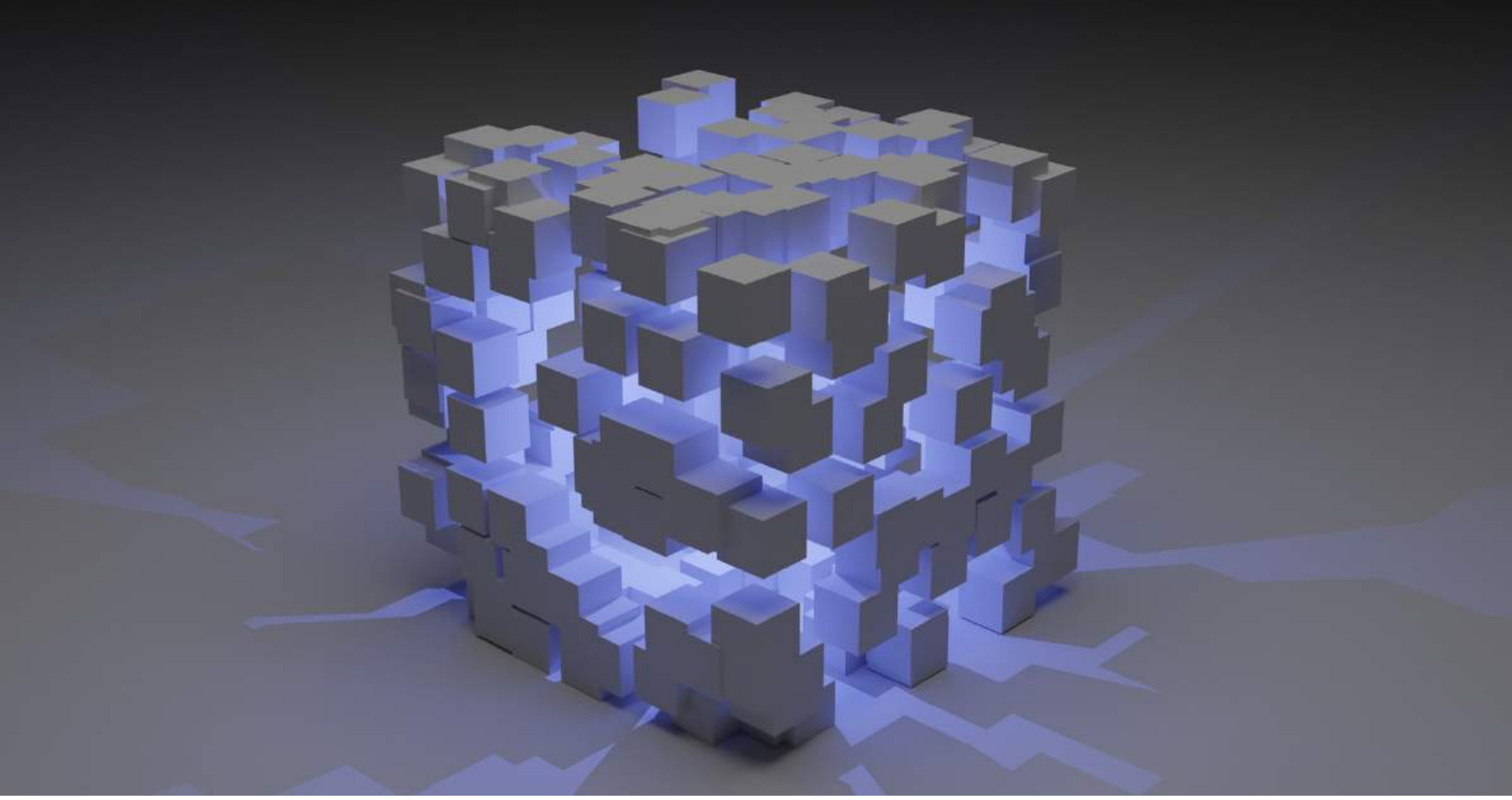
Master's Thesis

Decoding Digital Democracy

Investigating the Role of Smart Contracts in DAO Governance



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Abstract

Decentralised Autonomous Organisations (DAOs) embody the dynamic possibilities for new governance systems enabled by technological change. Participants in DAOs require neither a real-life relationship, nor a manager or central governing body, to harmoniously collaborate and advance their shared purpose, as they themselves democratically shape the terms of their cooperation. These terms are then encoded into and enforced by smart contracts—software programs—running on blockchain technology, automating standard management processes. While DAOs represent a novel research frontier, the research to date is bereft of studies that include the technical features of smart contracts in the investigative purview, alongside the social facets of DAO governance. This thesis seeks to bridge this gap by delving into the complex intersections of technology and governance in a single-case study, guided by the research question *"How do the technical features in smart contracts help to shape the governance mechanisms in Gitcoin, a Decentralised Autonomous Organisation (DAO)?"*. The study adopted a novel dual methodological approach, utilising both netnography and source code analysis to investigate the Gitcoin's sociotechnical governance mechanisms. This methodological framework can serve future research, furthering our understanding of sociotechnical dynamics in DAOs. The findings demonstrate the key role of smart contracts in enabling Gitcoin's governance mechanisms, and also revealed some intriguing disparities between governance mechanisms as practiced by the DAO and the actual functionality coded into their smart contracts, which are mainly used instrumentally. These discrepancies highlight the importance of considering DAO governance from a sociotechnical perspective, and suggest that Gitcoin has (tacitly) yet to fully harness the potential of decentralised governance that smart contracts offer.

Keywords: *DAOs, blockchain governance, decentralisation, smart contracts, sociotechnical, Gitcoin, organisations*

1. Introduction

In the emergent field of blockchain technology, Decentralised Autonomous Organisations (DAOs) represent a paradigm shift in organisational governance. DAOs are online organisations which operate in a transparent and autonomous manner, by way of rules encoded into software programs known as smart contracts (Lumineau et al., 2021, p. 506; Axelsen et al., 2022, p. 52). Their participants are decentralised networks of actors, often anonymous or pseudonymous, who converge over the internet to pursue a common purpose (Mini et al., 2021, p. 1, Beck et al. 2018). By collaborating and negotiating online, DAO participants democratically shape the software protocol which in turn governs their interactions and provides structure for their collective pursuits (Mini et al., 2021, p. 1; Hsieh & Verne, 2022).

Six years after the first DAO was established, there were more than 5000 active DAOs (Hsieh & Vergne, 2022; Axelsen et al., 2022, p. 52), and at least 200,000 active DAO participants (Mini et al., 2021, p. 1). DAOs are also now receiving significant investment from venture capital firms (Ziegler & Welpe, 2022, p. 1), with some DAOs having market caps of over US$3B (Schirrmacher et al., 2021, p. 5). These statistics qualify DAOs as worthy objects of scholarly attention, and a corresponding body of research has been growing in recent years (Beck et al., 2018, p. 4; Ziegler & Welpe, 2022, p. 1).

The innovative approach to organisational governance taken by DAOs falls under the category of 'blockchain governance', as it is deeply rooted in the capabilities of blockchain technologies. A blockchain is an 'append-only' database, which ensures the immutability and integrity of its data through its inherently decentralised storage (Mini et al., 2021, p. 2). On a 'permissionless blockchain', this data is also transparently visible for all stakeholders globally (Axelsen et al., 2022, p. 53). Blockchain governance facilitates cooperation and coordination in a manner distinct from traditional forms of governance (Beck et al., 2018, p. 2, Lumineau et al., 2021, pp. 500). It does so through the use of smart contracts, which are essentially software programs, running on blockchain technology. Smart contracts are capable of automatically enforcing agreements between collaborating parties, which they accomplish by executing outcomes based on the fulfilment of transparent, immutably predetermined conditions (Halaburda et al., 2019, p. 2; Schirrmacher et al., 2021, p. 4).

Smart contracts play a primary role in the governance mechanisms of DAOs (Beck et al., 2018, p. 28; Mini et al., 2021, p. 1; Axelsen et al., 2022, p. 52; Wright, 2021, p. 43). Since their inception, DAOs have been imagined as systems where automated processes take center stage, with human participation forming a more peripheral role (Buterin, 2014). The algorithms of smart contracts enable that automation: they have the effect of coordinating across time and space in the absence of a more typical central governing authority (Hsieh & Vergne, 2022), while also automating organisational processes such as allocating funds, tallying votes, and enforcing participation rules (Axelsen et al., 2022, p. 53). The growing number of DAOs and their sustained financial viability indicates that blockchain governance can provide the foundation for organisational success at scale.

However, as this research area continues to grow, it risks under-appreciating and under-exploring the role of the technical component of the governance mechanisms in DAOs. In spite of its technical underpinnings, existing studies into the phenomenon of DAO governance mechanisms have predominantly focussed on investigating its 'social component', by which I refer to the relationships and interactions of individuals or groups that serve to address their needs, goals, problems, or desires (Lee et al., 2015, qtd. in Sarker et al., 2019, p. 698). Such studies have been foundational in demonstrating that, for instance, complex social collaboration is integral in the governance process, as effective DAO governance requires that algorithmic control can be reshaped over time (Mini et al., 2021). However, the algorithms themselves, central to the governance process, have been mainly overlooked, and treated as a 'black box'—by which I mean taken to be entities which execute predefined tasks without an understanding of their inner workings

The lack of substantial investigation into the unique characteristics of the algorithms in DAO smart contracts limits our understanding of DAO governance, because, like the social forces in DAO governance, blockchain technologies function with a high degree of complexity and material agency (Rossi et al., 2019, p. 1392). Once deployed, smart contracts act as if they have a volition of their own (Axelsen and Ross, 2022, p. 11), and understanding the specifics of their contributions to the mechanisms of governance systems is an important component in understanding the governance systems more broadly. In blockchain governance, not only do humans shape algorithmic processes, but algorithms simultaneously govern human interactions, a dynamic resembling Leonardi's (2011) conceptualisation of imbrication of agency. Thus, DAO governance represents a synergistic interplay between social and technological forces, and the research literature will not have comprehensively analysed the phenomenon until it probes deeper into its technical intricacies.

Furthermore, participation in DAO governance processes, which entails reshaping smart contract algorithms, is relatively open to the public (Ziegler and Welpe, 2022, p. 9), and as such, exploring the nature of these algorithms could benefit communities outside the context of academia (Tönnissen & Teuteberg, 2018). Various taxonomies and source code analysis-based studies have already elaborated upon the business logic and technical details of smart contracts (Bistarelli et al., 2021; Hofmann et al., 2021; Tönnissen & Teuteberg, 2018). However, a study is yet to examine the concrete smart contract implementation of a specific DAO at a granular level in order to produce an in-depth, technically–informed outline of its governance mechanisms. This absence is noticeable, considering the growing number of DAO participants involved in this dynamic interplay between technology and humanity.

The present study therefore proposes a reorientation of the research perspective to give the technical component of DAO governance its due emphasis. This new focus prompts an exploration into the intricacies of smart contracts and their role in shaping the overall governance mechanisms within DAOs. Consequently, the following research question is formulated: *How do the technical features in smart contracts help to shape the governance mechanisms in Gitcoin, a Decentralised Autonomous Organisation (DAO)?* This question forms the basis of a single-case study approach, with Gitcoin as the subject, enabling in-depth data collection and analysis, with the intention of establishing an informative foundation for future research to pursue a balanced, sociotechnical understanding of DAO governance. To that effect, this study employs dual methods for collecting and analysing data. Netnography is used to understand the nuances of a DAO's governance mechanisms from a social perspective, while a source code analysis is applied to dissect the underlying smart contract algorithms. By integrating both the technological and social components into an analysis of DAO governance, this thesis aims to provide a holistic understanding of how these components coalesce to shape DAO governance.

The theoretical relevance of this study lies in its potential to open the 'black box' of smart contracts in the context of DAO governance research. By providing a detailed, technical analysis of the algorithms underpinning a DAO's governance protocol, currently absent in the literature, this study can illuminate the role and implications of the algorithmic mechanisms at the heart of DAO governance. In doing so, it complements the quantity of socially–oriented studies that exist in the area of DAO governance research, and helps to rebalance the direction of the existing research by providing a nuanced understanding of the technical aspects of DAO governance. Crucially, such a study has the capacity to emphasise the necessity of a balanced sociotechnical perspective by demonstrating potential gaps in our understanding of DAO governance that can occur when its technical dimension is overlooked.

From a practical standpoint, the insights derived from this study serve several stakeholders involved in DAOs. For practitioners—especially developers and entrepreneurs initiating DAOs—an increased understanding of smart contract implementation could assist in the design of more effective governance structures. Additionally, given the low barriers to participation and the highly democratised nature of DAO governance, the findings could be advantageous to a broader audience. For both technical and non-technical participants in DAOs, this study offers a deeper comprehension of the intricacies and rationale behind smart contract implementations. In doing so, this research equips them with critical insights that can inform their participation and decision-making within the DAO ecosystem (Tönnissen & Teuteberg, 2018).

This thesis is structured as follows: first, a literature review introduces relevant concepts and findings from the existing research related to governance, smart contracts, and DAO governance. Next, the methodological design of the study is elaborated in greater detail, including the model for data collection and analysis. Subsequently, the gathered data is presented, providing a comprehensive description of the contribution of smart contracts to the governance mechanisms of the DAO under investigation. The thesis then proceeds with a discussion of the findings, including making inferences relevant to the research area, before highlighting and summarising the overall contributions of the paper. Finally, concluding remarks will be made, which include the limitations and suggestions for future research.

2. Literature Review

2.1 Governance

Governance is a complex and multifaceted phenomenon, which has been studied extensively in various disciplines, including in organisational theory, management, and information science (Stoker, 1997; Adams et al., 2010; Shliefer & Vishny, 1996; Hatch, 1997). At its core, governance refers to the structures and mechanisms through which decision–making authority exists and is exercised in the context of a system comprised of individual actors (Stoker, 2004, qtd. in Ansell & Gash, 2008). The term is often associated with formal institutions such as governments and corporations, but governance encompasses a range of informal arrangements, social norms, and technical processes that influence individual behaviour (Gulati et al., 2012; Mini et al., 2021; Lumineau et al., 2021).

Governance, irrespective of the form it takes, is a critical prerequisite for successful collaboration. Its presence fosters the trustful conditions that allow separate entities to harmoniously coordinate their actions (Lumineau et al., 2021, p. 504). In instances of informal governance, these conditions can naturally arise as a result of a previous or ongoing relationship between parties (Hoetker & Mellewigt, 2009, p. 1028). However, lacking an inherent foundation of mutual trust, more formal arrangements become necessary, delineating mutual expectations, obligations, and penalties for noncompliance (Poppo & Zenger, 2002, p. 708). Traditionally, these kinds of arrangements have required the presence of a central governing authority—for example, a state government or an organisational executive body—to orchestrate behaviour, and to provide the means of imposing noncompliance penalties and adjudicating disputes (Lumineau et al., 2021, pp. 505-6). This centralised governance model has facilitated productive cooperation in society, including within organisational collaborations, to a degree that would not be possible solely through personal relationships.

However, in more recent times scholars have noted a growing divergence from traditional governance models based on hierarchy and centralisation, to more complex collaborative arrangements involving multiple stakeholders (Ansell & Gash, 2008). A multitude of factors contribute to this changing landscape, with technological advancements acting as a significant catalyst. The advent of the internet, for instance, challenged existing governance norms by extending collaboration possibilities beyond traditional governance boundaries. This shift created novel conditions where identity was not a precondition of participation, addressing individual transgressions became more challenging, and the trust between group members and towards centralised authority figures diminished (O'Mahony & Ferraro, 2007, p. 1101). Such evolving conditions prompted the demand for novel governance models capable of meeting the unique challenges presented by the new technological landscape. Technological developments are thus a significant driver of novel governance arrangements and less traditional characteristics.

Given the prevalence of unorthodox governance arrangements and the evolving conditions of the external environment, it's necessary to investigate the range of possible characteristics in governance. Moreover, identifying the most effective governance style for different scenarios is important, as different practices yield varying outcomes, each carrying a unique mix of benefits and costs (Huber et al., 2017, p. 565). However, all governance systems must address certain fundamental concerns. For instance, regardless of the governance model, the possibility of disputes between collaborators during their pursuit of individual and collective interests is constant (He et al., 2020, p. 1838), and there must be, at minimum, some means of addressing these disputes—some kind of mutual foundation of authority between collaborators (represented by a central governing body or individual in the centralised governance model) is a precondition for effective governance (O'Mahony & Ferraro, 2007, p. 1081).

Decentralisation is one governance characteristic that has been increasingly favoured by practitioners in recent times, as well as being a fixation of recent research (Axelsen et al., 2022, p. 56; Richardson et al., 2002, p. 218). It is heavily associated with direct democracy, and has the benefit of impeding individuals from wielding governance power in ways that are personally beneficial but that disadvantage other system participants (Buterin, 2017). As such, in a decentralised system, one's lack of trust in a central authority figure is made redundant, and such a system is therefore beneficial in circumstances where such trust may be low—for example, situations where governance is mediated by the internet. In practice, the mechanisms of governance can span a spectrum from centralised to decentralised, and decentralisation has been successfully applied across a range of political, organisational, and technological systems (Axelsen et al., 2022, p. 56). Thus, exploring the means by which these systems retain the necessary foundation of authority between participants—despite the absence of a centralized authority—becomes an intriguing area of study, leading us to consider the instrumental role of smart contracts.

2.2 Smart Contracts

Smart contracts are essentially software programs that automatically execute encoded rules upon the fulfilment of certain conditions (Schirrmacher et al., 2021, p. 4; Devine et al., 2021, p. 6). Though not fundamentally blockchain-based, they are heavily associated with blockchain technology—the concept of smart contracts only gained prominence around 2014, as it became evident that the digital assets which could be stored on blockchains extended to software programs (Evans et al., 2016, p. 12; Buterin, 2014, p. 1; Wright, 2021, p. 44). Smart contracts digitise both the representation and the execution of declarations of intent (Lumineau et al., 2021, p. 512; Tönnissen & Teuteberg, 2018), and, stored on a permissionless blockchain, they acquire the characteristics of immutability and transparency.

From 2015 onwards, the widespread implementation of smart contracts commenced, owing to their association with the newly–established Ethereum blockchain (Hofmann et al., 2021, p. 2; Buterin, 2014, p. 1; Halaburda et al., 2019, p. 2). While several blockchains now exist as platforms for smart contracts, Ethereum remains the most popular in both practice and research (Hofmann et al., 2021, p. 2). Once a smart contract is stored as data on a blockchain, it will merely execute processes in a deterministic and predictable manner (Mini et al., 2021, p. 3; Schirrmacher et al., 2021, p. 4; Halaburda et al., 2021, p. 2; Axelsen et al., 2022, p. 53). In Ethereum smart contracts, this execution happens on the Ethereum Virtual Machine, a computer environment which runs on computers connected to the Ethereum network (Tönnissen & Teuteberg, 2018; Hofmann et al., 2021, p. 3).

2.2.1 Governance Enabled by Smart Contracts

Smart contracts represent a foremost method through which governance systems can attain the characteristic of decentralisation while preserving a mutual foundation of authority for participants. They serve as the basis for blockchain governance, allowing cooperating parties to specify obligations and rights that are "automatically enforced based on digitally–encoded triggers" (Halaburda et al., 2019, p. 2; Tönnissen & Teuteberg, 2018; Lumineau et al., 2021, p. 506). All possible outcomes are immutably encoded into the smart contracts and transparently available for examination. Thus, collaborators are enabled to anonymously enter into agreements, safe in the knowledge that they will be automatically compensated for any transgressions by other parties as per the conditions of the contract. Crucially, these agreements can be conducted and enforced without the presence of more traditional governance characteristics such as intermediary facilitators, a central authority, or pre-existing relationships (Tönnissen & Teuteberg, 2018; Vacca et al., 2021; Axelsen & Ross, 2022, p. 10).

2.2.2 The Benefits and Risks of Blockchain Governance

The emergence of blockchain governance represents a turning point in organising collaborations (Lumineau et al., 2021, p. 500). It has opened up unprecedented new possibilities due to the ability of smart contracts to enable cooperation and coordination between distinct entities lacking a reason for mutual trust (Evans et al., 2016, p. 65; Axelsen & Ross, 2022, p. 10). However, smart contracts also hold the potential to disrupt existing governance systems on a massive scale. Where the mechanisms of traditional forms of governance are costly in terms of time and enforcement, smart contracts promise practitioners lower costs due to reduced intermediary processes, greater efficiency, and higher levels of security and trust (Lumineau et al., 2021, p. 512; Tönnissen & Teuteberg, 2018). To illustrate the practical advantages of blockchain governance, consider the commonly–cited example of a rental car agreement. If a customer began defaulting on the rental payments, a smart contract could simply detect the occurrence of this condition and automatically lock the car via an internet connection, without any cumbersome effort expended by the rental company (Buterin, 2014).

The benefits of smart contracts are also derived from their immutability (when stored on a blockchain). Collaborators can be sure that the agreements they have entered into cannot be cancelled or amended without their consent. In cases where a contract is designed to be "upgradable", a new version is deployed to the blockchain, with the previous version being essentially deactivated (Lumineau et al., 2021, p. 503; Tönnissen & Teuteberg, 2018). The characteristic of immutability has other important implications, as does the inability of smart contracts to understand nuance or context. Careful assessment of the feasibility of the use case, as well as all possible outcomes, are of critical importance during smart contract design, as the execution consequences of a poor technical implementation can be grave (Beck et al., 2018, p. 33). In our rental car example, if the smart contract developers were to overlook even one edge case, the customer could end up locked out of the rental car by no fault of their own.

2.2.3 Analysing Smart Contract Code

Developing a comprehensive understanding of how a software program will behave can be achieved through a comprehensive analysis of its source code (Cardoso et al., 2017). Considering that a major advantage of smart contracts is the ability to accurately anticipate contract behaviour under various conditions (Mini et al., 2021, p. 4), examining source code becomes a critical activity for harnessing the technology's full potential. There are several programming languages in which smart contract code is written, but the majority of smart contracts on the Ethereum blockchain are written in Solidity, a language similar to the ubiquitous JavaScript (Tönnissen & Teuteberg, 2018; Hofmann et al., 2021, p. 3). Inexperience with analysing such code can therefore pose a challenge in research or practice involving smart contracts, and even where such experience exists, software programs can be very complex and context-dependent. This challenge exists as part of a broader pattern: the technical complexities associated with blockchain technologies complicate investigations into the characteristics of their applications—for example, researchers have noted the difficulties, due to technical complexities, associated with ascertaining the true level of decentralisation in a DAO (Axelsen et al., 2022, p. 71).

However, previous efforts of researchers and practitioners can be leveraged to help decode the often-complex nature of smart contract code. For example, an understanding of the mechanics of Solidity can be gained from Zhang and Anand (2022) and Zheng et al. (2021), which include case examples of smart contracts implementations, explaining the purpose of coding features in relation to their system design goals. These works are helpful resources for developing a knowledge of Solidity and an understanding of a practitioner's perspective. However, targeted towards practitioners, such publications may be less useful for researchers than previous research into the intricacies of smart contract composition, such as the taxonomy developed by Hofmann et al. (2021). This taxonomy sought to categorise smart contracts at a technical level, thus providing a vocabulary with which to understand them. The authors identified six categories of common code patterns, which is a relatively small number given the potential complexity of smart contracts. Nevertheless, this taxonomy, and others which resemble or extend it, can serve as a useful foundation for categorising smart contract code while conducting a source code analysis (see Appendix A).

2.3 Governance in DAOs

Decentralised Autonomous Organisations represent one of the foremost applications of blockchain governance, as well as a radical departure from traditional organisational structures. In DAOs there are no centralised managers issuing orders or assigning tasks to employees (Lumineau et al., 2021, p. 509; Frew, 2020, p. 20; Axelsen et al., 2022, p. 52). Members of DAOs self–govern by use of 'digital governance tokens' (Mini et al., 2021, p. 1), which are managed by smart contracts (Axelsen et al., 2022, p. 53), and grant a share of executive voting power in the organisation (Jensen et al., 2021, qtd. in Schirrmacher et al., 2021, p. 5; Mini et al., 2021, p. 3). To participate in a DAO, in most cases one need simply to purchase or receive an amount of these tokens (Ziegler and Welpe, 2022, p. 9).

Typically, DAO governance actions originate from proposals, openly submitted by a participant to the rest of the organisation. Proposals may relate to a range of governance matters, from a particular course of action to a specific policy, to the fundamental rules that should govern the organisation (Lumineau et al., 2021, p. 509; Mini et al., 2021, p. 3; Belkowski & Falcke, 2022, p. 28). Once submitted, proposals may be discussed, debated, and finally voted on by token-holders (Frew, 2022, p. 20). This proposal system thereby gives structure to the interactions of DAO governance participants (Ziegler & Welpe, 2022, p. 9). If appropriate, the results of proposals are ratified by being encoded into algorithms contained in smart contracts (Mini et al., 2021, p. 3; Lumineau et al., 2021, p. 509; Beck et al., 2018). The governance protocol of the organisation resides in these algorithms, and actively guides the activities of the DAO by ensuring the rules and expectations of participation are followed, essentially automating management (Frew, 2022, p. 20).

DAO participants are free to come and go as they please, but participation assumes acknowledgement and acceptance of the democratic rules of the organisation (Lumineau et al., 2021, p. 509). The democratic nature of DAOs is significant. Typically, direct democracy within organizations struggles with managing complexity and scaling effectively (O'Mahony & Ferraro, 2007, p. 1081). However, DAO governance not only overcomes these limitations but also harnesses the advantages of direct democracy. These advantages include adapting to changing conditions over time—a crucial activity for any organization (Wright, 2021, p. 43)—and ensuring that governance structures align with collective interests (O'Mahony & Ferraro, 2007, p. 1100; Belkowski & Falcke, 2022, p. 30).

In studying the governance mechanisms of a DAO, there are many elements that must be taken into consideration, as there are numerous distinct decisions that a DAO can take when designing its governance structures. Previous research has already identified a number of these design choices. In their data-driven taxonomy of DAOs, Ziegler and Welpe (2022) identify a set of dimensions by which DAOs can have differing characteristics, with nine of these dimensions being relevant to DAO governance (see Appendix B). These dimensions revolve around three broad themes: voting, process, and tokens (Ziegler and Welpe, 2022, p. 7). Over 23 different characteristics were identified among the nine dimensions (which may not be exhaustive), which speaks to the complexity involved in analysing DAO governance structures. This taxonomy represents a useful resource for researchers; it could be leveraged as a tool to provide structure to the analysis of a DAO's governance structures.

2.3.1 Trends in DAO Research

As with the broader category of blockchain governance, the role that technology plays in enabling DAO governance and in cultivating successful collaboration between participants can be described as crucial (Osipenko & Sorensen, 2022). The encoding and automated execution of governance protocol into smart contracts allows these organisations to bypass the need for a centralised governing body (Lumineau et al., 2021; Hsieh & Vergne, 2022). Digital tokens also represent crucial incentives in DAO governance, enabling equity-based compensation in addition to facilitating voting-based decision-making (Schirrmacher et al., 2021). Furthermore, several of the governance dimensions identified by Ziegler and Welpe (2022) relate directly to technological characteristics—for example, DAOs vary by whether their voting processes occur directly 'on-chain' (mediated by blockchain technology) or not (p. 7). However, their analysis of current trends in the area of blockchain research, Rossi et al. (2019) observed a general pattern of researchers leaning away from technology– or protocol–centred research.

This trend is also observable in regards to DAO governance research. In fact, the knowledge gap that this trend leaves is particularly acute in regards to DAO governance, as very few of the technically–focussed blockchain studies that do exist, such as that of Hofmann et al. (2021), address DAO Governance. A review of the more recent blockchain literature indicates that this trend has been sustained over time. Consider Jensen and Ross's characterisation of DAO governance as occurring "through three channels" (2022, p. 47):

governance forums, voting tools, and Zoom calls; or Belkowski and Falcke's (2022, p. 27) description of the stages and gates of DAO governance (all human–centred). Even the studies which include technological factors in their purview, such as smart contract algorithms, tend not to specify the precise mechanisms which they refer to as 'algorithms'.

These characterisations may be coherent, and make for valuable contributions in the context of their respective discussions. Investigating the social side of blockchain governance is undoubtedly a necessary and vital endeavour, given that human participation is critical to blockchain governance, and different decisions taken by humans have different consequences for governance structures. However, a purely social lens risks under-appreciating the contribution of technological factors in the area of DAO governance as it does not articulate the sociotechnical reality of the phenomenon.

The sociotechnical lens posits social and technical components as mutually interdependent (Sarker et al., 2019, p. 698), and therefore provides a fuller description of DAO governance mechanisms. Rossi et al. (2019) hypothesised that current research trends could lead to this interdependency being taken for granted over time, as well as to "blockchain infrastructure" being taken for granted in its totality (Rossi et al., 2019). For this reason, Rossi et al. (2019) recommend that future studies take a more technical approach (p. 1390), and specifically recommend further research into the mechanisms of smart contracts (p. 1394).

3. Methodology

3.1 Research Design

Considering the novelty and intricate nature of conducting research into the technical features of DAO governance (Axelsen et al., 2022, p. 71), this study adopted a qualitative, exploratory approach. The utilization of exploratory research is apt when the research field is either nascent or has not yet been thoroughly investigated, as it allows for discovery and in-depth understanding (Stebbins, 2001). Such a research strategy allows theory to emerge from rich data, offering a beneficial point-of-departure for fields of study currently lacking data-informed theory (Siggelkow, 2007, p. 21). Aside from the lack of technically–oriented research, DAO governance represents an area with relatively limited existing research—indeed, the phenomenon itself has only existed for seven years (Hsieh & Vergne, 2022)

In light of the same considerations, this thesis adopts a single-case study design, concentrating on Gitcoin as the unit of analysis. While case studies may encompass single or multiple cases (Eisenhardt, 1989, p. 534), and although the prospect of investigating multiple cases was considered, I ultimately determined that immersion in the detailed examination of a single DAO was more conducive to a comprehensive exploration (Siggelkow, 2007, p. 21), allowing for a more solid (though less expansive) theoretical foundation for future research. This decision aligns with the context of the research, where the interplay between smart contracts and DAO governance is yet to be thoroughly explored.

From a sociotechnical perspective, DAO governance is composed of two distinct components: social and technical. Thus, two distinct research methods were employed, each attuned to its respective component. Source code analysis, a prevalent technique in software engineering for understanding the behaviour of a software program (Cardoso et al., 2017), was used in this study to deconstruct the algorithms in DAO smart contracts. My professional experience in the field of software engineering equipped me with the requisite background knowledge to apply this technique in a research context.

However, source code analysis would be ill-suited for collecting data on the nontechnical aspects of DAO governance. I opted to use netnography for that purpose, a well-established qualitative research method typically used for collecting online community data (Kozinets et al., 2014, p. 262). This technique has demonstrated efficacy in DAO research (Schirrmacher et al., 2021, p. 6), given that DAOs operate primarily online, thereby necessitating online data collection methods. Netnography is considered an online rendition of ethnography, which allows a researcher to become immersed in a subject's cultural context and community interactions, enabling a deep apprehension of their behaviours and perspectives (Kozinets et al., 2014, p. 262-3). By immersing myself in Gitcoin's online community, I was able to cultivate extensive contextual knowledge of the community's customs pertaining to governance, which I could then synthesise with the results of the source code analysis, in order to construct a holistic understanding of DAO governance.

The application of netnography, a naturalistic practice (Kozinets et al., 2014, p. 263), resonated with the study’s overarching naturalistic approach, a highly-regarded methodology for comprehending phenomena as they exist in their natural setting (Lincoln & Guba, 1985). That is, this research sought to understand Gitcoin's governance mechanisms as they operate in situ, without intervening or manipulating any conditions for data collection. Accordingly, the study adopted a cross–sectional temporal orientation (Baum, 2021, p. 21), as its focus was to investigate the contribution of the smart contracts to the governance mechanisms of the DAO, and considerations to process or code changes over time lie outside of that scope.

3.2 Empirical Setting

Gitcoin is a community–oriented, philanthropic organization that promotes collaboration between software developers, providing an ecosystem for funding and development of open-source projects ("Gitcoin DAO", n.d.; Gitcoin, n.d.-a). Its declared mission is "to empower communities to build and fund their shared needs" (Gitcoin, n.d.-c), primarily operationalised through two central open–source digital products: the Gitcoin Grants Stack, a decentralised application which enables online communities to conduct fund–raising for companies and projects using a fund-matching protocol (Gitcoin, n.d.-d), and Gitcoin Passport, a "proof of identity" mechanism augmenting the Grants Stack by preventing manipulation of the fund–matching protocol (Gitcoin, n.d.-e).

Operating as a DAO, Gitcoin invites its community members to participate in decision-making processes concerning the organisation’s development and governance (Gitcoin, n.d.-b). It espouses community, decentralisation, and democratic governance as its fundamental values. Given this study's focus on a comprehensive, single-case study design, careful consideration preceded the selection of Gitcoin as an appropriate case. The intent was to identify a case likely to yield meaningful insights into the phenomenon of DAO governance for both researchers and practitioners (Eisenhardt, 1989, p. 537; Siggelkow, 2007, p. 21). The section process was guided by the following criteria:

a) *Longevity and Activity*: The chosen DAO needed to be active and at least five years old. This stipulation ensures that the DAO's governance mechanisms are well-established, comprehensible to its community, and proven effective for the DAO's continued existence.
b) *Accessibility and Legality*: The DAO's smart contracts had to be publicly available and easily accessible, circumventing any potential concerns regarding data accessibility and legality.

c) *Technical Implementation*: Considering the technical aspect to this study, it was crucial that the DAO had a robust technical implementation. While this criterion was not straightforward to measure a priori, a well–implemented technical system was inferred using relative financial success of the DAO as a measure, considering the link between well–encoded governance mechanisms and functional collaboration (Osipenko & Sorensen, 2022). With Gitcoin having over US$80M in liquid assets at the time of writing (DeepDAO, n.d.), it distinguished itself as a financially healthy DAO, suggesting a high likelihood of well-orchestrated governance mechanisms.

Apart from satisfying the aforementioned criteria, other attributes increased Gitcoin's appeal as a case study. Unlike many DAOs, Gitcoin operates an official public governance forum, which serves as a hub for participation in its governance processes (Gitcoin, n.d.-b). This offered additional facilitation for ease of data collection and suggested the probability of well-documented governance processes. Coupled with Gitcoin's considerable reliance on smart contracts (Gitcoin, 2023), these factors indicated it as a case likely to yield a wealth of data during both the netnography and the source-code analysis.

3.3 Data Collection and Analysis

In this study, the processes of data collection and analysis were inherently interwoven, a point which will be presently elaborated. Determining an answer to the research question—*'How do the technical features in smart contracts help to shape the governance mechanisms in Gitcoin, a DAO?'* —relied upon determining the answers to two empirical questions:

i) What are the governance mechanisms of Gitcoin?

ii) Which technical features contained in Gitcoin smart contracts are relevant to those governance mechanisms?

A preliminary answer to the first question could be derived from the netnography output, a method that characteristically combines descriptive and analytical elements (Kozinets, 2014, p. 263). Consequently, the netnography inherently blended data collection and analysis. Throughout the immersion experience, I was simultaneously compiling and examining data for patterns, themes, and salient features related to Gitcoin's governance mechanisms. Similarly, in answering the second empirical question, the source code analysis incorporated elements of both data collection and analysis. Once the pertinent code files had been identified, ascertaining the relevance of the files' internal code to governance fundamentally entailed analysis, in order to form a basis for discarding it or including it in the dataset.

3.3.1 Netnography

The netnography was conducted during May 2023. I used two primary netnographic data collection methods: archival data digging and lurking (Kozinets et al., 2014, p. 266), to collect data from Gitcoin's official resources and online communities. Archival data digging is a low-cost technique that involves mining existing online data, while lurking involves non-intrusive observation of online communities, allowing for the creation of detailed field notes (Kozinets et al., 2014, p. 266). Resulting data were maintained in an 'immersion journal' slide deck.

The netnography was informed by Ziegler and Welpe's (2022) data–driven taxonomy of DAOs—specifically, the 9 dimensions of their taxonomy which relate to DAO governance. These dimensions were applied to the netnography data as it was collected, facilitating the identification of Gitcoin's key governance characteristics. Applying these dimensions gave structure to the data collection process, guiding me towards relevant data points amidst the quantity of data that existed by directing me to answer a series of smaller empirical questions (e.g., 'What is the supply cap of Gitcoin's governance token?'; 'Is the governance process fully on-chain?' [Ziegler & Welpe, 2022, p. 9]). The nine dimensions are revisited in Table 1 (Section 4) of this paper, and can also be found in Appendix B.

In addition to establishing a fundamental set of governance characteristics of Gitcoin, these smaller questions guided me towards data areas generally relevant to Gitcoin governance. Consequently, I did not restrict the data collection to the identification of governance characteristics as per Ziegler and Welpe (2022) but stayed receptive to additional data relevant to the first empirical question, aiming to create a rich data set. For further analytical structure, I used an adapted form of data-driven open coding (Gibbs, 2018). This process entailed separating data points relevant to the first empirical question into two overarching categories that had begun to emerge from the immersion journal data: (i) roles in Gitcoin governance, since a hierarchical structure related to governance became evident; and (ii) processes where participants with these roles interact to enable governance. This process bore some resemblance to the 'Gioia Methodology' (Gioia et al., 2012), but due to circumstances such as the manageable size of the dataset, there were two key differences: the first-order codes were sorted into the two overarching categories (which bore resemblance to 'aggregate dimensions') without needing intermediary second-order categories (Tracy, 2013); and the process did not necessitate the use of coding software, and was performed manually. Figure 1 displays a visualisation which contains examples of codes belonging to the overarching data categories.

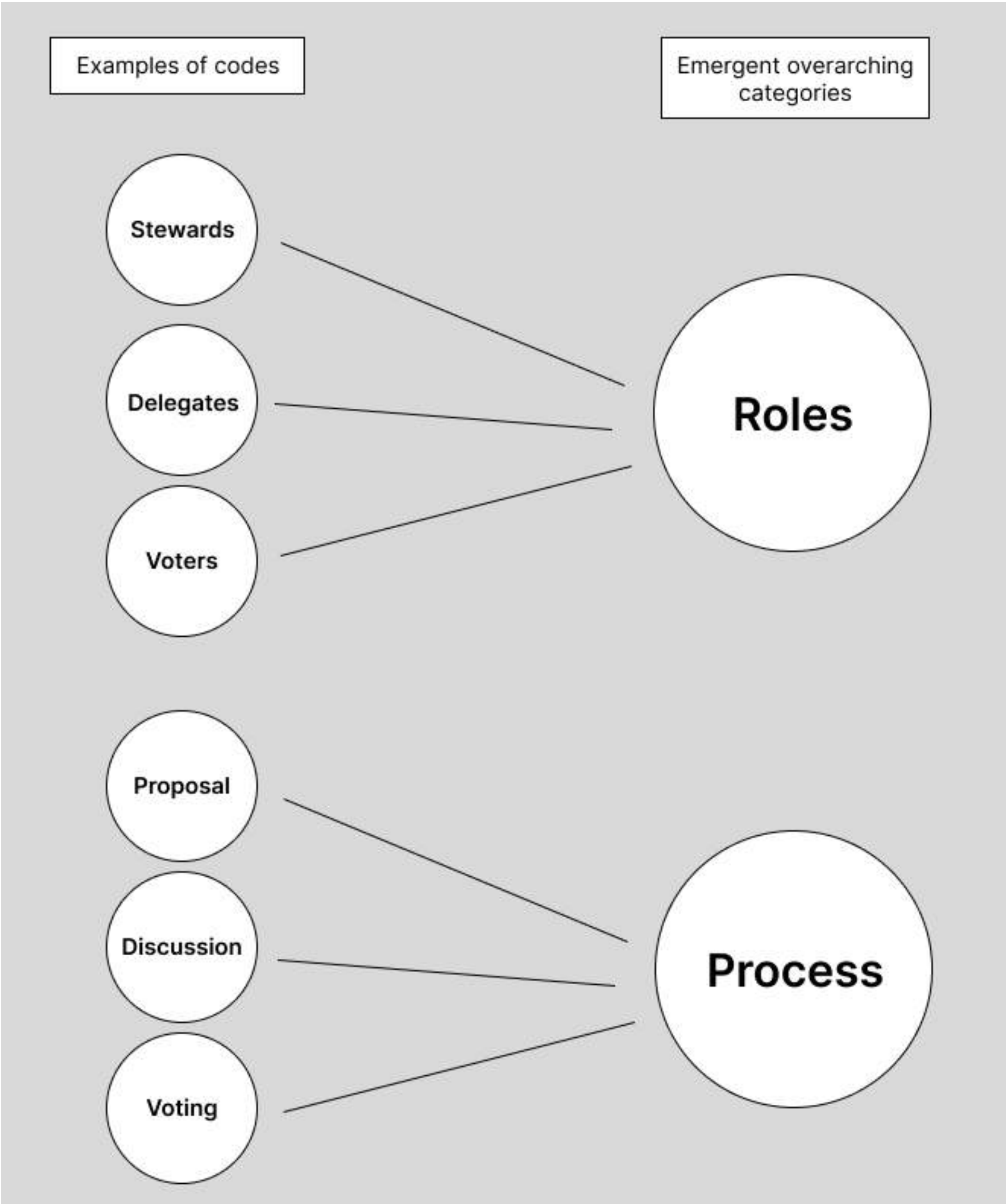

Figure 1: Examples of codes and overarching emergent categories during netnography data analysis

Multiple rich sources were utilised for triangulation purposes, to ensure empirical validity through cross-source consistency, thereby enhancing the robustness and credibility of any emerging theory (Eisenhardt, 1989, p. 538). Gitcoin's official governance forum (gov.gitcoin.co) was the primary source consulted. Archival data on the forum—such as previous governance decisions and established DAO process information—took the form of 'posts' and 'comments' by participants, and there was little distinction between participant interactions and the sharing of community information. As such, the archival data digging and lurking tended to blend together. This forum represented a hub of rich information, pertaining to governance discussions and proposals, processes and customs, DAO values, and more. However, significant community discussions and processes also occurred on external platforms, necessitating additional sources complementary to the governance forum, such as Snapshot (https://snapshot.org/#/gitcoindao.eth), Discord (https://www.discord.com), and GitHub (https://github.com/gitcoinco).

As the data collection and analysis advanced, the answer to the first empirical question became increasingly refined. Theoretical saturation, which signifies a threshold where additional data cease to add value beyond what is already derived from existing data (Glaser & Strauss, 1967, p. 61), served as a method to determine whether sufficient data had been collected and the first empirical question adequately answered. This point was identified when I noticed a repetition of specific patterns and themes during online immersion, with a vanishing emergence of novel insights, indicating that the netnography process was sufficiently exhaustive.

3.3.2 Source Code Analysis

Following the netnography, I accessed and analysed Gitcoin's publicly available smart contracts, to develop an understanding of the technical underpinnings of the platform's governance mechanisms. These smart contracts are maintained in a repository on GitHub, a public platform for hosting and managing code repositories. Gitcoin maintains various software programs and products—for example, the Gitcoin Grants Stack—so the repository contains numerous directories and files (https://github.com/gitcoinco). Nonetheless, the repository is well-organised and clearly labelled, and includes a dedicated directory for governance-related smart contracts, which I 'forked' (made a copy) for the analysis.

The source code analysis was informed, as applicable, by the six categories of common code patterns from Hofmann et al.'s (2021) technical taxonomy of smart contracts (see Appendix A). I used this taxonomy-based process to categorise contracts, providing structure to the analysis while remaining alert to emerging patterns that could extend or diverge from these frameworks. For instance, the categories include "Core Functionality" and "Helpers". After determining the meaning and purpose of a specific code element, I could classify it as part of the contract's core functionality, a helper, or something else. This approach enabled a thorough examination of the data and facilitated the discovery and understanding of the relevant smart contract features, benefiting from the relevant findings of existing research. Ultimately, I found no reason to extend the taxonomy, as all governance-related code fit into one of the categories, but I noted some overlap between two categories, as later displayed in Table 2 of Section 4.

However, as mentioned, categorising code was dependent on first understanding its meaning and purpose. Gitcoin's smart contracts are written in the Solidity programming language, and despite my experience analysing code written in other, similar languages, it was first necessary to consult the official Solidity documentation (https://docs.soliditylang.org/en/v0.8.20/), and apply the concepts and information contained in the documentation while reading the code (before any considerations could be given to answering the second empirical question). This application entailed determining the different kinds of code possible in a Solidity contract, determining which were present in the Gitcoin contracts, and determining what each aspect of a certain kind of code meant. I documented this process assiduously in a 'source code analysis slide deck', given that much of the value of this study lies in its potential to 'decode' smart contracts, in the hopes that details of my knowledge acquisition regarding Solidity could benefit other researchers and practitioners. The results of this Solidity code analysis have been included in this study's findings because they form the foundation for the subsequent analysis proper: once I knew what the code meant, it was straightforward to analyse its functionality (i.e., what it does) in order to determine relevance of code to DAO governance mechanisms, thereby answering the second research question.

While the Solidity analysis enabled an understanding of individual code elements, the analysis proper entailed studying these elements to ascertain how they interacted and the effect produced. Data was thus represented by descriptions of the code's functionalities, which I maintained in the source code analysis slide deck. The analysis was aided by the presence of a file in the directory which provided a text description of the code's functionalities by an unidentified party. The author could have been one of the code's developers or not, and their expertise was uncertain, so this file was treated as a supplementary resource for the analysis, rather than as an authoritative source.

After analysis, data were evaluated for relevance and categorised according to Hofmann et al. (2021). The relevance of emerging data was determined based on its potential impact on DAO governance, as suggested by the literature review and the preliminary answer to the first empirical question—for example, specific code implementing voting mechanisms or managing a governance token. Besides discarding irrelevant data, I omitted reference to any code which could be taken-for-granted, using the criteria that this type of code must be included in the way that it is, and without it the smart contract could not work at all. The justification for this omission is that to analyse such code would not produce any meaningful insight relevant to the research question, as such code must be considered a necessary precondition for creating a smart contract, and does not represent any design decision taken by the DAO or smart contract's development team.

3.3.3 Synthesis and Interpretation

After answering the second empirical question—'Which technical features contained in Gitcoin smart contracts are relevant to the governance mechanisms?', the first empirical question—'What are the governance mechanisms of Gitcoin?'—could be revisited and given an updated answer that considered the full sociotechnical context of Gitcoin governance. This was achieved via a synthesis of the findings, which were represented by the existing data-driven answers to the two empirical questions. The juxtaposition of the two answers (preliminary and final) to the first empirical question (i.e., comparing descriptions of Gitcoin's governance mechanisms before and after considering its technical aspects) formed the basis of providing an answer to the overall research question.

The synthesis of the findings was accomplished by a second application of triangulation (Eisenhardt, 1989, p. 538), this time between netnography findings and source code analysis results. This triangulation was critical not only for deriving an answer to the research question, but also for ensuring empirical validity—a secondary benefit of the choice to use dual research methods. This triangulation process entailed comparing the functionalities contained in the smart contracts with the governance mechanisms as revealed by the netnography, and making explicit the ways in which the smart contracts enable, contribute to, or otherwise shape the overall governance process. Moreover, this process facilitated the identification of divergences between the smart contract functionality and the netnography findings. While many of these divergences and alignments were evident during the source code analysis, given the completion of the netnography at that point, the synthesis process formalised those findings, explicated them, and added to them.

Finally, the implications of the results were laid out as they were interpreted and discussed in light of the existing literature on smart contracts, DAOs, and governance. This interpretation helped to situate the findings within the wider discourse on blockchain technology and decentralised governance, contributing an understanding of how the technical aspects of smart contracts contribute to governance mechanisms in DAOs. A visualisation of the novel methods employed in this study can be found in Figure 2.

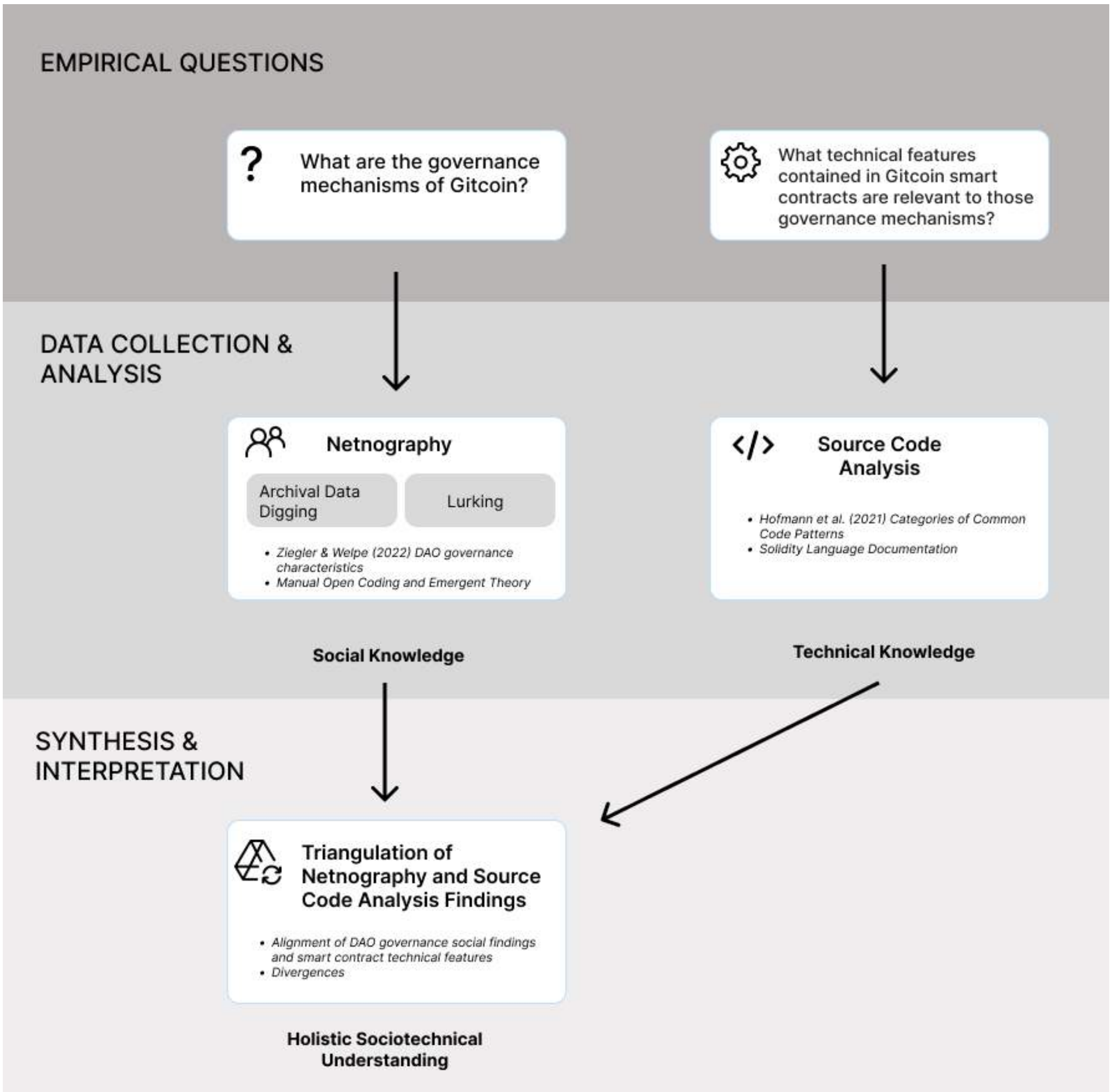

Figure 2: Visualisation of the methodological process employed in this study

3.4 Ethical and Legal Considerations

To ensure the ethical conduct and legality of this research, the following measures were taken:

a) *Anonymity*: When recording data in the immersion journal during the netnography, any personal information, such as usernames or other identifiers, was anonymised to protect the privacy of community members. Additional anonymisation techniques were also used, including paraphrasing and data aggregation, in situations where there was a concern that online statements made by DAO participants may not have been intended as public statements and could be traceable back to their online identity. Data originating from one individual was only considered when it was absolutely clear that the public nature of their contribution was understood (Schirrmacher et al., 2021, p. 7)—which occurred relatively frequently, as the Governance Forum is largely comprised of contributions by specific individuals, even in regards to fundamental elements of the forum, such as the "Forum Guidelines and Code of Conduct 2023". Nevertheless, respecting privacy rights is a fundamental concern in netnography-based studies (Kozinets et al., 2014, p. 268), and this thesis endeavoured at every opportunity to protect the privacy rights of DAO participants, even in the context of publicly-made statements.

b) *Respect for intellectual property*: This study endeavoured to discern the intellectual property status of all data it collected, and to exclude data from the analysis that may be protected by copyright or not intended for public consumption. The smart contract code used in Gitcoin governance protocol is open-source, itself adapted from other smart contract implementations, and is therefore not subject to copyright (Open Source Org, 2006).

c) *Adherence to legal agreements*: Appropriating information from a setting in which participation may be subject to a Terms of User agreement is a perennial risk (Kozinets et al, 2014, p. 269). Each agreement entered into during the course of data collection was meticulously scrutinized and adhered to.

4. Results

This section presents the findings from the data collection and analysis processes conducted as part of the study's methodological design.

4.1 Netnography Results

The results of the netnography are elaborated in the following two subsections, which relate to the two categories that emerged during the data collection and analysis process (i.e., the *roles* that DAO participants can have, and the *process* by which these participants interact to enact governance). Table 1 contains the nine governance characteristics held by Gitcoin along the dimensions of Ziegler and Welpe (2022), which guided the data collection.

Table 1: Characteristics of Gitcoin Governance, based on dimensions taken from Ziegler and Welpe's (2022) data-driven taxonomy of DAO characteristics

Governance Token Supply	The supply of GTC, Gitcoin's governance token, is capped at 100 million.
Governance Token Type	GTC follows the ERC-20 standard, a standard commonly used on the Ethereum blockchain, on which it runs.
Governance Voting Power	Gitcoin's characteristic along this dimension does not conform to any characteristic identified by the authors. Gitcoin's characteristic could be described as 'Tokens owned or delegated'.
Limits to Governance Voting	There are no limits to governance voting in Gitcoin.
Fully On-Chain Voting	Gitcoin relies on off-chain voting, and uses on-chain voting only as an integration formality.
Entry Barrier to Governance Participation	Users must create an account by providing their email address to participate in governance discussions, a negligible entry barrier.
Governance Process is Fully Public	This is not the case with Gitcoin, with several aspects still recalling its origins as a centralised organisation—for example, many discussions relevant to governance still happen in private online spaces.
Process Creation Restriction	There is no restriction (other than providing an email address), although proposals which do not confirm to the established proposal format may be removed from the governance forum by a moderation team.
Governance Process Execution	Manual, carried out by members of the community controlling at least 1 million GTC (1% of the total supply).

4.1.1 Roles in Gitcoin Governance

Participants in Gitcoin governance may hold one of several roles, as well as belong to one of several groups. Appendix C contains a visual representation of these roles. Initial participation has a low entry barrier: it is possible to contribute to the public discourse that helps to shape Gitcoin without incurring any cost. After making an account on the publicly–accessible governance forum, any interested party is considered a *community member*. All community members can participate in governance discussions on the forum, as well as make governance proposals.

To actually become a *voter*, capable of influencing the outcome of proposals via mechanisms of direct democracy, community members must possess a share of Gitcoin's governance token (GTC). When a proposal is active, a voter has a window of time in which to cast their vote via an external off-chain platform. Voting power is weighted based on how many governance tokens a voter holds. Thus, those with a larger investment have a proportionally greater influence over the direction of the platform. However, voters may instead choose to become *delegates*, by delegating their voting power to a *steward*. Stewards are members of the Gitcoin community with extra governance responsibilities, as well as additional voting power (to whatever degree delegates entrust them with their voting power).

The DAO seeks to provide delegates with ample information for making the decision to vest their voting power to a steward via a "Steward Health Card" system. Each health card displays each steward's personal statement (usually a small biography and the values in which they believe); their voting history; the total number of tokens they control; how many delegates have entrusted voting power to them; and even a "Steward Health Score" which is algorithmically calculated, based on their recent and historical levels of overall participation. Participation as a steward is open to anyone who submits a profile.

To elaborate on some aspects of Gitcoin Governance associated with the steward role: they are expected to dedicate a certain amount of time each week to contribute to discussions, attend routine stewards meetings, and are generally encouraged to establish a public presence, as well as to make proposals. Once a proposal is made, it must receive input from at least five stewards before qualifying for a vote. Some proposals may be to establish 'workstreams'. Workstreams are coordinated efforts towards advancing Gitcoin's purpose, and approving workstream proposals is how the community determines what is in or out of scope for the DAO. Workstreams must have a steward responsible for the project. Additionally, the governance forum has a moderation team of three stewards who ensure that forum posts and discussion follow the appropriate guidelines. The moderation team can remove and delete content from the forum, although it is implied that this power only exists as a precaution, given the low entry barrier for governance participation. The netnography found no evidence of the moderation team having been elected.

Such elite roles existing in the community partially opposes the ethos of decentralised governance. The 130 currently-serving stewards control a significant share of the voting power and community influence. However, there is some alignment of this system with the practical realities of the situation: stewards ensure commitment to Gitcoin's purpose and values, as well as drive the development of the DAO. Additionally, it must be acknowledged that Gitcoin governance can still be considered democratic in the sense that governance power is (mostly) consensually bestowed to stewards by the community, and the barrier to stewardship is quite low.

Some groups also play a role in Gitcoin governance. Firstly, the DAO is associated with, although separate from, The Gitcoin Foundation, a company incorporated in the Cayman Islands, which provides limited liability for token holders and technically controls several of Gitcoin's charitable assets. The DAO explicitly states that the goal of its governance is to include and empower all stakeholders, and to create a more fluent system over time. However, despite continued efforts towards decentralisation of the organisation, some aspects of its governance remain reminiscent of its origins as a centralised company, with The Gitcoin Foundation an illustrative example.

Secondly, there is a "Cross Stream DAO Ops" group (CSDO), which is the "day-to-day governing team" of Gitcoin. This group is comprised of two members of each workstream. It is logical that such a team may need to exist, as advancing the DAO's purpose through workstreams would involve a lot of minor daily decisions that may be impractical for the community to discuss and vote on. Voters therefore approve proposals for workstreams with the understanding that they are simultaneously granting a degree of autonomy to the workstream—whose members are incidentally the final named role in Gitcoin, *contributors*, and are reimbursed for their efforts via the budget which is approved for the workstream as part of the proposal. It must be noted that CSDO also contains an unelected member of The Gitcoin Foundation, a clear remnant of centralised power persisting within Gitcoin governance.

Finally, a "Steward Council" exists, which serves as an "externally–aware advisory board" to the DAO. Its members are a combination of workstream–participating stewards and stewards who are less active in Gitcoin and more active in other DAOs or decentralised platforms. Currently, all members are nominated by the workstreams, and then voted upon by the community. This council does not have any direct governance power, but in practice they are a concentrated discussion group which wields significant influence in reviewing proposals, shaping discussion, and advising CSDO. Council members meet regularly and also receive renumeration in the form of digital tokens (and therefore additional voting rights).

'External stewards' may only serve for a limited period of time, but workstream-based stewards have no limit on council participation.

4.1.2 Gitcoin Governance Process

Proposals form the basis of Gitcoin governance—they often evolve out of community interactions, and are formally discussed and refined by the community before being voted upon and possibly implemented. Some proposals may evolve out of private discussions on other online platforms, such as Discord (for example, the monthly stewards meeting, the steward council, or CSDO). However, it is encouraged to hold discussions on the official forum for transparency, and to ensure that voters can make informed decisions. The template for making a proposal can be seen in Appendix D. Proposals are based on a range of potential goals and requests, but generally fall into one of three categories:

i) *Funding Proposals*, which usually ask for community approval to build something (for example, a new software tool) in the form of a workstream.

ii) *Ratification Proposals*, which ask the community to approve of an action by the community or by a workstream (for example, improving or amending the Gitcoin documentation).

iii) *Governance Proposals*, which ask the community to approve a certain policy, procedure, or structural change (for example, whether the Gitcoin Grants Stack should allow the inclusion of projects backed by venture capitalists).

After being posted in the governance forum, proposals can be discussed by the community. Once a proposal has been posted for at least five days, and has input from at least five stewards, it meets the criteria for qualifying for a vote. Voting happens in two stages: firstly, as mentioned, the community holds an off-chain vote on the external platform Snapshot, meaning that the results of a vote do not incur any 'transaction fees', which are the costs of making a transaction on the blockchain. The voting period is five days, and the outcome of the vote is considered binding. In order to pass, a proposal must receive a majority of votes cast in favour, and at minimum 2.5 million GTC must have participated in the vote (a stipulation referred to as 'quorum').

After an off-chain vote has passed, the proposal qualifies for an on-chain vote, using the external platform Tally. In Gitcoin governance, on-chain voting is only used as a method of transparently implementing the proposal, meaning that it is only used in cases where funds must be released from the treasury or where technical (smart contract) changes must be integrated. As such, all on-chain votes must all be in favour of the proposal, and a minimum number of community members are advised to participate. Should a community member disregard the rules and vote against the proposal, all stewards are expected to rally together to ensure that the vote passes. Thus, Gitcoin governance leverages the benefits of on–chain voting (automatic blockchain-based integration of results) in a way that minimises transaction fees. A diagram of the governance process as revealed by the netnography can be viewed in Figure 3.

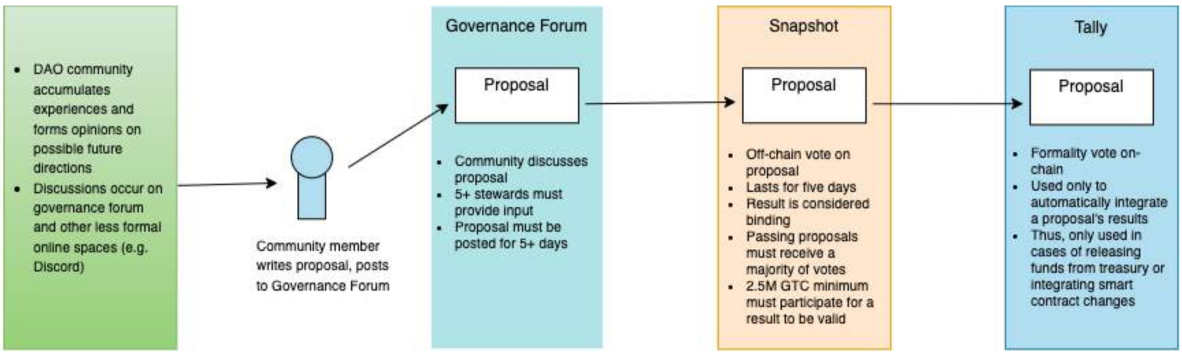

Figure 3: Diagram of Gitcoin's governance process

4.2 Source Code Analysis

This presentation of the source code analysis results includes both the output of the initial process which sought to understand the mechanisms of the Solidity programming language as used in the contracts, as well as the determination of the actual technical features relevant to governance contained in these smart contracts. Table 2 displays a summary of the categorisations of code patterns as per the Hofmann et al. (2021) undertaken as part of the analysis process.

Table 2: Summary of the categorisation of the coding patterns present in Gitcoin's governance protocol, based on the six categories of code patterns identified in Hofmann et al.'s (2021) technical taxonomy of smart contracts	
DApp Design	The governance protocol is composed of multiple smart contracts. Documentation included with the smart contracts contained the following description of the governance protocol: "Gitcoin protocol is governed and upgraded by GTC token holders, using three distinct components: the GTC token, governance module, and Timelock." Each of these three components mentioned is represented by a smart contract (*GTC.sol*, *GovernorAlpha.sol*, and *Timelock.sol*). Aside from the three primary governance contracts, the repository included two additional smart contracts which were used to facilitate the launch of the token, but had no detectable current relevance to Gitcoin governance.

Core Functionality	The contracts together form the basis for Gitcoin's decentralized governance mechanisms, facilitating the governance token system, the delegation system, the proposal-and-voting system, and the contract execution system. The majority of code exists for that purpose.
Helpers	The contracts do not leverage any external libraries to support their core functionality.
Contract Management	These contracts contain mechanisms which allow reshaping over time, from a minting mechanism in the *GTC.sol* contract, which allows for the minting of new tokens, to the core functionalities of *GovernorAlpha.sol* and *Timelock.sol*, which deal with the approval, queueing, and execution of proposals which fundamentally facilitate the realisation of changes to the system.
Safety Functions	Both *GTC.sol* and *GovernorAlpha.sol* leverage 'safe math' functions to prevent various technical security breaches (such as underflow and overflow attacks). Additionally, there is an entire library, *SafeMath.sol*, included in the governance directory, which *GTC.sol* and *Timelock.sol* leverage for the same purpose.
Tokens	There is a system of tokens, managed by *GTC.sol*, which is the core functionality of that contract. As the token is explicitly a governance token, with no economic value (according to the netnography), the token system may be considered part of the Core Functionality.

4.2.1 Decoding the Solidity Code

All three governance smart contracts are composed of elements which interact with each other to produce the functionality of the contract. These elements are state variables (*variables*, *constants*, and *mapping*s), type declarations (*structs* and *enums*), *event* emitters, and *function*s. State variables are values that are permanently stored in contract storage (Solidity, n.d.-a). Type declarations are used to ensure that variables conform to a certain datatype—for instance, a variable which is meant to have the value of a number (such as a variable which holds a voter's GTC balance) should not be able to be set to a string value (a collection of letters or characters). *Function*s are "executable units of code" (Solidity, n.d.-a), which execute processes that depend on and in some cases change the state values. Each contract also contains a *constructor function*, a special kind of function that runs only once, when the contract is initially launched, to initialise some state variables. When a *function* has run, an *event* emitter can then log data to the Ethereum Virtual Machine in order to communicate with external entities (Solidity, n.d.-a).

In summary, *function*s read and receive the values contained in state variables, and then execute organisational processes by, in many cases, assigning new values to state variables. *Type*s ensure that variable data conforms to a specific pattern, and *event* emitters enable communication of the results of *function*s. Therefore, the interaction of these identified elements in these three interrelated contracts form the basis of the algorithms which execute organisational processes in Gitcoin. The identified elements are further elaborated on in Appendix E, which breaks down an example of each.

The Solidity documentation recommends structuring the elements of a Solidity smart contract in the following order (Solidity, n.d.-b):

1. Type declarations
2. State variables
3. Events
4. Functions

The contracts contain evidence of consistency and adherence to the Solidity guidelines. All three contracts place functions at the end of the contract. However, some inconsistencies between the contracts and divergences from the Solidity guidelines exist, which represent notable exceptions:

- *Timelock.sol* does not contain any type declarations, places events at the start of the contract, and is more than half the length of the other two contracts.
- There is some intermingling of type declarations and state variables in *GTC.sol* and *GovernorAlpha.sol*, which may be in line with a note in the Solidity documentation, proceeding the above recommendation, which states "It might be clearer to declare types close to their use in events or state variables" (Solidity, n.d.-b). However, both these contracts prefer to declare state variables before types.
- In some cases, *GovernorAlpha.sol* uses simple functions in place of state variables. These functions only return a value when called, but essentially serve the same purpose as a state variable.

There are multiple reasons why these exceptions might exist in the structure of these contracts, and it is difficult to ascertain with certainty the reasons for not precisely following the Solidity guidelines, as the developers did not leave comments which explain these decisions. However, the inconsistencies between the contracts are indicative that they have been forked and amended over time, presumably by different developers with different code readability preferences. In fact, these contracts were forked from elsewhere: the netnography already revealed that the governance protocol is based on the protocol of two other DAOs: Compound and UniSwap. This was further substantiated by some documentation included with the smart contracts, as well as another observation: *GovernorAlpha.sol* implements its own 'safe math' functions instead of leveraging the *SafeMath.sol* library (*GTC.sol* both contains its own safe math functions, and leverages the library). It's possible that some exceptions may be conscious choices based on attempts to reduce the transaction fees associated with the contract, but unlikely that this would explain all exceptions, considering the lack of uniformity in design decisions.

4.2.2 Functionality of the Smart Contracts

As mentioned, the governance protocol is divided between three smart contracts, a modular implementation which contributes to system security (for example, if one contract were compromised, the others are less likely to be affected).

- *GTC.sol* manages the governance token, and has an additional layer of functionality for governance.
- *GovernorAlpha.sol* is responsible for managing the creation, voting, and execution of proposals within Gitcoin governance.
- *Timelock.sol* enforces a mandatory waiting period before implementing any system changes resulting from proposals.

The protocol works by invoking the proposal functionality of the *GovernorAlpha.sol* contract, which initiates the proposal process and manages the voting, in coordination with the token system established in *GTC.sol*. When a proposal is voted on and approved, the relevant data is then sent to the *Timelock.sol* contract. *Timelock.sol* enforces a mandatory delay by queueing the proposal, before executing it. As such, *Timelock.sol* actually holds the assets which pertain to the proposal's execution. A visual representation of the proposal process from a technical perspective was created by a participant in the Gitcoin community, and is displayed in Figure 4. The specific functionalities contained in each individual contract are detailed in Table 3.

Table 3: Detailed breakdown of the functionality related to governance found in Gitcoin's smart contracts.

Contract	Functionalities	Explanation
GTC.sol	*Initiation Functionality*	The *constructor* function assigns an initial amount of tokens to one account.
	Transfer and Delegation Functionality	These functions facilitate the safe transfer of tokens between different addresses (*_transferTokens*) and the delegation of voting rights (*_delegate*).
	Minting Functionality	Contrary to the fixed total supply declared at the contract creation, the contract includes a *_mint* function, enabling the addition of new tokens to the supply. This capability is tightly controlled and regulated by the *minter* role and the *mintingAllowedAfter* timestamp.
	Voting Functionality	The contract contains a system for tracking voting power through checkpoints (*_writeCheckpoint*), and moving votes between different delegates (*_moveDelegates*). This system ensures that changes in delegated voting power do not affect ongoing votes and that changes are accurately reflected for future votes. The *DelegateChanged* and *DelegateVotesChanged* events are emitted during these operations, rendering them transparent and traceable.
	Permit Functionality	The permit function allows holders to authorise a spender to spend tokens on their behalf using an off-chain signature, thereby saving on gas costs. This permission can contribute to streamlined governance processes, enabling token holders to more efficiently interact with the DAO's functionalities.
GovernorAlpha.sol	*Proposal Functionality*	The *propose* function allows a token holder with a minimum balance (the *proposer*) to put forth changes to the system, as long as they hold at least 1 million GTC, as defined by the *proposalThreshold* function. Proposals can be wide-ranging, including altering parameters or making system-wide modifications. These are implemented as an array of function calls, providing a versatile system capable of proposing virtually any modifications that the underlying system can support.
	Voting Functionality	Voting on proposals is facilitated through the *castVote* function. This function allows token holders to vote for or against proposals, with each token representing a single vote. The *quorumVotes* function defines 2.5 million GTC as the minimum number of votes that a proposal must receive to be eligible for execution.
	Queuing and Execution of Proposals	After a proposal has received sufficient votes and passed the quorum, it can be prepared for execution using the *queue* function. This function triggers a delay before the proposal can be executed, allowing for a final period of review and possible intervention. The execution itself is performed via the *execute* function. However, this function interacts with the separate *Timelock.sol* contract to manage the execution of the proposal.
Timelock.sol	*Administration Functionality*	The *admin* role, set in the constructor when the contract is deployed, is the authority that can queue, cancel, and after a delay, execute transactions. The admin role could be another smart contract, and is likely to be the *GovernorAlpha.sol* contract. An additional *pendingAdmin* role can be assigned, though they must explicitly accept the role via the *acceptAdmin* function, thereby preventing sudden, unilateral shifts in control.
	Time Delay Enforcement	Any transaction queued for execution must wait for a predefined delay period, ranging between the *MINIMUM_DELAY* and *MAXIMUM_DELAY* values of 2 days and 30 days. Changes to this delay can only be made by the contract itself, ensuring a predictable, mandatory waiting time between the proposal and implementation of changes. This time-buffer provides community members with ample opportunity to review proposed changes, and cancel them if necessary.
	Queueing and Executing	The *admin* can queue transactions which contain the following parameters: a target address, function signature, function data, and an execution timestamp (*eta*). The *executeTransaction* function can then be called to execute the proposals, and requires the same parameters that were used to queue the transaction. It checks that the transaction has been queued, the delay has passed but it's still within the grace period, and then it attempts to call the function on the target contract with the provided data and value.

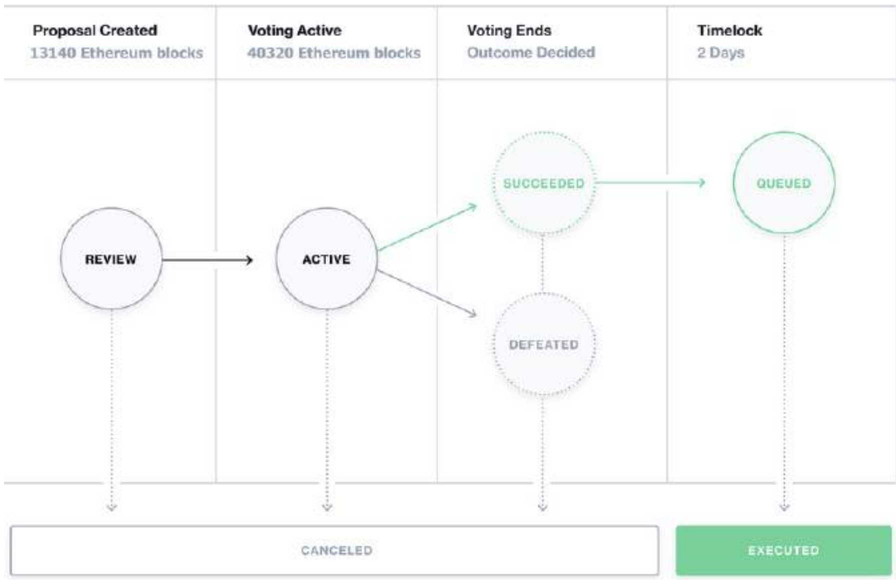

Figure 4: A Gitcoin participant's visualisation of the proposal process from a technical perspective ("Gitcoin DAO Governance Process v3", 2022)

4.3 Synthesis of Netnography Findings and Source-Code Analysis

As may be expected, the results of the source-code analysis align with many of the findings derived from the netnography regarding fundamental DAO governance mechanisms. Gitcoin operates by a system of blockchain governance, in which the dissemination of a governance token is used to divide voting rights between participants. This fundamental system is supplemented by a token delegation system, enabled by smart contracts, where voters can delegate their voting rights to another token holder. This novel system is not mentioned in any of the relevant DAO literature reviewed, such as Ziegler and Welpe's (2022) taxonomy. Proposals have a five-day on-chain voting period, followed by a five-day timelock period, after which they are implemented via the functionality in smart contracts. Thereby, the Gitcoin community members democratically shape their organisation, and processes of governance participation are enshrined in the code of smart contracts.

However, there are some notable divergences between the understanding of Gitcoin governance received via an analysis of the netnography data and what is actually technically possible or necessary as per the functionality contained in the smart contracts. I highlight these divergences here.

- *Minting*: Sources examined during the netnography, including official governance documentation, did not mention that minting was possible, and gave the clear understanding that the governance token was capped at 100 million GTC. However, the contract technically allows the minting of new tokens. One unspecified Ethereum address has the role of *minter*, and has the capability to mint new tokens at will. This *minter* wallet could be another smart contract which is democratically controlled, or a multi–signature wallet controlled by several DAO members with high levels of responsibility, or even a single DAO member.

- *On-Chain vs Off-Chain Voting*: The technical implementation of *GovernorAlpha.sol* differs in a fundamental way from how the community uses it. A researcher who only analysed this contract would understand that Gitcoin was leveraging on-chain voting, thereby implementing a fully decentralised democratic governance system. However, the netnography reveals that voting occurs off-chain on Snapshot, and the entire voting system contained in the smart contracts is a mere formality, used only as a tool to implement the result of the off-chain vote. This means that some aspects of the contract, such as the *ProposalState* enum's "Defeated" state, should never be realised in practice, though technically speaking, a coalition of DAO participants holding sufficient governance tokens (or even an individual) could prevent a proposal from passing on-chain, even when it has already been democratically approved in the off-chain vote.
- *Proposal Initiation*: In order to make a proposal on-chain, the source code analysis reveals that a proposer must hold 1% of the total GTC supply. The netnography did not reveal this, and it is unclear which of the limited number of possible individuals is responsible for therefore pushing proposals on-chain. There are two main reasons for which this would not be revealed by the netnography: (a) it has not been discussed or shared publicly by those that know about it; or (b) it has been shared publicly, but this instance was not observed in the archival data or during the lurking process. Whichever is the case would seem to be inconsequential, as it appears to be a key piece of information relevant to the governance process, and therefore should have been included in the key governance archival data examined during the netnography, such as the updated "Gitcoin DAO Governance Process" post ("Gitcoin DAO Governance Process v3", 2022). This omission of key information has implications for the transparency of the governance process, and the functionality itself has implications for the levels of decentralisation within the DAO.

- *Quorum*: The netnography revealed that 2.5 million GTC are the minimum votes that must participate on an off-chain proposal vote in order that it is considered eligible for execution. The smart contracts also refer to a 'quorum' via the *quorumVotes* function, but in that case, quorum refers to the amount of favourable votes that an on-chain proposal must receive at minimum (as well as being the majority of votes cast). Given that the contracts are adapted from other DAOs, it is possible that there is a difference in how this terminology (‘quorum’) is used between DAOs.

Overall, Gitcoin uses its governance contracts in an unconventional and instrumental manner. The documentation included in the smart contract repository suggests that the purpose of Gitcoin's smart contracts is to enable the community to propose, vote on, and implement protocol changes. However, the source code analysis yielded mixed results, confirming this only for the implementation feature. The voting and delegation system is enabled by the smart contracts, but only partially, as the DAO also leverages external tools such as Snapshot to enact voting processes. As such, the netnography reveals much of the smart contract voting mechanisms to be redundant.

Furthermore, community-wide proposal submission is also facilitated by external platforms (i.e., the governance forum). However, the proposal mechanisms in the smart contract are not rendered redundant—in practice, the technical implementation allows only a select few DAO members controlling a disproportionate share of the governance tokens to actually propose changes on-chain. Considered together, these divergences indicate a lack of alignment between the intentions of the written code and the DAO's actual practices, and also reveal a striking finding: the actual technical governance mechanisms of Gitcoin are effectively tacitly centralised, and its decentralised practices are reliant on 'good faith behaviour' of a few individuals.

5 Discussion

The present study undertook a detailed examination of the role that smart contracts play in DAO governance mechanisms, with a particular emphasis on the algorithmic aspects embedded in these smart contracts. The research question, *"How do smart contracts, from a technical perspective, contribute to the governance mechanisms in Gitcoin, a Decentralised Autonomous Organisation (DAO)"*, was approached through a two-part methodological framework: netnographic observation and source-code analysis. The analysis was focussed on Gitcoin, a well-established DAO with robust governance mechanisms.

In response to the research question, it can be stated that smart contracts provide an underlying technical architecture which acts as the foundation for governance, enabling a governance token system, a voting and delegation system, and a mechanism for implementing governance proposals. This technical framework also delineates certain constraints for governance processes requiring smart contract interactions. However, in practice the DAO's governance customs reveal a divergence from this underlying technical framework, leading to a more nuanced governance system overall. While the smart contract infrastructure largely aligns with the real-world governance structure, it often circumvents the DAO's public processes, indicating a discrepancy between what the community might understand and the reality of what the smart contracts enable.

This section will proceed to discuss the findings in the context of the body of research from which this study emerged, before outlining the contributions that this study makes to that research literature, as well as the limitations of the study, and will conclude by suggesting some avenues for future research.

5.1 Reflecting on and Contextualising the Findings

The findings of this study reaffirm the anticipated role of smart contracts as an integral component in DAO governance, a point that aligns with the assertions made in the introduction of this paper. As expected, smart contracts provide a cohesive underlying technical architecture in Gitcoin, essentially serving as a foundational layer for governance. They play key roles in enabling token-based voting rights, the delegation system, and the democratic implementation of governance decisions, thereby allowing participants to shape their organization in a democratic manner.

While the source-code analysis corroborated many aspects of the netnography regarding key governance mechanisms, it also revealed significant divergences. Certain elements of governance, such as minting of new tokens, the nature of voting (on-chain vs off-chain), and the stipulations for proposal initiation, differed in their execution as enabled by the smart contracts compared to their portrayal and discussion (or omission thereof) within the DAO community. These divergences highlight the gap between the technical functionality of the smart contracts and the understanding Gitcoin participants may have about the operational procedures of the DAO.

Such a gap between the technical functionality and the publicly–acknowledged governance features warrants further scrutiny, as there are various possible explanations based on available evidence. In regards to minting, there are advantages to a DAO retaining minting functionality—for example, it adds a level of flexibility to the DAO's operations, allowing it to potentially respond to changing circumstances. The advantages constitute reasonable grounds for inclusion, so it's unclear why Gitcoin has not been more explicit about the existence of such functionality. The launch of the GTC token was first announced via an official Gitcoin blog post, used in this study as a primary netnographic source. This post provided an opportunity to be transparent about the possibility of minting new tokens, as well as which Ethereum address holds the minter role, and under which circumstances it would be utilised. Such information is nontrivial, as minting new tokens could devalue the tokens already in circulation, and may affect their trading price, as well as the voting power of a token.

Retaining control of 1% of the total GTC supply in order to submit proposals on-chain is another governance omission revealed by the source code analysis. A generous interpretation of this technical feature might posit that this feature exists in order to prevent spam and to ensure a more secure system against malicious parties. However, the feature fundamentally entails a degree of elite influence over the system being maintained by a small group of individuals. The lack of transparency about this feature's existence, as well as that of the minting feature, does not correspond with the DAO's values of democratic governance and decentralisation.

A less charitable reading of these omissions would be that Gitcoin's initiators intended to retain a degree of centralised control over the system, in some cases tacitly, while openly advertising values such as democratic governance, which are associated with greater trust and positive attitudes of members towards an organisation (Richardson et al., 2002, p. 240). It would be possible to make this argument from the data that exists. There are certainly other features of Gitcoin governance which seem to accrue disproportionate influence to smaller numbers of individuals—for example, the stewardship program and the stewards council. However, I believe that the data do not conclusively support this line of thought. There are clear examples of the DAO's initiators making good faith attempts to decentralise power over time—for example, the selection of the stewards council has become more democratic since its inception, and individual stewards accumulate influence in accordance with the consent of other DAO participants.

Moreover, there is evidence to suggest that misalignment between Gitcoin smart contracts and stated governance processes is due to an incomplete or uncoordinated technical implementation. For example, it's hard to imagine that on-chain voting is the most efficient and cost-effective way of implementing the results of a binding off-chain vote. However, due to the fact that this specific implementation functionality was pre-existing and open-source, Gitcoin could straightforwardly fork it and adapt their governance processes around the functionality, rather than expend the resources to tailor functionality to accommodate their desired governance processes. Furthermore, the inconsistent definitions of "quorum", when comparing what the term refers to off-chain against on-chain, seems to be evidence of a governance system which was partially inherited, and has developed in an uncoordinated manner. The omission of the minter role could also plausibly be understood in this way.

In general though, it must be acknowledged that these findings challenge several notions gathered from the existing DAO governance literature, particularly regarding decentralisation of organisational power. Currently, the literature submits that blockchain governance has allowed DAOs to realise democratic organisations in which there is no need for executive–level management (Lumineau et al., 2021, p. 509; Hsieh & Vergne, 2022). In Gitcoin's case though, a nuanced hierarchical network exists within the organisation. This hierarchy may not be as overt as in a traditional organisation, and in many cases power is consensually vested in others. However, in practice the governance system facilitates the elevation of certain individuals to positions of influence, where they have access to functionalities and discussions with other high-influence participants which may have a significant impact on the DAO's direction. Anyone can contribute to governance discussions, but a moderation team, which seems to be unelected, retains gatekeeping power over the governance forum. Furthermore, a select few individuals controlling 1% of the supply of governance tokens are gatekeepers to the actual implementation of proposals on-chain.

Considering Gitcoin's origins as a centralised company, it would be justifiable to consider the organisation's present mix of centralised and decentralised elements as evidence of continued efforts towards decentralisation. Such efforts towards appear indicative of the former Gitcoin centralised management's aspirations to more fully decentralise the DAO, which may simply be unfeasible at this point in its lifespan. Decentralisation is a very complex phenomenon (Buterin, 2017), and Richardson et al. (2002) found that realising its benefits depends on a constellation of organisational and environmental conditions (p. 240; Huber et al., 2018, p. 581). It is not uncommon that DAOs are launched by a smaller group of individuals who control governance, with the promise to decentralise over time (Axelsen et al., 2022, p. 54;), presumably after creating the internal and external conditions where it is possible to do so.

Put another way, in terms of an assertion by Huber et al. (2018, p. 565) referenced earlier in this thesis, different governance practices entail different costs, depending on the presence of certain conditions. Under present conditions, which may not have been detectable during the data collection, perhaps taking on the governance costs associated with greater decentralisation would be impractical for Gitcoin. Human action is required to develop a DAO (Wright, 2021, p. 43), and perhaps decentralisation represents a bottle-neck to growth in the early stages of development. That is the contention of Axelsen et al. (2022, p. 54), who suggest that no DAO can begin decentralised, given the greater efficiency of having a smaller executive team before an organisation begins to mature. The case of MakerDAO, a decentralized finance DAO, provides additional evidence for this point: like Gitcoin, MakerDAO initially set up a legal foundation to facilitate their early development, but then dissolved the foundation and transferred all its assets to a digital wallet controlled by the community (Schirrmacher et al., 2021, p. 4). It is possible that Gitcoin is less mature than MakerDAO, but is on the same decentralization trajectory.

This thesis lacks the data and scope to make a clear judgement in regards to the underlying causes and appropriateness of Gitcoin's governance structure. However, it must be acknowledged that Gitcoin's current organisational practices fall short of the "transparency, fairness, inclusion, and incorruptibility" revered by advocates of DAOs (Mini et al., 2021, p. 2). Even if the current systems presently function effectively, with the respective gatekeepers acting fairly and taking all appropriate actions in good faith (for example, submitting proposals that they themselves disagree with), the system cannot be considered incorruptible, as it is reliant on human action, which is ultimately corruptible in a way that software protocol is not. This situation echoes back to Buterin's (2017) concern, mentioned earlier in this thesis, that systems lacking decentralisation are at risk of containing individuals capable of wielding governance power to benefit themselves at the expense of the community. Furthermore, the aforementioned lack of transparency about certain technical aspects of the governance process raises questions.

Whatever the explanation for the current processes, its identified problems primarily stem from an underutilisation of the possibilities afforded by the use of smart contracts. A primary characteristic of DAO governance is the leveraging of smart contracts is to automate processes and decentralise power (Mini et al., 2021, p. 2; Beck et al., 2018; Lumineau et al., 2021), but rather than design a maximally–decentralised and –democratised system enabled by smart contracts, Gitcoin relies on certain key individuals to trigger processes manually. The on-chain vote mimics decentralised democracy, but in practice a vote is already passed before it appears on-chain. The stated reason for this process is to minimise gas costs, but given that an on-chain proposer needs to control 1% of the total GTC supply, the current set-up is a hindrance to the realisation of a truly decentralised process. Whether or not it is a necessary arrangement at this time, it cannot be their end goal, considering their stated values.

5.2 Theoretical and Practical Implications

The main contribution of this study is a demonstration that the governance customs of a DAO do not necessarily match its smart contract implementation. The study revealed significant differences between what was publicly represented in a DAO (including in official blog posts and documentation) and the reality of its governance software protocol. The specific case of Gitcoin suggests that some DAOs may adapt smart contracts as the basis of their governance protocols, but may develop parallel governance practices which do not align with what the smart contract code stipulates. In such cases, the smart contracts may be used instrumentally by the DAO, and could conceivably be taken advantage of by certain high–influence participants to achieve certain goals, rather than serving as the direct facilitators of democratic and decentralised governance.

This contribution adds nuance to the understanding of DAO governance from both a practical and a theoretical standpoint, and confirms many of the original motivations for the study. The findings illustrate that governance arrangements in DAOs can be very complex, with subtle details having potentially major implications (such as the tacit inclusion of a minter role in a governance token contract). Researchers should not take smart contract algorithms for granted, as a source code analysis may fundamentally alter the understanding a researcher has regarding the nature of governance.

The novel approach taken in this study has thus proven to be methodologically beneficial. The bridging of netnography and source code analysis, two disparate approaches, succeeded in providing a more holistic understanding of a DAO. The success of the approach supports the notion that a sociotechnical perspective is best-suited for understanding DAO governance, and reinforces the contention of Rossi et al. (2019) that more technically–focussed studies in the blockchain research area are warranted. The integrated methodology of netnography and source code analysis used in this study could provide a framework for future research in DAOs and other blockchain-based organizations, enabling more nuanced insights into these complex entities.

In practical terms, DAO participants also benefit from an increased understanding of the technical details of governance protocol, and specifically from gaining the awareness that the protocol may not be designed as expected. This study has revealed that the reality of DAO governance protocol does not always align with the understanding of the casual, nontechnical participant. To be more precise, smart contract algorithms may not execute the outcomes expected by the participants under the conditions by which they are presumed to do so. This revelation is relevant to DAO participants, given that the protocol structures their interactions, and given that they have the ability to collectively determine that protocol (Mini et al., 2021, p. 3). Having this awareness makes DAO participants better-informed about the precise nature of the organisations, and also puts them in a better position to discuss possible technical misalignments and to propose changes in order to remedy them.

This study has further implications for the would-be architects of DAO governance protocols. As hypothesised, it is entirely possible, and perhaps likely, that the misalignments identified in this study between governance processes and smart contract implementation are due to an uncoordinated and incomplete technical implementation. This study promotes a careful and coordinated approach to the implementation of DAO governance smart contracts, through its establishing that the absence of such care can occur and may lead to technical misalignment, which could have disastrous consequences. An increased technical knowledge of governance mechanisms, as provided in this study, may reduce the possibility of misunderstandings between the intent of the contracting party and the implementation of the programmer (Tönnissen & Teuteberg, 2018).

Finally, this study may have implications for policy and regulation in the context of DAOs. Given the observed discrepancies between technical implementation and community understanding, regulatory bodies (whether internal or external) may need to consider how to approach the unique challenges presented by DAOs. This might involve developing guidelines around transparency, ensuring that DAO operations are as clear and accessible to participants as possible, to prevent situations where individuals may be intentionally misled.

5.3 Limitations and Future Research Directions

In spite of the contributions offered by this study, it nevertheless entails significant limitations. Gitcoin is a dynamic and rapidly evolving platform, with new proposals being made and passed on a regular basis. With the temporal orientation of the study being cross-sectional, its data may become outdated and invalidated by continuing organisational change. For example, the netnography data revealed that the DAO is already considering a radical update of the governance protocol examined as part of this study, from 'Governor Alpha' to 'Governor Bravo'. Such changes would not invalidate the contributions or implications of the study, as the findings remain accurate as of the time of writing. However, if implemented, they would introduce constraints on replicability. This possibility remains an inherent limitation of the DAO research area, given the novelty and rapid evolution of these organisations (Schirrmacher et al., 2021).

This study involved the interpretation of complex data in two different methodological contexts, and as such, there is an inherent possibility of subjectivity bias. Analysing qualitative data always entails the application of a human perspective, which, in spite of any commitment to scientific principles, is always beholden to past experiences, preconceptions, and various subconscious processes. Given that the study was conducted by one researcher, there was no clear mechanism built into the study to detect where subjectivity may be unduly interfering with scientific reasoning.

The source code analysis leveraged as part of the data analysis pertains to further limitations of the study. Smart contracts are complex artefacts, and just as a software engineer may make an error in developing a software program, a researcher may make an error while analysing the program. It is for these reasons that software engineers often write tests which ensure that the programs they create behave as expected, but no verification tests were used as part of this study. It is inherently possible that aspects of code may have been misinterpreted or misidentified.

The scope of this study also represents one of its limitations. This study sought to investigate only one DAO, in order to maximise the richness of the data, and in doing so compromised its ability to detect generalisable patterns. As such, there is no possibility of generalising the insights regarding governance in Gitcoin to the cases of other DAOs, other than to acknowledge the possibility. It is presently unclear with what frequency the misalignment issues identified might be observable in the cases of other DAOs, or whether Gitcoin might be an outlier in this regard.

In terms of further research, this single-case study fulfils its intention by opening several future avenues for productive investigation. Firstly, since DAOs are evolving entities, a study adapted from the present one, but which follows a longitudinal temporal orientation may extend and further develop the findings of this study. For example, following the changes in Gitcoin's governance over time may offer insights into the adaptability of DAOs and how they update their smart contracts to reflect changes in governance practices.

Secondly, the limitation of the present study related to its single-case study design could be overcome by conducting a similar study with an expanded scope. Comparing DAO governance protocol with community understanding across a range of DAOs may help to identify common patterns and variations. This design would help in drawing broader conclusions and developing a more comprehensive understanding of governance in DAOs.

Third, given that the main contribution of this study related to the possibility of technical misalignment with community understanding, subsequent studies could clarify this finding using methodologies specifically tailored for that purpose. For example, surveys or interviews with DAO members could be conducted to gauge their understanding of the governance mechanisms as reflected in smart contracts, and compare it with the actual functionality. Such a study could highlight and characterise discrepancies more specifically, and could lead to the development of better communication and education strategies.

Finally, blockchain governance is defined by the presence of smart contracts which regulate the interactions of consenting participants (Lumineau et al., 2021, p. 509), but in the case of Gitcoin, a select few individuals retain exclusive power to meaningfully interact with smart contracts. Assessing what this arrangement means for DAO governance generally is out of the scope of this study, but it would be theoretically interesting for subsequent studies to scrutinise the adherence of various DAOs in practice to the tenets of blockchain governance and decentralisation, and to therefore more precisely characterise the nature of governance in DAOs.

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7. Appendices

7.1 Appendix A: The Six Categories of Common Code Patterns in Smart Contracts, based on Hofmann et al. (2021, pp. 6-11)

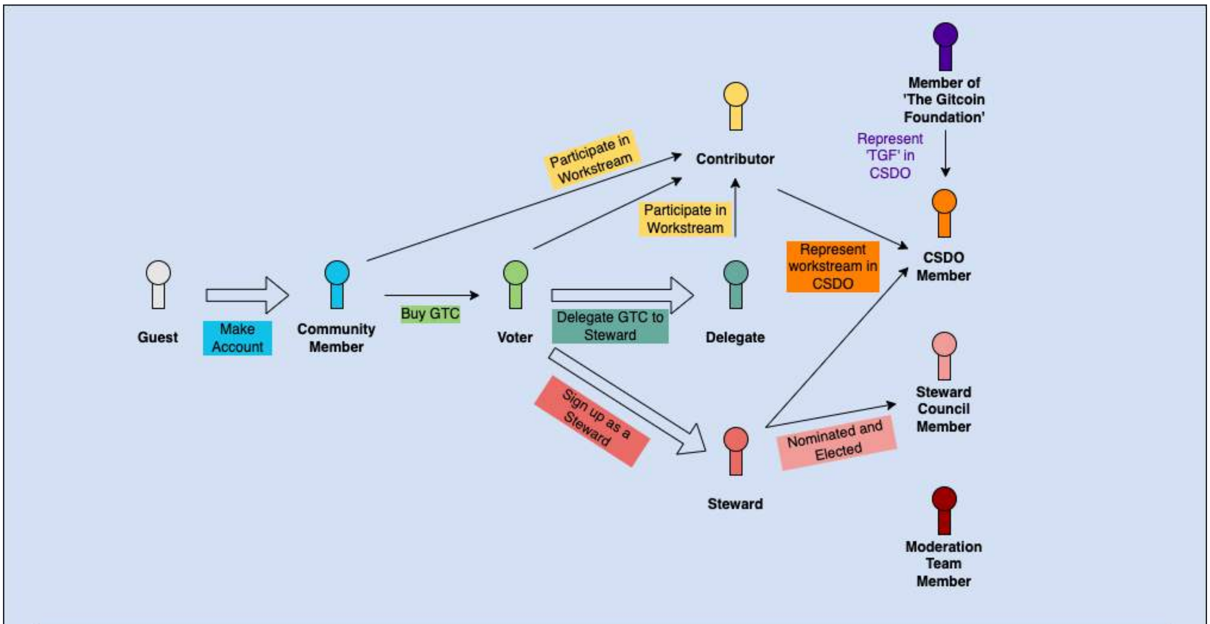
Category	*Definition*
DApp Design	The basic technical architecture of the application (i.e., whether the application used one smart contract, or multiple)
Core Functionality	How smart contracts internally organise and process their actual core functionality
Helpers	How smart contracts leverage external libraries to assist their internal core functionality
Contract Management	How the smart contracts can be reshaped over time
Safety Functions	Functionality which is not core, but that ensures the security and integrity of the smart contract
Tokens	Native units of value and incentive

7.2 Appendix B: Ziegler and Welpe's Nine Dimensions of DAO Characteristics Relevant to Governance (2022, pp. 9-10)

Dimension	*Elaboration*
Governance Token Supply	The token supply be capped or uncapped, with uncapped meaning that further minting of governance tokens is possible. The majority of organisations Ziegler and Welpe studied had a capped supply (2022, p. 9).
Governance Token Type	There are several different token types, based on, for example, different standards for token creation and use (such as ERC20).
Governance Voting Power	There are different ways to distribute voting power. The most common method found was via the number of tokens owned.
Limits to Governance Voting	Most often, there are no limits to governance voting powers of individuals, although some DAOs limit the number of votes possible from each individual address.
Fully On-Chain Voting	The purest form of decentralisation would entail that every governance step would be mediated via blockchain. This was most often not found to occur by Ziegler and Welpe (2022, p. 10).
Entry Barrier to Governance Participation	Ziegler and Welpe (2022) found four different entry barriers to the governance process, with the most common barrier found to be governance token ownership.
Governance Process is Fully Public	The visibility of the governance process varies between DAOs. It is in most cases fully visible and accessible to the public, but not always.
Process Creation Restriction	There are different possible restrictions to proposal creation in the governance process to prevent spam, for example, with the most frequent restriction surveyed being that proposal creation was restricted to those owning tokens.
Governance Process Execution	Governance process execution relates to whether the results of democratic voting processes are automatically executed by the algorithms contained in smart contracts, or whether they are executed manually and in good faith by an appointed member of the DAO

(Belkowski & Falcke, 2022, p. 28). Interestingly, a majority of the DAOs surveyed by Ziegler and Welpe (2022, p. 9) relied on manual rather than automated processes — therefore implementing a system that does not completely embrace the technologies on which they depend.

7.3 Appendix C: Visual Depiction of the Governance Roles in Gitcoin



Legend

Gives up current role and gains new role

Retains current role and gains new role

ROLE	Guest	Community Member	Voter	Delegate	Contributor	CSDO Member	Steward	Steward Council Member	Moderation Team Member	Member of 'The Gitcoin Foundation'
DESCR-IPTION	Can observe DAO but not contribute	Can contribute to governance discussions	Can contribute to governance discussions, owns GTC, and can vote on proposals	Can contribute to governance discussions, owns GTC, but has given voting power to a steward	Participates in a workstream and is usually compensated	Ensures workstreams are aligned, makes minor executive decisions with other members	Can have delegated voting power; supervises workstreams; has elite status in community	Advises CSDO; scrutinises proposals; discusses DAO direction; shapes DAO discussions	Retains executive and editorial power over Governance Forum; selection method unclear	Represents the DAO's legal corporate structure; one member participates in CSDO

7.4 Appendix D: Template for Making a Proposal on the Gitcoin Governance Forum (https://gov.gitcoin.co/t/gitcoin-community-proposal-gcp-template/134)

1. **Summary** - 2-3 sentences on what the proposal is and what changes are being suggested without going into deep detail.
2. **Abstract** - Expanded summary introducing the proposal, what it entails and details around what would change should the proposal be implemented.
3. **Motivation** - Describe the motivation behind the proposal, the problem(s) it solves and the value it adds. This is your chance to show why this proposal is necessary, and how the changes would benefit Gitcoin if implemented.
4. **Specification** - Describe the "meat & potatoes" of the proposal. Go into deep detail around the changes that will happen both on a technical and social level. The more detail, the better.
5. **Benefits** - Point out core benefits of the proposal implementation and how it will affect the system.
6. **Drawbacks** - Highlight any drawbacks from implementing the proposal and points to consider regarding the upgrade.
7. **Vote** - Clearly outline what voting "yes" and "no" entails. Please link to Snapshot 43 or include a forum poll directly on the forum to get a temperature check under Setting > Build Poll to vote.

7.5 Appendix E: Breakdown of the Elements of Solidity Code Identified during the Source Code Analysis

Code Element	*Description*	*Example*	*Example Breakdown*
Variable	A value in the contract that can be referenced or changed by a ***function***	*uint public mintingAllowedAfter;*	The value of this variable must be an integer, as its type is *uint*; it is *public*, and thereby accessible by other smart contracts; its label is *mintingAllowedAfter*, which seeks to express the purpose for which the variable is used (it is meant to hold a timestamp after which governance tokens can be minted); the semicolon signals the end of the declaration of the variable; and the variable is not given an initial value, being assigned a value later by a function which references it
Constant	An immutable value in a contract	*string public constant symbol = "GTC";*	The value of this constant must be a string; it is *public*; its label is *symbol* (again, seeking to express its purpose for readability, as with all labels); and its value (which, again, cannot be changed) is *"GTC"*. This constant therefore determines the shorthand currency symbol representing the governance token as "GTC"
Mapping	A series of "key-value pairs", whereby one value, a "key", refers to a value, and together this pair makes up a single datatype	*mapping (address => uint96) internal balances;*	In this case, the variable is labelled *balances*, is *internal* (cannot be read by other contracts), and is to be comprised of a series of Ethereum addresses which each map onto integer values. Thus, the variable holds the GTC balances of each Ethereum *address*, which change when a transaction takes place. The contents of the brackets are how this kind of variable stipulates the type for the key-value pair, with the key's type (*address*), coming before the arrow, and the value's type following (*uint96*, which is an integer of a different size than the aforementioned type *uint*)

Struct	Short for 'structure'; a custom type composed of multiple properties, which are like variables	*struct Proposal {* *uint id;* *address proposer;* ... *}*	This *struct* has the label *Proposal*, which, as with all labels in the contracts, seeks to express the element's purpose. The braces enclose the body of the *struct*. Within the body are its properties. *Proposal* has fourteen properties, but I have included two here for brevity's sake: each proposal must have an *id*, which must be an integer, and a *proposer*, which must be an Ethereum address. Custom types (*struct*s, *mapping*s, *enum*s) resemble types (e.g. *uint*, *string*, *address*), and are used to stipulate the form that a variable or constant must adhere to. As such, the *struct* labelled *Proposal* stipulates the data structure which a proposal sent to the contract must adhere to.
Enum	A custom type stipulating a finite set of constant values which a variable can take	*enum ProposalState {* *Pending,* *Active,* *Cancelled,* ... *}*	This *enum* has the label *ProposalState*. Its body contains eight possible states, three of which I have included in the example. Later variables or properties can then be declared which must contain a value as one of these possible states.
Function	The primary way of defining behaviour in a smart contract	*function balanceOf(address account) external view returns (uint) {* *return balances[account];* *}*	This *function,* with the label *balanceOf*, *return*s the Ethereum balance of an account. The first pair of brackets contain a parameter, which is labelled *account*, with type *address*, and the braces contain the function body. When the function is 'called', it must be called with any Ethereum *address* (as per the parameter), and the body of the function executes some code based on which *address* is submitted. This function has the simple functionality of checking the aforementioned *balances* variable for the balance associated with the *address* parameter it was called with. Note the other keywords preceding the function body, which stipulate that the function may be called from outside the contract (*external*), the function reads blockchain data (*view*), and its *return* type must be a *uint*
Event Emitter	Special functionality to log data to the blockchain	*event Transfer(address indexed from, address indexed to, uint256 amount);*	This example represents the event declaration (i.e., the event is declared, to be later emitted). The event is labelled *Transfer*, and takes three parameters (similar to a function): two addresses (labelled *from* and *to*), and an integer *amount*. The keyword *indexed* indicates that the event can be searched for in the blockchain using this parameter, once it is logged there. The event can then be actually emitted within the body of a function, as such — *emit Transfer(address(0), dst, amount);* — whereby the three "arguments" contained in the brackets are variables which correspond to the three parameters specified in the event declaration