockchains influences the long-term viability. This research focusses on creating such theory. Understanding DAOs, their governance elements and the effect of governance element configurations on long-term viability. Further in creating this theory, the business objectives of DAOs and the effect of the entanglement of infrastructure and application governance are taken into account. The theory should be able to understand the potential best fit of governance elements of a DAO in combination with the blockchain governance infrastructure which it was built upon with the business objective of the DAO as moderating variable.

If the combination of business objective, governance elements and deployed infrastructure for new DAOs are not taken into account in an integral way , one could easily run into governance challenges. The new phenomenon of entanglement of infrastructure and application governance, especially in permissionless blockchains, further increases the necessity of a sound governance design for DAOs.

Considering the identified challenges, the problem statement of the PhD research is:

"We witness a sharp rise in DAOs both in numbers as well as in assets under management. But many DAOs fail to show longitudinal activity, which could be explained by governance challenges and suitability of business objectives. But little is known of the effect of business objectives, governance elements and governance entanglement of application and infrastructure of DAOs on permissionless blockchains on long term-viability of DAOs. This research gap should be addressed and should contribute on enhancing governance design of DAOs and increase long-term viability"

Based on the challenges that arise due to the situation described, the multistakeholder complexity of the situation, and the lack of previous research in the integrated approach of governance of both application and infrastructure, my research objective and questions are as follows.

2.2 Research objective

Based on the challenges and the problem statement, we distilled the following research objective for this PhD research project:

"Develop a theory to explain how governance and infrastructure elements influence the long-term viability of decentralized autonomous organizations on public permissionless blockchains."

The primary output of this research is a theory that explains how business objectives, internal governance elements, and external infrastructural elements influence the long-term viability of DAOs. The results will provide insights into effective combinations of business objectives of the DAO, governance design of the DAO *and* governance elements of the public permissionless blockchain infrastructure it was built upon.

In this way, DAO owners can effectively take the entanglement of the two governance layers into account when designing and building a new DAO on a public permissionless blockchain or even see if they would want to use a DAO at all given the potential governance challenges. This combination of infrastructure and application-level governance is crucial. Due to the entanglement of application and infrastructure, these can no longer be analyzed separately.

The purpose of a theory is to understand and explain how governance elements influence the long-term viability of DAOs. Long-term viability as a dependent variable is chosen as many DAOs fail to show continuous activity and quickly disappear. Long-term viability can thus indicate effective combinations of governance elements, business objectives, and chosen infrastructures. Although this is a good indicator, one should also always in mind that there can be other reasons for DAOs to stop operations. The design of the governance can thus be very crucially important for long-term viability. New technologies and implementations are now widely available and subject to human initiative for almost every service industry and public good (including the use of DAOs), good design is increasingly important as design failures are common. One important reason for that is the absence of a comprehensive and systematic understanding of that system (Friedman, 2003). This is why a theory in understanding the effect of business purpose, governance elements and infrastructure elements on the long-term viability of DAOs is important in the design and setup of a DAO to increase the chances on the long-term viability of that DAO.

2.3 Research Philosophy

As we are building towards a new theory on the influence of various elements on the long-term viability of DAOs, we are creating new knowledge. However, how we perceive the world surrounding us, referred to within research philosophy as **ontology**, and how we view what constitutes acceptable knowledge, referred to within research philosophy as **epistemology**, influences our assumptions and, therefore, possibly the conclusions of our research (Saunders, Lewis, & Thornhill, 2009). The research philosophy a researcher adheres to is thus important for the readers to interpret the results as such. Guba and Lincoln (1994) even argue that the research philosophy paradigm is more important than the research methods. Although various paradigms exist, positivism and interpretivism are the main research philosophy paradigms. Other paradigms or variances commonly encountered in these two main research philosophies are realism, constructivism, symbolic interpretivism or pragmatism (Saunders et al., 2009; Žukauskas, Vveinhardt, & Andriukaitienė, 2018). All these paradigms have a different view on or mix of ontology and epistemology. This will also influence preferred research methods and data collection (Saunders et al., 2009; Žukauskas et al., 2018).

2.3.1 Ontology and epistemology

Ontology can be identified as the theory of the nature of reality or our assumptions of reality. Within ontology, two important stances exist: objectivism and subjectivism or objective or subjective realities (Hatch, 2018; Saunders et al., 2009; Žukauskas et al., 2018).

Objectivism states that the studied phenomenon is objective and exists as an objective entity (Saunders et al., 2009). This implies that the phenomena studied are publicly observable and the facts are replicable (Diesing, 1966). Subjectivism states that a study's objective is not static nor objective but constantly changing and prone to perceptions from the actors inside the phenomenon and the researchers studying it (Saunders et al., 2009).

The epistemology closely relates to ontology and focusses on how researchers believe knowledge about an object is retrieved or what constitutes acceptable knowledge (Saunders et al., 2009;

Žukauskas et al., 2018). Epistemology influences how researchers collect and conduct research on their data (Hitchcock & Hughes, 2002). Epistemology focusses on questions like how reality should be described, how knowledge is created, and if the objects researched are real and less open to bias or that it is influenced by the standpoint and background of the researcher and individuals involved in the research is less tangible or relates to feelings and thus could be up for subjectivity (Saunders et al., 2009). This, as stated, can influence the choice of research and data collection methods, where one researcher will focus more on "hard data" or facts, others on feelings or other less objective measures of observed elements (Hatch, 2018; Saunders et al., 2009; Žukauskas et al., 2018).

2.3.2 Paradigms

There are two major paradigms in research philosophy; positivism and interpretivism. Although there are various additional philosophies, a widely accepted variant is pragmatism, where ontology, epistemology, research methods, and strategy are based on the research questions (Žukauskas et al., 2018). This also implies that multiple philosophies and approaches can be used during your research (Saunders et al., 2009). A brief overview of the views on ontology, epistemology, and research methods and tooling is shown in Table 3 below.

Table 3: Overview Research philosophy – paradigms and views on ontology, epistemology, and preferred research & data gathering methods adapted from Guba & Lincoln (Guba & Lincoln, 1994), Saunders et al. (Saunders et al., 2009), Zukauskas et al. (Žukauskas et al., 2018) and Mackenzie & Knipe (Mackenzie & Knipe, 2006)

View on	Positivism	Interpretivism	Pragmatism
Ontology	Objective reality. Reality is a given and independent of the researcher.	Reality and researchers are intertwined due to subjectivity. Reality changes based on viewpoint.	Based on the research questions, either objective or subjective standpoint is taken.
Epistemology	Based on observable, objective phenomena. The values of the researcher play no role.	Knowledge is formed by experiences and subjective meanings.	Knowledge stems both from objective, observable phenomena as well as from subjective meanings.
Preferred research and data gathering methods and tooling	Predominately quantitative research – qualitative research is possible – Surveys, (quasi) experiments, highly structured, large data samples and measurements.	Qualitative research – Case studies, interviews, observations, visual data analysis.	Both quantitative and qualitative research – Mixed Methods, tooling from both positivism and interpretivism.

Positivism is the research philosophy that relates most to the natural scientist (Saunders et al., 2009) or referred to as "scientific method or research" (Mackenzie & Knipe, 2006) and relates directly to objectivism (Žukauskas et al., 2018). It perceives reality as objective, it is observable, and the values of the research do not play a role in the observations. One can create a theory or conclusions that can have a clear causal relationship or consist of laws-like generalizations (Remenyi, Swartz, Money, & Williams, 1998). Researchers following this research paradigm will predominately use quantitative methods for data gathering and analysis and will create hypotheses to be tested and (dis)confirmed (Mackenzie & Knipe, 2006; Saunders et al., 2009).

Interpretivism in social sciences research philosophy is viewed as the opposite of positivism and ontology-wise related to subjectivism (Mackenzie & Knipe, 2006; Saunders et al., 2009). The views, values, and backgrounds of social actors and researchers influence the perception of reality. Reality is too complex to describe in general terms and law. Science and "speculative philosophical problems are intertwined (Saunders et al., 2009; Žukauskas et al., 2018). The researcher must understand that, due to different views by different persons, multiple realities exist, and thus the result of the research cannot be measured objectively as reality is a social construct (Mertens, 2019). The typical research methodology would be qualitative analysis through interviews, observations, and document reviews (Mackenzie & Knipe, 2006).

The pragmatism paradigm takes the standpoint that the research question should be leading and that the researchers should not see the research philosophies as mutually exclusive in the course of a particular study (Saunders et al., 2009) and should be a continuum instead of opposites (Tashakkori & Teddlie, 1998). Pragmatism focusses on the what and how of research problems and does not commit to one system (Creswell & Creswell, 2017; Mackenzie & Knipe, 2006). In this paradigm, mixed methods, both from positivism and interpretivism, are used using quantitative and qualitative analysis (Mackenzie & Knipe, 2006; Saunders et al., 2009).

2.3.3 Research paradigm and approach taken in this study

Our research is based on the pragmatic research philosophy, although positivism is the predominant philosophy throughout the study. We view DAOs as objective research objects, and the elements that are being researched towards creating the theory are objective and measurable. The interpretivism elements stem from the fact that to create measurable elements, we have to create categorizations and frameworks that can then be used for objective measurements. Also, the identification of challenges as well as the initial theory generation comes from literature review, observations, and interviews. However, the majority is focused on measuring and analyzing objective facts and verifying the theory through hypotheses, working towards a deterministic or law-like generalization of causal relationships between various elements related to the long-term viability of DAOs. After inducting a theory through literature review and observations, the proposed theory is deducted by means of hypothesis testing and modification.

2.4 What constitutes a theory?

In this research, we build a theory that goes beyond taxonomies and represents dynamic relationships between dependent and independent variables using a positivistic research approach. The foundation of a theory is formed by systemic inquiry and critical thinking (Friedman, 2003). Suppes (1967) states that a scientific theory consists of an abstract logical calculus and a set of rules that assign empirical content to that. Friedman (2003) describes that in its most basic form, a theory is a model that illustrates how something works by showing its elements in relationship to each other. He emphasizes the difference between a static relation description, like taxonomy, and dynamic relationships, a theory. Bacharach (1989) states that a theory has a set of boundary assumptions and constraints, is a statement of relations among concepts within those boundaries, and is used to organize and communicate. A theory can be used to frame and organize observations and help generalize answers that can be used in other situations (Friedman, 2003). As Hemple (1965) states, theories can explain and predict objects and events. Parsons & Shils (1951) classify theories into four categories: basic (ad hoc classification systems) and taxonomies, conceptual frameworks, and most advanced (empirical-theoretical systems).

A sound theory needs to be able to be tested empirically (Bacharach, 1989; Friedman, 2003). It should use theory and real numbers (Suppes, 1967). Whetten (1989) emphasizes four elements of a theory, 1) the what, 2) the how, 3) the why and 4) who-where-when. The what and how (1 and 2) describe what is researched and how are elements in the what related. The why (3) explains how the elements are related. The who-where-when (4) emphasizes empirical elements and the theory's possible and impossible uses (limits). Bacharach (1989) details this in terms of a system with various elements. He states that a theory can be viewed as a system of related constructs (approximated units related by propositions) and related variables (observed units related by hypothesis). These should answer the how, when, and why of a theory. The boundaries and generalizability of the research, based on the empirical data, can be bound in space and time, this in correspondence with the before mentioned who-where-when. Classifications, frameworks or taxonomies are not a theory or a lower level classification of theories, but can be used for describing the what and to translate structs into variables (Bacharach, 1989; Friedman, 2003; Parsons & Shils, 1951). Both Kaplan (1964) and Varian (Varian, 2016) emphasize on iterations from theory to empirical and vice versa in creating a theory.

Using various research methods (see section 2.6) and answering multiple research questions (see section 2.5), we answer the what (chapter 1 and 3, paper 1), how, why (chapters 4 to 6, paper 2 to 4), and who-where-when (chapters 2 to 7, paper 2 to 4). By answering these questions, we build a theory with dynamic relationships between independent and dependent variables. In a series of papers and our conclusions, we identify the boundaries, constructs, and variables of our theory on the long-term viability of DAOs, which will eventually be visualized in a model of the theory.

2.5 Research Questions

Our research aims to build an empirical explanatory theory. To build the theory and obtain the research objective, research was performed and described in four papers answering a series of research questions:

1) In our first paper, we set the stage regarding blockchain and DAOs. We work on definitions, create initial frameworks, and identify general blockchain and DAO governance. By doing so, we create constructs and form the initial boundary of our theory, focusing on the what and how. The main research question is:
    a. What are governance challenges in blockchain-based applications?
    In the process, we answer the sub-questions:
        i. What types of blockchain and blockchain-based applications can we distinguish?
        ii. Are there emerging governance challenges in blockchain and blockchain applications, and if there are any, what are they?
        iii. To what extent are these challenges applicable in all types of blockchain and all types of applications?
        iv. Can we distinguish between various governance layers, besides the technical in blockchain applications and if any, what are these layers?
        v. Are there unique new challenges that are specific to blockchain applications rather than to current IT systems, and if there are any, what are they?

    These questions are answered using qualitative analyses. The data is gathered through literature review, observations, and interviews.

2) The second paper focuses on creating definitions and taxonomies related to DAOs and looks at emerging developments related to DAOs and the governance of DAOs. We elaborate more on the what and how in an iterative way. By iterating, we sharpen the boundaries of the theory. Furthermore, this part of the research conducts the first empirical analysis by

identifying and testing the first variable of the eventual theory starting with the why. We do so by answering the following questions.

a. What is a comprehensive definition of DAOs?
    i. What are definitions based on existing literature?
    ii. What empirical elements do we see that have a common ground in DAOs?
b. How do the decentralized characteristics of DAOs influence the survivability of a DAO?
    i. What does decentralization mean within DAOs?
    ii. What is the link between the level of decentralization and the long-term viability of a DAO?
c. What are emerging developments around DAOs and what is their potential implications on the existing DAO definitions and characteristics?
    i. What are emerging developments relating to governance and DAOs?
    ii. How do these developments influence the characteristics of DAOs and the definition of DAOs?

The questions in the second paper are answered using a mix of qualitative analysis by performing a literature review and observations and quantitative analysis by performing both empirical research and statistical analysis.

3) The third paper focuses on researching the effect of variation in governance elements on the long-term viability of DAOS. We create multiple frameworks (classifications or taxonomies) needed to identify and test various constructs and variables of the theory. This paper focuses on the how and why. In this paper we develop our preliminary theory. We do so by answering the following questions:
    a. What are key elements within DAO governance?
        i. What are key governance elements in DAOs?
        ii. What are clear taxonomies or classifications of dimensions in DAOs' governance elements in practice?
    b. What is the impact of variations of these elements on the long-term viability of DAOs?
        i. What is the impact of variations in accountability on the long-term viability of DAOs?
        ii. What is the impact of variations in decision models on the long-term viability of DAOs?
        iii. What is the impact of variations in incentives on the long-term viability of DAOs?

    These questions are again answered using a mix of qualitative analysis by performing a literature review and observations and quantitative analysis by performing both empirical research and statistical analysis.

4) The final research paper focusses on adding new elements of business objectives and infrastructure and moderating variables to existing elements of DAO governance in relation to the long-term viability of DAOs. This paper builds additional frameworks for classifying and translating constructs into variables and hypotheses that are tested as relation in the theory and set up the theory, iterating on the preliminary theory as set in paper 3 building further on the how and why. This is done by answering the following questions:
    a. How can the typical business objectives of DAOs be categorized within the broad spectrum of objectives?
        i. What are detailed business objectives of DAOs?
        ii. Can these business objectives be categorized?

iii. Can we distinguish super-categories?

b. Taking business objectives into account (as the independent variable and as a moderating variable), how do internal governance and external infrastructure elements influence the viability of DAOs?
   i. Does the business objective of a DAO influence the long-term viability of a DAO?
   ii. What is the influence of various DAO governance elements on long-term viability, taking business objectives as moderating variable into account?
   iii. Do we see differences in DAO business objectives deployed on different blockchain infrastructures or protocols?
   iv. How does transaction cost (or "gas-fee") influence the governance of DAOs?

This last paper also uses a mix of qualitative analysis by performing a literature review and observations and quantitative analysis by performing both empirical research and statistical analysis.

In summary, the research focus, and main and detailed research questions per paper are displayed in Table 4 below.

Table 4: summarizing the research focus and questions per research papers

Paper	Focus	Main Research Questions	Research Method
Governance challenges of blockchain and decentralized autonomous organizations	Understanding governance challenges of blockchain and blockchain-based applications	What are governance challenges in blockchain-based applications?	Literature review, expert Interviews, online data collection. Qualitative analysis.
Ins and out of decentralized autonomous organizations	Unraveling definitions, characteristics and emerging DAO developments and analyzing the effect of decentralization on long-term viability	What is a comprehensive definition of DAOs? How does the decentralized characteristics of DAOs influence the survivability of a DAO? What are emerging developments around DAOs and what is their potential implications on the existing DAO definitions and characteristics?	Literature review, online data collection. Qualitative and quantitative analysis.
The influence of governance elements on the long-term viability of Decentralized Autonomous Organizations (DAOs) – An empirical analysis	Categorizing and empirically analyzing the effect of governance elements on the long-term viability of DAOs	What are key elements within DAO governance? What is the impact of variations of these elements on the long-term viability of DAOs?	Literature review, online data collection. Qualitative and quantitative analysis.
Theorizing the viability of Decentralized Autonomous Organizations: limitations and opportunities of governance by design and business purposes.	The effect of business objectives, internal DAO governance elements, and external blockchain protocol elements on DAOs' long-term viability	How can the typical business objectives of DAOs be categorized within the broad spectrum of objectives? Taking business objectives into account (as the independent variable and as a moderating variable), how do internal governance and external infrastructure elements influence the viability of DAOs?	Literature review, online data collection. Qualitative and quantitative analysis.

2.6 Data collection, research methods

For this PhD research, the following data collection methodologies are used:

- Literature review
- Expert interviews
- Online data collection

With this data, the following data analysis methods are used:

- Qualitative analyses of blockchain and DAO governance processes and elements
- Quantitative analysis of DAO data and governance process data
- Quantitative analysis of blockchain infrastructure data with regard to transaction costs.

Each of them will be discussed in the next subsection.

2.6.1 Literature review

Throughout the research, an extensive literature review will be conducted based on the Structured Literature Review method as described by Kitchenham (Barbara Kitchenham, 2004; Barbara Kitchenham et al., 2010). The steps that are taken are:

1) Identification of research
2) Selection of primary studies
3) Determine quality/relevance
4) Data extraction

The keywords used for searching are Blockchain Governance, DAO governance, Governance of Blockchain, Governance of Blockchain Applications, Governance of DAOs, Decentralized Governance, Open-Source Governance, Corporate Governance and IT Governance. The literature is both scientific literature and grey literature, being literature from non-scientific sources like websites, blogs or non-peer-reviewed papers like whitepapers. The grey literature was used as the amount of scientific literature was low at the start of the research, and many DAO and blockchain-based projects were published primarily on whitepapers. The primary way to find scientific literature is through Google Scholar. The secondary way to find scientific literature is through the use of references found in the reference lists of the literature as found in the primary way. The tertiary way, used in a later stage of the research, is based on our research papers being referenced by others. The grey literature is identified using a long, extensive Google alert service and proactive Google searches. Based on the keywords “blockchain”, “smart contracts” and “decentralized autonomous organization” a daily alert as of January 2018 for a daily (hyperlink based) overview of news, blog post, and other online articles is created as a source for primary links to these articles. The secondary way to find grey literature is through links in the articles found in the primary search and the use of news and blog platforms (coindesk.com, cointelegraph.com, medium.com). All papers use Literature review to answer research questions 1a, 2a, 3a and 4a.

2.6.2 Expert interviews

For the start and first paper of this research, some expert interviews were conducted to identify challenges in blockchain and blockchain-based application governance. The experts are based on previous relevant research conducted with DAOs and/or on their reputation within the blockchain industry. The experts have various backgrounds, from academia to practical backgrounds as pioneers and entrepreneurs in the blockchain and DAO industry. In this way, a broad spectrum of expertise will be covered.

The interviews are structured interviews to compare the views of the experts. Structured interviews means that all the questions are equal to all interviewees (Yin, 2011). The structured interviews aimed to collect various views on the same fixed topic from experts from various backgrounds, especially where there is little literature on the specific topic. Besides the addition of literature, the expert interviews were used for the qualitative analysis of the governance of both blockchain protocols as DAOs answering research question 1a.

2.6.3 Online data collection

Data is collected as much as possible directly from the primary source, either being the blockchain infrastructures or DAO deployment platforms. To collect data concerning blockchain infrastructures, dedicated blockchain browsers etherscan.io and polygonscan.com are used. The preferred way is to look into the DAO data directly using direct links to the individual DAOs using platforms like aragon.org, daohaus.club, snapshot.org or any purpose-built website or application for that specific DAO. If that is not possible, derived sites like apiary.1hyve.org or deepdao.io are used. If that is not possible, using the smart contract addresses of the DAOs are used (if known) to look up the data directly in the blockchain using commonly used and accepted blockchain browsers like etherscan.io.

With regards to DAOs, the following data is gathered for analysis:

- Time period build – this will show the growth of the number of DAOs over time,
- Platform build – this will provide insight into which protocols they are built and thus will determine which protocols need to be considered in the model,
- Number of tokenholders – the number will provide valuable insight in the level of decentralization of DAOs in practice, which could have consequences for governance structures and even the definition of DAOs,
- Value in the DAO – This will provide insight into the use of the DAO,
- Activity through public voting – in combination with the value in the DAO this also provides valuable insights in the use of the DAOs,
- Governance structure – how is governance and her elements set up in this specific DAO,
- DAO business objective – what is the business objective of the DAO.

The collection will exist of the following data with regards to the blockchain infrastructure:

- “Gas-fee” or transaction pricing – this will show the cost of actions that are performed on the blockchain protocol.

The purpose of the collection of this data is to have (numeric as well as ordinal or categorial) values and data on the governance of various DAOs and blockchain protocols for quantitative analysis purposes. In this way, an analysis can be made of various governance characteristics of these protocols and DAOS, as well as for the comparison of these protocols and DAOs to each other. These values are used as input for the theory.

2.6.4 Qualitative analyses of DAOs, protocols and governance processes

For the qualitative analyses of DAO definitions, blockchain protocols, and DAO governance processes, research is performed on how these governance processes of the various blockchain protocols and

DAOs work in practice and what constitutes a DAO. Besides the desk research, expert interviews are part of the input for the qualitative analysis. Also, experiments with setting up DAOs using various DAO deployment platforms and various governance types of DAOs are performed. The objective is to find common patterns and create an overview and commonality in the various structures, taxonomies, and processes by compiling and reassembling the output of the described data-gathering methods (Yin, 2011). These patterns, structures, and taxonomies are used to create frameworks and definitions, which are then used to translate constructs into variables and define clear boundaries for our theory.

Regarding the analysis of DAO governance, case analysis was performed using online systematic observation (Yin, 2011), in addition to the quantitative analysis, to thoroughly understand the workings of governance processes and elements of DAOs. Based on the different possible governance structure cases within platform-based DAOs (Aragon, DAOstack and DAOHaus), an analysis was made on how these governance models of these DAOs work in practice and used in the description of the governance processes and to create the frameworks in the second paper.

2.6.5 Quantitative analysis of blockchain and DAO data and governance process data

For various parts of the research qualitative analysis and quantitative analysis regarding blockchain protocols and DAO business objective, governance and activity is performed. There are multiple purposes for this quantitative analysis.

1. Firstly, in addition to the qualitative analysis, to be able to create taxonomies, frameworks, and definitions in order to translate constructs into variables that are tested with hypothesis,
2. Secondly, to be able to test hypotheses regarding blockchain protocol elements and their effect on DAOs and to test hypotheses regarding DAO governance elements and business objectives relations,
3. Thirdly, to be able to plot these characteristics and their dynamic relation within the theory,
4. Fourthly, for narrowing down the research objects (boundaries for the theory) for qualitative analysis by determining true amounts of active DAOs as a result of the new DAO definition.

The data was thus used not only to analyze the governance of DAOs but also as part of further defining DAO definitions, frameworks, and taxonomies in addition to the qualitative DAO governance analysis.

The methods of analysis consist of comparative analysis as well as various types of statistical analysis. The statistical analysis we use is partial eta squared (η^2), which is a statistical method to estimate the effect size of different variables in ANOVA or general linear model (GLM) (Cohen, 1973; Richardson, 2011) and perform survival analysis through ROC curve (Fawcett, 2006; Heagerty & Zheng, 2005). Furthermore, statistical analysis uses Pearson Correlation analysis (P. Sedgwick, 2012) and binomial logistic regression and Chi Square Tests (King, 2008). These qualitative analyses are used to answer research questions 2b, 3b, and 4b.

3. Paper 1 – Governance Challenges of Blockchain and Decentralized Autonomous Organizations[1]

Governance Challenges of Blockchain and Decentralized Autonomous Organizations

Olivier Rikken*, Marijn Janssen, Zenlin Kwee

Faculty of Technology, Policy and Management
Delft University of Technology (TU Delft)
Jaffalaan 5, 2628BX Delft, The Netherlands

*Corresponding author: Olivier Rikken, Lieven de Keylaan 3, 2101 VD Heemstede, The Netherlands. Tel.: +31 6 113 94 292; E-mail: o.k.rikken@gmail.com.

Governance Challenges of Blockchain and Decentralized Autonomous Organizations

Abstract

The rise of blockchain has resulted in discussions on (new) governance models with multiple actors collaborating. Incidents and problems occurred due to flaws in blockchain protocols, smart contracts and Decentralized Autonomous Organizations (DAOs). Often it is unclear how decisions are made concerning evolvement of blockchain applications. In this paper, we identify and analyze potential challenges regarding governance of blockchain initiatives in various types of decentralized networks using literature and case study research. The governance challenges are classified based on a framework consisting of different layers (infrastructure, application, company and institution/country) and stages (design, operate, evolve/crisis). The results show that in various stages and layers, different challenges occur. Furthermore, blockchain applications governance and blockchain infrastructure governance were found to be entangled adding to the challenge. Our research shows a specific need for further research into governance models for DAO applications on permissionless blockchains, linked to the products and services offered whereas in permissioned blockchains and other type of applications, existing governance models might often be feasible. For developing new governance models, we recommend learning from the lessons from the open source community.

Keypoints for practitioners:

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- Using a framework consisting of different layers (infrastructure, application, company and institution/country) and stages (design, operate, evolve/crisis) is useful to analyze potential governance challenges in blockchain implementations.
- Unlike in non-blockchain applications, in blockchain applications there exists a high entanglement of application and infrastructure, where the application can be dependent on the governance of the infrastructure, which can complicate governance models.
- In permissionless blockchains, especially for DAO applications, further research is needed towards new governance models.
- In permissioned blockchains, although not always easy, existing governance models can be applied.

Keywords: *Blockchain, Decentralized Autonomous Organization (DAO), Governance, IT-governance, Permissionless, Smart Contracts*

I. Introduction

A decade ago, the idea for a decentralized, peer-to-peer system, was published by Satoshi Nakamoto in the Bitcoin white paper (Nakamoto, 2008). Although initially designed for a peer-to-peer cash system, the new system offers the possibility of transacting in which the information integrity and security is safeguarded by the system. Such systems are expected to result in a major organization change, as the role of a trusted third party (TTP) would be embedded in the system design instead of an organization or person. This is possible due to a combination of decentralized storage, consensus mechanisms and cryptography, leading to characteristics like (semi-)irreversibility and persistent storage (Nakamoto, 2008; Swan, 2015; A. Wright & De Filippi, 2015). These characteristics make it extremely hard to single handedly reverse or delete a datapoint or transaction.

Yet, trust also dependent on the network participants. As various of these networks are open and anybody is able to join without any entrance barriers, many of the participants in the network are often unknown (Matilla, 2016). Although it is argued that this openness and unknown network participants results to a shift to a trustless environment (Bahga & Madisetti, 2016; Swan, 2015), the trust of correct execution is embedded in the technological solution. The elimination of TTP organization poses various key governance questions: Who is responsible for what? Who decides on changes in the blockchain application and organization? Who can be held accountability for which failures? And who takes risk mitigation measures when incidents happen?

In particular, various of these accidents resulted in the need to arrange *crisis* governance. Three most debated incidents with regards to governance are the DAO incident (Falkon, 2017), Parity multisig wallet hack (Palladino, 2017) and Parity II or token and cryptocurrency freezing incident (Akentiev, 2017), leading to a loss of several $100 million. Due to *entanglement of application and infrastructure* the solving of these issues was dependent on governance of the infrastructure. However, only in the DAO incident, governance action was indeed taken by the infrastructure community. In the other cases, no action was taken by the infrastructure community and the value was lost due to a lack of effective governance possibilities in the application itself. Due to the decentralized character, there is no single owner of the infrastructure which complicates governance. As there was no TTP anymore to (un)do actions or could stop ongoing actions, it triggered discussions around various regulatory and governance questions. It led to the first formal investigation by an American regulator, the Security and Exchange Commission (SEC) (T. Commission, 2017).

The networked nature of blockchain and DAOs makes governance not straightforward. *Governance* represents the framework for decision rights, incentives and accountabilities to encourage desirable behavior in the use of resources (P. Weill, 2004). Governance mechanisms determine how communication, responsibilities and decision-making structures are formalized (Peter Weill & Ross, 2005b). Governance should define decision-making authorities and accountabilities in a decentralized network consisting of several parties. Often blockchain is associated with automated self-governance, i.e. the governance is embedded in the system, through consensus mechanisms. However, this concerns only the governance of the exploitation or "block-to-block" operation (governance *by* blockchain) and does not contain the governance about development, updates or dealing with failures (governance of blockchain) (Ølnes, Ubacht, & Janssen, 2017). This signifies that other and even new kinds of governance models and mechanisms might be required, however, there is limited insight into the governance challenges that should be addressed by these models. The need for new governance

models are even presented as one of the main barriers to adoption of the technology (Batubara et al., 2018).
The aim of this paper is to identify governance challenges in blockchain applications. Governance is challenging as the need for governance and the governance challenges are dependent on the many variations of blockchain implementations. The underlying premise of our research is that each variant might encounter different challenges. The main variants are either private or public-closed blockchains (private/public permissioned blockchain) versus public-open blockchains (public permissionless blockchain) (Mainelli & Smith, 2015; Walport, 2016). This paper has three main contributions. First, we elicit governance challenges in the different forms of blockchain variants. Second, we distinguish various decentralized application types and their specific governance challenges. Third, we classify challenges using various layers and stages of governance in blockchain projects. This paper is structured as follows. In the next section the research method is presented followed by a literature review in section 3. From the literature review we derive the type of applications which will be used to develop a blockchain governance framework in section 4. Section 5 describes the governance challenges using the governance framework and finally, we draw conclusions and outline further research needs.

II. Research Method

To identify the governance challenges literature review was conducted and interviews were conducted. Structured literature review was performed based on the systematic literature review approach by Kitchenham (Barbara Kitchenham et al., 2010). Based on this approach, 51 articles, papers, blogs and transcripts, with total pages of over 850, were analyzed. The initial search was initiated via scholar.google.com based on the keywords “blockchain” AND “governance” in the period of December 2018-February 2019.
In addition to the literature, we conducted interviews with four experts to gain a deep insight into the typical governance challenges and approaches of how to tackle the challenges. The interviewees were selected based on their practical experiences in governance of blockchain projects. The number of people meeting this main criterion is limited due to the limited focus on practical governance of blockchain so far. Interviews were conducted with an industry expert in decentralized Application development from Swarm City, an industry expert in decentralized consensus mechanisms and two researchers (an academic scholar as well as a researcher from a not-for-profit organization) who are researching and teaching various blockchain topics, including blockchain and smart contract governance. Finally, the development of the number of DAOs in time are shown.

Table 5: Basic Research Data

Type of data	Amount / number of pages (last date searched)
Interviews	4
Papers/blogposts	850+ pages (27 March 2019)
Blockchain protocols analyzed	18 (30 January 2019)
DAO count	516 (21 February 2019)

Although many articles touch upon the subjects of blockchain and governance, the most cited articles are either describing the *application of blockchain to discuss new possibilities of state governance* or *to which extent blockchain and decentralized platforms can be considered as hyper-political tools*. For example the work of Atzori (Atzori, 2017) explores if blockchain is capable in managing social interactions on a large scale and dismisses traditional central authorities while Jian & Zhang (Jia & Zhang, 2017), argue that blockchain as a technology should be governed by law by a state. Hsieh and colleagues (Ying-Ying; Hsieh, Vergne, & Wang, 2018) focus primarily on governance lessons from cryptocurrencies instead of application built on top of a blockchain, whereas Casinoa and colleagues (Casinoa, Dasaklisb, & Patsakisa, 2019) focus on applications that can support governance like identity management, Voshmgir (Voshmgir, 2017) discusses disrupting governance in itself by using blockchain, and Yermack (Yermack, 2017) the potential corporate governance implications of blockchain technology. Although these provide some insights, they do not target governance of blockchain and blockchain applications and projects as a main research area.

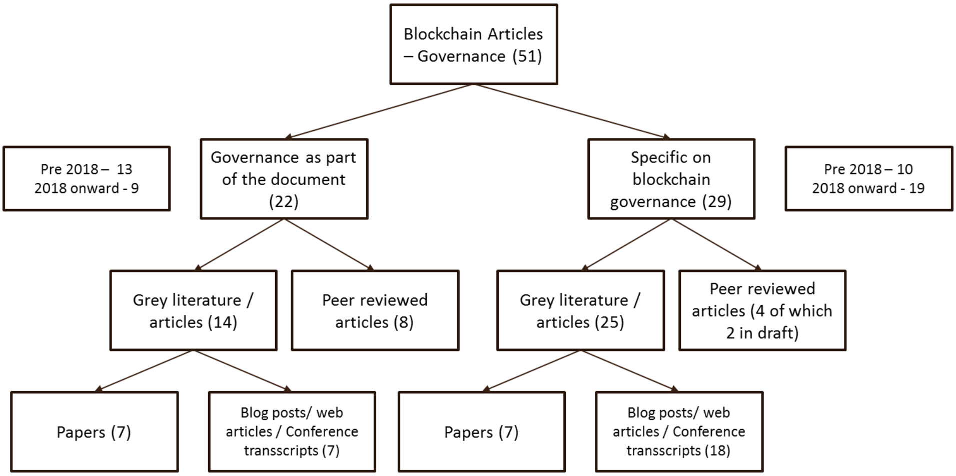

Figure 7: Literature breakdown

We found 51 publications to be relevant. Figure 7 shows the detailed breakdown of the literature. The number of peer-reviewed papers that specifically go into the governance of blockchain in itself and or the governance of blockchain applications is very low. Of the 51 articles, papers and blogs found to be relevant only four were peer reviewed articles in which blockchain governance in itself was the main topic. Two papers were published in 2016, one publication in 2018 and a draft document in 2019. None of these address the entanglement of infrastructure and application specifically. Although we see a clear rise of articles and blogs addressing the topic of blockchain governance, the amount of peer-reviewed literature that specifically addressing blockchain (application) governance lags behind. Some of the most up to date and interesting insights and discussions on this topic can be found in various blogposts on Medium by blockchain core developers like Vlad Zamfir (Zamfir, 2018a, 2018b) and Hareeb Qureshi (Qureshi, 2018).

III. Literature Review

III.1 Forms of blockchain: There is no one blockchain

The initial problem with the blockchain governance discussion is that the term blockchain is a generic technology referring to various implementations of blockchain. Blockchain protocols can have crucial differences. The most important distinction made in the literature is the categorizations of public versus private and permissionless versus permissioned blockchains (Beck et al., 2018; Peters & Panayi, 2015).

Permissionless versus permissioned refers to if the protocol is free to anyone to enter as validating or full node, sometimes also referred to as miners. In permissionless networks, everybody is able to submit transactions and validate them (permissionless), or one needs to be accepted by the standing nodes or organization(s) to become a validating or full node (permissioned). Public versus private refers to the distinction if all information is visible for everybody (public) or not (private).

Table 6: Overview of blockchain types-description-example infrastructures

Type	Description	Examples (Daniels, 2018; Voshmgir, 2019)
Public Permissionless	No entry boundaries for reading, writing and validating. Everyone can become user, node and can develop applications on top. Sometimes referred to as “true blockchain.	Bitcoin, Ethereum
Public Permissioned	Open for reading, boundaries in becoming a validator/node. Open for use, but network control remains with selected validating nodes. Sometimes open for building external applications on top.	Neo, Ripple
Private Permissioned	Boundaries for reading, boundaries in becoming a validator/node. Access granted through owners, network control with selected validating nodes.	Hyperledger, Corda (both can support Public Permissioned as well), consortia blockchain initiatives like R3 and B3i
Private Permissionless	Boundaries for reading, open for validating. Non-existent, although some argue to have set up a model like this.(Daniels, 2018)	None

This distinction between these types is important as governance, risk, compliance and privacy aspects varies per quadrant. Besides, the choice of blockchain is also relevant in the “make or buy” decision (O van Deventer, Brewster, & Everts, 2017). This decision refers to if one agrees to use an existing, open and free infrastructure, permissionless blockchain, where all nodes are not in ownership, or closed infrastructure, permissioned blockchain, where one builds and runs their own blockchain. This is a crucial decision in the design of product or service one want to offer.

When questions arise with regards to responsibilities, accountabilities and governance in permissioned environments, it is relatively easy to pinpoint the companies and institutions that run the infrastructure and are in control of the protocol, including elements like access right management as this is with the validating/master nodes (Peters & Panayi, 2015). As these are known it is relatively

easy to adopt existing governance models. When governance actions need to be executed, changes can relatively easy be implemented when needed due to limited amount and verified nodes that need to update. Their developers' community is often equally transparent. Traditional approaches of governance of IT can directly be applied as a result and stakeholders can be held responsible (Post & Kas, 2019). Ripple is a clear example of a permissioned blockchain and while it is decentralized across approved nodes, like any other centralized company, it has top managers who make decisions on resource allocation and control the direction for code development (….) reflects a more centralized form of governance (Ying-Ying; Hsieh et al., 2018).
In the permissionless environment actors, nodes, miners, users and developers are less known and reaching consensus over change becomes much harder. In itself not necessarily a negative feature. It is stated that Bitcoin's sustainability can largely be attributed to its recognition of the need for a slow evolution (Curran, 2018). A clear example of how difficult this process can be and can lead to deep division amongst actors, is the Segregated Witness (SegWit) scaling discussion in the Bitcoin network. It took several years to reach consensus and eventually, by lack of full consensus, resulted in a split (hard fork) of the network (A. van Wirdum, 2017). The reason this process is so difficult is due to the fact that the issue is often political and not so much technical. Bitcoin's block size debate is perhaps the most prominent example of a blockchain community facing complex governance problems that goes beyond the technical (Sclavounis, 2017). The base of this political discussion over a seemingly technical update was that the actors (miners, exchanges, nodes, users and developers), had conflicts of interest of the desired outcomes.
Although both permissioned protocols and permissionless protocols are blockchain, in the permissioned protocols, there is still a clear group of nodes and or owners where in the permissionless environment this group becomes fuzzy, which makes traditional governance methods in permissioned environments still valid. This calls for research into governance models on *public permissionless* blockchain protocols.

	Permissionless	Permissioned
Compared to traditional situations	Unknown group of users No "centralized" and fluid group of nodes running the network Development open to "anyone" Unknown of tradition (IT and Corporate) governance models are possible	Known group of users, "Centralized" group of nodes running the network. Traditional (IT and corporate) governance models possible

Figure 8: Permissioned and permissionless vs traditional IT situations

III.2 Types of applications

Applications build on blockchain are called decentralized Applications (dApps) (Raval, 2016). Many of these applications are not directly embedded in the core software of the blockchain itself but use core elements of that particular blockchain, like cryptocurrencies. They are solutions build on top of existing blockchains, through external applications, like wallets, but also often by implementation and deployment of smart contracts. Although smart contracts are developed on top of a blockchain, they are very much entangled with the infrastructure as the infrastructure in a blockchain is also the data layer. Once smart contract application code is deployed, it cannot be taken off-line as it stored in the data layer (blocks) of the blockchain. The name smart contracts is deceiving as they are neither contracts in most cases nor smart, but in basic deterministic computer code or programs that are deployed on a blockchain (Rikken, van Heukelom-Verhage, Naves, & Terpoorten, 2018).

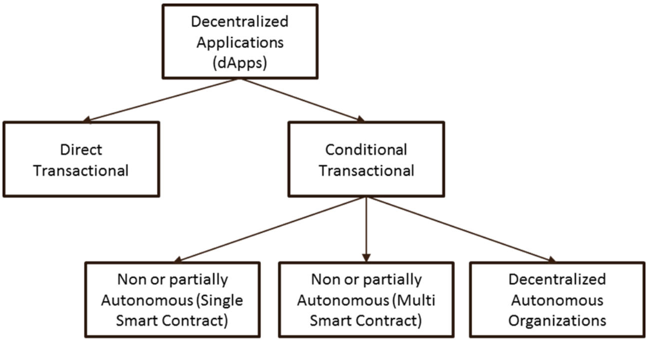

Figure 9: Types of dApps

We distinguish four types of dApps that run on and or make use of blockchain, visualized in Figure 9. The direct transactional applications and under the conditional transactional applications, the single Smart Contract applications, the Multi Smart Contract applications and Decentralized Autonomous Organizations. Description of the applications and examples are in Table 7. This distinction in types of blockchains and types of applications is important in the analysis of the governance of blockchain projects.

Table 7: Application types - descriptions - examples

Application type	**Description**	**Examples**
Direct transactional application	applications are largely run outside the blockchain on traditional webservers; make use of core applications or characteristics of blockchains as cryptocurrency transactions between 2 parties or; store description in transactions to timestamp and immutably store description as means of evidence; transaction hash or address is stored as pointer off chain to trace the transaction or account; simpler form is search engine like application that allows users to browse transactions, accounts, etc. on blockchain	Wallets, Browser, Evidence trail apps
Conditional transaction application - dApp– partially autonomous (Single smart contract)	applications representing relatively simple smart contract products and services; can be offered by various companies; can be any product or service that companies can think of where blockchain infrastructure have an added value; always one-off solutions, meaning that per set up, product, or agreement, 1 smart contract is created and discarded after use; whole application is programmed in one smart contract deployed on a blockchain; the smart contract can be replicated; once programmed the deployment can be triggered manually, by sending the code to blockchain in a transaction via e.g. an online browser/compiler or via a pre-coded function of a website, creating new smart contract account or automatically through "create" functionality in an already existing smart contract; dApp can be triggered through transactions or messages via interaction through e.g. wallets and smart contract addresses.	escrow smart contracts, product passports, multisig wallets

Conditional transactional application dApp – partially autonomous (Multi smart contracts	these applications are closely related to single smart contract ones; often more complex; multi smart contract set up is an architectural design choice comparable to modular or monolith IT design; for security reasons, one could prefer multiple contracts interacting to reduce surface of the individual smart contracts. Smaller surfaces are easier to understand and test, posting smaller risk (Everts & Muller, 2018); downside can be that this modular set up leads to smart contract interaction, which could impose the risk of reentrancy (Atzei et al., 2016), one of the most used hack methods at the moment.	prediction market, internal cash management, marketplaces smart contract structures
Decentralized autonomous organization	DAOs first described as Decentralized Autonomous Companies (DAC) in 2013; a cryptocurrency as shares in a DAC where source code defines bylaws. Goal of DAC is to earn profit for shareholders by performing valuable services for the free market. (Larimer, 2013); DAOs at the moment mostly in start-up phase; the exact line between conditional transaction applications and DAO is fuzzy; biggest distinctions are: 1) DAOs in principle don't represent a single application, but company without a traditional physical company structure. Idea is that it operates fully autonomously where humans might have, as users, voting power in parts of the processes. Where conditional transactional applications are developed and maintained by companies with earning models, DAOs don't as they are "owned" by the users. 2) Decision-making and execution thereof done by business rules of the DAO, based on objective input, votes of the users or use of oracles, being a source (technical , like a database, or person who has been issued this role) that takes up role of "source of truth" for a smart contract (Rikken, Naves, et al., 2018) or DAOs.	DAOs don't represent single application, but company, often with single product or service; The DAO, Aragon

IV. Towards a Blockchain Governance Framework

Governance is a concept that is not easily understood as there are many players involved. Momentarily there is no standard framework for understanding blockchain governance. In general *governance* contains the decision-making authorities, incentives and accountabilities to encourage desirable behavior in the use of scarce resources (P. Weill, 2004). Contrary to popular belief blockchain governance is often not fully technological enforced, nor autonomously self-governed, as stated by one interviewee: "Now we see mostly off-chain governance. With regards to on-chain governance, not all theoretical models are possible because agreement is often best reached off-line". At best first forms of on-chain governance, where updates are automatically pushed after reaching a quorum in online voting, are just implemented and experimented with at the moment and only in part of governance processes.

Governance of blockchain applications go beyond solely governance of the infrastructure. We decompose various governance layers, namely the infrastructure layer, the application layer, the company and or individual level and the institutional layer. Others define various layers as well. De Filippi and McMullen identify layers like the internet layer, the blockchain layer and the application

layer (P. De Filippi & McMullen, 2018). The Williamson (1998) framework for economics of institutions distinguished between multiple layers attaching timelines and occurrence frequency per layer.
Here, lower layers have a shorter timeline than the layers on top. Furthermore, governance is not static and typically evolves over time as the situation changes new governance mechanisms might be needed and old ones might not be needed anymore. Therefore, we will distinguish between various stages to show the different nature of governance in time. In the various stages and layers, different actors will have different levels of involvement. The majority of interviewees acknowledges the stages and layers as well, stating “Most definitely multiple levels”, “It makes sense to make a grid with regards to the levels and stages” and “recognizing various layers and stages”. These layers and stages result in the model shown in figure 10 and will be elaborated on in following (sub)chapters.

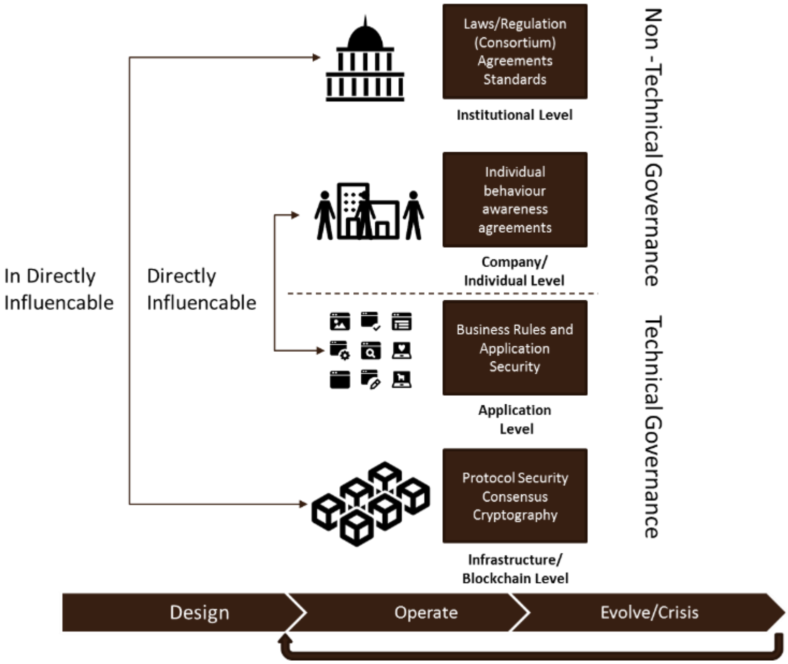

Figure 10: Blockchain governance framework

IV.1 Stages

Governance evolves over time and in blockchain governance we can identify various stages requiring different actions, decision-making processes and often even models. Different stages likely represent the need for different coordination mechanisms. Besides two described stages of governance, operational governance (governance *by* the infrastructure) and update governance (governance *of* the infrastructure) (P. L. De Filippi, B., 2016), design or creation is seen as third phase in the governance-cycle. Governance is how actors cooperate in order to create, run or evolve inputs that make up a blockchain (Sclavounis, 2017). The stages that are distinguished in our model are design, operate and evolve/crisis. The stages should be seen as a continuum instead of a linear, the evolve/crisis will go into a new design stage or immediately into the operate stage as shown below. The evolve/crisis stage is sometimes referred to as transition (ITIL), maintenance (A2 Data Governance) or control (COBIT) stage.

Table 8: Explanation of the stages

Stage name	**Purpose of the stage**	**Time**	**Stakeholders roles/decisions**
Design	Design of the solution – company – project	Non time critical – except in business continuity	Process/cooperation of an individual or group
Operation	Daily operation – decisions and actions – going concern	Time constraint restricted to rules, protocol and/or business rules of the solution	Executed by the nodes through the consensus mechanism
Evolvement/ Crisis	Update process	Time criticality depends on kind of update. Crisis implicates high time pressure.	Through (hard/soft) fork software updates of the infrastructure or code of applications through various mechanisms

In general, consensus mechanism is what people have in mind when referring to automated blockchain self-governance. “On paper, blockchain technology seems to be ironclad” (Reiff, 2018). But this just covers the operate stage, the most interesting stage of governance is the evolve or crisis stage as here quick decisions and updates are needed. So far, little formally structured mechanisms were put in place specifically to deal with this. Blockchain governance is still nascent (Zamfir, 2018a).
Although proper design governance can prevent issues, one can never foresee everything upfront. The most important questions lie within evolve/crisis stage instead of design or operate stage. While initial design is important, over long enough timelines, the mechanisms for change are most important (Ehrsam, 2017). As Mario Laul states during the Aracon1 panel discussion, “you need rules to change the rules., ……, Can't take humans completely out in this., ……, Need to have a clear process to change the rules” (Choi et al., 2019).

IV.2 Governance layers of blockchain projects

As shown, there are governance differences in the blockchain infrastructure types. In addition, there are differences in the governance stages in blockchain projects. Finally, one can make a distinction between various governance at various layers. By making use of layers the governance complexity can be easier decomposed and described. Our framework distinguishes four layers of governance in blockchain projects; infrastructure, application, company and institutional.

IV.2.1 Infrastructure layer

Embedded in the blockchain protocol. What makes the blockchain infrastructure unique is that it withholds both the protocol (rules) and the (immutable) data layer and is decentralized. Although what decentralization means is often debated and open to misinterpretation (Walch, 2019). In infrastructure governance a distinction of the governance *by* and governance *of* the infrastructure can be made. Governance in the operate stage, governance *by* the infrastructure, is arranged through the consensus mechanisms. Here the execution of the protocol itself is arranged fully autonomous. The execution is performed by the infrastructure, the nodes, using the specific consensus mechanism for that blockchain. Once a process is set in motion, the infrastructure will execute this process without

the possibility of interference by an individual, for example, disconnecting it to stop execution. The blockchain also contains the data layer. The data is stored in the blockchain. Once submitted, the data is extremely hard to alter, undo or delete, only by consensus of the nodes. In the most common used blockchains alone we can identify 10 different consensus mechanisms, some further literature and use case study lets us identify even more than 15 main categories, multiple even having various sub categories (Cachin & Vukolic, 2017).
With regards to the governance *of* the infrastructure (evolvement governance), there are two main categories, off and on chain governance. Although we can distinguish two main categories, there is basically a unique mechanism per blockchain protocol for upgrade of the protocol with sometimes even possibilities for various governance mechanisms per protocol in itself. In practice, in public permissionless blockchains, no single person or instance can make a decision or determine the evolvement of the infrastructure. There needs to be consensus in the community on updates. Depending on the kind of blockchain the governance of this layer is in-directly (permissionless) or only partially influenceable (permissioned). The level of influence is often determined by the combination of number of full/validating nodes in combination with elements like CPU power contributed in the network or stake reserved in the network depending on the consensus mechanism.

IV.2.2 Application layer

This can be a mix between traditional applications (centralized websites and apps) and embedded characteristics like native cryptocurrencies of a blockchain, or decentralized applications (dApps) where the majority of the application is built on a blockchain, by making use of smart contracts. In its most extreme form these are named DAOs. "The general concept of a DAO is that of a virtual entity that has a certain set of members or shareholders which, …., have the right to spend the entity's funds and modify its code" (Buterin & al, 2014, p. 22). There are 4 types of blockchain applications, all with different governance structures:

1. Direct transactional - governance of these applications can be either off-chain, in traditional IT environments using traditional governance methods or dependent on governance of the infrastructure.
2. Conditional transaction, single smart contract - execution or operate stage of the smart contract business rules are performed by the infrastructure protocol in combination with external triggers. Regarding evolve governance, in the permissionless blockchains, once deployed, contract code is fixed and cannot be updated. Intervening actions only possible through governance of the infrastructure. To update non-parameterized elements, structures or the business rules in the code, one needs to de-active the smart contract, e.g. through self-destruct commands (if integrated in the design of the smart contract) and deploy a new one. A way to arrange governance responsibilities and process is by employing smart contracts where parameters in the code set up as variables that can be updated. Of utmost importance is that access to functions is properly arranged, e.g. in Ethereum possible through "modifiers", arranging access on function level. Upcoming solutions are "proxy functions" referencing to future deployable smart contracts adding functionality.
3. Conditional transaction, multi smart contract - Governance possibilities of these type of applications largely overlap with governance of single smart contract. A difference is that one can replace modules, in this case individual smart contracts, without replacing the whole application. All applications described are likely to be implemented by traditional company or

supplier types and governance of these applications can be tied and often integrated to governance structures as arranged in the company layer. Here is where Decentralized Autonomous Organizations differ.

4. DAO - DAOs are technically and governance wise much like conditional transaction applications, build in single or series of smart contracts, operating, once deployed, exactly as programmed in the business rules of the smart contracts. Possibilities for interference by humans in theory little to non and no formal company structure is behind it.

The amount of direct transactional applications is hard to estimate. With regards to conditional transactional applications and DAOs there are exits estimates. In March 2019, the amount of dApps was around 2650 (stateofthedapps, 2019). The amount of DAOs have been very low, as DAOs needed to be coded manually. This changed as of October 30st 2018. When Aragon launched, it became possible to deploy a configurable DAO without the need of manual coding. This led to a Cumbrian explosion of DAOs as is shown in figure 11 below.

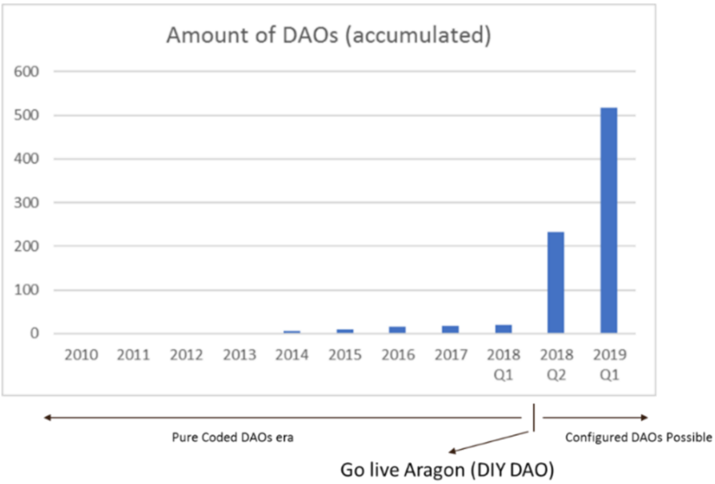

Figure 11: Accumulated amount of DAOs. 2018 and 2019 count can have a slight double count. Colony makes use of Aragon and it remains unclear if the DAO list of Aragon contains these DAOs.

The governance on the application layer is closely entangled with the governance on the infrastructure level and cannot be separated any more. As in all types of applications, governance possibilities with regards to data, smart contract code and or specific blockchain products/services and or characteristics are dependent on the infrastructure governance actions.

IV.2.3 Company layer

Behind most blockchain applications are individuals using the applications and formal organizations or independent projects building/running the application. With regards to individual responsibilities, a crucial responsibility within blockchain, private key management, is back at the individual due to lack of a TTP in the network. Once lost, the individual cannot perform actions with the account related to that private key anymore. Although this responsibility is back at the individuals, projects or companies will have to take responsibility to inform the users on that.

Governance in projects or companies should in the majority of cases not be different for blockchain related initiatives than other IT applications and have to be embedded in roles, responsibilities and processes of the projects or organization. Responsibilities and accountabilities should be clear. There are a few, not specific for blockchain though, situations where governance structures are hard(er) to define.

- open-source projects without a formal organization or structure behind it, e.g. a group of (definable) individuals, although not formally organized, working together on a project through sites like GitHub,
- open-source developments where people work together via e.g. GitHub without any formal organization behind it, but also not identifiable to (a group of) individual(s). Most public permissioned blockchains are, in theory, developed in this way as anyone can anonymously propose software updates.

Governance is complicated when the application being developed is a DAO, where no legally formal organization is set up, and here is no prior determined set of owners. If users can be seen as the owners, as is the case for various DAOs, the owner base can be extremely fluid and due to the pseudonymity often undeterminable.

IV.2.4 Institutional level

Country, industry or overarching countries. Blockchain poses some interesting challenges due to its decentralized nature and as blockchain is developed by people globally, sometimes completely anonymous. Combined with elimination of central controlling parties, the element of jurisdiction is much harder to determine than before (West, 2018), especially in permissionless blockchains. As the network runs independently on servers globally, jurisdiction cannot, in various cases, be determined on presence. Additionally, regulatory views differ per country about products and services on blockchain and even within countries (Directorate, 2019).

There is no logical overarching jurisdiction for blockchain related projects, products and services. Other than the ERC20 standard, developed by the industry itself, there are hardly any global standards. Besides that, power to execute enforcement of regulation is extremely hard. Controlling power of institutionalized organizations are no longer automatically part of the governance ecosystem (Meijer & Ubacht, 2018). Draghi stated even that the ECB has no power to regulate cryptocurrencies (Union, 2017). It poses the same enforcement problems as with websites as “thepiratebay”. Although banned in various countries, a practical ban turned out to be difficult. Only due to new business models like Netflix and Spotify, customers changed behavior. Some countries have high regulatory concerns, other less so. On the other hand, some countries need large regulatory reforms, others are need less so. This currently results in four regulatory approaches:

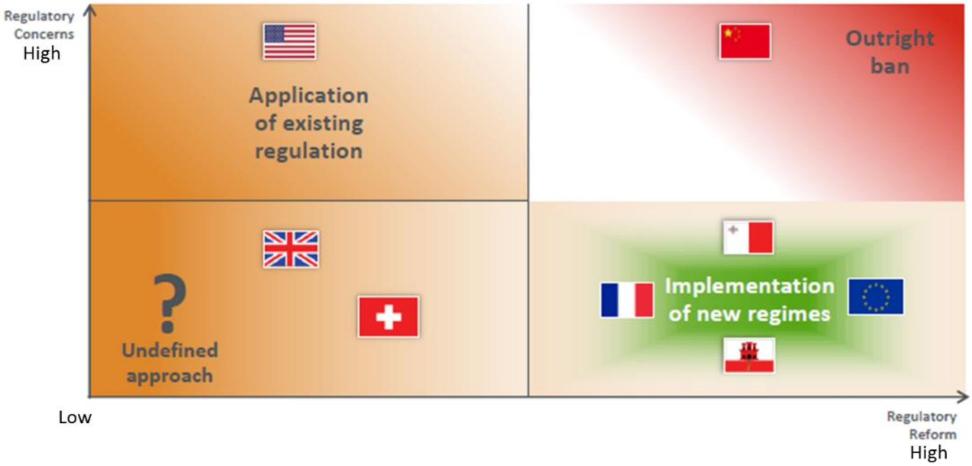

Figure 12: Global regulatory approaches ICO's (Source: presentation by John Salmon - Hogan Lovells 2018)

This regulatory quadrant example reflects Initial Coin Offering (ICO) regulation, seen as one of the straighter forward products and services. Regulations becomes even more complex and much less debated with more complex structures like new ecosystem set ups especially in the case of DAOs.

V. Governance Challenges

As blockchain projects and implementations consist of various stages and in various layers, the challenges can be categorized accordingly. We will discuss the governance challenges hereafter.

V.1 Governance challenges per stage

We identified several governance challenges per stage. In the design stage a main challenge is the "make or buy" choice of the infrastructure (O van Deventer et al., 2017). This will influence the governance on all other layers. The amount of control needed on infrastructure is dependent on the product or service, which also could directly connect to choices on institutional level (jurisdiction). Another design challenge is lack of peer review in the design phase. The Cardano protocol is born on this challenge. They want to change how cryptocurrencies are designed and developed. The Cardano protocol embraces a collection of design principles, engineering best practices and avenues for exploration, small groups of academics and developers competing with peer reviewed research (Foundation, 2019).
In the operation stage, on infrastructure, application and company level, the challenge is if it requires a combination of automated and manual decisions. In voting on any topic other than block consensus needed for daily operations, this post practical problems like unresponsiveness of the participants (Buterin, 2017; Vessenes, 2016). When decisions are needed, we should not overestimate the willingness to vote, as Mario Laul quotes: "People don't always want to be involved" (Choi et al., 2019).

This was clearly shown in the DAO incident where in the majority of cases, the voting quorum as not met (DAOStats, 2016; Vessenes, 2016).
With regards to the evolvement stage, the biggest challenges are unknown unknowns. There is little known in practice in blockchain project governance. there is a clear need to experiment and research (Ehrsam, 2017; Qureshi, 2018). As some blockchain protocols require agreement by network majority, speed of decision-making could be a potential challenge. Evolve and crisis governance can have similar challenges on elements like voting majority as the operational stage or peer review challenges as the design phase. Especially time pressure in crisis situations demands quick responses.

V.2. Governance challenges per layer

V.2.1 Infrastructure layer

There are many infrastructure layer governance challenges, especially in permissionless public blockchains. How to govern permissionless blockchains that are not dominated by single organizations is the area where most work need to be done and research is needed as these show significant governance problems (Hacker, 2019). In permissioned protocols, level of decentralization is limited and participants are known thus traditional approaches to governance can be applied to Permissioned Public and Permissioned Private blockchains (Kadiyala, 2018), although it can still be challenging (Oskar van Deventer, Berkers, & Vos, 2018). It is appropriate to think about blockchain-based corporate governance forms in terms of their degrees of decentralization (Ying-Ying; Hsieh et al., 2018).
Permissionless blockchains have not one infrastructure. Due to the many protocols, challenges can differ enormously. With regards to operate challenges or governance *by* the infrastructure this is related the consensus mechanism. Per consensus mechanism, specific governance challenges occur, like “whales” (large token holders) in proof of stake or geographically concentrated mining power in proof of work. The specific challenges should be analyzed in more detail to describe the various pros and cons of these consensus mechanism.
The most common challenge for consensus mechanisms is changing the user or node bases. The most common challenge is immutability being breached by 51% attacks (a (group of) miner(s) obtaining CPU power majority in the network and that can then continuously build the longest chain creating the possibility of transaction alteration), due to changes in or lack of sufficient large base of voters. Long seen as theoretical problem, recent events show that this has become reality in Ethereum Classic (Moos, 2019), leading to changes in transaction history and double spending of cryptocurrencies.
Another challenge is mob democracy/justice (Chinyem, 2018; Qureshi, 2018). Decisions are not made on rationale, but on herd-majority-voting. Voting systems struggle with voting power balancing. The “one man one vote” challenge was found in 5 articles (Berreman, 2018; Choi et al., 2019; Ehrsam, 2017; Qureshi, 2018; Steis, 2018). The unstoppable execution of transactions and code itself is also another challenge. Although a powerful characteristic of blockchain, it renders obsolete the commonly known governance act; take application offline – stop underlying infrastructure from executing – altering or deleting wrong data.
This challenge is an important consideration if blockchain is needed for a solution in the first place, especially in combination with the purpose of the application. Blockchain has been referred to as

“most hostile environment for applications” (Everts & Muller, 2018) due to immutability, transparency and permanence nature.

The governance *of* the infrastructure has various challenges as well. As with governance *by* the infrastructure, the evolve/crisis governance mechanisms differ much per blockchain and needs to be researched in more detail.

There are some general challenges that can be identified. In off-chain governance, more traditional processes on voting and stakeholder management are set up in decision-making of protocol updates or data changes, through traditional voting mechanisms. The transparency lies in minutes regarding update-meetings are published and in theory any can join the meetings. The challenge is that these are very technical discussions. Few persons can participate in practice (Curran, 2018). This could lead to unbalanced power of developers. Countervailing power is that nodes need to adopt the changes and can choose not to. This could lead though to a hard fork, often seen as undesirable due to potential economic loss of various actors.

In on-chain governance, through smart contracts or DAOs votes are open to all users of that particular blockchain. After a threshold is met, the update is pushed through (Curran, 2018; Qureshi, 2018). The challenge here is that people without proper knowledge regarding the impact can vote as well (Qureshi, 2018).

A popular believe is that a DAO fully autonomous decides for an update, but their governors are inevitably humans (Qureshi, 2018) that cast votes through voting systems, representing democratic like systems. Here the challenge is that often users are not known, acting under pseudonyms and can easily create additional pseudonyms (Qureshi, 2018), breaching the one person one vote principle and do not necessarily represents a real democratic system. Similar challenges of inequality in voting power can be found in other on and off chain governance systems. As there many different systems, this should be further researched.

V.2.2 Application layer

With regards to challenges in the application layer we can identify various challenges per type of application.

Direct transactional applications - this type of applications doesn’t build additional integrated logic in the blockchain. The challenges are not specific for blockchain but are, as these applications run on traditional infrastructure, similar to traditional applications, except specific blockchain data storage, being transaction and transaction related data that is stored immutable and permanent (in permissionless blockchains) on the blockchain. Here governance challenges are one-on-one to infrastructure layer challenges.

Conditional transaction application – (*Single smart contract*) - Challenges in these applications are challenges directly related to the infrastructure and transaction applications as well. Any change in underlying data structure or transactional data can influence input and outcome of smart contracts. A specific challenge is in evolvement of these applications. Once deployed, the code of smart contracts cannot be altered on most permissionless blockchains. Besides governance challenges if something goes wrong with the underlying data in the infrastructure, the challenge is the impossibility of altering hard coded logic of smart contracts (Everts & Muller, 2018). Another challenge could be the length of smart contracts. Long smart contracts increase risk of surface attack (Everts & Muller, 2018).

Conditional transactional application – (*Multi smart contracts*) - Challenges in these applications are related to challenges on the infrastructure layer, the transaction applications and single smart contract applications. Additional challenges are that these applications often represent more complex products and services with multi actor environments. Examples are initiatives like Augur and Swarm City. Large part of operational governance is done by pre-defined business rules, executed by the infrastructure, but part of the decisions can be made off chain, as these applications are not fully autonomous. With evolve governance, in principle, applications like Swarm City are developed and deployed by teams with centralized governance (Beck et al., 2018). Responsibilities towards these applications pinpoint to these teams. Additional challenge is the risk of reentrancy attack as result of the modular setup.

DAO - For DAOs same challenges can be identified as with other applications and the infrastructure layer. Besides those challenges, one major additional challenge compared to other application types, is lack of traditional company structure, especially after the design stage as teams/owners become fuzzy. This might not result in governance challenges in operate stage of applications due to predefined business rules and automated execution but lies predominately in the evolve stage. As no governance for evolve or crisis management is arranged on a company level, it must be designed and embedded in the application layer. Specifically on DAOs in the evolve stage, “we need rules to change the rules” (Choi et al., 2019). Another challenge is how to deal with unethical behavior or mis-use of code. There is only one real example in this regard, “the DAO”. Eventually governance actions were taken on infrastructure level clearly showing the entanglement of application and infrastructure. But also other DAO like cases, like “Swarm City”, clearly demonstrate that the emergence of the blockchain economy demands rethinking of governance (Beck et al., 2018).

A challenge for governance of all blockchain applications is transparency of code base of smart contracts. This can lead to voting behavior for updates in these applications with malicious intends. This was witnessed in “the DAO” incident with “proposal 59” where the hacker voted in favor of an update proposal that contained flaws that he would later exploit (Slacknation, 2016). There is limited knowledge about the governance challenges in the evolvement phase. Most DAOs are not live yet but are in the design/test phase. As they all differ in basic design the, implemented or designed, governance models should be researched in more detail.

The high entanglement of infrastructure and application governance in blockchain also leads to an entanglement of the challenges. Some of these governance challenges might be new due to the hostile development and deployment infrastructure blockchain, but most of the challenges are not different from traditional IT application challenges. Most of the time, a clear (IT)-organization is related to the application and traditional governance actions can be taken. Only in case of DAOs, especially in evolve/crisis stage, governance challenges can differ significantly from traditional applications. Here traditional processes, roles and responsibilities appointed to identifiable human lack as result of no formal traditional organizational forms.

Application Level

	Direct Transactional	Conditional Transactional	DAO
Design	Traditional governance models possible	Traditional governance models possible	Traditional governance models possible
Operate	Traditional governance models possible	Partially Traditional governance models possible– Data stored tied to governance structure of the blockchain	Possible new governance structure needed – Data stored tied to governance structure of the blockchain
Evolve-Crisis	Traditional governance models possible – Data stored tied to governance structure of the blockchain	Traditional governance models valid – Data stored tied to governance structure of the blockchain	Possible new governance structure needed – Data stored tied to governance structure of the blockchain

Figure 13: Applicability Traditional Governance models: Color coding refers to suitability of traditional governance models.

V.2.3 Company layer

If a clear company or project organization is set up for the creation of a dApp, the governance challenges on the company layer don't differ to traditional companies and or projects. Only if there is no traditional company anymore, but a true open-source development of a DAO, could post new challenges. Interesting is that almost per definition a DAO is set up as global entity which is not tied to countries. This could lead to cultural differences, including different governance insight (Choi et al., 2019) which can be a complicating factor from the start. Also, DAOs might be subject to different legislation.

If companies have become obsolete due to implementation of DAOs this poses a challenge in accountability in crisis situations. This complicates even further if the DAO was developed in an open-source development, where it is virtually undetermined who the developers are.

V.2.4 Institutional layer

A challenge for any blockchain project in this layer is the choice of jurisdiction or accountability over multiple jurisdictions (West, 2018) in combination with the product or service offered, especially if the application is one of the first three types, implying that a company owns the application. If applications run for example financial or data services, choice of jurisdiction is crucial. The challenge is predominately that, in this early stage of the technology, laws and regulations towards products and services like Initial Coin Offerings, can alter much in time (Salmon, 2018) and even in hindsight be enforced.

A complicating factor arises with DAOs. The challenge again is that a DAO cannot be governed as a company. As it is decentralized, no logical jurisdiction can be derived based on location. Additional to this challenge is that, because of open-source development, no developer can be pointed as responsible. Deriving jurisdiction based on location or nationalities of employees becomes extremely hard. So far, no clear legislation is known around DAOs.

V.3 Concluding on governance

Many claim that, as we are creating new ecosystems and initiatives on blockchain technology, governance structures need to redesigned or traditional structures are obsolete (Reiff, 2018; Sedgwick, 2018; Zamfir, 2018b). In many cases this might not or only partially be true when taking various levels of governance into account and effectively deploying them. Where blockchain technology can lead to irreversible problems, as in the QuadrilaCX case in December 2018, where due to the death of the owner, access to funds was lost as no one had the password or private key (De & Baydakova, 2019). One could easily argue that this needs new governance structures on infrastructure or application level. But this could easily be arranged on company level, by decent, non-technical, processes and backups in traditional governance manners.

The real challenge is in the governance models in the public permissionless environment. Permissioned blockchains are easier to fit on existing governance models as validating nodes are known and identifiable. Design, operate and evolvement actions are relatively easy to manage. Including updates and roll back actions. Even within public permissionless environments, in various situations like direct transaction application and conditional transactional applications other than DAOs, existing governance models like ITIL and COBIT can be feasible. The fact that an application is built on a public permissionless blockchain by an identifiable person, group of persons or company does not discharge them from the responsibility and accountability of the application they offer. Here governance parts, that cannot easily be enforced by the blockchain, should be covered on company or application level. The only situation where discharge of responsibility might be feasible is a crisis situation where the underlying infrastructure fails, the blockchain breaks down. Or maybe in case the code of the application build can be misused in an unforeseeable way, like the Parity 1 incident. This could give ideas for new crisis management structures, e.g. through ethical hackers (Rikken & Vroegh, 2018), but does not change initial responsibility, especially if these applications were offered against a premium.

The new questions come forward if these initiatives, on public permissionless blockchains, are created and operated, in an open, decentralized way. Future blockchain applications like DAOs will show an increasing form of autonomy (Angelis & Ribeiro da Silva, 2018). Human interference might fade to the background. If DAOs are developed open source, without identifiable developers, where no humans are needed anymore to run it raises the question of who is accountable and how the evolvement and potential crises can be governed.

A complicating factor is entanglement of infrastructure layer with the application structure. Once deployed, the application code and transacted data cannot be changed nor deleted. In companies lack of technical enforceable operation and evolve governance can be compensated by governance processes and or clear regulation. But what about organizational forms that only exist in code? Regulation might be unclear, nobody might feel responsible and there is a lack of standards, what leads to a range of potentially new governance challenges.

The multitude of challenge like the entanglement, immutability of data, lack of organizational or company structures and fluid and unknown actors clearly show the need for further research towards blockchain governance models. But our overview of challenges also shows that in the majority of blockchain cases, governance models from companies and or IT are still valid. Especially in permissioned blockchains and in the design stage in permissionless blockchains. Also, in the majority of blockchain applications, effective governance can be arranged in other layers than infrastructure or application.

VI. Conclusions and Further Research

Blockchain incidents, due to decentralization and lack of controlling trusted third party, raised a new debate around how the governance of blockchain should be arranged. Governance is not easy due to the decentralized nature, immutability, lack of organizational or company structures, fluid and unknown actors in permissionless blockchains and the entanglement of *application and infrastructure* elements. Governance of applications was found to be dependent on the governance of the infrastructure due to this entanglement. The governance of the infrastructure is often controlled by different groups of stakeholders. This often results in a lack of effective governance actions as a whole. When analyzing governance challenges of different blockchain types, governance stages (design, operate, evolve/crisis) and governance layers (infrastructure, applications, company, institution/country), our framework proved to be useful for classifying the governance challenges. Furthermore, we expect that this governance framework can be used as a support for developing blockchain governance.
As shown, predominantly applications on permissionless blockchain protocols post potentially new governance challenges. In all other blockchain types existing governance models could be suitable as potential accountable actors are known and directly in control. Furthermore, in permissioned blockchains, updates and data roll backs are relatively easy compared to permissionless environments. As shown in Figure 14, when zooming in further, potential new challenges are *predominately in DAO applications in the operate and evolve/crisis stage*.

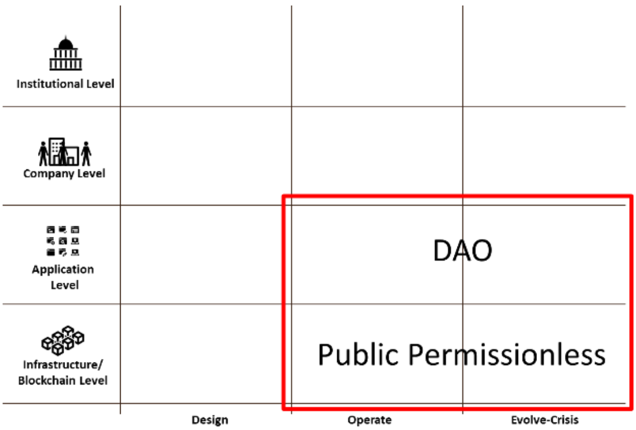

Figure 14: Area where possible true new governance questions arise

This because distinction between users, developers and infrastructure running base becomes fuzzy and as there isn't necessarily an organization anymore. Once deployed, the users, whom can be highly fluid, and code govern DAOs. The fluid and unknown user base might not be problematic in the operation stage, but might pose real problems in evolve state, especially in crisis. It can even become impossible to pinpoint natural persons or companies resulting in unclear accountabilities. This lack of responsibility and accountability can be very problematic in swift decision-making and execution of governance actions. If DAOs are designed and built open source, traditional roles and responsibilities and accountability might shift completely.

As blockchain is growing as infrastructure and applications develop more towards autonomous applications like DAOs further research must be conducted toward effective governance structures in this area. These governance structures should be put into a model where the link can be made between purpose and regulatory regime of the DAO and the best fit for governance models, taking entanglement with the infrastructure it is built on into account.

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4. Paper 2 - The ins and outs of decentralized autonomous organizations (DAOs) unraveling the definitions, characteristics, and emerging developments of DAOs[2]

The Ins and Outs of Decentralized Autonomous Organizations (DAOs)

Unraveling definitions, characteristics and emerging developments of DAOs

Olivier Rikken MSc MBA*, Delft University of Technology, Emerging Tech Horizons RD
Prof Dr Marijn Janssen**, Delft University of Technology,
Dr Zenlin Kwee***, Delft University of Technology.

* Corresponding author, o.k.rikken@tudelft.nl, Jaffalaan 5, 2628 BX Delft, the Netherlands
** M.F.W.H.A.Janssen@tudelft.nl
*** Z.Roosenboom-Kwee@tudelft.nl

Abstract

Despite the increase in the number of blockchain-based Decentralized Autonomous Organizations (DAOs), there is no consensus on what constitutes a DAO. This paper provides an in-depth study of DAOs by analyzing their definitions, characteristics, and emerging developments. Existing definitions in the literature hardly recognize common functionalities and intermingle coded DAOs, DAO deployment platforms, and blockchain DAOs. We developed a comprehensive DAO definition by reviewing the literature and empirically analyzing 1,859 DAOs. The findings show that many DAOs were inactive and that a threshold of 20 tokenholders is a tipping point for DAOs to survive over time and keep sustained levels of activity. Finally, based on an empirical analysis of 9,845 perceived DAOs, we identified the emerging development of off-chain voting. This emerging development challenges the autonomous nature of DAOs. We recommend further research to investigate the effect of governance structures on their long-term sustainability and viability for both on-chain and off-chain DAOs.

Keywords: Blockchain, Decentralized Autonomous Organization (DAO), Decentralization, Definition, Governance, Long-term viability

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I. Introduction to Decentralized Autonomous Organizations (DAOs)

Decentralized autonomous organizations (DAOs) are blockchain-based applications for the automated execution of governance processes. DAOs are first referred to as a 'coded organization' by Larimer (2013). The code automates a large part of the governance of the organization, and humans are no longer actively needed to execute operations. In this way, DAOs can automate transactions, operations, and decision-making by organizations.

DAO governance is decentralized by nature since the use of blockchain ensures that there is no need for central execution. The governance of a DAO often consists of participants casting their votes. After that, the decisions are automatically executed without the need for a trusted third party (TTP) or a central authority (e.g., a notary) to ensure the integrity or guard the content of the data (Duan & Da Xu, 2021; Truong, Lee, Sun, Guitton, & Guo, 2021). This creates a new way of organizing, managing, and governing organizations.

In the first generation of blockchain infrastructure protocols (e.g., Bitcoin, which was first introduced in the 2008 Bitcoin whitepaper by Satoshi Nakamoto (Nakamoto, 2008)), it was hard to include any decentralized logic in transactions. However, the advancement in the second-generation infrastructure protocols (e.g., Ethereum and Hyperledger) has made this substantially easier. The infrastructures cater to smart contracts or chaincode creation and functionality (Sturm, Scalanczi, Schönig, & Jablonski, 2019). Smart contracts are coded on, deployed on, and executed by a blockchain (Qin, Tan, Guo, & Shen, 2021; Rikken, van Heukelom-Verhage, et al., 2018; Zheng et al., 2020). As such, blockchain-based smart contracts are accounts that can store and execute business logic described by code in a decentralized way. Hence, these can be used as building blocks for DAOs (Buterin, 2014). Due to this additional functionality in the second-generation blockchain infrastructure protocols, there is an upsurge of blockchain-based decentralized applications (Raval, 2016).

In blockchain-based decentralized applications, direct and conditional transactions are possible. The *direct* transactional application uses the blockchain to record the transactional outcome of the use of the application. This means that the transaction is recorded directly *on-chain* based on the transaction request from a wallet and/or reads from the blockchain adhering only to the rules of the *off-chain* part (wallet) and the blockchain protocol core software. In contrast, a *conditional* transaction application has parts of its code and the execution logic embedded in the blockchain through smart contracts. Such a transaction requires interaction between a wallet and a smart contract (where part of the logic is embedded), adhering to the entire rules of the off-chain part, the smart contract code, and the blockchain protocol core software. The conditional transactional applications are often used for creating DAOs (Rikken et al., 2019).

Although the rise of these protocols led to the first experiments with DAOs, the possibilities of DAOs only gained more exposure to a broader audience with the creation and the hack of "the DAO", which is the first large-scale DAO implementation (Dhillon, Metcalf, & Hooper, 2017; Jentzsch, 2016). The number of perceived DAOs has risen exponentially over the years, particularly during the period 2018-Q3 2022 as shown in Figure 15. Note that we use the term '*perceived',* as there is no consensus on the exact characterization of a DAO. Moreover, diverse definitions of DAOs exist in practice and the literature (P. De Filippi & Hassan, 2020). Yet, there is no unifying definition (Baninemeh, Farshidi, & Jansen, 2023). As a result, there is unclarity regarding whether a blockchain application initiative can be qualified as a real DAO, how a DAO is set up, or what the functional purpose of a DAO is. This unclarity in what constitutes a DAO makes it hard to determine how many DAOs exist.

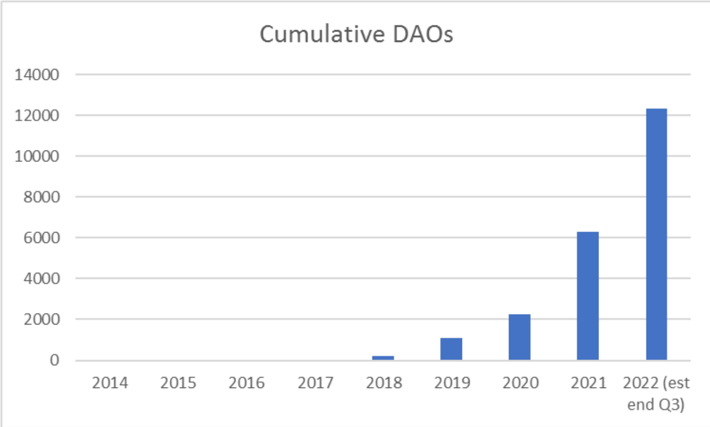


Figure 15: Perceived DAOs over time (Note: The term "perceived" is used here due to unclarity in current definitions regarding what a DAO really is)

Existing research focuses predominantly on either approaching DAOs from a descriptive, theoretical perspective (Hassan & De Filippi, 2021; Ying-Ying Hsieh, Vergne, Anderson, Lakhani, & Reitzig, 2018; Samman & Freuden, 2020; S. Wang et al., 2019), or analyzing a single or small number of DAOs or certain events like "the DAO incident" (Ashizawa, Yanai, Cruz, & Okamura, 2022; Beck, 2018; Dhillon et al., 2017; Ehrenberg & King, 2020; Hickey & Harrigan, 2022; Slacknation, 2016). Other studies focus on literature review and ontology of DAOs or the legality of smart contracts in DAOs (Pranata & Tehrani, 2022; Valiente & Rozas, 2022). Few, but a rising number of studies, conduct somewhat larger empirical research on DAOs. El Faqir et al. (2020) estimated the number of DAOs by analyzing only one particular DAO type (i.e., DAOstack) (El Faqir, Arroyo, & Hassan, 2020). The limited number of studies of DAO governance mainly analyze the governance at a general level: relating them to corporate or IT governance and not specifically to decentralized governance of DAOs (U. W. Chohan, 2017; DuPont, 2017; Mehar et al., 2019; R. Morrison, N. C. Mazey, & S. C. Wingreen, 2020), by looking into DAO platform selection criteria (Baninemeh et al., 2023) or DAO forks (Overhage & Widjaja, 2022). Additionally, only a few studies on DAO governance focus on the voting power distribution within DAOs (Fritsch, Müller, & Wattenhofer, 2022), the differentiation in governance tasks, and the effect on operational performance (Zhao, Ai, Lai, Luo, & Benitez, 2022a), where a smaller set of use cases were empirically analyzed. There is thus a lack of in-depth empirical studies of DAOs with a large dataset.

Considering the abovementioned research gaps, this paper aims to (1) develop a comprehensive definition of DAOs; (2) examine the decentralized characteristics of DAOs; and (3) analyze emerging developments and their potential implications on the existing DAO definitions and characteristics. For the first aim, we analyzed both scientific and grey literature. In addition, we performed an in-depth empirical analysis of 1,859 perceived DAOs to find the key characteristics of DAOs. This empirical analysis was also used to examine the decentralization characteristics of DAOs (the second aim). To identify emerging developments, the previous 1,859 DAOs and an additional 8,000+ perceived DAOs (9,845 DAOs in total) were analyzed.

Accordingly, the three aims of this paper result in three main contributions. First, as there is no consensus on what constitutes a DAO, we crystalize and develop a comprehensive definition of a DAO based on a set of characteristics derived from the existing DAO definitions supplemented with the key characteristics as found in our empirical analysis. Second, considering that DAOs are often only decentralized in name but not in practice (Chainanalysis, 2022b), we examined the influence of the number of tokenholders for a DAO to survive over time by performing a survival analysis of the number of tokenholders and its relationship with the activity level (survivability) of DAOs. This provides the first empirical evidence of the minimum level of decentralization in DAOs. Third, we analyze emerging developments that can influence and even challenge the existing definitions and characteristics of DAOs.

This paper is structured as follows. In the next section, the research methods used are described. Section 3 presents the literature review and an in-depth analysis of DAO definitions and characteristics. This analysis results in a unified DAO definition. Section 4 covers the results of our DAO empirical analysis; a categorical analysis of DAOs; a survivability analysis and the minimum level of decentralization. Here, an overview of all potential and self-proclaimed DAOs are categorized and subsequently. The analysis of emerging developments is presented in Section 5. We end the paper with key conclusions and recommendations for follow-up research.

II. Research Approach

To answer the first question, we reviewed existing definitions and characteristics of DAOs through a systematic literature review (Barbara Kitchenham et al., 2010). We used the following keywords search in Google Scholar: “blockchain”, “governance”, “decentralized autonomous organiz(s)ation”, “DAO” and their combinations (November 2019 – January 2023) and a long running daily Google alert service (keywords “Decentralized Autonomous Organization”, November 2020-January 2023). After screening for the relevant literature, we obtained 75 articles (papers, blogs, webpages, and transcripts) with total pages of over 600. Figure 16 shows the decomposition of the number of papers over the various categories. Of the reviewed literature, 61 papers have DAOs as the main topic. In the remaining 14 articles, DAOs are not the main topic but are mentioned and discussed in one or more parts as part of a broader discussion or research. Of the 61 articles having DAOs as the main topic, 4 specifically focused on “the DAO” incident or hack in 2016, whereas the remainder of 57 articles focused on DAOs in general, discussing various elements, from definitions to governance.

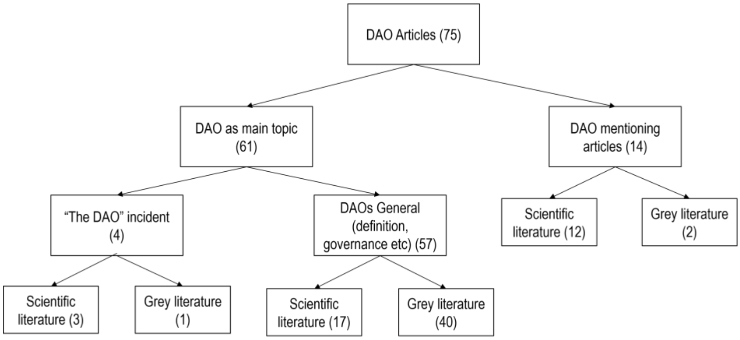


Figure 16: Literature breakdown (number of hits are shown in brackets)

Besides reviewing the literature, to address the first research question (comprehensive definition and characteristics), we empirically analyzed the characteristics of 1,859 DAOs (Table 9). The 1,859 DAOs were collected by using various DAO websites and Google searches on “DAO” or “Decentralized Autonomous organization(s)” and Google Alerts on “Decentralized Autonomous Organizations”. From the 1,859 DAOs, 1,635 DAOs were analyzed on functional and implementation characteristics. This was needed because out of the initial 1,859 DAOs, only 1,635 DAOs actually had active individual web pages where on-chain activities (the activity level and functionality offered by a DAO) are monitored.

For each DAO, we documented the individual link to the unique website of that DAO, analyzed all the (sub)pages and activities, manually counted the number of tokenholders and amount of public votings (proposals), and examined various characteristics. If no unique websites were found, the activity and tokenholders were tracked by via block-browsers (e.g. etherscan.io) using the DAO smart contract addresses or via installment of a dedicated block-browser apps (e.g. Bisq). This is a laborious process as it took between two to ten minutes to gather all the required details for each DAO. For the long-term viability analysis, we even had to revisit each DAO multiple times to record the change in activity over time.

Table 9: Research Data

RESEARCH QUESTION	TYPE OF DATA	SEARCH PERIOD	DATA	SOURCES (LINKS)
RQ1 DEVE-LOPING A COMPRE-HENSIVE DEFINITION	Scientific literature (papers) and grey literature (blogs, transcripts, webpages)	Until Jan 2023	600+ pages	Google Scholar, blog links (e.g., medium.com and hackernoon.com), Google Alert.
	Blockchain protocols	Until Jan 2023	14 blockchain infrastructure protocols	Not applicable
RQ2 EXAMINING THE DECENTRA-LIZATION CHARAC-TERISTICS OF DAOS	First batch of perceived DAOs	Nov 2019 – 2 July 2021	1,859 perceived DAOs	apiary.1hive.org, aragon.org, dauhaus.club, daostack.io, pokemol.com, etherscan.io, colony.io, scout.cool, district0x.io, and links to various individual DAOs, Google Alerts
RQ3 ANALYZING EMERGING DEVE-LOPMENTS	Second batch of perceived DAOs	3 July 2021 – 30 June 2022	9,845 perceived DAOs, i.e. the 1,635 DAOs from the first batch plus 8,210 additional DAOs	Same links as the first batch and additional links from snapshot.org and boardroom.info Google Alerts

Note: The full datasets are available at: https://data.4tu.nl/datasets/edfa3d4c-f347-4a79-b8fb-c80e9cb385de

To answer the second research question (examining the decentralization characteristic of DAOs), we analyze the 1,859 potential DAOs using 14 different blockchain infrastructure protocols. Here, we analyzed these DAOs individually based on a number of characteristics: name, year and month of creation, status, how each DAO was built and the blockchain infrastructure protocol the DAO was built on. Furthermore, we recorded the functionality of those DAOs by manually opening all the individual/dedicated sites of the DAOs where the on-chain data was presented. We counted the number of participants in the form of tokenholder accounts in each DAO, the amount and number of cryptocurrencies and tokens on the balances in the treasury of the DAO, and its activity in the form of public votings (proposals). We analyzed the activity level over time, i.e., the change in the number of tokenholders (new account holding tokens or account no longer holding tokens), transfer of value from and to the treasury and public proposals. Individual votes by tokenholders on proposals were not included in counting the number of activities. To observe any changes during this period (continued or discontinued activity), we examined the same group of DAOs six to fifteen months later. Furthermore, a quantitative analysis in the form of statistical survival analysis was performed to investigate the tipping point in the level of the core number of tokenholders for ensuring the long-term viability of DAOs (activity levels). The analyses help to understand the relationship between the number of tokenholders and the viability (activity level) of DAOs, thus quantifying part of decentralization in DAOs.

Finally, to answer the third research question (i.e., analyzing emerging developments), we performed a literature study of the emerging developments (based on the same literature used for addressing the first research question). We combined this with empirical research into a total of 9,845 perceived DAOs, by comparing the growth in the different types of DAOs, following the same methodology as described for the first research question.

III. DAO Definitions and Characteristics

There is a steep rise in the number of perceived DAOs as shown in figure 15. This number is disputable, as DAOs are ambiguously defined (Baninemeh et al., 2023; P. De Filippi & Hassan, 2020). Ambiguous DAO definitions may lead to some confusion over whether a certain organization is a DAO or not. Clarity in the DAO definition is important for both users as well as researchers. For users, what defines a DAO can have consequences on their decision if they would like to participate in such an organization, whereas for researchers, conceptual clarity is key for understanding and analyzing an empirical situation.

As DAOs are multifaceted, various definitions approach DAOs from different perspectives: ranging from functional, organizational form and purpose perspectives, to technical creation, setup and scientific and practical perspectives. There is no clear consensus about what makes up a DAO in the literature (P. De Filippi & Hassan, 2020), which can be attributed to its emerging nature. In the next subsection, we discuss the similarities and differences in definitions and characteristics of DAOs by summarizing and developing functional and technological perspectives of DAOs. We then analyze the extracted and observed characteristics to identify the most common characteristics in the existing definitions. We create a comprehensive definition by combining these common characteristics with the observed characteristics in our empirical research.

III.1 Functional and organizational form (or purpose) perspective

There are various terms related to DAOs. In 2013, Daniel Larimer first coined the concept of DAOs in his post on the hidden cost of Bitcoin where he proposed the term *Decentralized Autonomous Corporation* (DAC), i.e., an organization with coded bylaws, a limited amount of services and a goal to generate profit for its shareholders (Larimer, 2013). Buterin (2014) described the DAC as a subversion of the DAO as the purpose of DAOs can be more general and does not necessarily have a financial purpose. Buterin also described smart contracts as the building block for DAOs instead of a fully running blockchain network.

In 2018, the concept of DAICO was introduced by Vitalik Buterin (2018). The acronym is actually the combination of DAO and Initial Coin Offering (ICO). This type of DAO is designed to improve the ICO model by introducing governance elements around the transfer of value of a DAO (Buterin, 2018). Another DAO type was also described in the same year, i.e., the Decentralized Autonomous Co-Operative (DACo) (Kershaw, 2018). The DACo is set up to control the new digital commons where collective decentralized behavior is incentivized to establish an organization with a common good in mind and for non-profit (Kershaw, 2018).

After DAICO and DACo, the Limited Liability Autonomous Organization (LAO) is another variant related to DAOs. LAO is another generation of DAO where the Ethereum environment is bridged to traditional legal regimes. These DAOs focus on setting up legal entities, providing legal structures, and binding legal agreements (LAO, 2019). One of the most recent DAO subtype is the Decentralized Party (DePa).

DePa is considered as a political party that operates like a DAO to establish transparency and clear accountability (Sergeenkov, 2021).

DACs, DAICOs, DACos, LLAOs, and DePas all make use of the overall concept of DAOs. Figure 17 shows that they can be considered a DAO specialization.

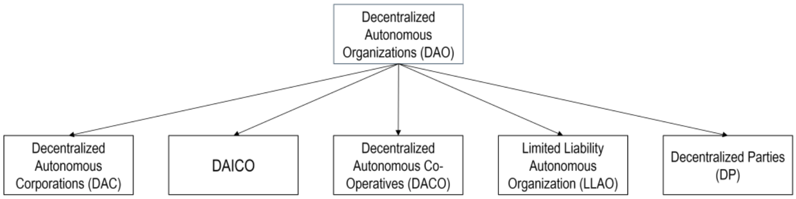


Figure 17: DAO subtypes

III.2 Functional characteristics in practice

We further analyzed the key functionalities for each of the DAOs. This enabled us to determine the common functionalities offered by DAOs. Functionalities include the storage of links to information, chat functions, agent (link to other smart contracts external to the DAO), allocations, addresses, dot votings (which are multiple option voting instead of binary option voting), rewards (dividend payments for tokenholders) and projects. These functionalities are all predominantly available in Aragon-based Parameterized Platform DAOs (see 3.3) (Aragon, 2023; AutarkLabs, 2019). Other DAO templates (e.g., Moloch through the DAOHaus Parameterized Platform) offer ragequit functionality. Ragequit refers to the ability for members to exit at any time with a proportional amount of funds to ownership (DAOHaus, 2023; Gist, 2019). There are two key functionalities that are consistently shared by almost all DAOs:

1. *Storage and transfer of value functionality*. The vast majority of DAOs analyzed have the ability to store and transact value as a result of a certain trigger, such as a decision outcome or an incoming transaction, in the form of cryptocurrencies or tokens. The total value stored and controlled by DAOs is estimated to have surpassed the $6 billion (Akhtar, 2021).
2. *Trusted notary functionality*. Nearly all of the observed DAOs have the functionality to organize, track, execute, and archive votings. This trusted notary function is often the trigger for the transaction of value, i.e., executing the transaction once the vote has reached a certain threshold.

Of the 1,635 DAOs analyzed, 96.3% contained both characteristics, 99.0% contained at least one of these two, 0.7% contained other or no functionality, and 0.3% of the functional purpose was unclear. These functional characteristics are not always described in the existing literature (P. De Filippi & Hassan, 2020; Diallo et al., 2018; S. Wang et al., 2019), while others do describe these functional characteristics (Jentzsch, 2016; Zachariadis et al., 2019). As these two characteristics are found in almost all DAOs, and without them, DAOs lose their primary functionality. Hence, we consider both characteristics as being vital for DAOs.

III.3 Technical creation and setup perspective

Apart from functional differences, some differences in DAOs are inherent due to the implementation of DAO applications. From a technical view, the existing literature refers to both blockchain infrastructure protocols and smart contract applications as DAOs. Ziolkowski, Miscione, and Schwabe (2020) mention DAO platforms, like Aragon, DAOStack and DAOHaus as being a DAO or a governance platform, while strictly speaking, these platforms only enable the deployment of DAOs. Standard DAOs can be created on these platforms based on a fixed number of templates. Previous literature (P. De Filippi & Hassan, 2020; El Faqir et al., 2020) distinguishes between typologies of DAOs, but often in only two groups, either self-coded or platform-based. The team of the Dash project (2021) argued that blockchains in themselves can be seen as DAOs. However, this would not result in any distinctive features, as blockchain is the platform on which the DAOs (and other applications) are developed. Based on the descriptions in the literature and our analyses, the subtypes of DAOs are visualized in Figure 18.

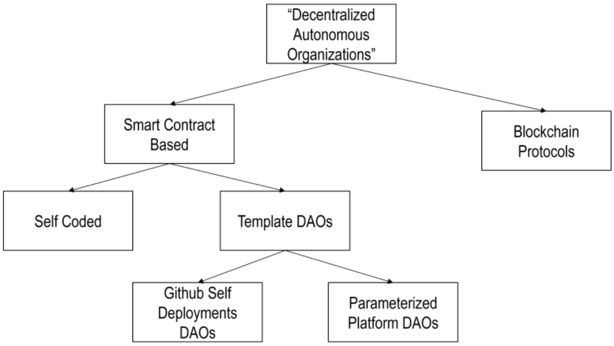


Figure 18: Breakdown of types of DAOs based on technology and deployment type

The various potential DAOs can be divided into two main subtypes: (1) smart contract-based and (2) full blockchain protocol. This distinction is important as it can have significant consequences for the DAO's governance due to the entanglement between application and infrastructure (Rikken et al., 2019). With blockchain-protocol-based DAOs, the blockchain protocol is the DAO in itself. As this is the case, the DAO and the infrastructure, are assumed to have the same governance group. There is no entanglement between DAO application governance and infrastructure governance. However, as smart-contract-based DAOs are deployed on an existing blockchain infrastructure, the governance of the application can become dependent on the governance structure of the infrastructure (Rikken et al., 2019). "The DAO incident" is a clear example of the entanglement of the application and the infrastructure level, which eventually led to the hard fork of the infrastructure as a result of a flaw in the application. There are various examples of blockchain protocols of DAOs like Decred, Steemit, NAVcoin, and BOSAGORA in which voting is done by native cryptocurrency, tokenholders or node-owners (Kim, 2020; Project, 2020; Team, 2020; S. Wang et al., 2019).

Subsequently, smart-contract-based DAOs can be divided into two main groups: self-coded (or self-built) DAOs and parametrized DAOs. Self-coded DAOs are completely built and deployed by the DAO owners themselves. Parameterized DAOs can be further subdivided into two subgroups. The first subgroup makes use of platforms like Aragon, DAOhaus, or DAOStack. For deployment, there are fixed templates for the type of DAO one wants to implement. Users only have to fill in a limited number of variables (no coding needed). The second subgroup uses precoded DAOs by copying the code from Github and deploying it themselves (like EOSDAC). In sum, all these subtypes have obvious consequences on the possible functional uses and their respective governance mechanisms.

III.4 DAO definitions in the white and grey literature

There have been various attempts by scholars and business practitioners to define DAOs. Although the existing definitions show some commonalities, they still differ, resulting in complex and ambiguous interpretations of a DAO. We deliberately analyzed definitions from both scientific literature and grey literature (business reports) as they can provide valuable theoretical and practical insights.

III.4.1 DAO definitions in the literature

Through a literature review, we identified 13 relatively unique definitions of DAO (see Table 3). Several authors cite existing DAO definitions and follow or build on each others' definitions. Kypriotaki, Zamani, and Giaglis (2015) described DAOs as decentralized entities using blockchain to run their activities autonomously and decentralized. They further point out that decision-making is done by coded logic through the use of smart contracts. As the decision-making is automated, this creates value for their customers. This definition is also adopted by Kondova and Barba (2019).

In 2018, Hsieh et al. (Ying-Ying Hsieh et al., 2018) described DAOs as organizations that organize themselves through a democratic process. This is done on a public peer-to-peer and cryptographically secured network, but was not necessarily referred to blockchain or smart contracts. They emphasized routine tasks and the idea that DAOs rely on voluntary contributions from the stakeholders of the respective DAO for all lifecycle stages (operate, manage, and evolve). They also mentioned that the code should be open source (Ying-Ying Hsieh et al., 2018). With this definition, they followed the previous works of Dietz et al. (2016) and Van Valkenburgh et al. (2015). Zwitter and Hazenberg (2020) further follow the descriptions of DAOs of Kondova and Barba (2019) and Hsieh et al. (2018).

DuPont (2017) described the DAO from "The DAO incident" perspective. He specifically mentions that a DAO is a new form of organization that is run on a public blockchain and that the governance roles are encoded in smart contracts creating new forms of social interaction and order. Next, Diallo et al. (2018) define a DAO as a system that runs on a blockchain in a decentralized way, but without specifying what this decentralization exactly entails. They mention that pre-defined rules are used to control the operations.

According to Diallo and colleagues, a DAO should be immune from internal and external attacks and much more robust due to the reduction of human processes (Diallo et al., 2018). In 2019, Zachariadis, Hileman, and Scott (2019) described a DAO as a distributed autonomous organization. They emphasized that it can replace functions, like voting and various forms of transfer of value, by blockchain-based code and execution (Zachariadis et al., 2019). In the same year, Wang and colleagues defined a DAO as an organization based on smart contracts on a blockchain where the management and operational rules are coded. A DAO can operate autonomously without central control or intervention possibilities. A DAO challenges hierarchical models and should lead to efficiency gain on various points like collaboration, decision-making, and communication (S. Wang et al., 2019).

In 2020, Hassan and De Filippi conducted a brief review of DAO definitions (2021). They concluded that a DAO is blockchain-based, using self-executing rules on a public blockchain. They also mentioned that there should be no central control and that governance is decentralized, enabling people to self-govern and coordinate themselves. They asserted that the exact meaning of the terms decentralized' and 'autonomous' in DAO is still very much debated. The terms can either mean that decentralization and autonomy in DAOs only refer to the infrastructure level (i.e. being built on a blockchain infrastructure) or that DAOs are also decentralized and autonomous on the application level, meaning that decisions and executed are made through a democratic process or decentralized governance setup, without a central authority or power. So far, regarding decentralized setup, a minimum level of participants in the process is unknown (Hassan & De Filippi, 2021; Ying-Ying Hsieh et al., 2018). This will be discussed in more detail in Section 0.

More recently, Bellavitis et al. describe DAOs as a collectively owned and managed organizations. Using blockchain-based smart contracts for coded rules, DAOs enable members to propose and vote on any corporate type of decision for various purposes (Bellavitis, Fisch, & Momtaz, 2022). Various other researchers and scholars used definitions with overlapping elements: from a decentralized system for operation and governance (Beck, 2018), and conditional transactional applications without a formal structure built on smart contracts and operating as programmed where human interference is limited (Rikken et al., 2019), to autonomous execution of decisions made by consensus of the tokenholders (Pranata & Tehrani, 2022).

III.4.2 DAO definitions in the grey literature

In the business context, there are various definitions of DAOs. In the 2013 Ethereum Whitepaper, Vitalik Buterin (Buterin, 2013) describes a DAO as a virtual entity where participants, either members or shareholders, can vote on the allocation of funds and updates of the code. Incentives are provided through bounties, salaries, or internal tokens. In this context, the DAO can look like a traditional legal company but uses blockchain technology for enforcement (Buterin, 2013).

The 2016 "The DAO" whitepaper by Jentzsch (Jentzsch, 2016) provided a broad description instead of a clear definition. He stated that the definition of DAOs is subject to much debate, particularly concerning the legal status and ownership. A pertinent discussion is about whether DAOs need to be operated by humans, human-created entities, or autonomous (run completely by code). Jentzsch further argued that the answers to those questions depend on various circumstances. In principle, the DAO is set up to automate governance decision-making (Jentzsch, 2016). The whitepaper describes that the functionality is around storing and transferring value and has basically no other functions. If other functions need to be done, a contractor needs to be put in place. Through a proposal, a contractor can ask for transferring value out of the DAO, after approval by the DAO members. Such code can run via smart contracts on the Ethereum blockchain (Jentzsch, 2016).

The parameterized DAO creation platform, Aragon, emphasizes in their manifesto the creation of true sovereignty that DAOs create (Aragon, 2020). Furthermore, Aragon emphasizes the change in governance relationship by moving towards an opt-in (participatory) environment. The participants are both in control of decisions and the execution for others, which is possible due to decentralized technologies without the need for a third party.

In 2019, Honigman (Honigman, 2019) described a DAO by dissecting the words. The DAO is autonomous (due to self-enforcing programmed operating rules), running on a public permissionless blockchain where value can be immediately transferred, and rules are enforced as a result of a decision. Decentralized can be interpreted in two ways: first, as a result of running on a blockchain and second, as the lack of hierarchical organization with executives and shareholders. Decentralization can be within an organization or a whole organizational network.

There are various similarities and distinct differences in the various definitions derived by scholars and industry practitioners. Our findings show no clear differences in how scientific literature and industry look at DAOs; they seem to echo each other. To have a more unified overview, we created an overview of DAO characteristics.

III.5 Overview of DAO characteristics

The various definitions of DAOs entail a wide range of DAO characteristics. Together with general blockchain characteristics such as transparency, decentralization, and cryptographic security, Hassan and De Filippi described online coordination, self-governance, blockchain-based, using smart contracts and coded rules for interaction, self-execution, and independence from central control as the most distinctive characteristics (Hassan & De Filippi, 2021). Samman and Freuden considered independence, transparency, and decentralization as DAO characteristics (Samman & Freuden, 2020). Cash identified seven characteristics or features of a DAO: autonomous, decentralized as in equal rights for each member, organized, smart contract-based, has a token for financing or transfer of value, and is based on blockchain technology and open source code (Cash, 2019). In 2019, Kondova and Barba (Kondova & Barba, 2019), followed by the Consensus team in 2021 (Shuttleworth, 2021), identified transactions of tokens or cryptocurrency, autonomous execution, consensus, contractors, proposals, and voting as key elements of DAOs. Pranata and Tehrani also mention autonomous execution as a key element (Pranata & Tehrani, 2022). In our empirical research, we observe two main functional characteristics of DAOs: the transfer of value and a notary function (Section 3.2). So far, although there is an overlap in key characteristics, there is no comprehensive categorization of these characteristics.

Based on the various definitions described, characteristics described in the literature, and analyzed characteristics during our empirical research, we define the following categories of characteristics:

- *Functional* characteristics: characteristics of DAOs focus on the functional side of DAOs in themselves, being the most common functionalities.
- *Governance* characteristics: characteristics that describe decision setup, making and execution
- *Technical* characteristics: characteristics based on the technical setup of DAOs
- *Other (Operational and legal)* characteristics: characteristics that either describe a specific operational element of DAOs or propose a legal form.

Table 10 shows the detailed characteristics of each of the four categories.

Table 10: Description of the four categories of DAO characteristics

Functional characteristics • (Conditional) storage and transfer of value – The storage and transfer of value in these cases are always in the form of cryptocurrencies. • Notary function for decision-making – This functionality refers to the element of being able to organize, track and archive voting. This is typically where a DAO differs from any multisig application.
Governance characteristics • Decentralized on the infrastructure level - Functionalities and rules are coded on blockchain (no one entity can stop infra) • Decentralized on the application level - not in the hands of a single person/party that can make all the decisions. • Autonomous decision-making - fully autonomous decision-making based on information presented • Organization and its code are fully transparent • Stakeholders reach consensus on decisions by voting based on predetermined voting rules (majority, quorum, no hierarchy) • Updates, bugs and optimizations need democratic voting and decision-making by share/tokenholders • The decision-making process always starts with a proposal or external trigger • Voting rights could be distributed either based on the number of tokens owned or evenly
Technical characteristics • Smart contract code – this characteristic is described various times in different literature. There are multiple blockchain protocols (not applications often called protocols, like a DeFi solutions call themselves), that consider themselves DAOs as well • Code is open source • Is (public) blockchain-based

Other characteristics
• Operational – two main characteristics
  o Autonomous Execution - A DAO acts and executes independently (not external or human-influenced) after triggers/decision
  o DAO “hires” external for operational work, based on shareholders’ decisions (no employees)
• Legal - Has a certain legal status or at least clear governance with regards to responsibilities and accountabilities

III.6 Mapping of definitions and characteristics to derive a comprehensive DAO definition

In Sections 3.4 and 3.5, we identified a wide set of characteristics related to DAOs, a wide range of DAO definitions, and key functional characteristics. We synthesize the characteristics from the described definitions and analyze which characteristics are found in which definitions. This is shown in Table 11. When a characteristic is mentioned in the definition, a green color is given, while only partially matched, the orange color is given. The red color is given when there is no matching.

From Table 11, it becomes clear that none of the existing definitions contains all characteristics. The most commonly mentioned characteristics (e.g., with the most matching in green/orange) are: decentralized at the infrastructure level (11 green /2 orange), often specified as blockchain-based, decentralized at the application level (5 green /6 orange), decisions are made and/or executed autonomously (2 green /7 orange).

The essential functional characteristics of DAOs of both notary and value functions exist in almost all analyzed DAO (As stated in Section 0, of 1,635 DAOs, 96.3% contain both, 99.0% contain at least one of these two). Surprisingly these functionalities are hardly mentioned in the existing definitions of both academic and industry, whereas they determine the general purpose or use of DAOs. Interestingly, the notary function of a DAO, supporting decision-making, is mentioned more often directly or indirectly than the transfer of value (which is the most common use case in practice). Also interesting is the fact that open source is hardly mentioned in the various definitions.

Based on combining the most commonly mentioned characteristics in the various existing definitions coupled with the observed characteristics that are present in almost all DAOs, we propose the following comprehensive definition of a DAO:

"A DAO is a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way".

The definition implies that, on the infrastructure level, data and actions are recorded and autonomously executed by smart contracts and/or a blockchain protocol. At the application level, decisions cannot be made by a single participant, but only by multiple participants utilizing various voting and governance mechanisms (reflecting the 'decentralization' component of DAOs).

Transfer of value can be interpreted in a broad manner. This can be in the form of the transfer of cryptocurrencies held by a particular DAO to a predetermined address, assigning voting rights to a certain address, or granting access to a system. Nevertheless, to address the first research question in this paper, we tried to find a definition that is not too broad and not too narrow.

A common discussion regarding DAOs is about what decentralized and autonomous characteristics means. According to Hassan and de Filippi in 2021 (Hassan & De Filippi, 2021), decentralized can be viewed from the idea that DAOs are built on (public permissionless) blockchains. Hence, decentralization stems from the inherent properties of the blockchain. They also conclude that no study yet examines the minimum size of DAO participants (i.e., tokenholders) involved in a DAO. Ramachandran and Qureshi (2020) argue that DAOs are not decentralized as small groups can issue changes, which is also witnessed in blockchain protocols that ought to be fully decentralized. (Walch, 2019). Although not based on empirical data, the number of 20 participants is estimated as a minimum size (Rachmany, 2020). Therefore, in the next section, we further empirically examined the significance of this decentralization level in the number of participants.

Table 11: Mapping definitions and characteristics (Green: a characteristic was mentioned or intended in the definition; Orange: only partially matched; Red: no matching)

DAO Definitions
1. Decentralized entities, by use blockchain run autonomously and decentralized. decision-making by coded logic through use of smart contracts. Automated decision-making, creating value for customers (Kypriotaki, Zamani and Giaglis, 2015)
2. Organizations that organize themselves through democratic process on public peer-to-peer and cryptographically secured network. Routine tasks, relying on voluntary contributions from the stakeholders or that DAO for all stages of the lifecycle (operate, manage and evolve). Code is open source. (Hsieh et al., 2018; Dietz et al., 2016; Van Valkenburgh et al., 2015)
3. DAO is new form of organization that creates new forms of social interaction and order. It runs on public blockchain. Governance roles are encoded in smart contracts. (DuPont, 2017)
4. System that runs on blockchain in a decentralized way. Operations controlled by pre-defined rules. A DAO is immune from attacks, both internally and externally and much more robust as result of reduction of human processes (Diallo et al., 2019)
5. DAO as distributed autonomous organization. Can replace functions like voting and various forms of transfer of value by blockchain based code and execution. (Zachariadis, Hileman & Scott, 2019)
6. An organization based on smart contracts on a blockchain. Management and operational rules are coded. Can operate autonomously without central control or intervention possibilities. Challenge current hierarchical models, should lead to efficiency gain on various points like collaboration, decision-making and communication. (Wang et al., 2019)
7. a DAO is blockchain based, using self-executing rules on a public blockchain. No central control, governance is decentralized. Enable people to self-govern and coordinate themselves. Decentralized and autonomous are still very much debated what is exactly meant by these terms. (Hassan & De Filippi., 2021)
8. Definition subject to debate as is legal status. Debate on ownership, if operated by humans / human created entities or that they are autonomous, run completely by code. Set up to automate governance decision-making. Functionality storing and transferring value and basically no other. For other functions, a contractor is needed. Approval by DAO members, based on their respective token amount, can transfer value. Run via smart contracts on Ethereum blockchain. (Jentzsch. 2016)
9. DAOs create true sovereignty, change governance relationship by moving towards an opt in environment where participant is both in control and executing for others. Possible due to decentralized technologies without need of TTP. (Aragon, 2020)
10. The DAO is autonomous as result of self-enforcing, programmed operating rules, running on public permissionless blockchain. value can be immediately transferred and rules enforced as result of decision. Decentralized can be understood in two ways. First as result of running on a blockchain and the second the lack of hierarchical organization with executives and shareholders. To organization can be an entity or something bugger like an organism of system (Honigman, 2019).
11. A decentralized, transparent, and secure system for operation and governance among independent participants" which "can run autonomously" (Beck, 2018, p. 57)
12. DAOs are technically and governance wise much like conditional transaction applications, build in single or series of smart contracts, operating, once deployed, exactly as programmed in the business rules of the smart contracts. Possibilities for interference by humans in theory little to non and no formal company structure is behind it. (Rikken et al, 2019)
13. Collective owner and managed organizations, using blockchain based smart contracts for coded rules. Members can propose and vote on any corporate type of decision. (Bellavitis et al., 2022)

Category	DAO Characteristic	DAO Definition												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Functional	(Conditional) storage and transfer of value	Green	Red	Red	Red	Green	Red	Red	Green	Red	Green	Red	Red	Orange
	Notary function for decision-making	Orange	Orange	Red	Red	Green	Red	Orange	Orange	Orange	Red	Orange	Red	Green
Governance	Decentralized at the infrastructure level	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Orange	Green
	Decentralized at the application level	Orange	Green	Red	Green	Orange	Red	Green	Orange	Orange	Green	Orange	Orange	Green
	Autonomous decision-making	Green	Red	Orange	Orange	Red	Orange	Orange	Orange	Red	Orange	Orange	Orange	Orange
	Organization / code are fully transparent	Red	Orange	Orange	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red
	Stakeholders reach consensus for decisions by voting based on predetermined voting rules	Red	Orange	Red	Orange	Red	Red	Orange	Green	Orange	Red	Orange	Red	Green
	Updates, bugs, optimizations need democratic voting/ decision-making by shareholders	Red	Green	Red	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red
	Decision-making process always starts with a proposal or an external trigger	Red	Red	Red	Orange	Red	Red	Red	Orange	Red	Red	Red	Red	Orange
	Voting rights could be distributed either based on the amount of tokens owned or evenly	Red	Red	Red	Red	Red	Red	Orange	Green	Red	Red	Orange	Red	Orange
Technology	Smart contract based (coded)	Green	Red	Green	Red	Orange	Green	Orange	Green	Red	Orange	Red	Green	Green
	Code is open source	Red	Green	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
	Is (public) blockchain-based	Green	Orange	Green	Green	Green	Green	Green	Green	Orange	Green	Red	Orange	Green
Other	Autonomous execution of decisions	Orange	Red	Red	Orange	Orange	Orange	Orange	Orange	Red	Green	Orange	Green	Red
	“hires” external parties for operational work	Red	Orange	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red	Red
	Certain legal status or clear governance with regards to responsibilities and accountabilities	Red	Red	Red	Red	Red	Red	Red	Green	Red	Orange	Red	Orange	Red

IV. DAO Empirical Analysis

The second research question is related to the ambiguity of the exact meaning of decentralization on the application level in DAOs, as described above in Section 0. Therefore, we analyze if more tokenholders (thus, a higher level of decentralization) have an effect on the survival rate of DAOs (i.e., activity level). For the empirical analysis, we identified the total number of active DAOs, analyzed characteristics and emerging developments, and gathered data on the individual DAOs to be used for statistical analysis.

The data was collected via (1) etherscan.org, an Ethereum blockchain browser; (2) apiary.1hive.org, where all deployed Aragon DAOs were displayed; (3) daohaus.club, where all deployed Moloch-based DAOs were displayed; (4) alchemy.daostack.io where all DAOStack DAOs were displayed; and (5) various direct links to the self-built and blockchain-protocol DAOs that were found through extensive internet research and Google Alert Services. For each DAO, all individual links were recorded. For every identified DAO, the specific data of this DAO was captured, i.e., age, number of tokenholders, number of activities in the form of public votings, type of DAO from a deployment perspective and the protocol it was built on by looking in the on-chain data (monitored through the dedicated websites). If the information on the dedicated websites was inconclusive, the blockchain browser etherscan.org was used to look directly into the on-chain data of the smart contract addresses related to the DAO. This observation of activities was done for a second time to observe changes in activities over time with at least 6 months apart between the first and second analysis.

When looking at the absolute numbers of self-proclaimed DAOs, there has been a clear rise in the number of DAOs over the past years (see Figure 15 in Section 1). We identified 1,859 potential DAOs, of which 1,635 seemed to be active, with traceable action via blockchain browsers and often individual reachable webpages per DAO. The analyzed number of 1,635 DAOs existing in this period is in line with other research (El Faqir et al., 2020). The other 224 are in various stages of development, but no deployment activity were observed.

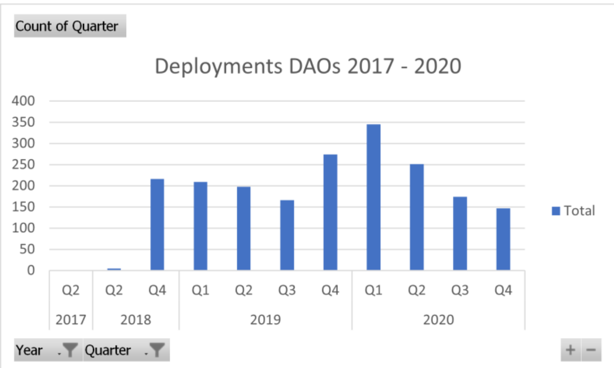


Figure 19: Number of perceived DAOs per quarter (2017 - 2020)

Figure 19 shows two interesting events. The first one is Q4 2018, with a steep increase in the number of DAOs. This can be attributed to Aragon's launch, which was launched in October/November 2018. This marks the era of the parameterized DAO. The second rise is in Q4 2019 caused by a new rise of Aragon-based DAOs combined with the launch of Moloch/DAOhaus in Q4 2019. We will analyze the emerging trend further in Section 5. The 1,859 analyzed DAOs do not include all the perceived DAOs that use Snapshot by Snapshot Labs, which only emerged as of mid-2020 (Hussey, 2021). These DAOs were not analyzed in detail, but only counted in absolute numbers as they only emerged as of August 2020, and hence there was insufficient time to make a second measurement of the activity level. These perceived DAOs and the continued growth of DAOs post-August 2020 will be discussed later in Section 5 (the overview of emerging developments).

When analyzing the DAOs based on deployment types or platforms, there were clear preferences and preferred blockchain infrastructure protocols. The distribution is shown in Table 12. Of the 1,635 active DAOs, the platforms or parameterized DAOs form the vast majority, with Aragon being the largest platform to create DAOs deploying 1,497 of the 1,635 observed active DAOs.

Table 12: Division of DAOs by deployment type - platform

Deployment Type	**Number of deployments until August 2020**
Aragon	1,497
Moloch	84
DAOStack	39
Self-Built	8
Blockchain	5
EOSDac	2

Although Colony mentioned that their platform can be used for creating DAOs, we did not find any active DAOs on this platform. Similar results were found by El Faqir et al. (2020). Furthermore, the ability to launch a DAO was disabled at the time of writing this paper.

When analyzing preferred blockchain infrastructure protocols, with the dominant DAO platform Aragon, Moloch, and DAOHaus, Ethereum is the protocol deploying most DAOs (1,620). After Ethereum, the subsequent protocols on which DAOs were created during the analysis period are xDAI (nowadays Gnosis Chain, 6 DAOs in total, all DAOStack based) and EOS (3 DAOs in total, of which 2 are created with EOSDAC). At the time of writing, other protocols like Tezos (Homebase), Solana (Grape Network), Binance Smart Chain (xDAO), Polygon (Aragon Client) and Polkadot (Idavol and Spanner Protocol) were implementing DAO-deployment platforms. However, instantiation was not yet possible at the time of the initial data gathering (until June 2020).

The identified 1,635 active DAOs were analyzed for activity levels multiple times during the time period December 2019 until March 2021 to monitor changes in activities due to voting proposals, transfer of value, or change in tokenholders over time.

IV.1 Empirical classification analysis of DAOs

Previous research has primarily focused on the potential or possible setup of DAOs and mentioned just several individual DAOs without further in-depth empirical research. Only one research (El Faqir et al., 2020) conducted an analysis of the estimated number of DAOs deployed. However, this study of El Faqir et al. (2020) merely presented an aggregated overview analysis of the activities of the DAOstack-based DAOs and detailed the activity of one case, Genesis Alpha DAO. Their motivation is that this DAO represented 53% of the whole DAO stack activity. They did not include data analysis of other DAO platforms, blockchain-protocol DAOs, and self-built DAOs. They acknowledged that their analysis needs further investigation in empirical research. Our paper addresses their call.

Hence, our study monitored the activity of all the 1,635 DAOs. Over the monitored period of time, the number of DAOs rose dramatically, especially as of Q4 2018. But when monitoring the true activity of the DAOs, one can see in Table 13 that only 7.5% or 124 DAOs have shown activity in the last 6 months of the monitoring period. There were 1,337 DAOs that did not show any recent activity. For 5 DAOs we could not measure the activity level, as the activity could not synchronize on their webpages despite various attempts. When monitoring activity over the whole monitoring period of 15 months, the activity level was 17.9% or 293 DAOs.

Table 13: Activity level of DAOs (December 2019 – March 2021)

Activity Level (Dec 2019 – March 2021)								
	High (10+ tx)	*Medium (2-10 tx)*	*Low (1 tx)*	*None*	*Not meas-urable*	*Count DAOs*	*Active last 6 months (March 2021)*	
Aragon	4%	7%	5%	84%	2	1,497	84	6%
DAOStack	26%	8%	8%	59%	0	39	9	23%
Moloch	13%	14%	7%	65%	0	84	21	25%
Blockchain Protocol	60%	0%	0%	0%	2	5	3	60%
Self Coded	75%	13%	0%	0%	1	8	7	88%
EOSDAC	0%	0%	0%	100%	0	2	0	0%
Count DAOs	91	114	88	1,337	5	1,635		
Active last 6 months (March 2021)	69	37	24	0			124	
	69%	32%	28%	0%				

When analyzing the DAOs that showed activity during the monitored period more closely, just 6% showed a high activity level, meaning that more than 10 transactions were performed during this period. The rest showed medium (2-10 transactions) activity (7%) or low (1 transaction) level of activity (5%). The threshold of 10 transactions for high was chosen as this, on average, comes to approximately at least one transaction a month for high activity during their active lifetime.

The analysis presented in Table 13 shows the blockchain protocol DAOs, and self-built DAOs show significantly higher activity levels. The most used platform in terms of absolute DAO numbers, Aragon, has a significantly lower activity percentage than all the other DAOs. Likely this is because these DAOs might have been created for experimentation only when Aragon was the first platform to offer the creation of parameterized DAOs.

Table 14: Average tokenholders per DAO per activity level (December 2019 – March 2021)

Average Tokenholders per DAO per Activity Level (Dec 2019 – March 2021)				
	High (10+ tx)	*Medium (2-10 tx)*	*Low (1tx)*	*None*
Aragon	21+	5.4	3.8	2.8
DAOStack	115	14.7 (3 DAOs, high 26, low 8)	1,645 (3 DAOs, high 4946, low 0 tokenholders)	18.3
Moloch	42	21	12	1.8
Blockchain Protocol	1000+ (3 DAOs)	n/a	n/a	n/a
Self Coded	1000+ (5 DAOs, high 1000+, low 55, 1 n/a)	n/a	n/a	227 (1 DAO)
EOSDAC	n/a	n/a	n/a	n/a

Next, we analyzed the average number of tokenholders in the various DAOs to analyze if there is a relationship between the number of tokenholders and the activity level (Table 14). Within the Aragon and Moloch platforms, we found a clear relationship between the average number of tokenholders and activity level, i.e., the higher the activity level, the higher the average number of tokenholders.

We further decided to perform a survivability analysis based on the activity level over time and the number of tokenholders.

IV.2 Minimum decentralization in DAOs

An ongoing discussion with DAOs is if the word 'decentralized' refers to the level of decentralization within a DAO itself or as the result of being built on a blockchain infrastructure (P. De Filippi & Hassan, 2020). When analyzing decentralization on the application level, we did so by analyzing the number of tokenholders in a DAO. Although the existing definitions directly mention decentralization on the application level or indirectly through the lack of central control, no minimum number was mentioned in any scientific articles. Only one blog by Rachmany (Rachmany, 2020) mentioned a DAO below 20 participants does not make sense. This opinion was not further substantiated with arguments or empirical evidence. An argument is that the low level of decentralization could imply that the term DAO is used for marketing only or have a centralized power posing as a community (Feichtinger, Fritsch, Vonlanthen, & Wattenhofer, 2023). With our data, we empirically tested the level of decentralization by analyzing the number of tokenholders in relation to long-term viability.

To check this minimum number of tokenholders in DAOs in relation to the activity level, we analyzed the number of DAOs that showed no voting activity and compared these with the number of DAOs that did show activity since their deployment. As in this total of 1,635 DAOs, many DAOs were setup for initial experimental purposes only, therefore, our analysis focused on a particular subset: i.e., only the DAOs that showed high activity over their lifetime. Within this subset of DAOs, there is a group of DAOs that still showed activity until the date of the research and a group that had shown no more activity over the past 6-15 months during our research. The results show that there were no DAOs with more than 20 tokenholders that showed no voting activity. As shown in Table 15, all the 683 DAOs without voting activity had 20 or less tokenholders. All of the active DAOs with more than 20 tokenholders showed activity. This confirms the expectation of Rachmany (Rachmany, 2020), suggesting that an active DAO should have at least 20 tokenholders.

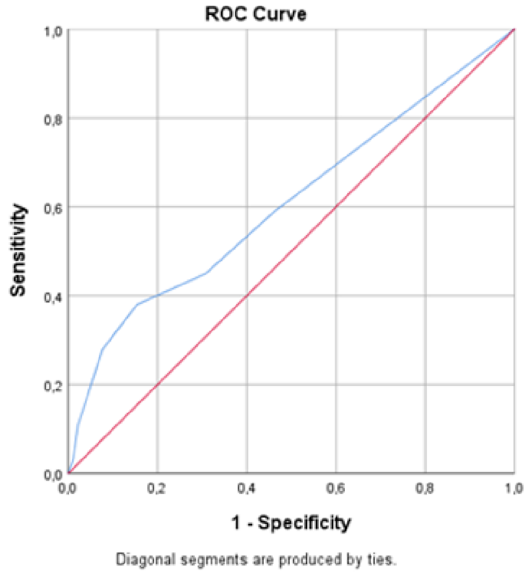
Table 15: Tokenholders per lifetime activity level

Lifetime Activity per Tokenholder Category						
	High	*Medium*	*Low*	*None*	*Unknown*	*Totals*
0 to 5	102	431	227	650	1	1411
6 to 10	32	29	6	6	0	73
11 to 20	22	11	3	8	1	45
21 to 50	21	4	0	0	0	25
51 to 250	27	1	1	0	0	29
250 plus	11	2	1	0	0	14
n/a	5	7	4	19	3	38
Totals	220	485	242	683	5	1,635

To further examine whether the results based on Table 15 are robust, we performed a survival analysis through ROC curve on the number of tokenholders and survivability in the form of both lifetime activity and current activity (Figure 6). To do so, we only selected the DAOs with high lifetime activity to filter out as many DAOs as possible that were put up as test or play-around only, resulting in the analysis of 220 DAOs. For the analyses, the ROC curve is created with two variables: survival (coded as 1 in our data) and the number of token holders with the following codes:

- Code 1: 0-5 token holders;
- Code 2: 6-10 token holders;

- Code 3: 11-20 token holders;
- Code 4: 21-50 token holders;
- Code 5: 51-250 token holders;
- Code 6: 250+ token holders.



Coordinates of the Curve

Test Result Variable(s): Token holders category

Positive if Greater Than or Equal To[a]	Sensitivity	1 - Specificity
,00	1,000	1,000
1,50	,589	,462
2,50	,450	,308
3,50	,380	,154
4,50	,279	,077
5,50	,109	,022
6,50	,031	,011
8,00	,000	,000

The test result variable(s): Token holders category has at least one tie between the positive actual state group and the negative actual state group.

a. The smallest cutoff value is the minimum observed test value minus 1, and the largest cutoff value is the maximum observed test value plus 1. All the other cutoff values are the averages of two consecutive ordered observed test values.

Figure 20. ROC curve (with coordinates) to examine the number of token holders and DAO survivability

As shown in Figure 20, the cut-off point from the graph is approximately at the coordinate .279 (sensitivity) and .077 (1-specificity), which refers to code 4.5 (i.e., above 20 tokenholders). This indicates that DAOs with tokenholders of at least 20 have a higher chance of survival, which confirms the previous analysis.

An important note to this analysis is that the number of tokenholders is based on absolute numbers. No distinction was made in differences in voting power of the individual tokenholders, various governance models and other possible factors that could influence the survivability of a DAO. The assumption underlying the analysis is that the number of tokenholders is equal to the number of accounts holding tokens. It is possible that a person or organization has multiple accounts and thus represents multiple tokenholders in a DAO. In their research on voting power distribution, Fritsch et al. also describe the challenge of address clustering (Fritsch et al., 2022), meaning that a person could use multiple accounts containing governance tokens. The effect of voting power distribution amongst tokenholders and address clustering separately and in its relation to the survivability of DAOs should be investigated in further research.

Furthermore, we took activity level as the denominator for survival. It can very well be that, due to the business purpose of a DAO, low activity is to be expected. Therefore, the purpose or goal of a DAO in relation to its activity level should also be investigated in future research. Adding the business purpose will also help filter out possible test or play-around DAOs that could distort the outcome.

Finally, DAOs using off-chain governance mechanisms, like Snapshot, were not included in this dataset as these DAOs were not yet available during the whole initial measuring period. Also, as a result of the analyzed dataset containing many early deployed DAOs, due to few alternatives available, there could be a bias towards certain deployment platforms like Aragon, DAOhaus (Moloch) and DAOstack. New deployment platforms that might contain new functionality, new user interfaces, and user-friendliness might influence the relationship between decentralization and long-term viability.

V. Emerging Developments

Our final research question investigates emerging developments that could influence the definition of DAOs in the future or could challenge or even disqualify many perceived DAOs due to their changing characteristics. For this, we analyzed, besides the 1,859 potential DAOs used in research questions 1 and 2, and an additional 8,000+ DAOs that were created in the period from mid-2020 until October 2021. After excluding DAOs without activity and specific (active) websites with information on the DAO found a total of 9,845 DAOs were used for identifying and analyzing emerging developments, e.g., (1) the trend to self-coded smart-contract or protocol-based DAOs; (2) parameterized platform DAOs; and (3) off-chain voting.

First, our empirical data show that since the creation of the first DAO in 2014, most of the DAOs created in the beginning were blockchain-based DAOs, thereafter closely followed by coded or *smart-contract-based DAOs.* These DAOs were all unique in their code, not making use of templates, as shown in Figure 21 below.

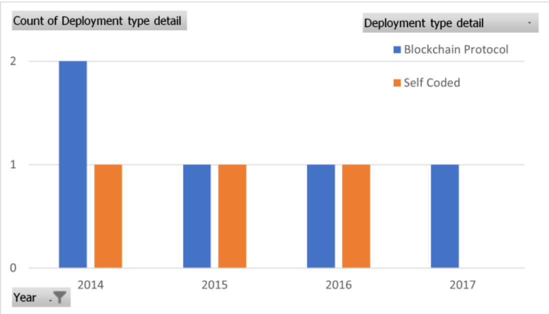


Figure 21: Deployment type DAOs (early trends 2014-2017)

Second, in 2018, after the initial rise of deployment of the manually coded DAOs and blockchain DAOs, the *parameterized platform DAOs* arose. These DAOs no longer need manual coding, but can be created by filling in parameters on a website. These parameters correspond with a standard smart contract template's variables, which are then deployed on the blockchain in the background once all parameters are filled and checked. The majority of active DAOs is currently created through these platforms. As shown in Figure 5, a clear sudden rise of DAOs occurred in Q4 2018. This rise resulted from Aragon's launch, offering the first parameterized DAOs creation platform. Figure 5 also shows a clear growth in Q4 2019 as the result of the launch of the DAOHaus parameterized DAO creation platform for Moloch-template DAOs. Although Aragon-based DAOs still remain the largest DAO platform created DAOs in total numbers, as of 2021, the Moloch-based parameterized DAOs created on DAOHaus took over as the dominant DAO platform for creating new DAOs as shown in Figure 22.

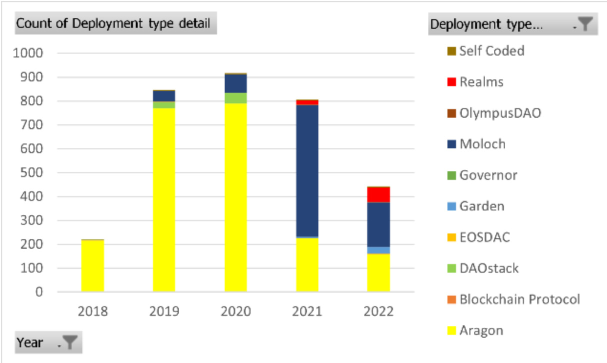


Figure 22: Division of deployment platform types of DAOs 2018-mid 2022 (numbers of self-coded, blockchain protocol, governor, OlympusDAO and EOSDAC DAOs are extremely small and not well visible in the diagram)

Also, during the rise of the platform DAOs, the number of choices regarding governance types (decision-making within DAOs) increased over the past years, e.g., Aragon added company, membership, and reputation in September 2019. However, many of these are still theoretical models (Emmett, 2019; Kondova & Barba, 2019; Parton, 2021; Ramachandran & Qureshi, 2020; V. Singh, 2019) as most of the new governance types are not yet integrated with the templates of the parameterized DAO creation platforms.

Third, the most recent development that we analyzed is *off-chain voting*. Traditionally, DAOs recorded all voting and transactions and execution thereof on a blockchain (so-called on-chain systems). There is a clear development of off-chain voting. This seems to be a direct result of the increasing "gas" prices (gas refers to the transaction costs for running smart contract code on Ethereum), making voting and usage of DAOs in practice more expensive. Through Snapshot, Boardroom and Aragon Govern mechanisms, off-chain voting is possible for Ethereum and Ethereum-based blockchain protocols like xDai, Binance Smart Chain and Ethereum testnets (Ortiz, 2021; Snapshot, 2021). This means that the vote itself is not recorded on the blockchain directly, but is based on token balances that the tokenholders had at the "snapshot" of the proposal. At the time of writing (mid 2022), the number of DAO projects registered on Snapshot exceeded 6,500, which is a rapid increase considering that Snapshot only surfaced around August 2020 (Hussey, 2021). Figure 23 shows the blockchain-based DAOs complemented by the emerging developments of specific hard-coded smart contract DAOs, platform-parameterized DAOs and off-chain voting DAOs over time.

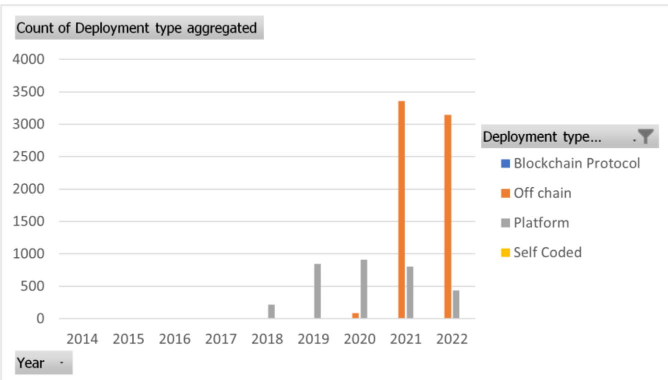


Figure 23: Emerging developments DAOs (2014–mid 2022)

Despite the benefit of using Snapshot (no need for gas as voting occurs off-chain; thus, no transaction fees need to be paid to cast a vote), the downside is that the voting outcome is not executed directly. Direct execution is not possible because Snapshot needs additional tooling to automate the execution of the voting as the voting in itself on Snapshot is not binding (Shevchenko, 2021). This development could lead to lower entry barriers for using DAOs due to the lower cost of governance. However, this simultaneously poses the challenge of a higher level of centralization or censorship, as there is no guarantee that the outcome of the vote is being executed. Hence this creates a dependency on the actors that are able to execute the vote at the expense of autonomy.

Besides in Snapshot, the separation of execution and decision and not integrating them into the smart contract structure, is also used in Boardroom DAO and Tally platforms. The difference is that within the last platform, multiple governance structures can be applied (Parton, 2021). These platforms often make use of Snapshot in the back-end with just a Tally or Boardroom front end.

In sum, aside from the benefits, we highlight two critical points of attention: (1) there is an increased centralization risk, and (2) this also challenges the autonomy of a DAO. First, the increased risks of centralization refer to the fact that after a decision is made, a small group (or even a single person) needs to follow up on the transaction, creating a potential single point of failure in the process. Second, as voting decisions are made off-chain using platforms like Snapshot, the voting results will no longer be automatically executed. Thus since the autonomous execution is removed, initiatives that use these types of constructions no longer need to adhere to the definition of DAOs. Therefore, rather than Decentralized *Autonomous* Organizations, these types of initiatives embody Decentralized Organizations in which processes are manually (instead of automatically) executed. Moreover, it seems that this autonomous issue became a real risk when the Tribe / Fei DAO incident occurred in mid-2022, in which a decision made via Snapshot was not executed according to the outcome of the decision (Kelly, 2022; Staff, 2022). The incident clearly shows the lack of autonomy in these off-chain governance DAOs.

Hence, since off-chain governance comes at the cost of autonomy, DAOs are no longer adhering to our proposed unified DAO definition. This implies that many perceived DAOs may lose their autonomy causing them to be disqualified as DAOs per definition. Despite the perceived exponential growth in Figure 15, following our definition, this may actually lead to the number of DAOs declining in the annual growth percentage in 2021. We suggest not to use the term DAO for these kinds of applications, as the autonomous and decentralized characteristics are violated, and use the term Decentralized Organizations (DOs) or Decentralized Partially Autonomous Organizations (DPAO) instead. Although the autonomous execution might be challenged, the intention is still to organize the organization in a decentralized manner.

VI. Conclusions and Recommendations

There has been a clear rise in the number of DAOs over the last few years. This rise in the number of DAOs is marked by the release of DAO creation platforms, like Aragon, Moloch DAO, and DAOstack. Although there is an increasing number of DAO creation platforms, Aragon remains dominant. Regarding the infrastructure used, multiple platforms can be used to create DAOs. Ethereum is the dominant platform so far.

The analysis of the empirical data shows a link between the number of tokenholders and the survival rate of DAOs. Our empirical result corroborates with the previously mentioned number of 20 tokens by Rachmany (Rachmany, 2020). The survivability analysis shows that DAOs with a larger number of tokenholders have significantly longer survivability than those with a lower number of tokenholders. Our analysis shows that the number of 20 tokenholders is the tipping point. Furthermore, this number can be viewed as an indicator of the level of decentralization on the application level of DAOs. It can be an important factor in preventing centralized powers and possible censorship by small groups within the DAO. A limitation of our analysis is that we only took into account the absolute number of tokenholders in the form of different account addresses. Hence, we have not yet incorporated relative voting power nor the possibility of one person or an institution being in control over multiple addresses. We recommend this for future research. Furthermore, we analyzed the relationship between tokenholders and survivability based on activity levels only. As the business objective of a DAO could very well affect activity levels, the purpose of a DAO should also be taken into account in further research.

Although many DAO definitions exist, there is no agreement on what constitutes a DAO. There are various characteristics that the different definitions have in common. Based on the analysis of definitions and by analyzing the common characteristics in these definitions, we derived the essences of DAOs and propose the following unified definition of DAOs:

"A DAO is a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way".

The definition implies that, on the infrastructure level, data and actions are recorded on and autonomously executed by smart contracts and/or a blockchain protocol. It also implies that at the application level, decisions are never made by a single tokenholder, but always by multiple tokenholders utilizing various voting and governance mechanisms.

New technology developments challenge the 'autonomous' part of DAOs. Off-chain initiatives that separate the decision-making from the execution of the decisions make DAOs less autonomous and run the risk of becoming centralized. This is because the follow-up actions must be triggered manually and are no longer automatically executed based on the decision outcome. These types of initiatives can better be classified as decentralized organizations (DOs) or Decentralized Partially Autonomous Organizations (DPAOs) instead of DAOs.

Although our definition will indeed exclude many of the projects that call themselves DAOs, we do believe that this definition helps provide a clear distinction between real DAOs and perceived (self-proclaimed) DAOs. For instance, DAO projects using Snapshot or Scattershot do not, by the same standards as real DAOs, autonomously execute decisions through smart contract execution on-chain directly triggered by that decision, but require an intermediate, often manual and off-chain action.

For future research, we also recommend the following four key research directions. The first one relates to many of the DAOs analyzed consisting of early deployed DAOs, at an early (experimental) stage and/or experiments, and numbers are rising fast. Thus the dataset could be biased toward earlier DAO deployment platforms like Aragon. Although the size of the subset of analyzed DAOs on survivability rate in relation to the number of tokenholders in this research was over 200 DAOs, we recommend repeating this analysis with a larger set of data with a longer lifetime to draw a more robust conclusion including more recent and upcoming platforms. Also, we divided the number of tokenholders in categories (categorical scale instead of a ratio scale in our analysis). We recommend that with a larger dataset, the analysis should also be performed at the ratio scale of the tokenholders. Secondly, besides the absolute number of tokenholders, research should be conducted on other possible drivers that potentially can influence activity and survivability, like governance, voting power distribution and address clustering, voting mechanisms, and business objective of a DAO. Thirdly, a classification of perceived DAOs that are closer to Decentralized Organizations (DOs) or Decentralized Partially Autonomous Organizations (DPAOs) could be set up, as this seems to be the organization emerging after DAOs. Finally, a deeper understanding of the off-chain voting DAOs trend is needed in further empirical research in which the true level of decentralization in these DAOs or DPAOs should be investigated, but also the number of tokenholders that can execute a voting or decision, as well as the survivability rate. In this way these DAOs or DPAOs can be compared to the DAOs where voting and execution are recorded and performed on-chain.

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5. Paper 3 - Governance impacts of blockchain-based decentralized autonomous organizations: an empirical analysis[3]

Governance Impacts of blockchain-based Decentralized Autonomous Organizations: An empirical analysis

Olivier Rikken MSc MBA*, Delft University of Technology, The Netherlands
Prof Dr Marijn Janssen**, Delft University of Technology, The Netherlands
Dr Zenlin Kwee***, Delft University of Technology. The Netherlands

* Corresponding author, o.k.rikken@tudelft.nl, Jaffalaan 5, 2628 BX Delft, the Netherlands
** M.F.W.H.A.Janssen@tudelft.nl
*** Z.Roosenboom-Kwee@tudelft.nl

Abstract

The rapid rise in blockchain-based Decentralized Autonomous Organizations (DAOs) offers policy-makers and decision-makers new opportunities to automatically execute decisions and processes that help enhance transparency, accountability, participation and trust. Yet, many DAOs have a limited lifespan. There is little empirical evidence of the effect of governance elements on the viability of DAOs. Using 220 on-chain governed DAOs, this paper analyses how governance elements (accountability, decision/voting, and incentives) influence the viability of DAOs in the long-term. The findings show that DAOs without weighted decision-making and without incentive structures are more viable than those with weighted decision power and incentive mechanisms. This suggests that financial and share-like DAO governance elements do not or may even negatively contribute to the long-term viability of DAOs. Also, voting power distribution is found to have a statistically significant influence on DAOs' viability. We further propose a preliminary theory that relates governance elements to the long-term viability of DAOs. These insights will help policy-makers in designing more viable DAOs. Future research should investigate how DAO objectives, the chosen deployment infrastructure and the type of users can impact the long-term viability of DAOs.

Keywords: Blockchain, Decentralized Autonomous Organization (DAO), Governance, Policy Design, Public Administration

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I. Introduction

Companies and policy-makers favor transparent and accountable governance. Decentralized autonomous organizations (DAOs) are organizations using blockchain to store and execute governance decision-making rules. DAOs can democratically manage an asset (e.g., money spending by organizations, stocks, shared treasuries for subsidies, management of commons) without the need for a central governance authority. In this way, decision outcomes of proposals initiated by a community of tokenholders can be automatically executed. A DAO records, guards, and executes the processes, decision rules, and decisions made in an almost immutable way, resulting in higher levels of transparency and accountability (Berdik, Otoum, Schmidt, Porter, & Jararweh, 2021; Cagigas, Clifton, Diaz-Fuentes, & Fernández-Gutiérrez, 2021; Chen & Bellavitis, 2020; P. De Filippi & Hassan, 2020; Jing, Liu, & Sugumaran, 2021; Rikken, Janssen, et al., 2023b).

In public administration, DAOs can create many opportunities for policy-makers. DAOs can increase citizen participation in community-owned and participative budgeting projects. Implementing a DAO for community-owned funds creates transparency, direct community involvement, control, and trust. These added values of DAOs have proven to be problematic in traditional participative budgeting projects (Rikken et al., 2022). The foresight of DAOs is to become the backbone of governance of future political parties, i.e., enhancing direct democracy (Sergeenkov, 2021). Also, in e-government, DAOs are expected to further improve transparency and efficiency and prevent human error and corruption (Diallo et al., 2018). DAOs in public management could replace current forms of public-private partnerships by redefining control and coordination (Tan, Mahula, & Crompvoets, 2022). According to the World Economic Forum, DAOs may also be used in funding public goods and investments and potentially lead to even broader societal innovations (Gogel, Kremer, Slavin, & Werbach, 2023).

DAOs were first described by Daniel Larimer and later by Vitalik Buterin, as organizations that exist based on smart contracts with various goals, including the transfer of cryptocurrency (Buterin, 2014; Larimer, 2013). This vision was built upon blockchain technology introduced by Satoshi Nakamoto (2008) through the introduction of Bitcoin. Blockchain technology provides key features of decentralization, cryptography, and transparency. The technology provides an electronic, public transaction record in which the integrity of the content no longer needs to be guarded and guaranteed by a trusted third party (TTP), like a bank or a notary. This leads to increased transparency, accountability, control, and efficiency (Beck, Stenum Czepluch, Lollike, & Malone, 2016; Rikken et al., 2019; Swan, 2015). At the same time, new forms of democratic cooperation are enabled. Overall, blockchain and DAOs have created new ways of governance.

Nevertheless, what decentralized and autonomous means is often unclear (Hassan & De Filippi, 2021). In an attempt to describe what a DAO is, Hsieh et al. (2018) emphasize on digitalization of democratic processes in DAOs, i.e., when DAOs organize themselves on a peer-to-peer network that is cryptographically secured. Hassan and De Filippi (2021) describe DAOs as a blockchain-based system for coordination and self-governance using self-executing rules independent from a central authority. Based on the key characteristics of DAOs, Rikken et al. (2023b) provided a definition of a DAO: “A DAO is a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way” (p.13).

There is an exponential growth in the number of DAO initiatives for all kinds of purposes, as shown in Figure 24. The number increased slightly above 12,000 projects by the end of Q3 2022. According to deepdao.io, in April 2023, DAOs hold more than $24 billion in assets under management. The rapid increase in the number of DAOs is, because nowadays, it is much easier to create DAOs. Before 2018, coding was needed to create a DAO. However, as of 2018, parameterized DAO deployment platforms came into existence. Since then, DAOs can be created by configuring a few parameters which can automatically be deployed (Baninemeh et al., 2023; Rikken, Janssen, et al., 2023b).

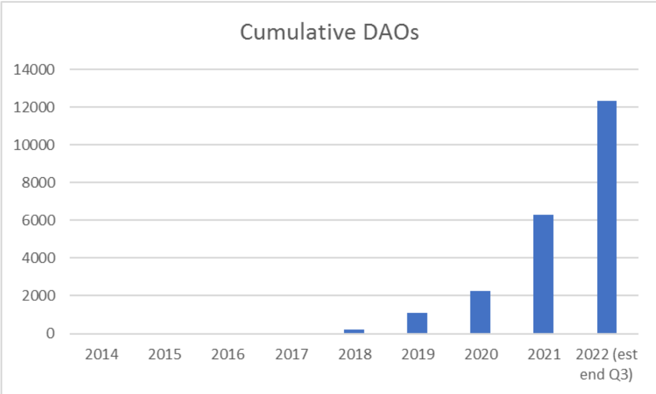

Figure 24: Cumulative DAOs (period 2014 – 2022) - Empirical research by Rikken, Janssen, & Kwee

This exponential rise of DAO projects and the increasing amount of assets under management also led to large hacks, security incidents, voting misuse, and execution incidents. These incidents indicate that research on the governance of DAOs is crucial (Cryptopedia, 2022; Lawler, 2021; Wan, 2022). Yet, DAO governance is still an under-researched area that needs further study. Most research on DAO governance has predominantly focused on theoretical descriptions of (potential) DAOs, describing governance elements like decision models, accountabilities, and incentives (Emmett, 2019; Kondova & Barba, 2019; Kotsialou & Riley, 2017; Parton, 2021; Thibauld, 2018), or the opportunities of DAOs for (corporate) governance in general (Kaal, 2019). There are discussions that current governance theories could potentially not suffice for DAOs (R Morrison et al., 2020). Rikken et al. (2023b) suggest a connection between the level of decentralization and the long-term viability of DAOs. This paper answers the call for further empirical research on governance elements of DAOs and their influence on the long-term viability of DAOs.

Empirically, there is limited research on DAO governance. The little empirical research on DAO governance only focuses on a comparative analysis of governance models between DAO deployment platforms (El Faqir et al., 2020; Faqir-Rhazoui, Arroyo, & Hassan, 2021), the governance around "the DAO" incident of 2016 (Dhillon et al., 2017; DuPont, 2017), and a study of individual cases of different DAO governance models (Sims, 2021). The study by Sims (2021) focuses on a descriptive analysis of governance models, which is useful for classifying possible governance models. However, the descriptive approach does not give any insights into the long-term viability of certain governance models. DuPont (2017) finds that the governance of DAOs could not yet be evaluated meaningfully due to insufficient data available at that time. This situation, however, has changed since then. Faqir-Rhazoui et al. (2021) and Rikken et al. (2023b) suggest that further empirical research is needed regarding the effectiveness of various governance models. Obscurity regarding the relation between various governance elements and the long-term viability of DAOs can hinder policy-makers and decision-makers in the adoption of new innovative organizational forms like DAOs. Under this circumstance, they could miss out on opportunities to increase transparency, trust, and citizen participation in public administration.

In this paper, we address the research gap in DAO governance by identifying governance elements (accountability, decision model, and incentives) and conducting an empirical analysis of the effect of these elements on DAOs' long-term viability. First, we zoom in on key elements of DAO governance by adopting the IT-governance theory of Weill and Ross (2005). Using this classification and building further on the research of Sims (2021), we empirically analyze current DAO governance elements and how they are implemented in active DAOs. Second, we analyze the impact of these elements on the viability of DAOs through statistical analysis.

This paper is structured as follows. The next section describes our research method. The third section of this paper zooms in on the various theoretical governance elements, which are subsequently categorized and visualized. We empirically analyze governance elements and their influence on DAOs' long-term viability in the fourth part. In the fifth section, we develop a preliminary theory of governance elements influencing the activity levels of DAOs and their interconnectivity, providing direction of requirements for future DAO (governance) design. The final chapter describes our conclusions and recommendations for further research.

II. Research Method

For this research, we employed both quantitative and qualitative analyses involving laborious tasks in data collection. First, DAO governance components were derived using a literature review of 79 papers, transcripts, blogs, and repositories, both scientific and grey literature (over 1,000 pages). Google Scholar search was used using the keywords "Decentralized Autonomous Organization" and "Governance" to identify the literature. Furthermore, this ongoing research project entailed a four-year daily Google alert search. The alerts were scanned daily, and every single DAO hit was read and further investigated. We scanned and read more than 2,000 online news, web articles, and sites on DAOs. We reviewed DAO application codes and live-tested DAO governance in practice to further advance our understanding of DAO governance.

For the analysis of the governance elements and their effect on the long-term viability of DAOs, we identified over 6,000 potential DAOs by using a daily automated Google alert search with the keywords "decentralized autonomous organizations" (alert first initiated in January 2018) and "smart contracts" (alert first initiated mid-2016), both until December 2021. Furthermore, the data was collected from two streams: (1) individual DAOs created using DAO deployment platforms (aragon.org, daostack.io, daohaus.club, colony.io, district0x, scattershot.org, snapshot.org, boardroom.info, eosDAC.io, withtally.com) using their respective websites and (2) overview websites where the information of these DAOs was displayed (apiary.1hive.org, etherscan.io, and deepdao.io).

Until the end of 2021, more than 6,000 initiatives were claiming to be DAOs. However, for our empirical analysis, we selected (verified[4]) DAOs for the empirical analysis of DAO governance elements and their effect on the long-term viability of DAOs. The reason for making this selection is that many DAO initiatives do not qualify as a DAO, and many DAOs show little or no activity. Most likely, this is because many DAOs are part of experimental projects (e.g., deciphering the possibilities of DAOs) by individuals. Given that many DAOs have "test" in their name does support this assumption (e.g., Mcdtest, Gastest and Mobiletest, all based on Aragon). These "test" DAOs could pollute our analysis

[4] Verified means DAOs are selected based on filters in Figure 25. Here we exclude experimental/test DAOs.

as they might not be set up for long-term use. A series of filters (as shown in Figure 25) were used to select the verified DAOs for further analysis. The first filter used was to check if the DAOs meet the main characteristics of autonomy and functional characteristics based on the DAO definition by Rikken et al. (2023b). Many DAOs are only DAOs in name because they do not autonomously execute decisions made by the respective DAO participants. Simply put, they do not meet the requirements in the definition of DAOs. These DAOs are also referred to as off-chain governance DAOs. This resulted in excluding a large number of potential DAOs like snapshot-based projects (which also call themselves DAOs), which do not execute decisions autonomously. These, therefore, are Decentralized Organizations (but not autonomous) or Pseudo-DAOs rather than Decentralized Autonomous Organizations (Rikken, Janssen, et al., 2023b; Sims, 2021). The lack of autonomous execution can lead to situations where a small group or even a single person can execute a decision that deviates from the decision made by the community of tokenholders or participants in a DAO. Such a deviation has already happened in the past (Staff, 2022). We thus only analyzed "on-chain" governance DAOs, where the execution of the decisions by tokenholders is autonomously executed by smart contract code (and thus not prone to manual censorship or tampering). We then filtered on the deployment status, filtering draft, planned, and unknown status DAOs. This resulted in 1,635 DAOs, which were further analyzed.

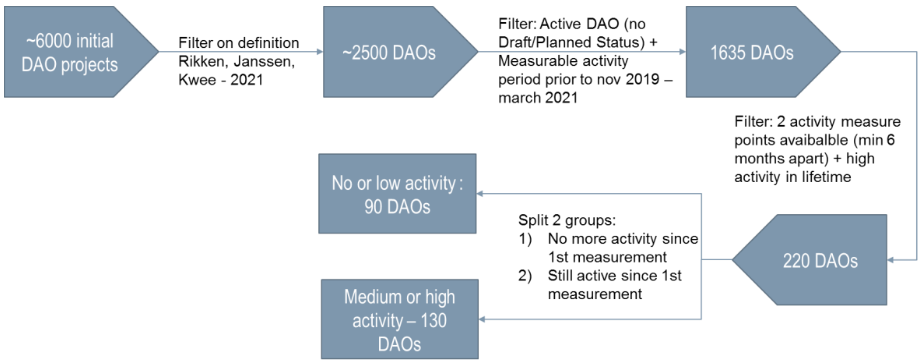

Figure 25: Process of DAO selection for analysis

We then filtered on lifetime activity level. Activity is measured as an incoming or outgoing transaction or a voting proposal that could be voted on by individual tokenholders (hence, not the vote of an individual tokenholder). For the analysis of DAOs' activity levels, we classified them into four categories: none (no activity), low (1 activity), medium (2-10 activities), and high (10+ activities). We further filtered and checked the data to determine whether there were at least two measurements in time on activity level (with at least 6 months in between) to observe any loss or continuation of activity. This resulted in 220 DAOs (see Figure 25). From these DAOs, we studied their governance elements and investigated the link of these elements to the long-term viability of DAOs. This group of 220 DAOs was further divided into two subgroups. One subgroup showed no or low activity between the first and second measurement (90 DAOs), whereas the second subgroup showed continued (medium or high) activity between the first and second measurement (130 DAOs).

The data obtained and the measurements of these DAOs (i.e., the level of activity, the value stored, number of tokenholders, last activity, governance elements) are used for a comparative and statistical analysis of the effect of various governance elements categories on the long-term viability (measured in continued activity levels). This is further described in section 4.

III. DAO Governance

Faqir-Rhazoui et al. (2021), as well as other scholars, emphasize the importance of research on DAO governance for long-term viability to create sustainable participatory organizations (Nabben, Puspasari, Kelleher, & Sanjay, 2021). This research idea is triggered by early crashes of a DAO (DuPont, 2017). Additionally, existing research mainly focuses on descriptive or limited detailing case analysis (El Faqir et al., 2020; Sims, 2021). Also, the importance of governance or decision-making is linked to potential liabilities resulting from the level of autonomy of a DAO (S. A. Wright, 2021). In his research on DAO of DAOs, Kaal (2021) identified governance as a key feature of DAO survival. Other researchers (Faqir-Rhazoui, Arroyo, et al., 2021; Rikken, Janssen, et al., 2023b; Zhao et al., 2022a) highlighted the need for more empirical and detailed analysis of DAO governance.

Structured literature review on blockchain governance (U. Chohan, 2017; Aggelos Kiayias & Philip Lazos, 2022; Liu, Lu, Zhu, Paik, & Staples, 2021; S. A. Wright, 2021) found accountability, decision-making, and incentives as the top three frequently mentioned elements of blockchain governance. When looking at DAOs in particular, traditional accountability may seem no longer applicable. This leads to the possible revisiting of the IT governance theory of Ross and Weill (R Morrison et al., 2020). Furthermore, one might need to consider more elements in relation to DAO governance.

An important element that could influence DAO governance is the specific blockchain infrastructure on which a DAO is built, since the governance of the application and infrastructure can be entangled (Rikken et al., 2019). Tan et al. (2022) described a three-level analysis of blockchain governance for the public sector with nine subcategories or elements. They emphasized the choice of infrastructure among elements like interoperability, application architecture, control of governance and organization of governance. Once deployed, the control of smart contracts' upgradeability and interaction costs with the DAO is largely given and cannot be directly influenced by the DAO participants, especially on permissionless infrastructures. The choice of infrastructure (permissionless versus permissioned infrastructure) can thus be an important factor for the governance of DAOs. However, the DAO dataset for the analysis in this paper only contains DAOs on permissionless blockchain infrastructures. This is because permissioned blockchain infrastructure DAOs are generally not transparent to outsiders. As such, the infrastructure choice is omitted from our analysis. Also, none of the DAOs are controlled by automated agents as tokenholders need to vote on decisions (and thus can be assumed to be human-controlled). Therefore, we do not take control of governance into account. Additionally, off-chain governance DAOs are excluded from our analysis (as explained in our DAO selection process, see section 2).

As DAOs can be seen as IT systems, we decided to use the theory of Weill and Ross (2005) as a basis for the analysis of the governance by the DAOs. Weill and Ross distinguish accountability, decision-making, and incentives as key IT governance elements.

III.1 Accountability, general DAO governance decision, and incentive models

To analyze the three governance elements, we use the following approach. We developed a categorization for the three governance elements based on literature review and empirical analysis. We then plotted these categories on the DAOs analyzed. Firstly, we analyzed the elements of accountability, followed by analyzing decision-making, and finally, the elements of incentives are identified.

Accountability

Despite being seen as an important element in governance, there is a disagreement on what accountability exactly means (Feigenbaum, Jaggard, & Wright, 2011; Peter Weill & Ross, 2004). One notion of accountability is about knowing the identities of all participants, so they can be punished for a breach or violation (Feigenbaum et al., 2011). Relatedly, Grant and Keohane (2005) define accountability as actors setting rights and judging the fulfillment of responsibilities or sanctions when certain actors do not meet their responsibilities. Research by Morrison et al. (2020) and Rikken et al. (2019) even suggest that in DAOs, accountability is diffused and thus could pose a challenge to governance and governance theories of DAOs.

Considering that only in limited cases DAOs are clearly defined, especially with regards to accountability and legal structures (Hoon, 2022; Sims, 2019), regulators want to attach accountability directly to the tokenholders of DAOs (C. F. T. Commission, 2022; Kharif & Verspille, 2022). Accountability, responsibility for activities, and decisions in regular organizational situations are often separated. In DAOs, these seem to be entangled due to direct participation in decision-making by the tokenholders. The ones responsible for decision-making also seem to be accountable. This suggests that tokenholders who are responsible for certain activities in a DAO are also accountable, with a possible exception in delegated voting structures. Hence, to be able to analyze accountability in DAOs, despite the anonymous or pseudonymous character of DAO participants, we interpret accountability as the combination of the number of tokenholders and voting power distributions. Rikken et al. (2023b) have analyzed the relationship between the number of tokenholders and long-term viability of DAOs. They find a significant relationship between the number of tokenholders and DAO's long-term viability. Due to the complex and intricate nature of accountability as a construct, in this paper, we operationalize accountability by using one proxy: voting power distributions.

To empirically investigate voting power distributions, we create a categorical measure with three categories: Dictatorship, Semi-Dictatorship, and Democracy (Figure 26). Dictatorships represent DAOs where one particular participant always needs to vote for a decision to be made due to an absolute majority in voting weight and/or quorum requirement. In Semi-Dictatorships, participants can decide independently of the largest voting weight participant as they can jointly reach the minimum required quorum. However, if the largest voting weight participant does vote, its vote will determine the outcome automatically. Democracies require cooperation between participants and will always require multiple participants to agree to come to a decision.

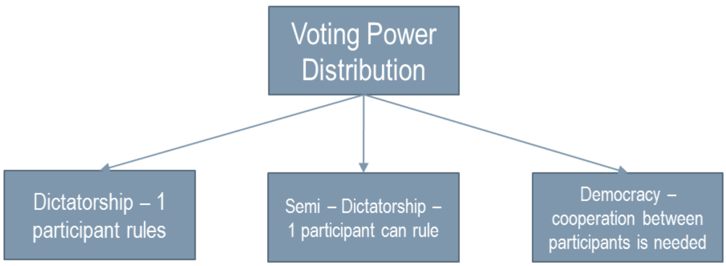

Figure 26: Voting Power Distribution

Decision/Voting models

A wide variety of governance mechanisms can be used in DAOs (Arsenault, 2020). In this section, we develop an overview of possible decision models/voting mechanisms resulting in the taxonomy presented in Figure 27.

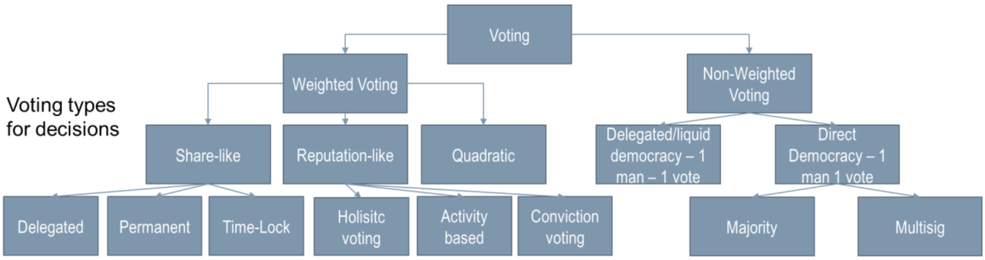

Figure 27: Categorization DAO voting models

The first breakdown in voting mechanisms of DAOs, as described in the literature and by empirical research, can be related to weighted or non-weighted voting. In non-weighted voting, all the participants in a DAO have an equal vote through the one person/account, one vote principle. Existing studies (Fan, Li, Zeng, & Zhou, 2020; HorizonAcademy, 2019; Kotsialou & Riley, 2017) describe two practical implementations of non-weighted voting: delegated/liquid democracy and direct democracy. In delegated/representative voting (liquid democracy), individuals can delegate votes to a person who then votes on behalf of multiple individuals. The individuals who have delegated their votes can switch their delegation if they want. None of the analyzed DAOs have a delegated structure based on a non-weighted base. Direct democracies represent strict "one account one vote" principle. This is practically implemented in the Aragon membership structure (Aragon, 2022). Each member or account has one vote, which is not transferable. We can distinguish two sub-types of direct democracy: majority rules and multisig voting (where a fixed number of members need to vote in favor to execute the decision).

In weighted voting, the participants do not have to be equal or do not have to assign an equal weight voting to a proposal. We distinguish three main sub-types within the weighted voting category: share-like, reputation-like, and quadratic voting.

For the first type of weighted voting, share-like voting, the voting weight can differ per participant based on the share in the DAO. Shares can be granted by performing activity, can be donated, or can be bought. They are transferable if the owner wants to sell them, without the need for a decision by the DAO. The share-like construction can be found in various purpose-built DAOs and DAOs deployed through platforms like Aragon and DAOHaus (Moloch-based). We can distinguish three subtypes within weighted share-like voting: delegated, permanent, and time-lock voting. Delegated voting with share-like construction works similarly to delegated voting in non-weighted voting constructions. Permanent share-like voting mechanisms are mechanisms where the share weight counts for every single proposal. With time-lock voting mechanisms, the weight of the share is locked into one proposal for the time of that proposal and cannot be allocated to other proposals.

The second type of weighted voting is reputation-like voting. The voting weight is based on the reputation of the participants. This reputation can change over time but is not transferable. The assignment of a new reputation is either algorithmically determined (DAO stack) or by DAO voting.

Almost all platforms, Aragon, DAOstack, and Colony, work with or support a form of reputation-based voting. We distinguish three subtypes within reputation-based voting: activity-based reputation, conviction, and holistic voting. In activity-based voting, one will gain a reputation based on their actions performed and/or voting participation. With this voting variant, reputation growth or decline is based on whether a participant votes in line with the outcome of the eventual decision. There are platforms like Colony that let reputation decay over time with inactivity. Conviction voting (Arsenault, 2020; Emmett, 2019) is a mechanism where an element of time is added to the voting. The eventual voting weight is based on the reputation level multiplied by a multiplier based on the duration that a certain vote was signaled. The longer a certain vote was signaled unchanged, the higher the voting weight gets. This voting mechanism was proposed by 1Hive and Giveth (Emmett, 2019), and is put into practice for the first time by Garden platform. In holistic (or progressive) voting mechanisms, as implemented by DAOstack, the primary majority needed is an absolute majority. But a prediction pool can set the predicted outcome of a vote. If a high enough amount of reputation is staked on the prediction, the needed majority becomes a relative majority, leaving the necessity for a quorum. The holistic system's weighting of voting in both voting and prediction is based on reputation of the participants.

Finally, in the third type of weighted voting, quadratic voting, a participant can spend a fixed amount of vote credit in a voting round consisting of various proposals. Based on the number of votes the participants want to spend on a certain proposal, they pay a quadratic amount of voting credit.

Incentive models

In this subsection, we derive a categorization of incentive models of DAOs. We divide the incentive models as described in the literature and as analyzed in our empirical research into three main groups: direct and indirect participant incentives and no incentive (Figure 28).

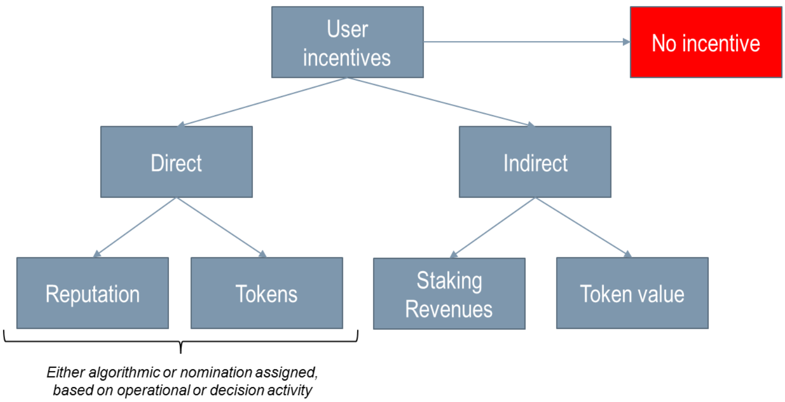

Figure 28: Incentive structure overview

The direct incentives in DAOs are divided into two direct subcategories (i.e., reputation, tokens) and linked to one indirect subcategory (staking revenues). Within reputation-based weighted voting, the direct incentive for a participant is gaining an additional (non-tradeable) reputation. This then leads directly to more influence in voting. DAOStack has a direct activity reputation token markup based on voting activity without the need for the DAO to assign additional reputation for the active participant. Aragon and Colony assign reputation through the nomination of other tokenholders. The second direct incentive model is through (tradeable) tokens. Active participation in the governance of the organization entitles a participant to earn additional (tradeable) economic/governance tokens or sometimes airdrop of other tokens (AirdropAdventure, 2022). Direct incentives are explicitly described in the Decred and Nexus Mutual DAO.

The first indirect incentive to participate in the governance process is through revenues obtained by staking tokens, as found in NAVcoin. By staking tokens, the participant gets the right to participate in governance, but participants do not necessarily need to be active in voting or other activities in order to earn that staking revenue. Even without voting, participants will receive staking revenue (so not necessarily for voting itself). The second indirect incentive to participate in governance analyzed is based on an increase in the value of the (tradeable) tokens. This is observed for Bisq, Dash, and Compound Finance, but this could also be applicable for all share-like models.

The "no incentive" category can be found in membership organizations. Membership organizations have no direct or indirect incentive at all as the token is non-transferable, no reputation or (economic) tokens can be earned, and no staking revenues are granted.

IV. Empirical study of governance decision and incentive models (of selected/verified DAOs and their effectiveness)

We analyzed 220 DAOs that show high lifetime activity, in-depth on their decision and incentive models. Within this group of 220 DAOs, as stated earlier, a group of 90 showed no or low activity in the 6 to 18 months between the first and second measurement, while 130 of these 220 DAOs showed high or medium activity. The analysis is meant to find a relationship between the decision models, incentive models, and the accountability of tokenholders and continuation or termination of activity (long-term viability). A detailed overview is shown in Table 16.

Table 16: Comparing the long-term viability of various DAO governance elements

	Categories	Total High LT Activity			Continuation of Activity (High/Medium)			Loss of activity (Low/None)			Δ to total	Δ to cont'd
Voting power	Dictatorship	220	29	13,2%	130	16	12,3%	90	13	14,4%	1,3%	2%
	Semi Dictatorship		20	9,1%		11	8,5%		9	10,0%	0,9%	2%
	Democracy		171	77,7%		103	79,2%		68	75,6%	-2,2%	-4%
Quora Restriction?	Relative Majority	220	46	20,9%	130	33	25,4%	90	13	14,4%	-6,5%	-11%
	Yes		147	66,8%		85	65,4%		62	68,9%	2,1%	4%
	Progressive		26	11,8%		12	9,2%		14	15,6%	3,7%	6%
	Two layer		1	0,5%		0	0,0%		1	1,1%	0,7%	1%
Quora Percentage	0 to 25%	148	90	60,8%	85	50	58,8%	63	40	63,5%	2,7%	5%
	25 + to 50%		12	8,1%		10	11,8%		2	3,2%	-4,9%	-9%
	50 + to 75%		32	21,6%		17	20,0%		15	23,8%	2,2%	4%
	75 + to 100%		9	6,1%		4	4,7%		5	7,9%	1,9%	3%
	Various		5	3,4%		4	4,7%		1	1,6%	-1,8%	-3%
Decision lvl 1	Weighted	220	170	77,3%	130	95	73,1%	90	75	83,3%	6,1%	10%
	Non - weighted		42	19,1%		31	23,8%		11	12,2%	-6,9%	-12%
	Unknow		5	2,3%		2	1,5%		3	3,3%	1,1%	2%
	Mixed		3	1,4%		2	1,5%		1	1,1%	-0,3%	0%

Decision lvl 2	Reputation	220	45	20,5%	130	25	19,2%	90	20	22,2%	1,8%	3%
	Share		125	56,8%		70	53,8%		55	61,1%	4,3%	7%
	Direct Democracy		42	19,1%		31	23,8%		11	12,2%	-6,9%	-12%
	Mixed		3	1,4%		2	1,5%		1	1,1%	-0,3%	0%
	Unknown		5	2,3%		2	1,5%		3	3,3%	1,1%	2%
Incentives	Yes - Tokens	220	2	0,9%	130	2	1,5%	90	0	0,0%	-0,9%	-2%
	Yes - Fee		1	0,5%		1	0,8%		0	0,0%	-0,5%	-1%
	Yes - Automatic Rep		26	11,8%		12	9,2%		14	15,6%	3,7%	6%
	Indirect - Staking Revenu		1	0,5%		1	0,8%		0	0,0%	-0,5%	-1%
	Indirect - Token Value		121	55,0%		66	50,8%		55	61,1%	6,1%	10%
	Indirect - SR and TV		1	0,5%		1	0,8%		0	0,0%	-0,5%	-1%
	No		63	28,6%		45	34,6%		18	20,0%	-8,6%	-15%
	Unknown		5	2,3%		2	1,5%		3	3,3%	1,1%	2%

Statistical analysis

After the first comparison analysis shown in Table 16, we statistically analyze the relationship between the governance elements and the long-term viability of DAOs. The effect size of each government element on DAOs' long-term viability was estimated by using partial eta squared (η^2), which is a statistical method to estimate the effect size of different variables in ANOVA or general linear model (GLM) (Cohen, 1973; Richardson, 2011). The partial eta squared was used here since the independent variables (i.e., government elements) are in categorical or nominal scales while the long-term viability is in ordinal scale (i.e., level of activities) and in ratio scale (i.e., the number of activities). Partial eta squared is computed as:

$$\eta^2 = \frac{SS_{effect}}{SS_{effect} + SS_{error}}$$

where SS_{effect} is the sum of squares for the effect of interest and SS_{error} is the sum of squares for the error term associated with that effect (Cohen, 1973). The indication of small, medium and large effects corresponds respectively to values of η^2 of .0099, .0588, and .1379 (Cohen, 1973, pp. 278-280).

For the measures of the three government elements, the independent variables used were in categorical or nominal scales:

1. Accountability is measured as voting power distribution denoted as the variable VPD (1=dictatorship, 2=semi-dictatorship, 3=democracy)
2. Decision/voting model is measured in two levels:
    a. Voting model level 1 denoted as the variable VL1 (1=non-weighted; 2=weighted)
    b. Voting model level 2 denoted as the variable VL2 (1=reputation; 2= share; 3=direct democracy). In the sample of 220 DAOs no liquid democracy or quadratic voting models were present. Therefore, these voting models were not included in the analysis.
3. The incentive model is denoted as the variable IM (1=no, 2=indirect, 3=direct)

4. Quorum denoted as the variable QR (1=progressive; 2=relative majority; 3=yes. Yes means there is a fixed quorum in place. In Relative majority there is no minimum quorum required. Progressive is a combination of Yes and Relative as described in section 3.

The dependent variables of DAOs' long-term viability (ordinal scale) are measured in both ordinal and ratio scales:

1. Level of activities (0 = no activity, 1 = low level of activities, 2 = medium level of activities, 3 = high level of activities)
2. The number of activities (measured in ratio or continuous scales).

As shown in Table 17 (in ***bold italic***), regarding the level of activities as the dependent variable (measured in ordinal scale), the voting mechanisms on level 1 (VL1) shows a small effect ($\eta^2 = 0.021$) and is significant ($p<0.05$). Incentives also show a small effect ($\eta^2 = 0.022$) and is slightly less significant ($p<0.1$). The interaction effect of accountability (voting power distribution) and quorum on the activity level appears to have a small effect ($\eta^2 = 0.019$) and is slightly significant ($p<0.1$). These findings indicate that more data points (larger sample size) are needed to further test other independent variables' statistical relationships/effects.

Table 17: Effects of different government elements and their interactions on DAOs' ***level*** *of activities using two-way ANOVA in GLM*

Governance Element	Variables	df	F-value	Sig.	η^2
Accountability	VPD	2	0.989	0.374	0.009
	VPD × VL1	1	1.022	0.313	0.005
	VPD × VL2	1	1.077	0.301	0.005
	VPD × IM	2	2.249	0.262	0.014
	VPD × QR	***1***	***3.813***	***0.052***	***0.019***
Decision/Voting	***VL1***	***1***	***4.555***	***0.034***	***0.021***
	VL1 × IM	2	1.267	0.284	0.012
	VL1 × QR	1	0.255	0.614	0.001
	VL2	2	2.281	0.105	0.021
	VL2 × IM	1	0.927	0.457	0.003
	VL2 × QR	0	.	.	.
Incentive	***IM***	***2***	***2.403***	***0.093***	***0.022***
	IM × QR	2	0.262	0.770	0.003
Quorum	QR	2	1.891	0.154	0.018

Subsequently, as shown in Table 18 (in ***bold italic***), when measuring DAOs' long-term viability in ratio scale (i.e., number of activities as the dependent variable), we found that only accountability (the variable voting power distribution (VPD)) showed (nearly) medium effect ($\eta^2 = 0.043$) and is statistically significant ($p<0.05$). Additionally, the interaction effects of accountability and incentives ($\eta^2 = 0.034$) and of accountability and quorum ($\eta^2 = 0.020$) show small-to-medium effects and are both statistically significant at $p<0.05$. There are no statistically meaningful effects on the other two governance elements (decision/voting and quorum).

*Table 18: Effects of different government elements and their interactions on DAOs' **number** of activities using two-way ANOVA in GLM*

Governance Element	Variables	df	F-value	Sig.	η^2
Accountability	***VPD***	***2***	***4.470***	***0.013***	***0.043***
	VPD × VL1	1	0.022	0.884	0.000
	VPD × VL2	1	0.020	0.888	0.000
	VPD × IM	***2***	***3.329***	***0.038***	***0.034***
	VPD × QR	***1***	***3.929***	***0.049***	***0.020***
Decision/Voting	VL1	1	0.000	0.996	0.000
	VL1 × IM	0	.	.	.
	VL1 × QR	1	0.023	0.879	0.000
	VL2	2	2.026	0.135	0.020
	VL2 × IM	0	.	.	.
	VL2 × QR	0	.	.	.
Incentive	IM	2	1.757	0.175	0.017
	IM × QR	1	2.647	0.105	0.014
Quorum	QR	2	0.349	0.706	0.003

In the following subsections, we further discuss the three main governance elements: accountability, decisions, and incentives.

Accountability

Voting power distribution in 13.2% DAOs (29 of the 220 DAOs) are dictatorships (see Table 1), 9.1% of the DAOs analyzed are semi-dictatorships, and 77.7% of the DAOs are classified as democracies. Based on the comparative analysis, no large difference was observed in the group of DAOs that stopped activity compared to DAOs with continued activity based on voting power distribution. But the statistical analysis did show a medium effect that was statically significant. Empirically, it thus seems that accountability (voting power distribution) does affect survivability, whereas democracies seem to have a positive effect on the long-term viability of DAOs.

Governance decision model and quorum effectiveness

The next element of governance we analyze in our empirical research focuses on the decision-making model and quorum rules of the governance mechanisms. As shown in Figure 4, we split the decision models into two levels: the first level is the division between weighted and non-weighted voting, with the second level detailing the first level.

Regarding the first-level voting (weighted vs. non-weighted), in five of the 220 DAOs analyzed, it is unclear if they are weighted or non-weighted voting systems. Three DAOs have a combination of weighted and non-weighted. We find a significant difference in the active DAOs compared to the inactive DAOs. Weighted decision model DAOs have a higher representation in the loss of activity group (83%) than the continued activity group (73%). Non-weighted voting model DAOs in the loss of activity group represent 12%. This is much lower than in the continuation of activity group, which is 24% for non-weighted voting DAOs. This suggests that non-weighted voting contributes positively to the long-term viability of DAOs. Based on the statistical analysis, this relationship is shown as well as a small effect and is significant at $p<0.05$ (Table 2).

When zooming in one level deeper in decision models, within the weighted voting group, the difference in loss or continuation of activity can predominantly be explained by the share-like voting group. The share-like group represents 61% of the loss of activity group, while in the continuation group, the share-like group represents 54%. This suggests that in weighted voting, share-like models contribute negatively to the long-term viability of DAOs. Although the statistical analysis shows a non-significant effect, there is a possibility that there is an effect, but more data points are needed.

Besides the decision models, we also analyze the effect of the usage of a quorum in the decision-making process on the effect of continued activity. Based on the comparative analysis, we find that if no quorum is used, but only a relative majority is needed for decision-making, this positively affects the continuation of activity. The percentage of the relative majority in the non-activity group is 14% against 25% in the continued activity group. The progressive quorum group (holistic voting) turns out to have a slightly higher rate of non-continuity (16%) versus 9% in the continued activity group.

Within the group of DAOs where a quorum is required, we further analyze whether the quorum percentages influence the continuation of activity. We find a clear difference, especially in the group where a quorum of 25+ to 50% is required. This percentage is 3% in the non-activity group, which is much lower than the 12% in the continued activity group, suggesting that a quorum between 25+% and 50% positively contributed to the long-term viability of DAOs. But according to the statistical analysis, only a small, non-significant effect could be observed, so more data is needed to check this relationship.

Our analysis shows a difference in long-term viability based on Level 1 and Level 2 decision models, but not on quorum. Hence, there is no clear explanation yet at this point regarding the differences in long-term viability based on decision models. A potential cause for the higher percentage of non-weighted or direct democracy decision mechanisms could be that these mechanisms come more naturally due to the decentralized character or the business objectives of DAOs; which is another interesting area worth investigating in further research.

Governance incentive

We finally look at the incentive element in the DAOs. We find a clear difference in the percentages of non-activity and continued activity in the group of DAOs that do *not* have an explicit incentive system. The percentage of DAOs with no incentive mechanism in the non-activity group is 20%, whereas this group in the continued activity group represents 35%. Incentives by reputation, or indirect token value show a larger percentage in the non-activity group than in the continued activity groups. Although small and significant with $p<0.1$ instead of $p<0.05$, this effect is also confirmed in our statistical analysis (Table 17). This suggests that no type of incentive positively influences DAOs' long-term viability. This observation might be perceived as surprising, but it could be explained in line with the observations regarding governance decision models. As DAOs are first set up in decentralized communities that might focus more on the commons or altruistic business objectives, incentivizing might not be so important to the communities that use DAOs. Therefore, we recommend further research to analyze the purpose or business objective, in combination with various governance elements of the DAO.

V. Discussion: An emerging DAO governance theory for the long-term viability of DAOs

Research on DAO governance so far is mainly limited to describing governance models and elements or single case studies. The little empirical research predominantly focuses on aggregated elements (like voting percentages and value of all DAOs from specific platforms), or their tokens and differences between platforms, or focuses primarily on a single use case (Appel & Grennan, 2023; Faqir-Rhazoui, Arroyo, et al., 2021; Sims, 2021). In this paper, we empirically examined how various governance elements can actually influence a DAO's long-term viability over many different DAOs and DAO platforms instead of primarily observing and summarizing the past behavior of a single use case.

A previous study by Rikken et al. (2023b) shows that the number of tokenholders (as a basic element of accountability) significantly influences the survivability of a DAO, where the crucial threshold lies around 20 tokenholders. Although no specific explanation was given on the possible reason for this relationship, we suspect that this can be explained by having a broader active community that keeps activities going and thus influences the long-term viability of a DAO in a positive way. In future research, it would be interesting to study the combination of the number of tokenholders and voting power distribution.

Our empirical findings based on the statistical analyses of governance elements coupled with the findings by Rikken et al. (2023b) result in a preliminary DAO governance theory. The theory shows possible influencing factors on the long-term viability of DAOs (Figure 6). Bacharach (1989) argues that a theory is a statement of relationships between one or more variables or constructs in an empirical environment. In line with this, the observed units or variables in our theory are the governance elements and the long-term viability, whereas the boundary of the theory is on-chain governance DAOs on permissionless blockchain protocols. Besides the three governance elements investigated in this paper (the grey and yellow boxes in figure 6), our analyses suggests that other factors (orange box in figure 6) might influence the long-term viability of DAOs. Moreover, these factors can also be interrelated.

An important element that has not yet been considered in the literature, but was found to be relevant in our research, is a DAO's goal or business purpose (e.g., an investment DAO or a philanthropic DAO). Based on our preliminary observations, we consider that the goal can directly influence the long-term viability as some goals of the organization or project might not be suitable for DAO-based governance (Yang, 2022). We also speculate that the business objective might have an influence on several factors of our theoretical model as a moderating variable on DAOs' long-term viability (Figure 29). Therefore, we propose that future research should investigate the connection between the goal or business purpose, governance elements, and the long-term viability of DAOs. This would require more in-depth data gathering as the goals or business purposes of DAOs have not yet been captured.

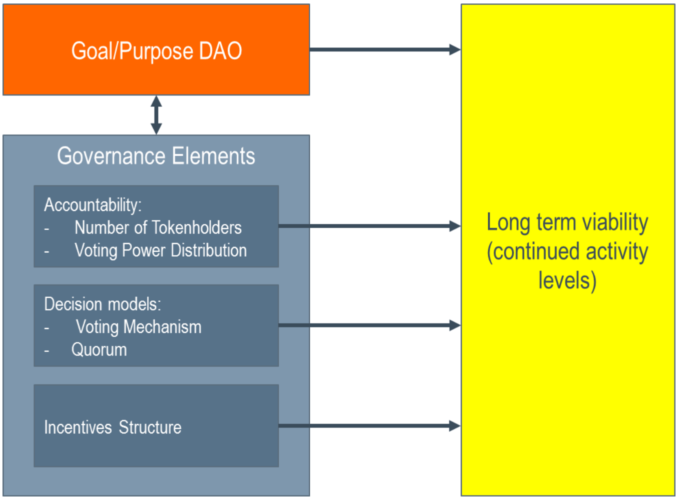

Figure 29: Preliminary theory for the long-term viability of DAOs.

Since our in-depth empirical analysis is restricted to 220 DAOs, we recommend expanding the DAO dataset. This can be used to verify our initial findings with the growing number of DAOs and maturing of DAOs and their governance models. The exponentially growing number of DAOs drives this recommendation.

To further expand this preliminary theory, another element that can be considered in future research is to include the effect of the choice of blockchain infrastructure that a DAO is deployed on. This can be the effect of the choice between a permissioned and permissionless infrastructure or the type of permissionless infrastructure. The choice of permissionless infrastructure (e.g., Ethereum, Polygon, Gnosis Chain, EOS, etc.) can have various important governance influencing factors. For instance, transaction speed or transaction pricings that differ per infrastructure may influence the cost of efficiency of governance.

Furthermore, other governance elements could potentially influence the long-term viability of DAOs that are not part of this research. These elements, like “emergency brake” mechanisms, such as rage quit, should be further researched theoretically and empirically to better understand these mechanisms and analyze their relationship with the long-term viability of DAOs. These additional influential elements can be further extended/added into and refined in our preliminary theory of the long-term viability of DAOs.

Finally, the DAOs analyzed are all on-chain governance DAOs. However, there is a steep rise in off-chain, less autonomous governance projects that refer to themselves as DAOs through platforms like Snapshot. We recommend including this type of off-chain DAOs as a separate category in further research to analyze if they behave similarly to on-chain DAOs.

In summary, Table 19 shows the identified factors that could influence the long-term viability of a DAO. Various of these elements are analyzed in this paper. Based on the comparative and statistical analysis, we show that all elements can have an effect on long-term viability, although various relations need additional data as the effect is not statistically significant in all cases. As such, the preliminary theory shown in Figure 29 has not been entirely evaluated yet, and we recommend future research to test this further in more detail.

Table 19: Possible Influencing Factors Usage DAOs

Factor (variables)	Description of Long-term viability influencing factors (observed units/variables)	Statistical Link to Long-term viability – Nominal - Ordinal
Goal or Business Purpose	The goal or purpose of the DAO can influence its long-term viability. Certain goals for DAOs could be more suitable for DAOs than others.	To be studied
Accountability	Combination of Voting Power Distribution and Number of tokenholders.	See Voting Power Distribution and Number of tokenholders below.
Voting Power Distribution	Does the voting require a democratic collation of multiple tokenholders or is there a semi-dictatorship or a dictatorship?	Medium effect – Not significant. Additional data needed
Number of tokenholders	The number of tokenholders influences the long-term viability/activity of a DAO, where a high number of tokenholders seems to lead to a higher activity level.	Strongly related – Significant (Rikken, Janssen, et al., 2023b)
Voting mechanism	Various voting mechanisms can lead to different decision-making processes, which can influence the long-term viability/activity.	Small effect – Significant on the highest level, not significant on the lower level – more data needed.
Quorum	The minimum amount of voting percentage needed for a decision to pass.	Small effect – Not significant
Governance incentives	Incentives to participate in the governance mechanism of that particular DAO.	Small effect – significant at $p<0.1$ instead of $p<0.05$
Infrastructure	The chosen infrastructure or the governance elements of this infrastructure can influence the long-term viability as a result of the entanglement of application and infrastructure.	To be studied

VI. Conclusions

DAOs provide a new form of governance, and there is limited knowledge about how DAOs should be designed to be viable in the long-term. Providing insights into the effect of governance elements' impact on the long-term viability of DAOs helps policy-makers and decision-makers in choosing the right setup of these elements when they want to use DAOs to achieve higher levels of transparency, inclusiveness, and accountability. Based on our in-depth analysis of 220 out of 6,000+ DAOs, we find that a number of governance elements can influence the long-term viability of DAOs. More specifically, the empirical analysis reveals the following relationships:

1. Power distribution, dictatorship, semi-dictatorship, or democracy, have a (nearly) medium effect on the long-term viability of DAOs (Table 18). Democracies contribute positively to long-term viability being statistically significant. This suggests that policy-makers should embed democratic governance in a DAO to create a more long-term viable DAO;
2. Non-weighted voting systems (1 account – 1 vote) significantly and positively contribute to the long-term viability of DAOs (Table 17). The findings suggest that policy-makers should ensure that each citizen and other stakeholders have an equal share and are heard;
3. When detailing the voting mechanisms even further, although there seems to be a relation on a cursory examination, this is not significant but should be researched with more data;
4. The usage of quorums has no significant influence on the long-term viability. We recommend researching this further using more data;
5. Finally, the lack of incentive structure for participation contributes positively to long-term viability (Table 17). However, the significance is less strong than level 1 voting mechanisms.

This suggests that policy-makers should not provide explicit (financial or reputation) incentives for citizens to contribute to DAOs. Intrinsic motivation and interest in the issues at hand might be more important.

Some of the conclusions based on our data are counterintuitive, like the influence of incentive structures on the long-term viability of DAOs. A possible explanation is that the early-stage DAOs are formed around more altruistic communities (more closely related to the original blockchain community). As such, the results might not be generalizable to all types of citizens. We have not so far found any conclusive empirical evidence, nor have we found any supporting literature on this. Hence, we recommend investigating this in future research. Overall, these hypothesized relationships form a preliminary theory on the influence of DAOs' governance elements on long-term viability (Figure 29). Based on empirical research and the preliminary theory, these findings can help policy-makers and businesses make better decisions in the governance design phase when they want to use a DAO structure to improve trust, transparency, accountability, and potentially increase citizen participation in public administration.

There is a need to collect more data in future research to further test our preliminary theory (as displayed in Figure 29) empirically. In particular, when analyzing the relationship between governance elements and the long-term viability of DAOs, we recommend including a DAO's goal or business objective and the choice of blockchain infrastructure upon which the DAO is deployed. Also, differences between user types might be made, as other users might have different preferences and incentives.

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6. Paper 4 - The influence of and interplay between business objectives, governance elements, and infrastructure on the long-term DAO viability: Empirical insights

The influence of and interplay between business objectives, governance elements, and infrastructure on the long-term DAO viability: Empirical insights

Olivier Rikken MSc MBA*, Delft University of Technology,
Prof Dr Marijn Janssen**, Delft University of Technology,
Dr Zenlin Kwee***, Delft University of Technology.

* Corresponding author, o.k.rikken@tudelft.nl, Jaffalaan 5, 2628 BX Delft, the Netherlands
** M.F.W.H.A.Janssen@tudelft.nl
*** Z.Roosenboom-Kwee@tudelft.nl

Abstract

Decentralized autonomous organizations (DAOs) promote governance-by-design by embedding governance in technology and application. Despite their exponential growth, many DAOs face challenges, like security hacks, governance issues and misalignment of business objectives, impeding their full potential. Existing DAO research predominantly delves into theoretical studies of DAO governance and their potential business objectives or analyze single DAO use cases. There is a need for empirical research with large, longitudinal data sets of DAOs to understand factors influencing the long-term viability of DAOs. Our research fills this gap by gathering these datasets and empirically analyzing them on business objectives, governance elements, infrastructure elements and their entanglement. By crafting DAO business objectives and governance frameworks, we examine how these factors collectively affect long-term viability. Our empirical findings highlight specific business objectives-governance combined setups are conducive for DAOs and found an entanglement between infrastructure and application that can significantly influence DAO governance. This suggests that the choice of blockchain-based infrastructure is a crucial determinant for DAO viability. We combined our findings and prior studies into a theory on long-term viability influencing factors for DAOs. Future research can examine infrastructure elements' impact on DAO governance (particularly voting behaviour and incentives) and include off-chain DAO governance mechanisms.

Keywords: Blockchain, Business objective, Decentralized Autonomous Organization (DAO), Governance, Governance-by-design, Decentralization, Infrastructure Entanglement

I. Introduction to Decentralized Autonomous Organizations (DAOs) and previous research

DAOs depict a novel alternative approach to collaborative governance. DAOs are characterized by collective ownership and management, enabling full autonomous and transparent execution of governance decisions. This has the potential to significantly enhance transparency of governance and decision-making processes within organizations and operational efficiency thereof. Ever since the introduction of blockchain through the Bitcoin protocol by Satoshi Nakamoto in 2009 (Nakamoto, 2008), blockchain has been used for many objectives, ranging from financial applications using tokenization and Decentralized Finance (DeFi) (Chen & Bellavitis, 2020; Helliar, Crawford, Rocca, Teodori, & Veneziani, 2020; Katona, 2021; Tian et al., 2020), to smart contract applications (Mohanta et al., 2018; Rikken, van Heukelom-Verhage, et al., 2018) and applications beyond financial use cases in various industries related to evidence trail use (Al-Megren et al., 2018; Carvalho, Merhout, Kadiyala, & Bentley II, 2021; Jing et al., 2021; Julie Frizzo-Barker, Peter A. Chow-White, Philippa R. Adams, Jennifer Mentanko, & Dung Ha, 2020; P. Zhang, Schmidt, White, & Lenz, 2018).

DAOs are often viewed as the next step in the use of blockchain for more powerful solutions to create new types of organizations and collaborative web-based governance models (P. De Filippi & Hassan, 2020; Dwivedi et al., 2022). In essence, DAOs are blockchain-based systems for transacting value and providing notary functions where data and actions are recorded and autonomously executed (Rikken, Janssen, et al., 2023b). In practice, DAOs aim to automate actions and decisions at the center through execution by smart contracts with humans at the edges (Buterin, 2014). This can be called ‘governance-by-design’ in which the governance processes and decision-making authorities are embedded in the technology.

The business objectives of DAOs are very diverse, ranging from governing blockchain infrastructures (Dash, 2021) to creating possibilities of participatory budgeting for governments (Rikken, Janssen, & Kwee, 2023a) and management of commons (van Vulpen & Jansen, 2023) and DAOs aim to lower or eliminate the need for trust in organizations (Šimůnek, 2023). The exponential growth in DAOs suggests the suitability of DAOs for many objectives, but a growing number of industry leaders are questioning the suitability of DAOs for certain objectives (Ivanov, 2022; Pahulje, 2022). This is reinforced by various incidents related to the governance of DAOs (Hart, 2022; Sun, 2022). Enhancing governance-by-design with a focus on business objectives can bolster the long-term viability of DAOs. Hence, it is crucial to consider business objectives during the governance design process.

Despite rising in numbers, many DAOs fail to reach long-term viability (Jennings, 2023; Rikken, Janssen, et al., 2023b). There is little empirical research on the broader business objectives of DAOs and their link to long-term viability. Research that has been conducted on possible suitability, opportunities, and challenges for specific purposes as DAOs for commons (van Vulpen & Jansen, 2023), or environmental DAOs (Dean-Saadati & Webster, 2023), or the categorization of DAOs without analysis on the effect on long-term viability (Appel & Grennan, 2023).

Governance-related research on DAOs predominately has either been on the theoretical side of governance of DAOs or describing single case analysis of the governance of specific DAOs or describing DAOs as governance possibilities in government or companies (Beck, 2018; P. De Filippi & Hassan, 2020; Dhillon et al., 2017; DuPont, 2017; Ying-Ying Hsieh et al., 2018; Kaal, 2019; Mehar et al., 2019; Samman & Freuden, 2020; Sims, 2021; S. Wang et al., 2019). Due to the proliferation of DAOs, we see rising (although still fairly limited) empirical research being conducted on DAO governance. There have been empirical studies to provide an overview of platforms used and the distribution of DAOs across various platforms or infrastructures. Additionally, there have been studies to compile accumulated overviews of voting behavior and to analyze specific DAO case studies focusing on governance elements (El Faqir et al., 2020; Faqir-Rhazoui, Arroyo, et al., 2021; Zhao, Ai, Lai, Luo, & Benitez, 2022b). Another study focuses on the effect of governance on digital assets or token prices (Appel & Grennan, 2023), while others propose a governance framework for future design based on an analysis of a couple of DAO case studies with different business objectives (Murimi, 2022).

Regarding research on governance elements, some studies analyzed governance elements of DAOs based on the analysis of a few individual DAOs (Sims, 2021) or investigated governance elements and activity levels in general (Zhao et al., 2022b). Other research focuses on desired governance elements and suitable DAO-creating platform selection for these desired governance elements (Baninemeh et al., 2023). Empirical research by Rikken, Janssen and Kwee has examined the impact of DAOs' governance elements on their long-term viability (Rikken, Janssen, et al., 2023a). Overall, existing studies have suggested further empirical research on DAOs should include an analysis of the goal or business objective in combination with internal governance elements and elements external to the DAO (Faqir-Rhazoui, Ariza-Garzón, Arroyo, & Hassan, 2021; Rikken et al., 2019) and how they altogether may influence their long-term viability.

In this paper, we aim to identify and evaluate influential factors that contribute to the long-term viability of DAOs. Here, the DAO's business objective is integrated as the independent variable and as a moderating variable to answer the following research questions: (1) How can the typical business objectives of DAOs be categorized within the broad spectrum of objectives?; (2) Taking business objectives into account (as the independent variable and as a moderating variable), how do internal governance and external infrastructure elements influence the viability of DAOs? Based on the conclusions of our research and building on prior studies, we propose a theory of the effect of internal and external governance elements and the business objective on long-term viability of DAOs.

This paper is structured in the following way. The second section presents the theoretical framework and hypotheses. The third section describes our research approach. In section four, we introduce our DAO business objective categorization, along with the analysis framework of DAO governance. We present the results of our analysis regarding the effect of combining business objectives with governance elements and its influence on the long-term viability of DAOs. Here, we also discuss the effect of infrastructure's external elements on DAOs (internal) governance elements. In section five, we present and discuss a theory of the effect of governance elements of DAOs on the long-term viability of DAOs, including the influence of business objectives and infrastructure governance elements. In section six, we present our conclusions and recommendations for future research agendas.

II. Theoretical framework and hypotheses development

The promise of DAOs is providing the governance-by-design of collective communities without the need for a hierarchical structure. This decentralized structure means that participants collectively are in control, and that is censorship resistant due to the absence of central majority powers (Buterin, 2014; P. De Filippi & Hassan, 2020; S. Wang et al., 2019). The challenges in DAOs, however, can be multifold. Accountability can be unclear due to shared and scattered ownership (Rikken et al., 2019). This leads to the discussion whether participants are jointly accountable. For instance, in a court case of the CFTC vs. Ooki DAO case (CFTC, 2022), the judges held all tokenholders accountable (as in general partnerships) for the actions of the DAO (Boniel, Neuburger, & Choy, 2023; Boutros, Spangler, Schleppebbach, & Leyh, 2023). Also, decision-making and misaligned incentives lead to various incidents. Some of the notorious incidents are “the DAO” hack in 2016 due to misuse of coded rules (DuPont, 2017) and Axie Infinity, Beanstalk, MakerDAO and MangoMarkets as a result of majority take-overs in decision-making (Kharif, 2022; McSweeney, 2020; Phelps, 2022). DAO governance and coordination costs are seen as important concerns by industry leaders and scholars (Feichtinger et al., 2023; Fitsimones, 2023; Lewellen, 2023). These incidents and concerns all call for further studies on suitability of DAOs for various business objectives and to DAO governance, taking internal and external factors into account as business objective driven governance-by design could positively contribute to long-term viability of DAOs.

Earlier research (Ellul et al., 2020; Rikken et al., 2019) suggests a potential entanglement of the governance of the infrastructure and the application and the importance of additional research toward this entanglement. This implies that external infrastructure elements outside a DAO's control could influence the DAO's governance in itself (Ellul et al., 2020; Rikken et al., 2019; Schreurs, 2018; Zachariadis et al., 2019).

II.1 DAO Business Objectives

Not all projects that started as a DAO are deemed to be suitable for a DAO, as the chosen governance does not fit their business objective (Ivanov, 2022; Sun, 2022). Kiayias and Lazos (2022) argue that properties of governance systems should be seen in context, with business objectives in mind. Also, from a risk and governance perspective, business objectives, environment, and product-market fit influencing risk management practice should be considered (Drew, Kelley, & Kendrick, 2006; H. Wang, Barney, & Reuer, 2003). Previous research recommended considering the goal or business object as a moderating variable when looking into the effect of governance elements on the long-term viability of DAOs (Rikken, Janssen, et al., 2023a).

Our first hypothesis is related to the relationship between business objectives and the long-term viability of DAOs. Based on opinions from industry leaders (Pahulje, 2022; Rachmany, 2020; Sun, 2022; Yang, 2022), we consider certain business objectives to suit DAO structures better (in terms of long-term viability) than others. Although empirical research on business objectives for DAOs is limited, research by Peña-Calvin et al. (2023) shows financial DAO purposes are far more present than others, which could suggest that this business objective is more suitable for DAOs. Conversely, DAO tracking site deepDAO.io shows that the top 20 DAOs by treasury have more non-DeFi purposes. Also, research by Rikken et al. (2023a) suggests that business objectives could explain why certain DAOs show better long-term viability compared to others. Thus, the business objectives of DAOs could influence their long-term viability. DAOs can be divided into various business objective categories. We summarized business objective categories into two main categories, economic (for-profit) and non-economic DAOs. Building on the abovementioned research and observations by industry leaders, we test the effect of business objective of DAOs on long-term viability through the following hypothesis:

H1: Economic DAOs demonstrate lower long-term viability than non-economic DAOs.

In order to test this hypothesis, we incorporate the business objective category of DAOs, following the categorization outlined in section 4, for each of the individual DAO we analyze. In this way, we can analyze the relationship or effect of business objectives, combined with governance elements (accountability – incentives – decision models) as described in section 4, on the long-term viability of DAOs.

II.2 DAO Governance

Research on DAO governance is still in a fairly early phase. It is even argued that existing governance theories might be insufficient for DAO governance design (R Morrison et al., 2020). Definitions of DAOs also vary. DAOs are defined as loosely organized communities or fluid organizations that use smart contracts for governance (Axelsen, Jensen, & Ross, 2022), self-organizing communities using blockchain for coordination to manage a decentralized application with rules and principles specified in and deployed by smart contracts (M. Singh & Kim, 2019; Zhao et al., 2022b), or blockchain-based systems for the coordination and governance of people using blockchain-based self-executing rules (Hassan & De Filippi, 2021). For this research, we use a more generalized definition proposed by Rikken et al., being a system for storage and transaction of value as well as enabling notary functions for voting where actions are autonomously executed and data is stored in a decentralized way (Rikken, Janssen, et al., 2023b).

The governance of organizations is a complex system where various components, elements and dimensions play a role. In corporate governance, balancing risk and decision-making is crucial within the organizational setup (R Morrison et al., 2020). Incentives are also seen as an important element in balance with decision-making and accountability (Baker & Anderson, 2010; Coles, Daniel, & Naveen, 2006). Within organizational governance, three models can be described, the agency or transaction cost where humans are opportunistic and self-prone, the stakeholder where executive act in the interest of corporate owners and needs of other stakeholders, and the steward model where managers' motives align with a broad range of objectives of different parties (Caldwell & Karri, 2005). But where corporate and organizational governance assumes a formal organization with clear reporting lines, executives, management layers and accountabilities, within DAOs, there tends to be no formal legal organization and absence of managerial layers with conventional reporting lines as a result of high automation of processes.

Various studies (Appel & Grennan, 2023; Beck et al., 2018; W. Ding et al., 2022; Ying-Ying; Hsieh et al., 2018; Aggelos Kiayias & Philip Lazos, 2022; R Morrison et al., 2020; Rikken et al., 2019; Schwartz & Adlerstein, 2022; Werner & Zarnekow, 2020) emphasize on the lack of a central traditional organization and the possible effect on governance of blockchain and blockchain-based systems. In IT governance, the argument is that accountability, decision rights and incentives need to be in balance (Peter Weill & Ross, 2005b). Earlier research on blockchain and DAO governance emphasizes voting system, incentives, security and timeliness as key components (Aggelos Kiayias & Philip Lazos, 2022). Using the platform governance mechanisms of Hein et al. (2016) and Werner and Zarnekow (2020) found mechanisms of ownership rights, governance structure and decision as the main elements. Zhao et al. (2022b) analyze task allocation, reward distribution and information provision. Rikken et al. (2023a) and Beck et al. (2018) take accountability, decision model or making, and incentives as their basis for analysis, whereas Appel and Grennan (2023) showed the positive correlation between the token price of a DAO as an incentive and the governance participation in DAOs. Murimi (2022) proposes a framework with consensus, cooperation, and conflict regulation as the base for governance design.

When looking at governance, most studies mention a form of decision model, incentive and accountability or responsibility as crucial components and elements. Previous research on governance elements shows that these different governance elements and their dimensions can affect DAO long-term viability (Rikken, Janssen, et al., 2023a, 2023b). Some counterintuitive findings regarding the influence of incentives and the long-term viability of DAOs were found, which could be explained by analyzing business objectives as a moderating variable (Rikken, Janssen, et al., 2023a; Zhao et al., 2022b). Therefore, we formulate the proposition that specific combinations of business objectives and governance components (accountability, decision model, and incentives) influence the long-term viability of DAOs in different ways. We test this proposition by splitting it into four hypotheses (2a – 2d) based on the governance components (accountability, decision model, and incentives).

Accountability

The accountability component of our DAO governance analysis framework as explained in section 4 is operationalized by two elements, e.g., the number of tokenholders and the voting power distribution amongst the tokenholders. Previous research by Rikken et al. already showed that number of tokenholders has an effect on the long-term viability of DAOs (Rikken, Janssen, et al., 2023b). Rikken et al. (2023a) and Zhao et al. (2022b) mention voting power distribution as an important element, but did not consider business objective. These two elements can reflect accountability in DAOs, given that regulators aim to put accountability in DAOs from a legal perspective directly to the tokenholders of DAOs (Kharif & Verspille, 2022; Schwartz & Adlerstein, 2022). Rikken et al. (2023a) distinguish three dimensions regarding voting power distribution: dictatorship, semi-dictatorship, and democratic voting power distribution as further explained in section 4. Building on the abovementioned studies, we formulate the following hypothesis:

H2a: Democratic voting power distributed DAOs exhibit greater long-term viability in non-economic DAOs than economic DAOs.

Decision model

In any governance model the way the decisions are made is essential. The decision model component of our DAO governance analysis framework is operationalized by the elements of voting mechanisms and quorum(Rikken, Janssen, et al., 2023a). Previous research on decision models and voting types found a correlation between differences in voting types and operational performance (Zhao et al., 2022b) and types of decision models and long-term viability (Rikken, Janssen, et al., 2023a), although not always statistically significant and not taking DAOs business objectives into account. Zhao et al. (2022b) base their research only on the analysis of a single DAO (MakerDAO), whereas Rikken et al. (2023a) identify three main decision model categories based on a survey of DAOS: share-like, reputation-based and membership-based decision models. This leads to the following two hypotheses:

H2b: Share-like decision models exhibit greater long-term viability for economic DAOs than for non-economic DAOs.

H2c: Membership-based decision models exhibit greater long-term viability than reputation-based decision models in non-economic DAOs.

Incentives

As stated in section 2.2, incentives are the third important element in governance. Previous research by Appel & Grennan (2023) took incentives in the form of return on token prices as the dependent variable. It showed a positive relationship between incentives and participatory decision-making. Rikken et al. (2023a) showed a relation between different incentive structures and long-term viability. They make a distinction between direct, indirect and no incentives. However, previous empirical research analyzing the incentive effect of DAOs did not take into account business objectives. Building on existing studies, we formulate the following hypothesis:

H2d: Non-incentivized DAOs exhibit greater long-term viability for non-economic DAOs than economic DAOs.

II.3 Influence of choice of infrastructure on the governance of DAOs

To create DAOs, one needs to deploy smart contracts, creating smart contract accounts on-chain to store and execute the underlying code, which determines the autonomous character of DAOs. Ethereum is the most frequently used infrastructure (also called blockchain protocol) for deploying DAOs (El Faqir et al., 2020; Faqir-Rhazoui, Arroyo, et al., 2021; Rikken, Janssen, et al., 2023b). Although there is little to no research on why certain infrastructures are preferred for DAO deployment, this could be driven by various factors. One factor could be available DAO deployment platforms, smart contract, and token standards for certain infrastructures. Another factor could be the size of the user base (active, unique, externally owned accounts) on an infrastructure and, thus the potential users the DAO can reach through that infrastructure. Also, the transaction cost of a particular infrastructure could be an important factor. Hence, we formulate the following hypothesis:

H3: The business objective of a DAO influences the choice of blockchain infrastructure the DAO is deployed on.

With this third hypothesis, we want to see if certain business objectives of a DAO appear more on certain blockchain protocols than others, as could potentially be expected as a result of a larger user base or more DAO and token smart contract standards on certain protocols than others.

II.4 Infrastructure elements possibly influencing DAO governance

Besides the influence of business objective and governance element choices within the DAO application on the long-term viability of the DAO directly, the choice of infrastructure should also be taken into account. Due to the entanglement of application and infrastructure, elements under control of the governance of the infrastructure (external to the direct influence sphere of the DAO), could influence governance elements of DAO applications in itself (Rikken et al., 2019). Especially in public permissionless blockchains, governance elements of the decision model and incentives could be influenced by transaction fees or transaction prices (also called "gas fee") as elaborated on in the next paragraph. This could lead to inefficient voting processes, leading to security risks (Faqir-Rhazoui, Ariza-Garzón, et al., 2021; Fisch & Momtaz, 2022).

Transaction (tx) pricing

To deploy and interact with DAOs, one needs to create and transact with specific smart contract accounts of the DAO, e.g., to register votes on-chain. Faqir et al. (2021) already looked into the effect of transaction price on DAO activities. This research is limited to the Ethereum network, a limited number of DAO deployment platforms, and did not take conversion to dollar price for transactions into account but restricted this to the price in the local cryptocurrency (Ether). On Ethereum and other Ethereum Virtual Machine (EVM) based blockchain protocols like Gnosis Chain (formerly xDAI), Avalanche and Polygon (sometimes referred to as MATIC), these transaction prices are determined by the so-called "gas", the "gas-price" and the price of the local cryptocurrencies like Ether (for Ethereum), Avax (for Avalanch), MATIC (for Polygon) or xDAI (for Gnosis Chain). Gas is the unit measuring the amount of computational effort required to execute specific operations like smart contract code execution or deployment. "Gas-price" is the price per gas unit, e.g. 21.000 gwei (one gwei is 10^9 wei, wei is the smallest division of Ether) (Minimalism, 2022). To determine the transaction fee or price in cryptocurrency for transactions, one multiplies the amount of units of gas times the gas price. For fee or price in fiat currency (e.g., dollar or euro), one multiplies this amount by the cryptocurrency price, e.g., price of Ether (Ethereum) or xDai (Gnosis Chain). The amount of "gas" to be paid for certain transactions is not determined by the (governance of the) DAO, but by the (governance of) the infrastructure (protocol), that the DAO was built on. Therefore, there is a clear entanglement between infrastructure governance (determining transaction cost by setting the amount of "gas" per computation/ transaction and the "gas-price") that can influence governance of DAOs (transactions needed to be performed e.g., to vote on or create a proposal).

This relation is being tested with our fourth hypothesis:

> H4: The "gas-price" of an infrastructure affects the governance of DAO applications due to the entanglement of infrastructure and application.

With hypothesis 4, we want to test the relation of external factors outside the direct influence sphere of the governance of the DAO and how they might influence the governance of the DAO in itself. The external factor being analyzed is the fluctuation of transaction price (gas price) in US dollars for transactions on an Ethereum Virtual Machine (EVM) based network.

The hypotheses are visualized in Figure 30. Only the relationships of business objectives, governance elements and long-term viability are tested in an integrated way (H2a-2d) in the model. The other relations (H1, H3 and H4) are tested as 1-1 relations.

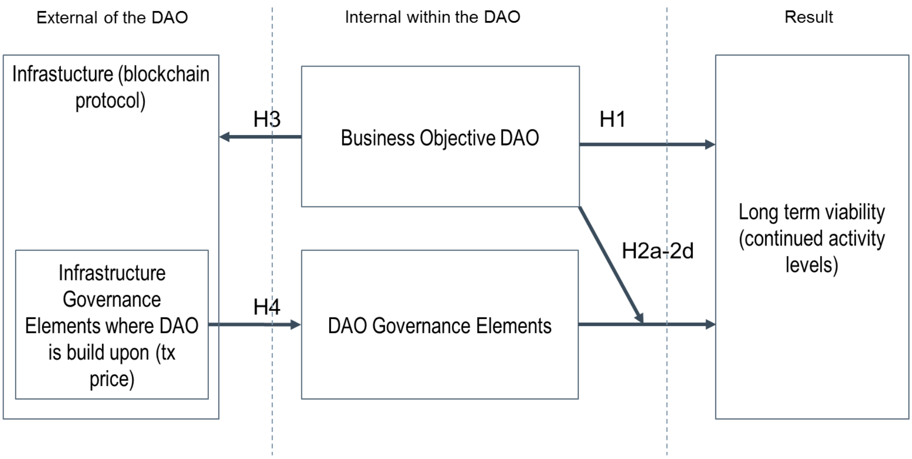

Figure 30: Visualization of hypotheses

III. Research Approach

A combination of theoretical and empirical research answered the first research question on typical DAO business objectives and how these can be categorized. We used a combination of induction and abduction to create the categorization of business objectives. Previous defined business objectives and objective categories were gathered by performing a literature review on both scientific literature as well as grey literature (Barbara Kitchenham et al., 2010). We used the following keywords search in Google Scholar: "business objectives", "goals", "purpose", "decentralized autonomous organiz(s)ation", "DAO" and combinations thereof and the search was performed until August 2023. We screened relevant literature through a stepwise approach, as shown in Figure 2. Using this method, we found 82 relevant articles and publications (papers, blogs, webpages, and transcripts) and reviewed 500+ news articles. The literature breakdown is displayed in Figure 31.

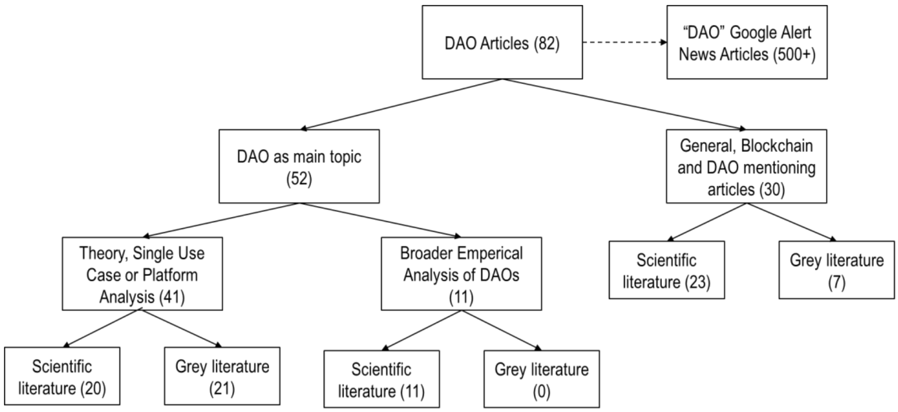

Figure 31: Steps of literature breakdown

Next to the literature review on the business objectives of DAOs, we gathered information on 12,000 perceived DAO projects in which we analyzed various subsets. This list was assembled by gathering information on DAOs over an extensive period of time (beginning 2019 until end 2022). Various sources were used to gather this information. A daily automated Google alert search on "smart contract", on "blockchain and on "decentralized autonomous organizations" resulted in over 10,000 news hits with articles mentioning DAOs. Besides that, various DAO deployment and tracking sites like DAOhaus.club and alchemy.daostack.io were used. Finally, automated scripts were created for the most common DAO project platforms (Aragon and Snapshot) to gather information of new deployed DAOs. Details of the data gathering are displayed in Table 20. All mentioned DAOs were registered and first classified (if possible) on the year of deployment, month of deployment, status (planned, active, in development, inactive), deployed infrastructure, build type (self-build, deployment platform etc.) and links to all individual DAOs. For a large subset also, activity levels, governance elements, main functionalities, name, and value were registered for further selection and analysis. Besides these characteristics, we manually classified the business objective of 684 DAOs . For some DAOs, for determining their business objective, dedicated websites, whitepapers and git books with description of the business objectives of the DAOs were used. However, the majority of DAOs do not have a dedicated website or whitepaper with clear business descriptions suitable for categorization of the business objective of the DAO. For these DAOs we looked into all individual transactions and the various voting proposals (over 20.000). We determined the business objectives based on the transaction description, summary information of voting proposals, and added attachments or links in individual voting proposals.

We gathered as much information as possible directly from original sources (dedicated websites or directly of the smart contracts accounts, through blockchain browsers like etherscan.io and polygonscan.com) instead of via an intermediate website to ensure data accuracy as much as possible.

To answer the second research question, testing hypotheses one to three, we used the data gathered in the empirical analysis as described above and did a comparative and statistical analysis on a suitable subset (403 DAOs) of the 12,000 DAOs. The selection was made as displayed in Figure 32.

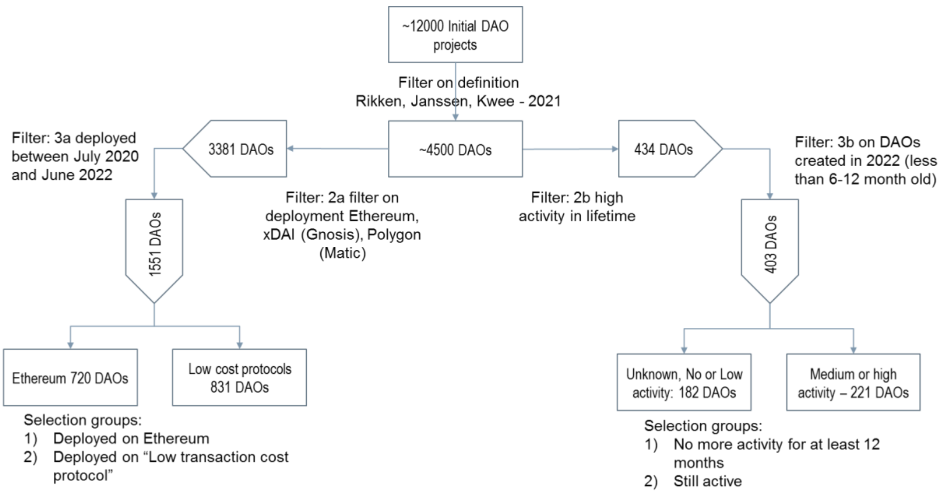

Figure 32: DAO selection for analysis on business objective – goal – long-term viability

The initial list consisted of around 12,000 DAO projects. The first filtering was done based on the DAO definition as provided by Rikken et al. (2023b), resulting in a list of about 4,500 DAOs. Then a filter was performed, excluding all DAOs showing medium, low or no lifetime activity, resulting in a list of 434 DAOs. Finally, a filter was made on DAOs that were only created in the last 6 to 12 months, as we wanted to test on long-term viability. This resulted in a group of 403 DAOs that existed for a longer time and showed higher lifetime activity, meaning that during the lifetime, they had handled more than 10 proposals, with the lowest activity being at least 10 proposals and transactions and highest activity DAOs having more than 1,000 proposals and transactions.

Hypothesis four was answered by performing empirical research on DAO data, based on the list of over 12,000 DAOs of which a larger set of 1,551 were selected, and by analyzing the average price in US Dollar per transaction on the Ethereum network per month. The set of 1,551 was selected based on DAO definition, deployed infrastructure (Ethereum, Gnosis Chain, Polygon), and a confined deployment period. The average transaction price was obtained from Etherscan.io. The period analyzed for answering these questions was mid-2020 until mid-2022 as the number of alternatives for DAO deployment to Ethereum was very limited before mid-2020.

Table 20: Research Data collection

RESEARCH QUESTION	TYPE OF DATA	SEARCH PERIOD	DATA	SOURCES (LINKS)
RQ1 BUSINESS OBJECT CATEGORIZATION	Scientific literature (papers) and grey literature (blogs, transcripts, webpages)	Until of August 2023	500+ pages	Google Scholar, blog links (e.g. medium.com and hackernoon.com)
	Subset of Register of perceived DAOs (over 12.000 in register)	Until August 2022	684 DAOs	apiary.1hive.org, aragon.org, dauhaus.club, daostack.io, pokemol.com, etherscan.io, colony.io, scout.cool, district0x.io,snapshot,io, boardroom.info, tally.io and links to various individual DAOs

RQ2 – INTERNAL GOVERNANCE ELEMENTS - RELATION DAO BUSINESS OBJECTIVE – GOVERNANCE ELEMENTS – LONG-TERM VIABILITY	Subset of Register of perceived DAOs (over 12.000 in register)	Beginning 2019 – August 2022	434 DAOs	apiary.1hive.org, aragon.org, dauhaus.club, daostack.io, pokemol.com, etherscan.io, colony.io, scout.cool, district0x.io,snapshot,io, boardroom.info, tally.io and links to various individual DAOs
RQ2 – EXTERNAL INTRASTRUCTURAL ELEMENTS - ANALYZE INFLUENCE OF ENTANGLE GOVERNANCE ELEMENTS OF APPLICATION (DAO) AND INFRASTRUCTURE (BLOCKCHAIN PROTOCOL)	Subset of Register of perceived DAOs (over 12.000 in register) Overview of transaction pricing per day on the Ethereum network	Mid 2020 – Mid 2022 Mid 2020 – Mid 2022	1551 DAOs	apiary.1hive.org, aragon.org, dauhaus.club, daostack.io, pokemol.com, etherscan.io, colony.io, scout.cool, district0x.io,snapshot,io, boardroom.info, tally.io and links to various individual DAOs etherscan.io

IV. Analysis and Results

When analyzing the relationship between the objective, governance and long-term viability of DAOs, we analyzed 403 DAOs. Among these 403 DAOs, approximately half of them showed continuity of activity over time, while the other half did not, suggesting a lack of long-term viability. To test our hypotheses and answer our research questions, we performed both a comparative data analysis (H1-3) and statistical analysis using Pearson Correlation analysis (H4), binomial logistic regression and Chi-Square Tests (H1 and H2).

IV.1 DAO business objective categorization

To analyze the relation between business objectives, governance model, and long-term viability of DAO, we first have to classify them. In previous research, the classification of governance elements was already suggested, but business objectives, despite the overall common functionalities of transaction of value and notary functions of DAOs, are multifold (Rikken, Janssen, et al., 2023a). For DAOs, no clear categorization has been established for business objectives. The Chain analysis team describes DeFi, Social Clubs, Grant-Makers, Play-to-Earn initiatives (P2E), NFT generators, Venture funds, Charities and Virtual Worlds (Metaverses) as main business objectives (Chainanalysis, 2022a). Harmony (2022) mentions Wallets, Research, Community, Validator, Developer, Basic and Matching, whereas Smith (2022) categorizes them in 5 main categories, DeFi, Investment, Grant/Launchpad, Collector and Social. Wright (2021) mentions Disrupting Finance & tokenized assets, Arts, Reimagining Work, Automating Enforcement of Ethical Policies in business processes and Restructuring the basis of governance and democracy. Hennekes (2022) mentions eight main categories, Protocol, Grant, Philanthropy, Social, Collector, Venture, Media and SubDAOs, and Stelzner (2022) describes four main use cases, Investment, NFT Platforms, Single-Purpose and Security Vaults. Ding et al (2023) use eight categories, Collector, Grant, Media, Protocol, Philanthropy, Venture, Social and Sub DAOs. Appel and Grennan (2023) describe three main categories, DeFi, Web3 and Infrastructure (Appel & Grennan, 2023). Pena et al. mention (2023) Granting, Service, Peer-Production and "Other". Based on our observations and descriptions of various DAOs, more (sub)categories could be added, being Oracle (Augur, Tellor), Impact (DAOctopows, EarthFund, BanyanDAO), Charities (MedHack, UnicornDAO), Political (3OH DAO, OMA3 DAO), Co-Ownership (BroncoDAO, MBS), CCO – crowdfunding (DAOHAUS CCO, DAOSquare RICE CCO) and broader Web3Platform DAO representing a mix of objectives (GEMs).

The various categories mentioned by the different authors demonstrate substantial overlap. We looked at classifications in previous non-DAO research to narrow down the number of categories. An overview of five main business object types is mentioned. Organizations can be categorized in economic objective, social objective, human objective, national objective or global objective (Chand; Craig & Campbell, 2012). Taking the wide range of described business objectives into account, we propose the division into eight categories for business objectives of DAOs with the various subcategories as shown in Table 21 below.

Table 21: Business Objective Categories of DAOs

Business Objective Category	General Aim	Description	DAOs business objectives as described in various sources
Economic	For-profit organizations	DAOs that aim to create a profit for their tokenholders in the form of cryptocurrencies, (liquidity pool) tokens and stablecoins	DeFi, Play2Earn, Venture, Investments, CCO, Media, Developer, Work, Service, Co-ownership, Product, Protocol (dApp), Peer-Production
Social	Common/social goal without a profit goal	DAOs where the participants work together towards a common/social goal without a profit goal	Clubs, Social, Matching, Hackathon, Peer-Production
Research & Development	Collecting and sharing knowledge	DAOs that aim to collect funds and distribute it for research and development work for the common good - non-profit	Grants, Oracle
Human	General purposes non-profit	DAOs where the primary goal is to give back to society of the collected funds	Charities, Philanthropy, Basic, Impact
National	General utilities on a national level	Democratic decisions of political parties aimed to increase citizen participation and general use decentralized national notary functions	Political, Restructuring basis of governance and democracy – General use or national notary functions
Global utilities	Global general utilities	DAOs that aim to set up and maintain global general utilities that are open to use for anyone like blockchain infrastructures and virtual worlds	Metaverses, Infrastructure, Protocol (Infrastructure)
Art	Art creation, ownership and trading related business objective	DAOs that specifically aim at art (collective ownership, creation, management and distribution)	NFT platforms, Art
Other	Other business objectives than the 7 other categories	Either the DAO has combined business objectives cross-category or does not fit the other descriptions as they facilitate a too narrow function or single process	Web3 Platforms (multiple business objectives e.g., Lyngyo), Sub, Singe-Purpose(e.g., constitution DAO), Validator, Collector, Wallet (e.g., Raid Guild War Chest), Automating Enforcement of Ethical Policies in business processes

These categories provide a structured approach for analyzing DAOs on business objectives, although they are not necessarily mutually exclusive for some individual DAOs. DAOs can have multiple objectives. Either within a category, e.g. multiple economic objectives like P2E and investment, or cross-category, e.g., Global and Economic like Metaverses and DeFi. Also, in classifying DAOs' business objectives there is always a chance of subjectivity. Different researchers can classify individual DAOs differently. These eight main categories can be divided into two main categories: economic DAOs and non-economic DAOs. Non-economic DAOs do not have an economic business objective, so all the business objective categories other that economic DAOs (from "social" to "other") are combined.

IV.2 DAO Governance Analysis Framework

Building on previous research by Rikken et al. (2023a), we made a DAO governance analysis framework where three components, the components' elements, and the dimensions per element are categorized. This framework was used for the classification of DAOs for further empirical analysis of their governance in our research. The framework is displayed in Table 22 below.

Table 22: DAO governance analysis framework – dimensions highlighted in grey were previously tested by Rikken et al. (2023a, 2023b) and thus left out of scope during this research

Components	**Component Elements**	**Dimensions**						
Accountability	*# Tokenholders*	Ratio scale (0 – indefinite)						
	Voting Power Distribution	Dictatorship			Semi-Dictatorship			Democracy
Decision model	*Voting Mechanism – lv 1*	Weighted voting				Mixed		Non – Weighted voting
	Voting Mechanism – lv 2	Share like		Reputation		Mixed		Direct Democracy/ Membership
	Quorum	Yes		No		Progressive		Multi-layer
	Quorum %	Ratio scale (0-100)						
Incentives	*Level 1*	Direct			Indirect			No
	Level 2	Token	Fee	Rep	Staking	Token Value	Combination	None

As voting power distribution combinations are not linear and possible combinations can be endless, the dimensions of voting power distribution are categorized. These dimensions are based on the division of Rikken et al. (2023a) (Dictatorship, Semi-Dictatorship or Democracy), whereas in a Dictatorship one tokenholder has all the voting power in a DAO and no decisions can be taken without this tokenholder. In a Semi-dictatorship, there is one majority tokenholder. If this tokenholder refrains from voting, the other tokenholders have enough potential quorum to reach decisions, but if the majority tokenholder votes, it will always go in their direction. In a democracy, a consensus of multiple tokenholders is always needed to pass votes (Rikken, Janssen, et al., 2023a). It should be taken into account that, although voting power distribution might seem democratic, a person or instance can hold multiple accounts and thus, has a higher concentrated voting power than it appears in the forefront (Fritsch et al., 2022).

The decision model component has two component elements: voting mechanism and quorum. On the highest level (lv 1) voting mechanism can be distinguished in weighted voting vs non-weighted voting. Voting power in DAOs is commonly represented by a voter's tokens in an account. In weighted voting models, the weight per voter account can differ. In non-weighted voting models, each voter account, in principle, has one vote. This voting mechanism can be detailed (lv 2) in weighted voting consisting of share-like or reputation-like voting models. In share-like weighted voting, the tokens representing the voting power can be earned or bought and traded against a market price. Having more tokens means more voting power. In reputation-based voting, tokens can be earned and thus, voters can have different voting weights but cannot be traded and don't have a market value. In non-weighted voting there is a direct democracy or membership structure where all tokenholders have an equal amount of voting power and tokens cannot be traded. In some cases, delegation of a voter's vote is possible, where they can withdraw their delegation and re-delegate it to another delegate. Sometimes we see a mix of weighted and non-weighted voting within one DAO. Weighted voting models can also have delegation possibilities.

Besides voting mechanism, the other decision model component element is quorum. We can divide this into two levels. The highest level is the existence of a quorum system. Dimensions are yes, no, progressive or multi-layer. If there is a quorum, a certain percentage needs to have voted and voted in favor for a decision to pass. If there is no quorum system, regardless the number of tokens that voted, the result of the vote will count as the outcome of the decision. In progressive voting, as found in DAOs deployed using DAOstack, based on a prediction pool on the outcome of the vote, the vote is either with quorum or without (Faqir-Rhazoui, Arroyo, et al., 2021; Rikken, Janssen, et al., 2023a). We see mixed or multi-layer forms with both quorum and voting processes, sometimes depending on the type of vote (strategic vs. operational) (Zhao et al., 2022b). If there is a quorum, the quorum percentages can differ. Therefore, the dimension of quorum in percentages if applicable in a DAO is a ratio scale from 0% to 100%.

Incentives are also detailed into two levels. The first level is a categorization of direct, indirect or no incentive. A *direct* incentive is when, in actively governance participation, an incentive in cryptocurrency or tokens is given. An *indirect* incentive is if there is no direct incentive mechanism, but being active in DAO's governance could create value indirectly, through the value of tradeable governance tokens rising (Appel & Grennan, 2023). The third dimension is the absence of an incentive mechanism. There is no direct or indirect gain from participating in governance, other than the DAO is long-term viable (Rikken, Janssen, et al., 2023a).

The incentive component element is further detailed in the following dimensions. Direct incentives can be in the form of additional (tradeable) governance tokens of that DAO, a fee in the form of payment (e.g., stablecoin or cryptocurrency) or non-tradeable reputation tokens. Indirect incentives can be in the form of staking revenue or token value of the governance token or a combination thereof. By staking tokens one obtains the right to vote and gets a fee for staking, regardless of whether they are actively voting. This could thus be argued as a direct incentive as well, but differs as staking reward is given regardless being active in the governance process. The token value in itself can be seen as indirect incentive. Suppose one actively participates in the governance of a DAO and helps to increase the long-term viability of a DAO, this can then be positively reflected in higher governance token value that the token holder can trade. With no incentive, there is no incentive to participate in the governance, the token is not tradeable, has no market value, and no direct incentive is given (Rikken, Janssen, et al., 2023a).

IV.3 Interrelationships Business Objective, Governance Elements, Long-term Viability

The results of the comparative analysis of the DAOs regarding the first hypothesis, the relation between business objective and long-term viability, are displayed in Table 23 below. Please note that in our categories in the table, besides the categories described in section two, two other categories were added: test and unknown. Test implies that these DAOs were used for test purposes. Unknown means it was not possible to derive the business objective based on the information on hand. These are presented as separate categories.

Table 23: DAO Analysis Business Objectives - Long-term Viability

		Categories	Total High LT Activity			Continuation of Activity (High/Medium)			Loss of activity (Low/None)			Δ to total	Δ to cont'd	Survival Rate per category
Goal		Economic	403	161	40,0%	221	96	43,4%	182	65	35,7%	-4,2%	-8%	59,6%
		Social		35	8,7%		22	10,0%		13	7,1%	-1,5%	-3%	62,9%
		Research & Development		49	12,2%		27	12,2%		22	12,1%	-0,1%	0%	55,1%
		Human		4	1,0%		1	0,5%		3	1,6%	0,7%	1%	25,0%
		National		0	0,0%		n/a	n/a		n/a	n/a	n/a	n/a	n/a
		Global		20	5,0%		17	7,7%		3	1,6%	-3,3%	-6%	85,0%
		Art		16	4,0%		16	7,2%		0	0,0%	-4,0%	-7%	100,0%
		Other		9	2,2%		6	2,7%		3	1,6%	-0,6%	-1%	66,7%
		Test or unknown		109	27,0%		37	16,7%		72	39,6%	12,5%	23%	33,9%

As various DAO business objective categories were quite small, as stated earlier, we aggregated them into three main categories for statistical analysis. Economic DAOs, non-Economic DAOs (social, research & development, human, global, art, and other combined) and Test or unknown.

For the binomial logistics regression test, we ran the model with Activity Level as the dependent variable:

- 0: None or Low (loss of activity)
- 1: Medium or High (continuation of activity)

The independent variables are in categorical scales:

- Business objective (Economic, Non-Economic, Test or Unknown)
- Incentive (Yes, No, Indirect, Unknown)
- Decision Level 1 (Weighted, Non-Weighted, Unknown/Mixed)
- Voting Power Distribution (Democratic, Non-Democratic – being combination of dictatorship and semi-dictatorship)

Hypothesis 1

H1 – Economic DAOs demonstrate lower long-term viability than non-economic DAOs.

Based on our data, we could see differences DAOs business objectives and long-term viability. Especially, the Art and Global categories stand out with percentages of total DAOs with continued activity of 85% and higher. The human DAO category has very low continued activity rates, but there were only four DAOs in this category, which could significantly influence the outcome. Categories Economic, Social, Research & Development and Other all have rates around 55% to 66% continued activity. When aggregating them, we see a survival rate of 67% for all non-economic DAOs against 60% for the economic DAOs.

The logistic regression model was statistically significant, $\chi^2(8) = 58.507$, $p < .001$. The model explained 18.1% (Nagelkerke R^2) of the variance in DAO's continuation of activities and correctly classified 67% of cases. Non-economic DAOs were 0.415 times more likely to exhibit continuous activities than economic DAOs, significant at p=0.002. Other significant results that are associated with the continued activities of DAOs are weighted (p=0.011), non-incentive (p<0.001), and democratic DAOs (p=0.081).

This means that hypothesis 1 is confirmed. Non-economic business objectives seem to be more suitable as DAO setup than economic DAOs. For hypothesis 1, note that the number of DAOs in some non-aggregated categories under the non-economic DAOs was very low.

Hypothesis 2a

H2a – Democratic voting power distributed DAOs exhibit greater long-term viability in non-economic DAOs than economic DAOs.

Table 24: Long-term viability analysis on democratic voting power distribution

	Categories	Total High LT Activity	Continuation of Activity (High /Medium)	Loss of activity (Low/None)	Survival Rate per category	In general
Voting power distr	Economic	140	85	55	60,7%	60%
Democracy	Non - Economic	117	82	35	70,1%	67%
321	Test or Other	64	22	42	34,4%	34%

Regarding hypothesis 2a, our data substantiates that non-economic DAOs exhibit a higher percentage of long-term viability when voting power distribution is more evenly distributed than in economic DAOs. The general long-term viability is 67% in non-economic DAOs, which rises to 70% when a democratic voting power distribution is in place. DAOs with an Economic business objective with democratic voting power distribution show similar long-term viability to the overall group of economic DAOs. Where 60% of the overall group is long-term viable, in the democratic voting power distribution, this stays 60%.

In the statistical analysis, we compared the means of two categorical variables (business objective and activity level) using Chi-Square test. The results are shown in the tables below. Importantly, from the 'Chi-Square Tests' table, you can see that $\chi(2) = 22.135$, $p < .001$. From Phi and Cramer's V values, we can see that the strength of association between variables is very strong.

Table 25: Statistical tests – H2a

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	22,135[a]	2	<,001
Likelihood Ratio	22,083	2	<,001
Linear-by-Linear Association	7,374	1	,007
N of Valid Cases	321		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 26,32.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,263	<,001
	Cramer's V	,263	<,001
N of Valid Cases		321	

This means there is a statistically significant association between business objectives and activity level for the democratic voting power distributed DAOs. H2a is confirmed at p<0.001. One does need to take into account that additional voting power centralization elements like multiple accounts per token holder (more voting power in practice) were not taken into account in this analysis.

Hypothesis 2b

H2b - Share-like decision models exhibit greater long-term viability for economic DAOs than for non-economic DAOs.

Table 26: Long-term viability analysis on share-like decision models

	Categories	Total High LT Activity	Continuation of Activity (High/Medium)	Loss of activity (Low/None)	Survival Rate per category	In general
Decision lvl 2	Economic	106	68	38	64,2%	59%
Share like	Non - Economic	101	72	29	71,3%	67%
273	Test or Other	66	25	41	37,9%	34%

The data analysis for hypothesis 2b shows that, although the share-like decision models for economic DAOs benefit the long-term viability of economic DAOs, this is not significantly higher, even slightly lower in percentage than for non–economic DAOs. The long-term viability with share-like decision models rises from 59% to 64% for economic DAOs and from 67% to 71% for non-economic DAOs.

Table 27: Statistical tests – H2b

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	19,631[a]	2	<,001
Likelihood Ratio	19,441	2	<,001
Linear-by-Linear Association	8,888	1	,003
N of Valid Cases	273		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 26,11.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,268	<,001
	Cramer's V	,268	<,001
N of Valid Cases		273	

Table 27 shows that $\chi(2) = 19.631$, $p < .001$. The Phi and Cramer's V values show a very strong association between the variables (business objectives and share-like decision models). This means that there is a statistically significant association between business objective and activity levels for share-like decision DAOs, where non-economic DAOs show a higher continuation of activity than economic DAOs. Therefore, hypothesis 2b cannot be confirmed.

Hypothesis 2c

H2c – Membership-based decision models exhibit greater long-term viability than reputation-based decision models in non-economic DAOs.

Table 28: Long-term viability analysis on decision models in non-economic DAOs

	Categories	Total High LT Activity	Continuation of Activity (High/Medium)	Loss of activity (Low/None)	Survival Rate per category	In general - average non economic
Decision lvl 2	Democratic 1-1	18	14	4	77,8%	67%
Non-Economic 31	Reputation	13	3	10	23,1%	67%
133 inc share	Share (101) & Mixed (1)	102	72	30	70,6%	66%

When analyzing the data for hypothesis 2c, we can observe a clear difference in long-term viability of non-economic DAOs with a democratic or membership decision model versus with a reputation-based model. The membership decision model shows a long-term viability for non-economic DAOs of almost 78% compared to 66% of all non-economic DAOs. Reputation-based decision models show a much lower long-term viability of 23% compared to 66% in general.

Table 29: Statistical Tests - H2c

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	9,120[a]	1	,003		
Continuity Correction[b]	7,045	1	,008		
Likelihood Ratio	9,570	1	,002		
Fisher's Exact Test				,004	,004
Linear-by-Linear Association	8,826	1	,003		
N of Valid Cases	31				

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 5,87.

b. Computed only for a 2x2 table

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,542	,003
	Cramer's V	,542	,003
N of Valid Cases		31	

The Chi-Square test, see Table 29, shows $\chi(2) = 9.120$, $p = .003$. From Phi and Cramer's V values, we can see that the strength of association between the variables is also strong. H2c is also statistically confirmed at $p<0.05$. This confirms hypothesis 2c, that membership or democratic decision models contribute to the long-term viability of non-economic DAOs.

Hypothesis 2d

H2d – Non-incentivized DAOs exhibit greater long-term viability for non-economic DAOs than economic DAOs.

Table 30: Long-term viability analysis on non-incentivized DAOs

	Categories	Total High LT Activity	Continuation of Activity (High/Medium)	Loss of activity (Low/None)	Survival Rate per category	In general
Decision lvl 2	Economic	42	23	19	54,8%	59%
No incentives	Non - Economic	23	15	8	65,2%	67%
94	Test or Other	29	8	21	27,6%	34%

The data for hypothesis 2d shows a clear difference between the long-term viability of economic DAOs and non-economic DAOs when there is no incentive mechanism in the governance in place. The long-term viability of non-incentivized non-economic DAOs is 65%, whereas this percentage for economic DAOs is 55%. Therefore, non-incentivized governance elements look more suitable for non-economic DAOs.

The Chi-Square test, Table 31, shows $\chi(2) = 8.30$, $p = .016$. Phi and Cramer's V values display a rather strong association between the variables business objective and activity level for the non-incentive DAOs. This means that there is a statistically significant association at $p = .016$ between business objective and activity level for the non-incentive DAOs. H2d is also confirmed at $p<0.05$.

Table 31: Statistical Tests - H2d

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	,297	,016
	Cramer's V	,297	,016
N of Valid Cases		94	

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	8,300[a]	2	,016
Likelihood Ratio	8,544	2	,014
Linear-by-Linear Association	4,269	1	,039
N of Valid Cases	94		

a. 0 cells (0,0%) have expected count less than 5. The minimum expected count is 11,26.

Returning to the initial proposition that choices in governance designs (a combination of elements like incentives and decision processes) are better suited for specific business objectives in DAOs, can be confirmed overall. Hypotheses 2a – 2d clearly show differences in long-term viability of DAOs with different business objectives. Especially on voting power distribution, decision model and incentives, we do see differences when taking business objectives of DAOs into account.

Thus, the business objective itself, as well as differences in governance components and elements with the business objective as a moderating variable, can affect the long-term viability of DAOs.

Relationship DAO business objectives and choice of blockchain protocol

The third hypothesis was on the relationship between the choice of infrastructure (blockchain protocol) and business objective of DAOs.

> H3 – The business objective of a DAO influences the choice of blockchain infrastructure the DAO is deployed on.

Table 32: Relation Business Objective and Choice of Infrastructure

	Art	Economic	Global	Human	Other	Research & Development	Social	Test & Unknown	Grand Total
Ethereum	2	99	4	3	4	32	21	64	229
	1%	43%	2%	1%	2%	14%	9%	28%	
Matic	6	8	2			4	3	8	31
	19%	26%	6%	0%	0%	13%	10%	26%	
xdai	7	51	12	1	5	12	11	37	136
	5%	38%	9%	1%	4%	9%	8%	27%	

When analyzing the infrastructure used and business objectives, we do see some differences, although most of the percentages of types of business objectives are quite similar per infrastructure. The differences are predominately in Art related DAOs, which seem to appear relatively more on Polygon (Matic) and Gnosis-Chain (xDAI) than Ethereum. Ethereum seems to have the highest percentage of Economic DAOs with 43%, although Gnosis Chain with 38%, also has a high representation of Economic DAOs. The hypothesis can thus partially be confirmed.

Both Ethereum and Gnosis-Chain are EVM-based, meaning they can handle the same standards. Transaction costs do differ. Gnosis chain is a low transaction cost infrastructure with average transaction costs below $0.01 per transaction and Ethereum is expensive with transaction cost averaging over $15 from July 2020- June 2022. Deducting the above, transaction costs for Economic DAOs don’t seem to be a clear denominator for the choice of infrastructure to build a DAO on, although this could influence the governance of the DAO in itself.

Analyzing deployments per business objective per infrastructure over time is a venue for future research. Such analysis can reveal whether any discernible trends in changes in deployment percentages over time can be identified.

IV.4 Interrelationship Governance Elements Infrastructure – Governance Elements DAOs and their correlation

Hypothesis 4

> H4 - The “gas-price” of an infrastructure affects the governance of DAO applications due to the entanglement of infrastructure and application.

As stated, due to the entanglement of DAO applications governance and the deployed infrastructure, changes on infrastructure level could have an influence on the application level. We looked at the relation between average transaction price on Ethereum per month in US dollars and the number of DAOs deployed in that same period on Ethereum (mainnet). We further looked at the number of deployments of new DAOs on two low-cost protocols (Gnosis-Chain and Polygon) in the same period. The deployments per chain and transaction costs on Ethereum mainnet are visualized in Figure 33.

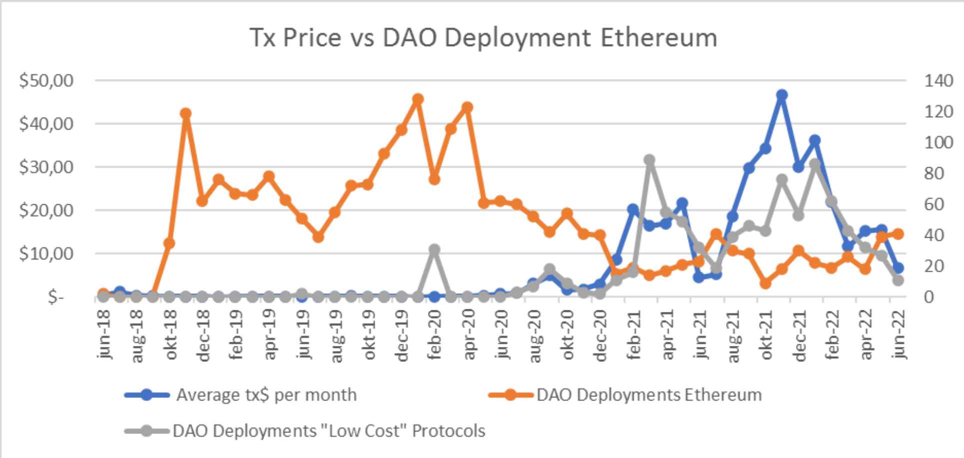

Figure 33: Average transaction pricing Ethereum and DAO deployments Ethereum and "Low Cost" protocols

When analyzing this data, we observed the following. The first important observation is the relation between the average Ethereum transaction cost per month and the number of deployed DAOs on Ethereum. As shown in Figure 33, when Ethereum transaction prices are rising, there is a decline in number of deployments of DAOs on Ethereum. As of 2020, alternative, low transaction cost, infrastructures, Polygon and Gnosis-Chain rose. The deployment of DAOs on those chains seems to correlate with transaction cost. A rise in transaction cost on Ethereum leads to a rise of DAO deployments on low-cost protocols. The other way around, with a decline in Ethereum transaction prices, the number of DAO deployments on Ethereum rise and number of deployments on low-cost protocols declines. We statistically analyzed the correlation between the three data sets using Pearson Correlation analysis. In this analysis, correlation is scored between -1 and 1. A positive correlation means a direct positive relation (A goes up, B goes up). A negative correlation implies a reverse relation (A goes up, B goes down). The closer the correlation is to -1 or 1, the stronger the correlation. The outcome of the analysis is displayed below in Table 33.

Table 33: Correlation - Transaction Pricing Ethereum - Deployment DAOs Ethereum - Deployment DAOs low-cost protocols

Time period mid 2020 - mid 2022	Correlation Eth$ - Ethereum Deployment	Correlation Eth$ - Low-Cost Deployment	Correlation Ethereum Deployment - Low Cost
Pearson Correlation	-0.670	0.790	-0,696
Sig. (2-tailed)	<0.001	<0.001	<0.001

Our analysis reveals a medium to strong correlation between all datasets and all correlations are statistically significant.

The direct influence of transaction pricing on deployments also suggests a direct relationship between transaction cost and DAO activity. As transaction cost cannot be influenced by DAOs themselves, as this is part of the governance of the infrastructure, this could pose the risk of inefficient voting as a result of low engagement by tokenholders in DAOs (Arnaucube, Escrich, Baig, & Kampa, 2022; Faqir-

Rhazoui, Ariza-Garzón, et al., 2021). This leads to potential security risks or even voting absence as voting and decisions to govern a DAO become too expensive. This in turn, can influence the long-term viability of DAOs.

Therefore, the governance of DAOs, due to the entanglement of governance of application and infrastructure, cannot be seen as separate from the infrastructure and hypothesis four can be confirmed. In future research, this can be researched on voting level and analyzing even more infrastructures using a similar approach, as our analysis focused on DAO deployment data.

V. Discussions, implications and limitations

V.1 Discussion

Building on previous research that introduced a preliminary theoretical model of governance elements and their relationship to long-term viability of DAOs (Rikken, Janssen, et al., 2023a, 2023b) and other DAO governance researchers (Appel & Grennan, 2023; Faqir-Rhazoui, Ariza-Garzón, et al., 2021; Fisch & Momtaz, 2022; Zhao et al., 2022b), combined with our findings, we present a theory of elements influencing the long-term viability of DAOs in Figure 34.

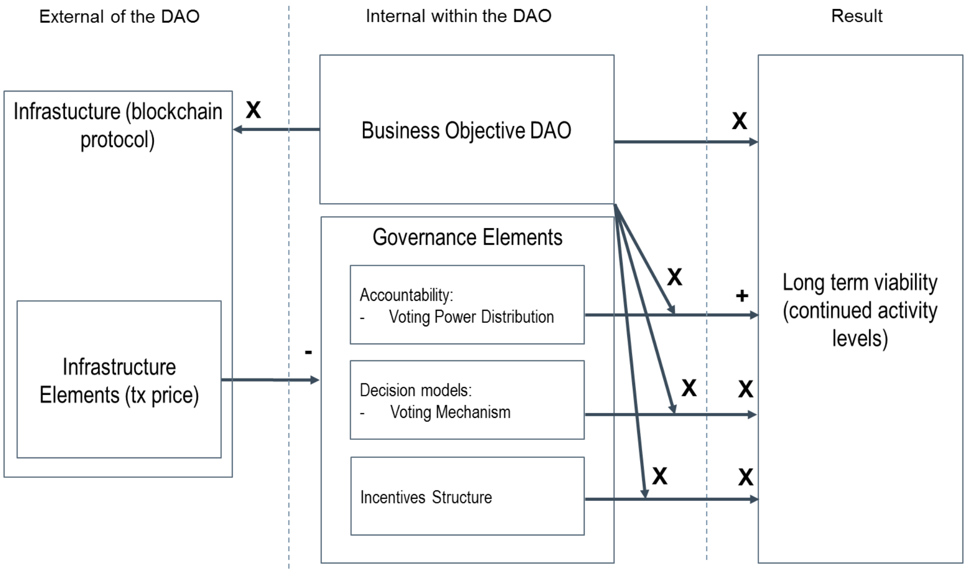

Figure 34: theory governance elements influencing long-term viability DAOs. + indicates positive relationship (A goes up/down B goes up/down), - indicates negative relationship (A goes up B goes down and vice versa), X indicated a categorial relationship.

Our theory shows the potential influence of the various factors on the long-term viability. As these are often in categories (instead of ratio scales), no mathematical connection can be shown for various relations indicating a form of linear or other arithmetic relation. In our theory, only transaction (tx) price as input and output variables are measured on a ratio scale and voting power distribution shows a mathematical relation. A "+" indicates a positive correlation (A goes up, B goes up). A "-" represents a negative correlation (A goes up, B goes down, and vice versa). An X indicates a categorical relationship or a nominal scale. Depending on the category of the independent variable, the relationship with the dependent variable is either positive or negative.

The relation between governance elements (incentives and governance set up) and long-term viability that was also found in other studies (Appel & Grennan, 2023; Rikken, Janssen, et al., 2023a; Zhao et al., 2022b). Appel & Grennan (2023) and Rikken et al. (2023a) found that inclusive decision-making positively affects DAOs' performance, which is confirmed in our study. The conclusion of the studies by Rikken et al. (2023a) and Zhao et al. (2022b) that voting power distribution affects the long-term viability, is also confirmed in this research. However, our study reveals what previous studies only suspected, that this should always be taken into account in combination with the business objective. Specific combinations of business objective and governance elements can lead to different effects on long term viability.

The findings of our research demonstrate that "gas-cost" (transaction cost) can influence DAOs deployment. The transaction cost thus could influence governance of the DAO. The "gas-cost" (transaction cost) is not in control of the application, but under control of the infrastructure governance structure. This relation between transaction cost ("gas cost") and activity, although in a much narrower scope (focusing on Ethereum only and, leaving fluctuation of cryptocurrency price in dollars out of scope), was also shown in other research (Faqir-Rhazoui, Ariza-Garzón, et al., 2021). Our research thus confirms this relation. By deducting both studies, one can conclude that when transaction prices ("gas cost") go up (either more gas per calculation or a higher price for the local cryptocurrency), it is likely that this negatively affects the governance of the DAO as decision-making (voting) becomes more expensive. This then creates a negative incentive to participate in the governance of the DAO by tokenholders.

V.2 Practical implications

To the best of our knowledge, we are the first to create a theory that considers multiple elements (business objective, governance elements and infrastructure elements) for DAOs. Based on our extensive empirical inductive research, we conclude that the business objective of the DAO can influence the long-term viability. As business objectives are categorized, the theory indicates the relation with an X (Figure 34). Organization's business objective should be considered when choosing a DAO structure as certain business objectives negatively influence the long-term viability, thus another structure could be more suitable.

Business objective and governance elements should always be considered in combination when designing a DAO's governance setup. Having added the element of business objectives as a moderating variable, we find that voting mechanisms, voting power distribution, incentive structures and their impact on long-term viability seem to differ per business objective category. Business objective, voting mechanisms and incentive structure are categorized on a nominal scale and thus indicated with an X in our theory. Voting power distribution is presented as an ordinal scale. As more democratic voting power distribution seem to positively affect the long-term viability of DAOs, a + sign was added.

Finally, due to the entanglement of infrastructure and application potentially influencing the governance of the application, a thorough analysis of the infrastructure a DAO wants to deploy on is crucial. This should especially focus on the relation between transaction costs ("gas fees") in dollar or euro prices over various blockchain infrastructures, as this could influence voting behaviour in DAOs.

V.3 Scientific implications

To the best of our knowledge, this study is the first and most extensive empirical research on DAOs, considering the combinations of business objective, governance components and entanglement with infrastructure in relation to the long-term viability of DAOs. In our research, only the business objective is used as moderating variable, so we recommend follow-up research to further test individual and integrated governance elements relationships. Changes in one governance element could influence other governance elements and thus should be tested as moderating variables amongst themselves in more detail.

Future research should also focus on integration with other studies and delve into off-chain governance DAOs (e.g., Snapshot-based) to ascertain if similar behaviour can be detected. These off-chain governance DAOs themselves could have different behaviour as a result lack of "gas-cost" in voting and the non-autonomous execution of decisions character of these types of DAOs. Also, in future research, it is essential to incorporate governance elements or forms that were omitted due to their absence in practical implementation or their non-existence in the DAOs observed over an extended period in our dataset.

Another assumption in our research and theory is that all tokenholders are unique entities (persons/businesses). There could be coalitions of persons or instances holding multiple account addresses and thus actually having a higher voting power (Fritsch et al., 2022). This should be taken into account in future research.

Moreover, despite our large dataset, we suggest revisiting this business objective analysis with an expanded and updated dataset in a few years' time. This is because certain categories still exhibit a relatively low number of DAOs, considering the newness of DAOs themselves. Gathering a higher number of high activity DAOs takes time, yet holds potential for uncovering valuable new insights. It also reduces the likelihood of subjective bias in business objective allocation, which may impact the analysis, and helps to mitigate any temporary trends associated with specific business objectives. For instance, the relatively high number of Art DAOs with long-term viability might be attributed to the extraordinary popularity of NFT projects during the 2020-2022 period.

Regarding the entanglement of DAO applications and infrastructure governance models, as we researched the deployment of DAOs in relation to transaction prices, we propose delving deeper into this interplay. Specifically, examining the actual DAO tokenholders voting in relation to transaction pricing could gain a more comprehensive understanding of this relationship, preferably across various infrastructures. Ideally, to further test the theory, the methods and analyses of this research and Faqir et al. (2021) should be combined.

Furthermore, we recommend looking at other elements related to the infrastructure and application governance entanglement, specifically the upgradeability of smart contracts on the chosen infrastructure. Since the business rules of DAOs are encoded in smart contracts, the (lack of) possibility to upgrade these smart contracts over time due to necessary changes in the DAO's governance could also influence its long-term viability.

VI. Conclusions and further research

DAO enable governance-by-design by embedding the governance in the infrastructure and application. Our empirical research, starting with over 12,000 DAO projects, clearly demonstrates that business objective and governance components and elements in combination with a DAO's business objective can influence the long-term viability.

The primary findings of our study highlight that non-economic DAOs exhibit superior long-term viability compared to economic DAOs. This suggests that DAO structures where profit does not seem to be the main goal are more suitable than when profit is the main goal. Even more, we conclude that specific configurations of governance designs (combination of elements like incentives and decision processes) are better suited to certain business objectives of DAOs:

- In non-economic DAOs, democratic voting power distribution has a positive effect on long-term viability;
- In non-economic DAOs, membership-based models (1 account 1 vote) have a positive effect on long-term viability compared to reputation-based models (weighted voting per account);
- Non-incentive governance models have a better long-term viability in non-economic DAOs than in economic DAOs;
- Share-like decision models are not necessarily more suitable for economic DAOs than non-economic DAOs.

Furthermore, we conclude that the element of transaction cost (“gas-cost”), being under control of the infrastructure the DAO is deployed on, due to the entanglement of infrastructure and application, could influence the long-term viability of a DAO. We find a medium to high and significant correlation between transaction cost and the number of deployments on Ethereum and deployments on two low-cost networks (Polygon and Gnosis-Chain). Therefore, designing and setting up a DAO will require a thorough integrated analysis of the infrastructure that is being used, the business objective of the DAO as well as the governance components and elements in combination with the business objective. A practical recommendation would be to first pick a DAO’s objective, then its form and when choosing an infrastructure, do take the effect on governance of infrastructure choice into account.

We combine the observations and conclusions of our research with those of other researchers into a theory on the relation of internal and external factors to the DAO (business objectives, infrastructure, governance elements) on its long-term viability, which can be used in the design of a DAO. In the process, we made a business objective classification and governance analysis framework that can be used as the basis in future research toward DAOs as presented in this paper.

Governance-by-design is a new phenomenon. Our overview of governance mechanisms shows that there is a need for a new governance theory for DAOs that include external infrastructural elements and business objectives. As more DAOs are being deployed and new DAO models (new business objectives, governance elements and infrastructures were DAOs can be deployed on) arise, we recommend testing our theory with a larger longitudinal dataset over time. Finally, we recommend that off-chain governance structure DAO projects be tested against our theory to see if they behave similarly to on-chain DAOs.

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7. Conclusion – Discussion - Recommendations

7.1 Conclusion

The sharp rise in the number of Decentralized Autonomous Organizations shows that there is great potential in this form of on-chain collaboration, governance, and transaction of value. Despite this growth, not all DAO projects are viable in the long-term. There was no theory on long-term viability of DAOs in relation to governance elements, business objectives and infrastructure elements entanglement. Data shows that a significant number of DAOs fail to show long-term viability after an initial reasonable amount of activity, and activity stops. This is not only confirmed by our data, but also, after initial enthusiasm, the first critical notes come from the early DAO adopting communities on the viability of DAOs. These critical notes are related to the suitability of DAOs for certain business objectives (Sun, 2022), or they are related to the suitability of certain governance models for DAOs (Ivanov, 2022). Also, there is still no clear consensus of what a DAO entails. We, therefore, based on theoretical and empirical research, developed a comprehensive definition and conclude that:

"A DAO is a system in which storage and transaction of value and notary (voting) functions can be designed, organized, recorded, and archived and where data and actions are recorded and autonomously executed in a decentralized way" (Rikken, Janssen, et al., 2023b, pp. 7-8).

As our research states, the long-term viability of DAOs can be influenced by many factors. We conclude that, besides business objective and governance elements within the direct control of a DAO project, infrastructural elements beyond the direct control of a DAO could also influence the long-term viability of a DAO. This is due to the entanglement of infrastructure and application level in blockchain-based applications. Therefore, throughout this thesis, we have worked towards our main goal:

"Develop a theory for explaining the long-term viability of decentralized autonomous organizations on public permissionless blockchains in relation to governance and infrastructure elements and business objectives."

By means of four scientific articles, as outlined in the table below, we answer the research questions in this thesis. The comprehensive analyses in the four papers enable us to draw key conclusions that lead to the development of a theory on internal and external elements influencing the long-term viability of DAOs.

Table 34: Overview of research papers

Paper	Focus	Main Research Questions	Key Findings	Implications	Contribution
Governance challenges of blockchain and decentralized autonomous organizations	Understanding governance challenges of blockchain and blockchain-based applications	What are governance challenges in blockchain-based applications?	Possible entanglement infrastructure and applications. True new questions might arise with DAOs as a result of fuzzy accountability	Factors outside of the control of a DAO application should be taken into account when designing governance as well	Made governance challenges explicit on the infrastructure level, created an overview of types of dApps and their specific governance challenges, and classified the challenges in layers and stages.
Ins and out of decentralized autonomous organizations	Unraveling definitions, characteristics and emerging DAO developments and analyzing the effect of decentralization on long-term viability	What is a comprehensive definition of DAOs?; How does the decentralized characteristics of DAOs influence the survivability of a DAO?; What are emerging developments around DAOs, and what is their potential implications on the existing DAO definitions and characteristics?	Found that level of decentralization in tokenholders can influence long-term viability. Showed emerging trend of off-chain governance.	First scientific empirical number on decentralization of DAOs. Showed possible risks of emerging development on the autonomy of DAOs	Created a comprehensive DAO definition, showed the relation between decentralization and long-term viability, and identified trends and risk thereof.
The influence of governance elements on the long-term viability of Decentralized Autonomous Organizations (DAOs) – An empirical analysis	Categorizing and empirically analyzing the effect of governance elements differences on long-term viability of DAOs	What are the key elements within DAO governance?; What is the impact of variations of these elements on long-term viability of DAOs?	Especially decision model and incentive elements can influence long-term viability of DAOs	If certain governance elements are chosen, this can potentially influence long-term viability of your DAO	Conducted a comprehensive empirical analysis of governance elements and long-term viability DAOs. Proposed the first preliminary theory of governance elements and long-term viability.
Theorizing the viability of Decentralized Autonomous Organizations: limitations and opportunities of governance by design and business purposes	The effect of business objectives, internal DAO governance elements and external blockchain protocol elements on DAOs' long-term viability	How can the typical business objectives of DAOs be categorized within the broad spectrum of objectives? Taking business objectives into account (as the independent variable and as a moderating variable), how do internal governance and external infrastructure elements influence the viability of DAOs?	Business purpose as moderating variable in independent variables like governance elements can influence long-term viability of DAOs. Choice of infrastructure can influence the governance of DAOs through elements no longer under the control of DAO	Design of governance of DAOs goes beyond governance elements. Business objectives and chosen infrastructure should always be taken into account in an integrated way when designing governance of a DAO	Created framework for DAO business objectives and DAO governance elements that can be used in future analysis. Showed enhanced relation between governance elements and long-term viability of DAOs taking business objectives into account. Created an updated theory that, besides internal governance elements, takes business objectives and external infrastructural elements into account in relation to long-term viability

During our research we answer the following main research questions:

1) *What are governance challenges in blockchain-based applications?*
As we conclude in our first paper, governance challenges are multifold as a result of multiple types of blockchain infrastructures (permissioned versus permissionless and public versus private) and different types of applications (direct transactional versus conditional transactional), which all pose their own challenges. But especially with DAOs on public permissionless blockchains there might be new challenges. This is as result of possible fuzzy accountability in DAOs as tokenholders are not always known. Another important challenge we find is the entanglement of application and infrastructure, which is quite specific for blockchain-based applications. This should thus be taken into account in the design of governance of blockchain-based applications.

2) *What is a comprehensive definition of DAOs?*
In our second paper, based on literature and empirical research towards many live DAOs we come to a comprehensive definition as presented earlier in this section. The definition contains as main elements the most common terms as found in existing definitions in literature extended with empirically analyzed general functionality of DAOs.

3) *How does the decentralized characteristics of DAOs influence the survivability of a DAO*?
In our second paper, we find that decentralization on the application level (number of different tokenholders) has an effect on the survivability (long-term viability) of DAOs. Using survival analysis, the turning point was found to be at 20 tokenholders. More tokenholders contribute positively to the long-term viability of DAOs.

4) What are emerging developments around DAOs ?
In the second paper, we look at emerging trends in DAOs and found that there is a very strong rise in the number of DAO projects that shift their governance from on-chain governance to off-chain governance by means of tools like Snapshot.

5) What are the potential implications of emerging development around DAOs on the existing DAO definitions and characteristics?
In our second paper, we argue that these DAO projects are actually wrongfully labelled as DAOs. These projects, as a result of their off-chain governance mechanisms, no longer autonomously execute decisions that pose (proven) risks and thus could better be labelled Decentralized Organizations.

6) *What are key elements within DAO governance?*
In papers three and four, we deep dived into DAO governance. Based on our literature review, we eventually took the three main elements of accountability, decision model, and incentives as key governance elements. In papers three and four, based on literature and empirical research, we create a clear taxonomy and framework for the three elements used in the analysis on long-term viability. Accountability is split into the elements of the number of token holders and voting power distribution. The decision model is split into voting mechanisms on two levels (weighted voting versus non-weighted voting and share-like versus reputation-based versus membership model or a mix thereof). Incentives are split into either direct incentives, indirect incentives, or no incentives.

7) *What is the impact of variations of these elements on the long-term viability of DAOs?*
   In the second and third papers, these governance elements are researched concerning the long-term viability of DAOs. As we show in the papers and the theory below, we find that variations in these elements influence the long-term viability of DAOs. The elements of incentives and decision-making models especially show an interesting effect where no incentive and democratic voting power distribution contribute positively to long-term viability. In our third paper, we argue that this can be explained by the business objective of a DAO and thus should be investigated as a moderating variable to governance elements in relation to the long-term viability of DAOs.

8) *How can the typical business objectives of DAOs be categorized within the broad spectrum of objectives?*
   In our fourth paper, we research the DAO business objectives. Based on literature review and empirical research we create a classification for business objectives of DAOs. As DAOs can describe their business objectives in a very broad way, we create eight main business objective categories (Economic, Social, Research & Development, Human, National, Global Utilities, Art, and Other). Out of these main categories, we create two super categories for analysis (Economic versus Non-Economic).

9) *Taking business objectives into account (as the independent variable and as a moderating variable), how do internal governance and external infrastructure elements influence the viability of DAOs?*
   In the fourth paper, we answer this final research question. We find that a DAOs business objective in itself indeed has an influence on the long-term viability of that DAO. Both direct as well as a moderating variable. Certain business objective – governance element combinations seem to positively influence the long-term viability of DAOs. Especially democratic voting power distribution and non-economic DAOs, no incentive mechanism and non-economic DAOs and membership structure and non-economic DAOs seem to positively influence the long-term viability. Share-like decision-making structure in general seem to positively influence the long-term viability, whereas reputation-like systems have a negative effect.
   With regards to the external infrastructure influence on DAO long-term viability of DAOs, we do find empirical evidence that elements under control, more specifically the transaction cost (“gas-fee”) influences the behavior of DAOs (deployments). Based on our research in the fourth paper, combined with the research from Faqir et al. (2021) we induce that the transaction costs does influence the governance of a DAO and, thus indirectly the long-term viability of a DAO.

Using a unique DAO data collection compiled over an extensive period of time, this PhD research shows that multiple elements can influence the long-term viability of DAOs, which we use to formulate our theory. As stated in the second and third paper, some are in the direct influence sphere of the DAO project. The final research paper shows that other elements outside the direct influence sphere of the DAO project once deployed, can have an influence on the long-term viability of a DAO or on governance elements of that DAO. Also, we include the business objective as a moderating variable, a variable that was overlooked in previous studies, which can influence the relation between various independent governance element variables and the dependent variable long-term viability.

By combining the outcomes of the various parts of our study, we formulate a theory on factors affecting the long-term viability of DAOs, which can be visualized in the model in the figure below. This theory is the first to combine internal DAO elements, external DAO elements and business objectives of DAOs in relation to the long-term viability of DAOs.

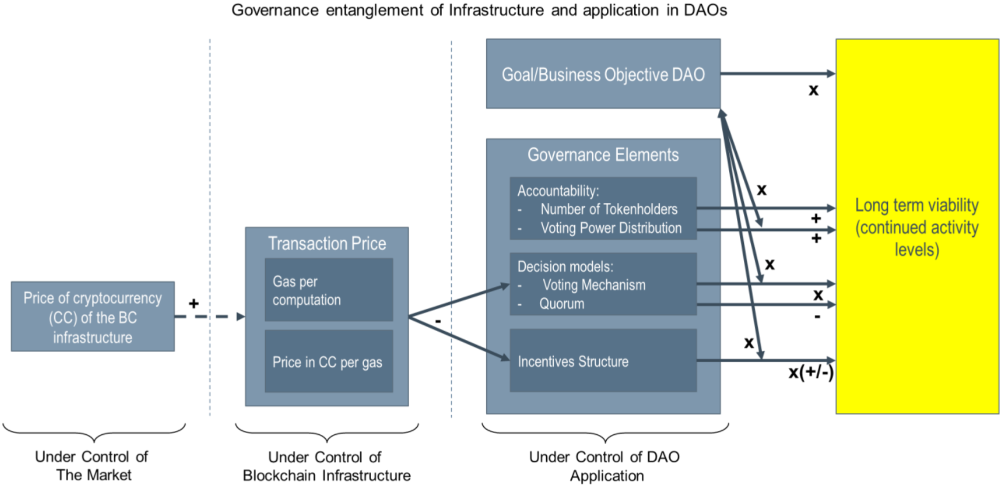

Figure 35: Theory - long-term viability influencing factors DAOs (+/- shows a positive or a contra relation, x a categorial relation between the independent and dependent variable)

As we conclude in our first article, within blockchain-based applications and thus also in DAOs, there is an entanglement of infrastructure and applications where elements outside the control of the governance of the application can have an influence on the application in itself. As we show in the fourth article and through research by Faqir et al. (2021), this entanglement materializes through the cost of transactions on an infrastructure. Gas per computation and price in cryptocurrency per "gas" are under the control of the infrastructure or protocol governance. Price of cryptocurrency, although not part of this research is even outside of the control of the protocol but controlled by the market. The transaction price could influence the voting and incentive structures within a DAO, thus influencing the long-term viability. We conclude that the choice of infrastructure in itself can be an important one, not only from a functional perspective (user base, etc.), but also for the governance of the DAO. Off-chain governance mitigations for (variations in) transaction costs through, e.g., Snapshot, as we discuss in the second and the fourth article, can lead to loss of autonomy, posing continuity risks in itself as decisions are no longer automatically executed by smart contract code.

Based on our findings in our third article on the effect of governance elements, we conclude that the effect of DAOs' business objectives as a moderating variable for certain governance elements should be taken into account. In particular in voting power distribution, incentives and decision models. Both directly as well as a moderating variable on the governance elements independent variables. With regard to business objectives, we find that the specific business objectives of all individual DAOs were very broad. We therefore propose a business object categorization that can be used for analysis of the relationship between business objective, governance elements, and the long-term viability of DAOs.

A new insight of our research is that the number of economic DAOs is higher on Ethereum than other infrastructures, both in absolute as well as in relative numbers. Although not part of this research, this can be explained by various factors. Ethereum has the highest user base and thus is most interesting for economic DAOs. Also, the fact that Ethereum is one of the longest-running protocols suitable for DAO deployment can play a role. This new insight is also important as it suggests that elements that are outside the influence sphere of the DAO, which can influence the governance of the DAO in itself might not be taken into account when infrastructure is chosen.

In general, another new insight from our research in Paper 4 is that DAOs with a non-economic purpose have a higher long-term viability than DAOs with an economic purpose. This can be explained by the inherent nature of DAOs focusing on more common or social goals and an altruistic community surrounding these initiatives, although this is subject to further research.

As stated in this dissertation, the governance elements for our research are derived from the definition of Ross and Weill and include the elements of accountability, incentives and decision models. We create a framework where these elements are all split into sub elements with various dimensions, which can be used for our quantitative analysis as well as in future research.

When looking at the element of accountability we split this into two sub-elements in our theory. The first is decentralization level, being the number of tokenholders. The second, voting power distribution, which was categorized in dictatorship, semi-dictatorship and democracy. We find that a higher number of tokenholders and a democratic voting power distribution seem to positively affect the long-term viability of DAOs, being the first to show the relevance of decentralization in DAOs other than in name. When taking the business objective as a moderating variable into account, we conclude that in non-economic DAOs, a democratic voting power distribution has a positive correlation with long-term viability compared to economic DAOs.

DAO decision models, as stated in papers 2, 3 and 4 can be categorized into three main groups, share like (weights per token holder can differ and tokens are tradeable), reputation-based (weights per token holder can differ but tokens are not tradeable) and membership (weights per token holder are equal and are not tradeable). Differences in decision models have an influence on the long-term viability of DAOs in multiple ways. In non-economic DAOs, membership-based decision models have a better long-term viability than reputation-based decision models. Share-like decision models seem to have a positive effect on long-term viability in general. The business objective does not pose a significant difference in this. Reputation-based decision models have a significantly lower long-term viability.

DAOs use different incentive models. Three main categories are observed in practice. Incentivized models are either 1) directly (direct reward for an action performed), 2) indirectly (by value of a tradeable governance token) or 3) DAOs do not have an incentive for participating in governance. Incentives also influence the long-term viability of DAOs. An interesting new insight is that, especially in non-economic DAOs, the lack of incentives positively affects long-term viability compared to economic DAOs.

DAOs offer many opportunities as new organizational or governance forms for blockchain-based projects, but they do not seem to be viable for all business purposes in the long term. To potentially improve the long-term viability, one must consider the elements of accountability, decision model and incentives carefully, while taking into the business objective of the DAO as well as design choices regarding the governance of the DAO.

Also, a novel insight is that the choice of infrastructure should be considered beyond functional elements like user base and ecosystem. Once a certain infrastructure is, elements of the infrastructure can influence the governance of a DAO and thus the long-term viability of that DAO without the DAO being able to influence these infrastructure elements.

7.2 Discussion and limitations

The theory built on this PhD study provides valuable new insights for designing the governance of DAOs. The long-term viability of DAOs can be influenced by making various choices concerning the (suitability of) the business objective, the chosen infrastructure to deploy one's DAO on and choices regarding governance elements. However, there are multiple elements that will need to be taken into account.

Despite the sharp rise of the number of DAOs over the past few years, DAOs are still relatively young. Thus, the behavior and long-term viability over a longer period of time remain to be seen. We try to mitigate the risk of drawing conclusions too early in two ways. First of all, we measure the activity of DAOs over a longer period of time. DAOs that only exist for a short period of time (less than nine months) are excluded from our data set as activity level over a period of time could very well be the result of the business objective requiring less active behavior of participants and not so much the lack of long-term viability. Secondly, we only include DAOs that show a certain minimum amount of activity (minimum of at least 10 active proposals which tokenholders could vote on) during their lifetime. This to mitigate the chance of including test DAOs in the dataset. In the final analysis, we reduce the dataset even further when the business objectives of DAOs are included as well, even though DAOs show enough lifetime activity. Based on the name containing "test" or proposals clearly showing that the DAO in itself was for test purposes only, DAOs are deleted for the dataset. In this way, we try to maximize the chance that the analyzed DAOs are for true business purposes. Using the long-term viability as the dependent variable on our model could pose a challenge in itself. The true average age of a DAO is yet to be determined as DAOs are only around for less than a decade. By comparing DAOs that seized operations against DAOs that stopped operations, our theory can say something about the relative long-term viability, but not about an absolute age or some form of linear relationship. In order to do so, it would be best to have a larger dataset of DAOs over a longer period of time as the number of DAOs for analysis is still fairly low for general conclusions. Also, our theory focusses on governance elements, infrastructure and business objectives as independent variables for long-term viability, but there can be various other reasons for DAOs to seize operations. Therefor longitudinal research with an increased dataset of DAOs is recommended.

During our analysis, we use a very strict definition compared to how the market interprets DAOs in general. As we state earlier, our research, as well as others (Chainanalysis, 2022a; Fisch & Momtaz, 2022), shows that many projects that are positioned as DAO projects are either not really decentralized and as we argue in our second paper, as result of off-chain governance often not autonomous although Van Vulpen, Sui and Jansen (2024) argue that this does not always affect decentralization. Especially with regard to the off-chain governance elements, our research uses this strict definition. This is because it immediately leads to a lack of autonomy and the risk of opposite execution of actions to decisions being made in a DAO. The element of decentralization is used as one of the independent variables in our theory. This strict definition handling in the selection of DAOs for the data set leads to the fact that a substantial number of projects that are positioned by the industry as DAOs, the off-chain (governance) DAOs, are not included. It would be interesting to research if these off-chain DAOs show similar behavior as on-chain governance DAOs, which can widen the boundaries of the theory. Another factor that should be considered regarding these off-chain DAOs is that off-chain governance can be a temporary solution. The off-chain governance elements are added to reduce the cost of governance as no "gas" costs are required for voting. The rise of platforms for DAO deployment on low-cost infrastructures could lead to a move away from off-chain governance, as on-chain governance poses less risks as explained, and costs would no longer be an issue.

The element of business purpose proves to have a significant influence on long-term viability in our theory. What needs to be taken into account is the fact that in the beginning of the research not only the number of DAOs was lower than at the end of the research, also the number of business objectives DAOs were used for. Where DAOs were predominately used for economic business purposes in the beginning, other business purposes were only explored in a later stage. For example the NFT art-related use cases really just took a flight as of 2021 (Golomb, 2021). Therefore, the analysis of the data we use in creating our theory has to, despite categorizing DAO business objectives in eight main categories, be consolidated into two super-categories. This can influence the result of the analysis, especially in combination with the age element. It could very well be that multiple of the DAOs that are left out of the analysis due to age selection, are part of categories that are less represented in the analyzed DAOs. Therefore, future research could paint a different picture on the relationship of business objectives and other factors on the long-term viability of DAOs. In particular, the non-economic business objective DAO category is a combination of seven different subcategories. If numbers in these subcategories are substantial enough to analyze on their own, this could lead to new insights. Also, as certain individual business objectives can be interpreted as grey areas between different overarching categories, grouping these individual business objectives into the subcategories and into super-categories will always have a certain amount of bias of the researcher. The low number of DAOs to be analyzed per category and overall suitable for analysis lead to the fact that we performed a relative concise statistical analysis to test our theory. With higher numbers of DAOs to be analyzed, more nuances and controls can be added to the categorization and theory in general. Also, although we used the term business objective throughout this thesis, it can be argued that, as not all DAOs are business related, in the future the term organizational or initiative objective could be more suitable.

When analyzing the causal relation between the independent (long-term viability) and the dependent variables in our theory, this is predominately done in a direct, one on one way. An exception is that business objectives are used as moderating variables in analyzing the relation between various governance elements and the long-term viability of DAOs. Using the individual governance elements as moderating variables in the relation to other governance elements and long-term viability is not taken into account in our research and thus is not incorporated in the theory yet. Due to the complex nature of governance in general, it could very well be that variations in one governance element (e.g., incentives) can have an effect when differentiating in other governance elements (e.g., decision model) on the long-term viability of DAOs.

Our theory focused predominately on more technical, measurable technical governance factors within DAOs. We follow the definition of Ross and Weill, and thus the main focus is on the elements of accountability, decision model and incentives. We translate these elements into quantifiable categories and (sub) elements that can be measured on-chain as much as possible. But one can argue that the (sub) categorization of the elements as proposed in our framework, although based on scientific sources and methods, can always have a form of subjectivity or bias in them. We try to mitigate this as much as possible by using multiple sources when combining them into the framework. The data is gathered by going to the original source as much as possible, like the individual governance web pages of the DAOs, and not using derived websites like deepdao.io for measuring elements. When in doubt, the data is verified on-chain directly using blockchain browsers like etherscan.io.

Besides the elements that are included in our theory, IT-governance theory can entail a wider range of elements other than these harder IT-governance elements. Furthermore, the long-term viability of DAOs could also be influenced by many other non-governance factors than the ones that were used in our theory. Elements like communication, user commitment on and the existence of an internal constitution, dispute resolution, informal behavior, and other soft elements, like possible geographical or cultural elements of the participants, which are not or could not be recorded or objectively measured are not taken into account. Implicit values can always influence assumptions (Weber, 2009). Also, elements like external economic circumstances and business cycles, which in themselves could influence the long-term viability of organizations, are not taken into account in our theory as well. When using our theory, this is a factor that should always be taken into account when designing the governance of a DAO. Also, human psychological factors like group pressure and strategical behavior in voting are not taken into account in building our theory.

The construction of the overall theory is a combination of follow-up research elements over time. This means that not for all relations in the theory as displayed, the exact same data set was used. For the majority of relations, the same data subset was used, but especially in paper 4, the original dataset was extended as the research at that point in time continued for a longer period so the dataset available is larger. The element of decentralization (number of tokenholders) and effect on long-term viability is not retested with the extended dataset, only with the original set in itself. Also, as stated in the papers 3 and 4, we did assume that all tokenholders were unique individuals, although one person can hold onto multiple accounts and thus could pose the risk of a sybil attack. This should be taken into account in the further development and testing of the theory. Furthermore, the relationship between external elements under control of the infrastructure and the possible effect on governance elements under control of the DAO is identified based on a much larger dataset, combined with findings from other research (Faqir-Rhazoui, Ariza-Garzón, et al., 2021; Zhao et al., 2022b). This dataset thus does not exactly match the other one. Therefore, also as visualized in Figure 35, the elements of number of tokenholders and the external element of gas pricing are not tested as moderating variables or in relationship with the moderating variable of DAO business objective as this would pose a false comparison.

Finally, when looking at building a theory, one should always take into account that it is a model that will always remain a reflection of reality and is, per definition, not reality in itself. As pointed out in the discussion above, there are many uncertainties in the relationship between the elements that can influence the long-term viability, the classification and categorization of the elements and even within the elements themselves. As for the analysis of the relationship between the variables, this is per definition, due to the nature of our research, done with historical data. Using this historical data, one tries to make a projection of future behavior. But circumstance within and in the perimeters of DAOs can change, which in the end can influence the viability of the theory. To mitigate this as much as possible, the analysis was done over a longer period of time, but the theory is not used in designing a DAO and test different setups going forward. Therefor the theory should, as it is a first version, based on a strict definition of DAOs and an early dataset, on a continuous basis, be updated, checked and challenged, not in the least as the governance elements in themselves can be altered or new will arise, e.g., different decision models or incentive structures, general accepted definitions might change and the number of DAOs in general and business objectives of DAOs will rise in an ever maturing market.

7.3 Recommendations for future research

DAOs are an emerging research area that is still under development. Over time DAOs can evolve, and so can our theory. Based on our research and the discussion as posed before, future research can focus on various elements.

Firstly, as we clearly state, our research concludes with a theory that poses a model based on research using a limited number of DAOs as at the time of this research, taking our selection criteria into account, the total viable DAOs for analysis is still fairly low. From 220 DAOs in our second paper to 403

DAOs in our fourth paper also leading to concise statistical analysis. With the continuously increasing number of DAOs that are created over time, combined with the extended lifetime of created DAOs, the proposed theory should be refined, checked, challengedand tested with an increased dataset. In this way, the relations within the theory and the overall theoretical model in itself can be continuously verified and, where needed updated, adjusted or even overthrown or replaced by a new theory.

Secondly, the business purpose, the governance elements, and the combination thereof are tested directly to long-term viability in our papers 2 to 4, which can pose a too simplistic representation as these elements could influence each other as well. The interrelationship between infrastructure (transaction fee or "gas pricing", paper 4), the governance elements themselves (paper 2 and 3) and business purposes to long-term viability should be researched in more detail where various independent variables can be used as moderating variables to each other in relation to long-term viability of DAOs. We recommend that more variables are also incorporated as moderating variables to one each other.

A third recommendation for future research is related to the upcoming trend of off-chain governance DAOs using systems like Snapshot. As we argue in our research paper 2 these projects do especially give in on the element of autonomy and thus are left out of our whole research as result of our strict definition. But, many DAO projects, due to the high cost of transactions on certain blockchain infrastructures, do use this method of governance often. These DAOs that integrate off-chain governance mechanisms as their main form of decision-making and execution can be researched separately as well. This to determine if these DAOs show similar behavior in their relations on business purpose, governance and long-term viability as on-chain DAOs in our theory and thus the theory can be used in a more generalizable way for a broader selection of DAOs or DOs than used in this research.

Fourthly, over the past years, the developments around DAOs have gone fast. From new creation and deployment possibilities to new trends in decision models as we show in paper 3, (off-chain) governance solutions as we show in paper 2 and incentives structures. In our research papers 2 and 3, we identify many of them, but due to the requirements of minimal age and practical elements of certain models, elements and structures not being life when commencing the research, some of the new governance models or elements like e.g., conviction voting, quadratic voting or depreciating token models, are not included in the dataset for analysis. As these are becoming an integral part of the DAO possibilities, these new governance models or elements can be included in future research.

Fifthly, with maturing and expanding DAOs over time, the governance models sometimes become more complex. Also DAO to DAO structures (Kaal, 2021) and DAOs containing sub DAOs are coming up. This leads to DAOs containing multiple governance layers, decision structures and incentive models within one DAO. The number of these DAOs in the dataset is extremely low as these DAOs were rare when this research commenced. Thus, we recommend breaking these multilayer DAOs down into sub-DAOs and analyze them by layer or to integrate them in future research as a separate category to determine if these multilayered can be included in the theory.

As a sixth recommendation for future research is to introduce more soft factors into the theory. As we state in our general conclusion above, more soft factors like communication, culture and informal behavior are not included. Especially cultural elements can be of importance as elements like decision-making, incentives and leadership style work different for different groups and individuals (Jung & Avolio, 1999). These elements could influence the long-term viability of DAOs as well and should thus be included into future research.

The seventh recommendation for future research relates to the entanglement between infrastructure and applications. Especially, the exact effect of elements like “gas” pricing and the effect on application governance behavior should be researched more thoroughly to measure any possible differences between infrastructures. Our research in paper 4 shows that “gas fee” (transaction costs), converted to dollar pricing, has an effect on DAOs from a deployment perspective and thus indicates the entanglement between application and infrastructure. As research by Faqir et al (Faqir-Rhazoui, Ariza-Garzón, et al., 2021) also indicated this relation on voting behavior within DAOs, although only related to gas pricing in local cryptocurrency on a single network (Ether on Ethereum), it is recommended to research the exact relationship between gas fee in dollars to actual voting behavior in DAOs as we also conclude in paper 4.

Eighthly, in paper 4 we create a framework of business objectives of DAOs and conclude that the business objective in itself as well as a moderating variable, can have an influence on long-term viability of DAOs. But as we state, DAOs are still in the early stage, meaning that the full potential is yet to be discovered, also from a business objective. This can go two ways, either the number of business objectives can increase as many of the uses are still to be unveiled or the number of business objectives will go down as many of the business objectives turn out to be less suitable for a DAO structure. This development can be researched further and more in-depth. Further research can also include qualitative research towards factors for “attractiveness” of decentralization and autonomy of organizations and business objectives, not only a statistical analysis of long-term viability or survival rate of certain business objectives relative to one another.

Finally, since the start of our research, besides multiple developments in possibilities for DAO applications, the number of possible infrastructures on which DAOs can be deployed has risen as well. In our research paper 4, the number of infrastructures is limited, predominately Ethereum, Polygon and Gnosis Chain. As the number of viable infrastructures for deployment rises and the infrastructure, through the entanglement between infrastructure and application, can play an important role within the governance and long-term viability of DAOs, these new infrastructures and the DAOs deployed on them should also be included in future research. The recommendations as described above are summarized in the table below.

Table 35: Summary recommendations for future research

Recommendations	
1	Extend DAO database to re-test and refine the variables and relations. Both in absolute numbers as well as in the length of lifetime of the DAOs tested.
2	Conduct research to interrelationship between the independent variable by using them as moderating variables to each other in relation to long-term viability.
3	Test off-chain governance DAOs to see if they show the same behavior as on-chain DAOs in our theory.
4	Include new (governance) elements and trends in future research towards the theory.
5	Investigate more complex and multilayer DAO governance models in future research in relation to our theory.
6	Include more “soft” factors like culture, communication etc. into future research towards the theory.
7	Deepen research toward transaction costs in Dollar or Euro prices in relation to voting behavior in DAOs.
8	Extend research with the business objectives for DAOs, both quantitative as well as qualitative, to reveal “attractiveness” for DAOs for certain business objectives.
9	Extend the number of blockchain infrastructures in future research to test hypotheses between external elements and internal elements.

8. Epilogue

In the final part, I want to look forward to the future of DAOs. New DAO technologies and their applications continue to develop as companies and projects search for new and better ways of governance. The time to implement new technologies and their applications and reach 1 million users seems to have shortened dramatically in the past few decades (Buchholz, 2023). Also, during this research, changes followed one another at a very fast pace. Looking back at this research, this proved to be a curse and a blessing at the same time. Especially as the choice was made to emphasize empirical analysis initially, finding enough data to analyze was relatively hard at the beginning of this research. A handful of DAOs were known to the wider public, but the numbers were low for quantitative analysis. Another complicating factor was the lack of understanding of what a DAO entails. This resulted in a discussion about whether certain projects should be included in the analysis. As the number of DAOs grew over time, more data became available. This posted various opportunities, not in the least in creating a comprehensive definition. Using the comprehensive definition as a guideline for DAO project selection for analysis helped speed up the research. Industry got a better view of what DAOs were and could mean, and scholars started to publish more on DAOs. This led to more DAOs, including more experiments, not only in number but also in the development of many experiments in possible setups and new processes and ways of working. Enthusiasm in the Web3 industry has grown dramatically, sometimes posing DAOs as a silver bullet for Web3 organizations.

How DAOs will evolve and how adoption will be embraced is yet to be seen. Since the implementation and the fall of "the DAO" in 2016, we have witnessed a Cambrian Explosion of DAOs, not only in absolute numbers, but also in types, business purposes, functionality versatility, and possibilities in governance setups. The choices in deployable infrastructures for DAOs have risen as well. During this research, the number of DAOs, depending on the exact definition, went from a few hundred to the tenths of thousands. The rise of various DAO deployment platforms and off-chain governance DAO possibilities on many different blockchain protocols results in the fact that even today, many new DAOs can be found, and the deployment of new DAOs surpasses hundreds, maybe even thousands, per month. However, although this might feel like a new star is clearly born, it does not necessarily mean that this will change business, collaboration and governance as one might expect.

Like various new technology and applications, DAOs might follow the so-called "hype cycle". According to research firm Gartner, the hype cycle typically consists of five stages: the technology trigger, the peak of inflated expectations, the through of disillusionment, the slope of enlightenment and the plateau of productivity (Gartner, 2024). A visual representation of the hype cycle is shown below.

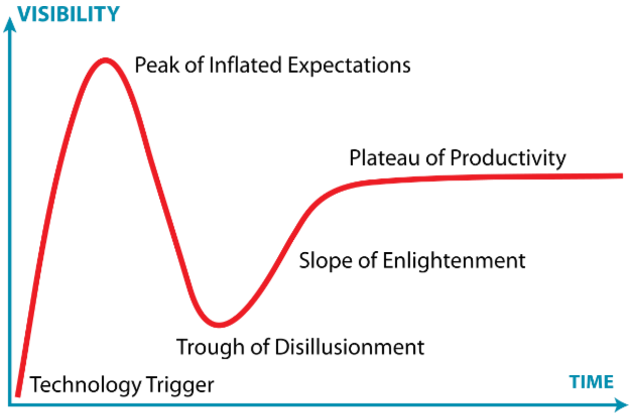

Figure 36: Visualization Hype Cycle Gartner – Source: gartner.com 2024

Given the state of blockchain technology and the vast growth of the number of DAO applications, one can easily argue that DAOs are somewhere around the peak of inflated expectations. This means that DAOs are seen by many as the solution for many of the (organizational) problems they have encountered. Despite the exponential growth, the first signs of realism are showing. Questions around suitable business purposes, questions about community-driven governance systems, uncertainties around the legal status of DAOs and blockchain-based applications in general and user-friendliness are all indicators that the through of disillusionment is being reached. This suggests that the industry will reassess if DAOs can make up to the promise that was created in the first stages. According to Gartner mid-2022, the time to the plateau of productivity for DAOs is a 5 to 10 year time frame (Litan, 2022). However, not all technologies and their applications will eventually reach full adoption (Goncalves, Laguna, & Iglesias, 2012). One could argue that DAOs are coming to crucial crossroads. This raises the question of what the future of DAOs will be. Will they reach broad adoption, or will DAOs fade out?

8.1 Future of DAO scenarios

DAOs might boom, disappear, remain only for a few enthusiasts, or even be embedded in daily life. In this epilogue, I want to speculate about the future of DAOs and then link them to future research needs. The future of DAOs can thus best be explored in different *scenarios.* Scenario planning is a technique typically used in times of uncertainty and complexity(Amer, Daim, & Jetter, 2013). In scenario planning, one outlines aspects of the future by looking for variables that can develop in different ways, creating hypothetical event sets or axes. By taking different configurations of these variables, one creates various predictions of this future (Amer et al., 2013; Kahn & Wiener, 1967). Using various elements or event sets and their developments we will explore how these variations can influence how DAOs and their implementations and usages will continue going forward. The elements or events considered in this epilogue are the so-called PESTLE (Political, Economic, Social, Technological, Legal and Environmental) elements, which form the basis for identifying future opportunities and risks (Perera, 2017). PESTLE is used to ensure that a wide variety of elements is included in the scenarios. For DAOs, fluctuations in the development of all these elements can influence their future development and use. However, PESTLE also contains too many elements to make it easy to communicate. Therefore, we consolidate the PESTLE elements into 3 essential axes for developing scenarios.

As DAOs and blockchain and its applications are closely connected, the political and legal elements could be considered a scenario axis. In many cases, no regulation exists, or it is unclear which regulation applies. For the future DAO scenarios, the scale of the axis for scenario planning can then be defined as uncertain or low, meaning unfavorable and unclear everywhere, to medium, meaning certainty on a local or national level, and favorable and clear cross-border. Although the legal element is very broad, two predominant focus areas can highly influence the future of DAOs. The first one is the legal status of DAOs from a corporate law perspective. Up until now, there is much debate on the legal status of a DAO. Most of the jurisdictions do not have a special legal form for DAOs. Some jurisdictions, e.g., Wyoming, created a special legal status for DAOs, while for certain jurisdictions, it is argued that based on choices in governance setup, it could fit under existing legal structures (Mienert, 2021; Rikken, Gideonse, & Putman, 2023) Not only with regards to the legal status of DAOs as an organizational form in corporate law, but more so, as DAOs provide an important treasury function and the transfer of value is done by means of cryptocurrency or tokens, the legal status of crypto assets could very well influence the future of DAOs as well. Given that unfavorable political, legal, and regulatory authorities have the power to ban or at least frustrate the usage of blockchain and its applications for a broader audience and a lack of legal status can make other actors who want to (economically) interact with a DAO hesitant to do so due to this uncertainty, this is considered the most important or influential axis for the main adoption.

The *technological* element is another axis to be considered. The technological development itself influences the ability of different types of users to create and use DAOs. User interface (UI) and user experience (UX), despite vast improvements made in the past for the trained eye, are still below par for the average user. Deployment of DAOs and adding non-standard functionality, the user interface for many DAOs and the use of wallets is still very much focused on tech-savvy persons. Besides the UI being counterintuitive, a “gas fee” (transaction fee) must be paid in cryptocurrency on permissionless networks for all transactions. The requirement of cryptocurrency in your wallet or through a dedicated service is a barrier to mass adoption. The improvement of the UX for end users might highly influence the future and mass adoption of DAOs. This axis is defined as low UX/UI improvement to high UX/UI improvement.

The third axis to be considered for future scenarios is the *social-economic*. The promise of DAOs is the possibility of active participation in governance of organizations. Although having direct control sounds positive and attractive to many, it is questionable if everyone wants to be involved in every decision that needs to be made in the governance of an organization or initiative. Not only might there be a form of voting fatigue, also from a cultural perspective, not everybody wants to be involved in decision-making. The element of potential personal accountability can also play a crucial role here. Also, regarding certain economic activities, one might want to be more involved than not, especially when the matter to be managed is within the direct interest field of the participants. Within this axis, one could also place the element of trust. A lower trust in third parties could suggest a higher willingness to participate in DAOs. Finally, the cost of governance, whether in time or direct, could influence the willingness to participate. The combined social and economic elements result in the final axis. This axis for developing scenarios will reach from low general participatory willingness to high participatory willingness.

Although normally included in a PESTLE analysis, the environmental element is left out of the three axes. Although blockchain is associated by many with high energy consumption, current developments in blockchain consensus mechanisms lead to a substantial decline in energy consumption (Wendl et al., 2023; R. Zhang & Chan, 2020). Based on the current developments in blockchain infrastructures facilitating DAOs along the board, the general tendency seems to be a higher willingness for more environmental friendly solutions due to climate change. Also the vast majority of DAOs is deployed on infrastuctures that use the updated, substantial lower energy consuming consensus mechanisms. Thus is not considered a differentiating element in the future of DAOs.

The resulitng axes and the represented PESTLE elements are visualized and summarized in Figure 37 and its caption below.

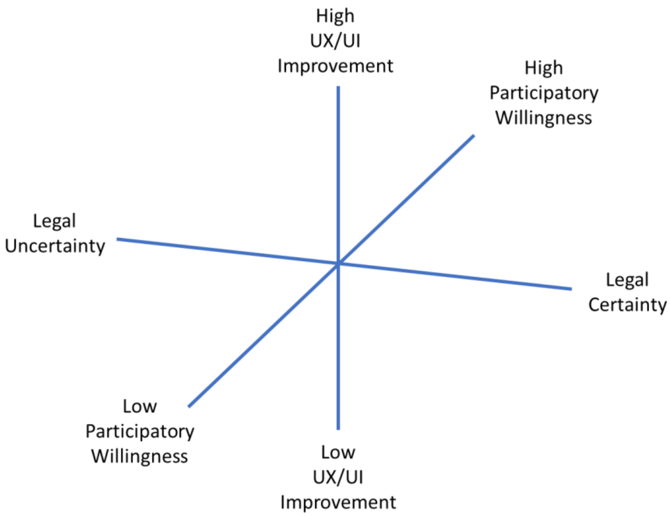

Figure 37: DAO future scenario axes – Legal axis representing Political and Legal elements, UX/UI representing technological elements and Participatory Willingness representing Social and Economical Elements

By differentiating in one or more axes, one can create the basis for different scenarios that can be used as thought experiments on how the future might look like. One can create various scenarios for the possible future of the three axes at a time. Three future scenarios were created by differentiating at least the legal axis, as is considered the main axis as elaborated above, and keeping others constant or slightly changed. All scenarios were named. An overview of the scenarios and differentiation in axes is shown in the table below.

Table 36: Scenarios vs Axes Differentiation

Scenario / Axis	**Legal - Axis**	**UX/UI - Axis**	**Participatory Willingness - Axis**
1 - Nice participatory and budgeting tool	Low	Medium	Low/Medium
2 - Keep the DAO simple, manageable and direct	Medium	Low/Medium	Medium
3 - The Cryptopunks' dream?	High	High	High

Based on these differentiations, the future scenarios of DAOs can be envisioned as follows.

Scenario 1 – Nice participatory and budgeting tooling

Although various efforts have been made, legal uncertainty of what a DAO entails from a corporate as well as uncertainty on financial regulations toward the status of tokens is still high, both for governance or voting tokens and tokens used for transfer of value. The development of UX/UI, as a result of this uncertainty, did develop, but not to the full potential of what it could have been. Despite this, the possibility of getting large groups engaged in governance in a broad range of projects has proven somewhat appealing for companies and employees or participants in other initiatives. Due to the legal uncertainty, it is hard and risky to use DAOs as stand-alone organizations. Also, the transfer of value between different entities or persons as a result of this uncertainty made a large majority of use cases and business purposes impossible.

However, within existing organizations, the DAO has proven to be a useful tool for improving employee engagement by creating participatory possibilities. Not only from a notary or governance perspective, making it possible to vote on various topics within the confinement of an existing organization or corporation, but even transfer of value is also possible, as long as it involves internal payments within the boundaries of the company. This could even go so far that in budgeting, per project, tribe or department, value in the form of an internal token is distributed to the internal DAO of the group, and the employees or participants can collectively vote on how to spend this in detail. The value tokens could be converted to fiat currency if external spending is needed, but these value tokens could also very well represent value in the form of hours that teams can spend on certain projects.

From a governance perspective, the decision model could either be **one member one vote or reputation-based**. Share-like systems would not be viable as these DAOs would be more community-driven with equality in mind and trading in would not be desirable. The incentive system could be either **no incentive or a direct incentive in the form of additional reputation** as tokens can not be traded and thus no monetary incentive is needed. The business purposes can actually be very broad. The used infrastructure is probably low-cost as interoperability or a large external user base will not play a role. As long as the reach of the DAO stays within the legal perimeters of the existing entity, any business objective, except national, global and stand-alone economic ones, could be viable.

Scenario 2 – Keep the DAO simple, manageable and direct.

In this scenario, there is a medium participatory willingness, a low/medium UX/UI improvement, and legal certainty at a local (national) level. DAOs, despite this local legal certainty, fail to grow to large skill companies due to cross-border legal uncertainty and a low participatory willingness of tokenholders due to accountability risk and who still see UX as relatively user-unfriendly. They either perceive DAOs as complicated and take too much of their time on governance, feel that they are not informed enough to make informed decisions, or feel that the cost of governance is too high.

This means that the DAOs that are successful and show long-term viability are DAOs with a clear goal, more often local participatory projects like neighborhood communities with a shared treasury where the information equality on matters is perceived as high and the voting frequency on decisions is relatively low. DAOs will be most suitable for an understandable small-scale (business objective), on a **low-cost infrastructure** as interoperability or a large user base is not a requirement due to the cross-border legal uncertainty leading to accountability risks for participating individuals if they decide to do business across jurisdictions. **An equal, membership-like voting model and no incentive system**, other than being part of the decision-making on spending community funds in this scenario, will most probably be the most common form of governance of DAOs that will be in existence. For other business purposes, DAOs can still be a good fit as long as the operations of the DAO are geographically restricted.

Scenario 3 - The Cryptopunks' dream

The UX and UI have improved dramatically over the years. Not only from an interface perspective but also the general usage of tokens and wallets has increased, not in the least, as a whole generation has been brought up with the technology and its applications and sees cryptocurrency and tokenization as a parallel possibility to existing transfer of value structures. This increase also led to the normalization of the usage of wallets, dApps and DAOs in a broader community. This was enhanced by the fact that regulators and politicians strongly enhanced their knowledge of the application of tokenized use cases. On the one hand, this leads to new fitting regulations where needed, on the other hand, the industry accepts that not all products and services built on top of decentralized technologies are new but could fit existing legal structures. The combination of improved UX, UI, and legal certainty led to a high participatory level.

This will lead to an ever-increasing number of DAOs for various business purposes. Despite the continuous growth, DAOs did not prove to be the silver bullet for all organizational problems; instead, they did serve the need for more direct governance, leading to many extremely horizontal organizations. Also, cross-country collaboration is a result of clear international regulation and increased online presence. The great possibilities for on-chain governance and joint treasury management will decrease the need for physical presence for collaborative decision-making and execution of decisions.

The growth of the number of DAOs didn’t necessarily mean that the size of DAOs in the number of participants has risen dramatically as active participation in governance in organizations still requires a certain amount of interest in the topic that needs to be managed. Therefore, the larger DAOs will likely have various delegated decision-making structures, where the general tokenholders will not vote on daily governance topics but can support certain delegates to do so. Also, general assemblies for strategic decision-making can be organized more frequently than is the case in non-DAO organizations due to the absence of the need for physical presence for decision-making and execution thereof. Direct decision-making possibilities by all tokenholders on the whole wide range of governance decisions will still only be witnessed in smaller DAOs. As DAOs will be spread widely in this scenario, the business purposes of DAOs will be broad as well, basically covering all types.

Beyond the scenarios

It is even possible to dream beyond these scenarios where users are willing to really step away from all current structures and strive for self-sovereignty and decentralization in all the elements of their lives. This means there are no more traditional bank accounts, only the transfer of value through my crypto-wallets. We participate in multiple DAOs for various purposes, from participating in my local “communityDAO” to jointly decide on the development of our neighborhood, to a “charityDAO” where someone can influence how their donations are spent, to obtaining income from working in one or more “workDAOs”.

These extremes will come with its own challenges. Elements that we took for granted for centuries, like centrally run governments and countries could very well become obsolete for a new generation and they might even challenge them. Working on various online and offline locations like digital nomads, using borderless crypto payment services is not unthinkable, but will also pose problems on elements like presence and taxation of which the revenues are used to build common infrastructures. Online reputation build-up amongst peers might become more relevant than a university diploma, but how can we make sure that it is founded on objective and independent knowledge building. By eliminating all central elements, responsibility and accountability is being reverted to individuals and participants in decentralized initiatives like DAOs. Without these centralized elements, on point governance will become even more crucial. How can we make sure that if we “DAO everything”, all the crucial, less interesting elements for an individual, but crucial for the collective, will stay operational? Especially when taking elements like voters fatigue and individualism into account. The lack of central elements and striving to full decentralization comes with extreme personal accountability and results in a lot of work for individuals they were not involved in before and it is interesting to see if they would realize that as most individuals do not care about governance per se.

Through these scenarios, we wanted to create insight into how the future usage of DAOs might look like. As described in the scenarios, especially regulation and legal certainty, that goes beyond corporate law as a result of the importance of transfer of value as one of the the main functionalities of DAOs, can have a decisive influence. High uncertainty can diminish DAOs to nice internal tooling at best, as described in scenario 1, but as certainty increases, the wide use of DAOs, even cross-border, can flourish! This results in further research needs.

8.2 DAOs and public values

DAOs seem to post great opportunities, creating possibilities for new business opportunities, cooperation, inherent global organizational structures from startup, and increased citizen participation. The inherent characteristics of DAOs represent multiple public values. Some important characteristics are openness and values related to "transformation of interest to decisions" (Jørgensen & Bozeman, 2007, p. 360), like user democracy, majority rule and citizen involvement. DAOs can automatically realize these values through transparency and openness through the use of blockchain technology, where information is open for all users and by providing direct voting power to all participants of the DAO. However, this automatic inclusion could also have unwanted negative impacts for DAOs.

Regarding transparency, two important features of DAOs are related to the transfer of value and voting. The potential financial flows of individuals are public in DAOs and blockchain in general. This results in the situation that the privacy of individuals could be at risk, especially if these information flows are connected to other information sources (Janssen & van den Hoven, 2015). Similar to the financial flows, voting and voting behavior by individuals within DAOs is inherently transparent if one does not use techniques like O-voting (Arnaucube, Kampa, & Baig, 2022). The availability of voting behavior could further endanger privacy and make people vulnerable. In some situations, the openness of voting can be desired, like when politicians represent their society, whereas in other situations, openness might not be desired, and privacy might prevail.

User democracy and citizen participation could be enhanced. This could pose a real opportunity, especially around participative budgeting initiatives (Rikken et al., 2022). However, the implication could be that a principal-agent risk can occur if public organizations use DAOs and other new technologies and applications thereof (Bharosa, 2022; Eisenhardt, 1989). When decision-making and execution are delegated to DAOs and their users (citizens), there could become a misalignment between the principal, the public organization, and the agent, the DAO on the one hand. Although on the other hand, the transparency of DAOs could benefit monitoring by the principal, thus inherently contributing to preventing the principle-agent risk.

Next to governance design, *value-sensitive design* (VSD) in DAOs and blockchain-based applications in the broader spectrum, although already important in current IT systems (Van den Hoven, 2007), will even become more crucial than ever. VSD can ensure that the right trade-offs are made per type of DAOs. Certain business objectives might require values other than those of others. Also, the other way around, DAOs could be one of the solutions that can help meet public values derived in VSD efforts meeting responsible innovation(Van den Hoven, 2007, 2013). This complicated relationship should be taken care of when instantiating DAOs and could be subject to future research.

8.3 Final thoughts

Whatever future scenarios will bring, one must always keep in mind that both scenario planning and modeling and building theories is an attempt to abstract from reality and will never be a true representation of the real world. The real world is always more complex, and the future is always bound to many more causal restraints than can be reflected by an oversimplified 3-axis model. There will be an infinite number of non-tangible elements that will influence the course of the future and that can influence the long-term viability of DAOs. Not in the least, strategic human behavior is something to be taken into account on top of the relative technical approach of modeling the long-term viability influencing factors. Also, cultural aspects could play a role as it cannot be taken as a given that democratization of all operations is seen as the best way forward in organizations. However, elements of sheer luck can also play a role in the future usage of DAOs. If the concept is backed by just the right influencer or the technology and the deployment possibilities are embraced by and imbedded in worldwide standard used platform, like facebook or LinkedIn, even partially, e.g., the integration of standard token wallets in the industry standard software or as a standard app in the most widely used mobile devices could lead to mass adoption. The other way around, a single bad event, or even worse, a series of incidents like massive hacks resulting in loss of value or misuse of identities on a large scale, could kill adoption overnight. As stated in the scenarios, DAOs can flourish and create a new era of true participative cross-border collaboration or diminish to just another nice little tool in the toolbox. Given the current interest in the market, from industry to government, I am hopeful that it will lean towards the broad adoption scenario.

It is often stated that change is the only constant. Given that the future will always be uncertain, circumstances will always change, and innovation and learning will always bring new ideas and possibilities, we will always have to adjust accordingly. This means that our scenarios, models, and theories should always be confirmed, reconfirmed, challenged, and continuously tested and updated. We should do this on a high-frequency basis, as the closer we come to this future, the better we can predict what is coming our way and how behavior will occur. Build, test, analyze, learn, and repeat, as we already recommended for future research. Ipse Dixit.

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Olivier Rikken

Heemstede, 2024

Curriculum Vitae

Work Experience

09/2019 – Current - Emerging Tech Horizons R&D – Founder and Partner – R&D, consultancy and implementation in emerging technologies
09/2019 – Current - 2Token Foundation – Member of the Board - Lead research team – research to regulatory status of various token types – Lead of various Working Groups covering topics on Stablecoins and Hosted Wallets – Creator of the Token Regulatory Roadmap
06/2016 – Current - Dutch Blockchain Coalition – Founder and Chairman of the Smart Contract workgroup. Human Capital Agenda Member – creator of the Dutch National Blockchain Course
01/2018 – Current - (Guest) Lecturer – Delft University of Technology, Leiden University, Twente University, Nyenrode Business University, University of Amsterdam, Vrije Universiteit Amsterdam, University of Curaçao, TIAS business school, Istanbul Aydin University, The Hague Applied University, Utrecht Applied University, Hanze Applied University
12/2016 – Current - BlockStart, Swarm City & The Share Council - Advisory Board – Blockchain companies & consortia
07/2018 – Current Yes!Delft – blockchain & business expert –start-up coach/reviewer
02/2018 – 12/2021 - ISO - TC307 Blockchain – participant WG3 Smart Contracts & WG5 Governance
12/2019 – 09/2021 - Ledger Leopard – CEO & Blockchain, Smart Contract and DAO application specialist
03/2016 – 08/2019 - AXVECO – Director Blockchain & Smart Contracts
09/2010 – 02/2016 - GE Capital – Operations leader, (Sourcing, Facilities, Project Bureau & Operational Excellence)
06/2007 – 08/2010 - Atos Origin – Executive Business Consultant – Thought Leader BPM
07/2005 – 05/2007 - DailyFresh Logistics – Business Engineer – MT - Process improvement and IT

Education

3/2009 – 12/2010 - Nyenrode Business University / Kellogg School of Management / Stellenbosch Business School – Executive MBA, graduated on: Effect of strategy changes on various aspects of organizations (MBA degree)
9/2000 – 7/2005 - Delft University of Technology, System Engineering, Policy Analysis and Management – Graduated on: Simulation of Logistics Systems using discrete simulation models (MSc degree)

Honours and awards

Top 5 Global thought leader blockchain – thinkers360 2019 – 2020 – 2021- 2022 - 2023
Top 10 thought leader – Emerging Technology 2020 – April 2020, thinkers360
Blockchain Leader top 100 – 2019 – Listed by Lattice80 in June 2019 in their top 100 global blockchain leader list
Best Public Speaker 2017 – Award for best public speech 2017 by Platform Outsourcing Netherlands for my blockchain introduction speech at June 22nd 2017
GE 2010-2015 – Various internal awards for projects and initiatives
FD career challenge - 2009 Dutch Financial Times young professional career challenge – runner up – winning a scholarship for my MBA

List of publications

Publications related to this dissertation

Rikken, Olivier, Marijn Janssen, and Zenlin Kwee (2024). " The influence of and interplay between business objectives, governance elements, and infrastructure on the long-term DAO viability: Empirical insights." In press.

Rikken, Olivier, Marijn Janssen, and Zenlin Kwee (2023). "Governance impacts of blockchain-based decentralized autonomous organizations: an empirical analysis." Policy Design and Practice Volume 6, Issue 4 (2023): 465-487. https://doi.org/10.1080/25741292.2023.2270220

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Other publications

Rikken, O., Janssen, M., & Kwee, Z. (2022, June). Creating Trust in Citizen Participation through Decentralized Autonomous Citizen Participation Organizations (DACPOs). In *DG. O 2022: The 23rd Annual International Conference on Digital Government Research* (pp. 440-442). https://doi.org/10.1145/3543434.3543662

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Rikken, O (April 2016) Why blockchain could enable a True p2p Insurance model, a new blockchain based insurance model, unbundling the traditional value chain. Coindesk.com

Rikken, O. (November 2015) BPM and blockchain – Miles apart or closer that they appear, how traditional BPM is still relevant in a decentralized environment. Bpmleader.com

Blockchain technology provides great opportunities for new applications of which Decentralized Autonomous Organizations (DAOs) are seen as one of the most promosing. The possibility to organize crucial functionalities like governance and transfer of value in a peer-to-peer way without the need of traditional trusted third parties or management layers and structures provides us with the possibility to re-imagine value and information chains and organizations in a whole new way, Creating new (business) value, increasing efficiency and promoting employee and citized participation. The number of DAOs and their assets under management has risen sharply in the past years, and with that also risks and governance issues. This research aims to look into the effect of various elements on the long-term viability of DAOs so this can be taken into account in their design.

About the author: Olivier Rikken, born 31-12-1977 in Curaçao, has always had a passion for innovation and technology. After obtaining his master degree at Delft University of Technology in System Engineering, Policy and Management, he worked in various industries and as entrepreneur worked on many implementations of new technology in business and industry processes. His focus always goes beyond the technological and functional, predominately taking a multidisciplinairy standpoint as true benefits are only gained if all actors and point of views are alligned.

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