Blockchain Governance: a Framework for Analysis and Comparison

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Abstract

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by Rowan VAN PELT

Although blockchain technology has received increasing attention from industries and academics, the topic of blockchain governance often remains poorly understood. Without sufficient insight into the way blockchains are governed, blockchain stakeholders cannot optimally perform or make informed decisions. For stakeholders relying on a blockchain, its ongoing development and sustainability are of paramount importance. Where businesses and individual end-users should consider the aspect of governance in their choice for a blockchain application or platform, it is also essential for regulators and developers to apprehend.

In this study, we propose a framework that defines the governance of a blockchain as a combination of six dimensions and three layers. The blockchain governance (BG) framework is constructed based on literature reviews into the domains of open-source (OSS) software governance and blockchain governance. We evaluate the designed framework through eight expert interviews with stakeholders from different backgrounds in the blockchain ecosystem.

The expert opinions indicate a strong perceived usefulness and operational feasibility of the BG framework. Moreover, this initial evaluation resulted in improvements to the framework in terms of understandability, completeness and simplicity. Furthermore, the BG framework is demonstrated by application in a multiple case study to analyse the governance of two blockchains. The case studies show that the framework can be used to describe, analyse and compare the governance of blockchains, however, it does not produce a value judgement and leaves interpretations in the hands of the user.

While further validation studies are recommended, the proposed BG framework is a solid basis upon which future research can be carried out. The strength of the framework is that it combines insights from literature into OSS governance, blockchain governance and opinions from blockchain experts into a framework that can be of added value for various stakeholders in different situations. We hypothesise that the BG framework can act as a reference framework in the establishment of a shared understanding and discussion surrounding the topic of blockchain governance.

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This thesis project marks the end of my Msc. in Business Informatics and six years of studying at Utrecht University. When I started this project my understanding of blockchain technology and governance was limited. It has been a very enjoyable but challenging journey to dive deeper into both topics by writing a thesis about blockchain governance. The structure of the master's programme provided me with useful foundations to conduct this project. Therefore, I would like to start by thanking the professors of Utrecht University for all their insights, knowledge and time during the preceding courses.

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Contents

List of Abbreviations

AE	**A**symetric **E**ncryption
BAL	**B**lockchain **A**cceleration **L**ab
BG	**B**lockchain **G**overnance
BIP	**B**itcoin **I**mprovement **P**roposal
BP	**B**lock **P**roducer
DAO	**D**ecentralised **A**utonomous **O**rganisation
DApp	**D**ecentralised **App**lication
DSR	**D**esign **S**cience **R**esearch
ECH	**E**thereum **C**at **H**erders
EEA	**E**nterprise **E**thereum **A**lliance
EF	**E**thereum **F**oundation
EIP	**E**thereum **I**mprovement **P**roposal
ETH	**Eth**er
EVM	**E**thereum **V**irtual **M**achine
GPL	**G**eneral **P**ublic **L**icense
ICO	**I**nitial **C**oin **O**ffering
IE	**I**nterviewed **E**xpert
OSS	**O**pen-**s**ource **S**oftware
PDD	**P**rocess-**D**eliverable **D**iagram
PoA	**P**roof **o**f **A**uthority
PoS	**P**roof **o**f **S**take
PoW	**P**roof **o**f **W**ork
WIP	**W**ork **i**n **p**rogress

Chapter 1

Introduction

In recent years, there has been an increasing interest in blockchain technology (Nofer, Gomber, Hinz, & Schiereck, 2017; Gaggioli, 2018). A blockchain enables a network of participants that do not know or trust each other to agree on the state of a shared administration, without relying on human intervention, a central point of control, or regulatory supervision (Tasca & Tessone, 2018; Atzori, 2016). Industries and sectors around the world are exploring the merits of blockchain technology by identifying use cases and developing proofs of concept (Zhao, Fan, & Yan, 2016; Ziolkowski, Parangi, Miscione, & Schwabe, 2018). Following its growth, regulators, policy-makers, and financial service providers have also started to pick up on the topic (Hacker, 2017; Rennock, Cohn, & Butcher, 2018). One reason for this sparked interest is the promise for an increase in efficiency due to the cutting out of middlemen. The fields of application for blockchain technology are potentially countless (Swan, 2015).

Besides movement in the industry, blockchain technology has also received an increased level of attention from scholars and academics (Zheng, Xie, Dai, Chen, & Wang, 2018; Beck, Müller-Bloch, & Leslie King, 2018; Garagol & Nilsson, 2018), with the number of publications growing almost exponentially every year (Zhao et al., 2016; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). Yet, there is an absence of established theory, few recognized experts, and studies that have mostly focused on the technical features and legal considerations of blockchains (Atzori, 2016; Garagol & Nilsson, 2018). Additionally, eighty per cent of the research focused solely on the Bitcoin blockchain (Yli-Huumo et al., 2016). Beck et al. (2018) state that there is especially a scarcity on the topic of blockchain governance. Moreover, the Dutch Advisory Committee on Blockchain Research recently published a research agenda, highlighting blockchain governance as one of its major overarching concerns and research challenges (Bodo et al., 2018).

At its core, every blockchain has a software repository that holds the source code which specifies the implementation of the protocol (Maddrey, 2018). Currently, thousands of different blockchains are under development, with most being forks of the source code from well-established open-source blockchains such as Bitcoin and Ethereum (Tasca & Tessone, 2018). The software protocol of a blockchain includes an accurate specification on how transactions are executed, at what speed new blocks of data are added to the chain, and what the size of these blocks of data may be (Hacker, 2017). People involved in a blockchain project need to determine how updates to the software protocol are made. These updates must be thoughtfully coordinated, and this is where governance comes in (van Deventer, Brewster, & Everts, 2017). In this thesis, blockchain governance is defined as "the means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute". This definition is further highlighted in Chapter 5. Due to the decentralised aspect of blockchains, its governance differs from existing governance structures, such as markets and hierarchies (Ziolkowski et al., 2018). In a blockchain project, the presence of a headquarter or CEO is not required, instead, progress can rely on a globally distributed network of developers who write the software protocol (Hsieh, Vergne, & Wang, 2017).

The governance of a blockchain project is crucial for its sustainability as it enables stakeholders to discuss and make decisions on how the blockchain should evolve (Filippi & Loveluck, 2016; Garagol & Nilsson, 2018). Effective blockchain governance is also essential in the successful implementation of blockchains and for their ability to adapt, change and interact (Tasca & Tessone, 2018). Due to the large size of certain blockchain projects, their governance is especially relevant in order to manage and coordinate an entire community towards the same goal (Garagol & Nilsson, 2018). Effective governance processes can be a competitive advantage for a blockchain, with the speed of adaptation being a crucial factor in the long term viability of a project (Finck, 2019). Furthermore, companies that are looking to utilize an existing blockchain have many reasons to care about the governance of the blockchain itself. As an example, for a company who lists their shares on a blockchain, the underlying software protocol has a similar importance as the rules and regulations of a traditional stock exchange (Yermack, 2017). Organisations or consortia exploring to adopt a blockchain have to complete a make or buy decision, in this decision, governance is a meaningful factor (van Deventer et al., 2017). An organisation should only use or develop upon a blockchain if its governance processes sufficiently match their own expectations of needs. Moreover, understanding how blockchains are governed is crucial in order to come up with recommendations for policymakers (Wright & De Filippi, 2015).

The importance of blockchain governance is further highlighted in the governance problems public blockchains have recently experienced. In 2016, The Ethereum blockchain suffered a governance crisis, when an exploited vulnerability in the source code of the DAO, an application built on top of the Ethereum blockchain, led to a theft of Ether equivalent to 50 million dollars (Hacker, 2017; Finck, 2019). In the midst of this controversy, core developers of Ethereum eventually decided to proceed with a controversial solution of returning the stolen Ether via a hard fork. Not everyone agreed with this decision, forking the Ethereum blockchain in two different versions. In Bitcoin, unresolved disputes over proposed changes in the protocol have also led to multiple permanent splits of the blockchain, putting the survival of the project at stake (Webb, 2018; Biais, Bisiere, Bouvard, & Casamatta, 2018; Clifford, 2018). Evidence also exists of governance being an obstacle when running a blockchain in a permissioned environment with other organisations (van Deventer, Berkers, & Vos, 2018). Together these reports demonstrate why blockchain governance is a key aspect for stakeholders in the blockchain domain.

1.1 Problem statement

As highlighted by Beck et al. (2018) , there is a lack of research on the topic of blockchain governance. Hsieh et al. (2017) note that we need a better understanding on how the governance of blockchains works, while Ziolkowski et al. (2018) state that: *"little is known about what and how key decisions are made and enforced in blockchain* *systems"*. Finck (2019) further argues that despite its importance, *"blockchain governance remains a largely uncharted field."* Moreover, claims in grey literature indicate that blockchain governance is *little researched* and *poorly understood* (Ehrsam, 2017). According to Zamfir (2019), it is not only difficult for stakeholders to *understand* how blockchain governance works, furthermore, he also claims that some people are not even *aware* about the fact that they are stakeholders themselves in the decisions made during blockchain governance. Recently, the Dutch Advisory Committee on Blockchain Research published a research agenda, highlighting blockchain governance as one of its major overarching concerns and research challenges (Bodo et al., 2018).

Tied to the aforementioned lack of research and comprehension we have identified an absence of available artefacts and tools that can be used to better understand blockchain governance. This gap exists while it is beneficial for stakeholders in the ecosystem to have a thorough understanding of a blockchain its governance. Where businesses and individual end-users should consider the aspect of governance in their choice for a particular blockchain application or platform, it is also a requisite for regulators and developers to apprehend. These thoughts are shared in a report by the EU Blockchain Observatory and Forum, in which it is described that for anyone relying on a blockchain project or platform, its ongoing development and sustainability are of paramount importance (Lyons, Courcelas, & Timsit, 2019). Motivated by these concerns, the intention is to create a conceptual framework of blockchain governance that captures its relevant concepts and gives stakeholders a tool to analyse the governance of a blockchain in a structured way.

1.1.1 Aims and objectives

Following the template by Wieringa (2014) we aim to unravel the artefact and problem context of our design problem.

> **Goal statement:** *This research aims to improve* the lack of understanding and tools available on the topic of blockchain governance *by* designing a conceptual framework *that* captures the main dimensions and layers of blockchain governance in a comprehensible manner *in order to* guide businesses, regulators, users, and other relevant stakeholders to analyse the governance of blockchains in a structured way.

1.1.2 Research questions

In order to realise the aims and objectives of this study, several research questions have been specified. The research is structured around the main research question (RQ):

RQ *How can the governance structures of blockchains be defined and compared?*

The research question addresses a practical problem and is addressed by following the Design Science Approach (Hevner & Chatterjee, 2010). To further structure this research the main question has been decomposed into several sub-questions (SQ).

SQ1 *What artefacts are used to characterise the governance of Open-source software?*

In order to have sufficient knowledge needed to start analysing the governance of blockchains, it is useful to draw from theoretical foundations in similar domains. For this question, a semi-structured literature review is performed on the governance of Open-source software (OSS). The outcome of this research question is an overview of models and frameworks used in the OSS domain to discuss and analyse their governance structures.

SQ2 *What concepts and structures does the governance of blockchains encompass?*

This subquestion highlights the characteristics and concepts concerning the governance of blockchains. Another semi-structured literature review is conducted to identify what has already been written about the governance of blockchains. The outcome of this question and SQ1 is input for the construction of an initial framework that captures the concepts and structures when talking about the governance of blockchains.

SQ3 *What are the perceptions of stakeholders regarding blockchain governance ?*

Expert interviews are conducted to answer this subquestion. After answering the first two subquestions a first version of the conceptual framework is designed. An interview protocol is created to answer this subquestion and to evaluate the draft framework. The goal is to get early information about the expected usefulness, completeness, simplicity, understandability, operational feasibility and usefulness of the draft blockchain governance framework.

SQ4 *How does the created blockchain governance framework influence the comprehension of a blockchain's governance?*

The outcomes of this subquestion serve as a secondary evaluation of the designed blockchain governance framework. The framework is applied in a holistic multiple-case study to analyse and compare the governance of two distinct blockchains. By doing so, the artefact is studied in depth in its intended business environment. Document analysis and data triangulation are used during the collection of relevant information.

1.1.3 Scope

During the course of this research, various decisions have been made which influenced the scope of this thesis. Most of these restrictions are set due to practical considerations such as available resources and time.

- **An intra-blockchain governance focus:** As will be explained hereafter in Section 5.2, the level of analysis in this thesis is set on governance within the context of a given blockchain project (e.g. the governance within Ethereum). While other levels of analysis such as regulation on blockchain governance are also relevant areas of research, these were considered too broad to fit within the scope of this thesis.

- **Businesses as a primary target audience:** The blockchain governance framework outlined in this thesis is designed with the primary stakeholder in mind businesses seeking to utilize available blockchains. Considering the practical context in which this research was conducted (Section 2.5), on-site input was received from a business user perspective. Likewise, the main focus lies on the framework being useful for a business analysing available blockchains in terms of their governance structures. However, the framework is still envisioned to be of practical use by other types of stakeholders such as developers, regulators and investors.
- **Main focus on public blockchains:** Most available literature on blockchain technology and blockchain governance is focused on public blockchains. As will be discussed hereafter in Section 3.5, private blockchains differ from public blockchains in that the reading, processing and submission rights of transactions are usually restricted to a selected set of participants. Due to this imbalance of focus in literature, the framework is more tailored to public blockchains. However, it is still expected to be applicable to both types of blockchains, as sources on private blockchains were also included.
- **Broad acceptance criteria on included blockchain governance literature:** Highlighted in Section 1.1, there is a lack of research available on the topic of blockchain governance. This is primarily due to the novelty of blockchain technology. Therefore the decision was made to also include relevant grey literature sources such as blog posts and conference talks in the literature review of blockchain governance.

1.2 Outline

First, Chapter 2 describes a detailed overview of the research approach and methods followed in this study. Next, Chapter 3 provides a high-level introduction to blockchain technology intended for readers unfamiliar with the topic. Chapter 4 and 5 present the results of the literature reviews on OSS governance and blockchain governance.

In Chapter 6, the design process of the draft Blockchain Governance (BG) framework based on the theoretical foundations from literature is described. Next, Chapter 7 reports the results of an initial evaluation of the draft BG framework by eight expert interviews, showing a strong perceived usefulness and operational feasibility of the draft BG framework. Furthermore, the evaluation resulted in an improved version of the framework which is presented in Chapter 8. The new version is further evaluated by application in a holistic multiple-case study in Chapter 9. After a discussion of the study design and limitations in Chapter 10, we conclude in Chapter 11 by giving answers to the research questions including recommendations for future directions of research.

Chapter 2

Research approach

Describing the research process in detail is necessary to allow other researchers to assess whether derived conclusions are scientifically acceptable (Bhattacherjee, 2012). This chapter details the research approach followed in this thesis and the involved research methods and techniques. First, the decision to follow the Design Science Research Approach is elaborated upon, accompanied by an explanation of its implications and processes.

Next, the use of the three main research methods are described: (i) a literature study prior to the framework design, (ii) expert interviews as an initial evaluation of the draft framework, and (iii) a multiple case study to evaluate the latest version of the framework.

The chapter closes by summarizing the planned research process in a Process Deliverable Diagram (PDD) in Figure 2.3. A PDD consists of two integrated diagrams. The left side of the PDD shows the research process based on a UML Activity diagram, while the right side of the PDD shows the deliverables based on a UML class diagram (van de Weerd & Brinkkemper, 2008).

2.1 Design science

In this study, we use the Design Science Research approach (Gregory, 2011). Wieringa (2009) defines Design Science (Research) as an attempt to create or improve things to serve human purposes better. The approach deals with *the creation of meaningful artefacts which aim to solve identified problems* (Hevner & Chatterjee, 2010). Design Science Research should not be confused with Design Research. While Design Research primarily focuses on the design of an artefact, Design Science Research also values the generation of new scholarly insights resulting from the process of designing (Gregory, 2011). The artefact produced as part of Design Science Research can have various different sorts of outputs. March and Smith (1995) identified four types: representational constructs, methods, models and instantiations.

Design Science Research is considered to be a suitable approach because this study aims to improve the identified problem of *a lack of understanding and tools available on the topic of blockchain governance* by designing a meaningful artefact in the form of *a conceptual framework that captures the dimensions and layers of blockchain governance*. This research goal is in line with the criteria of design science by Hevner and Chatterjee (2010) because a viable artefact is envisioned to be created in the form of a framework to solve a relevant problem.

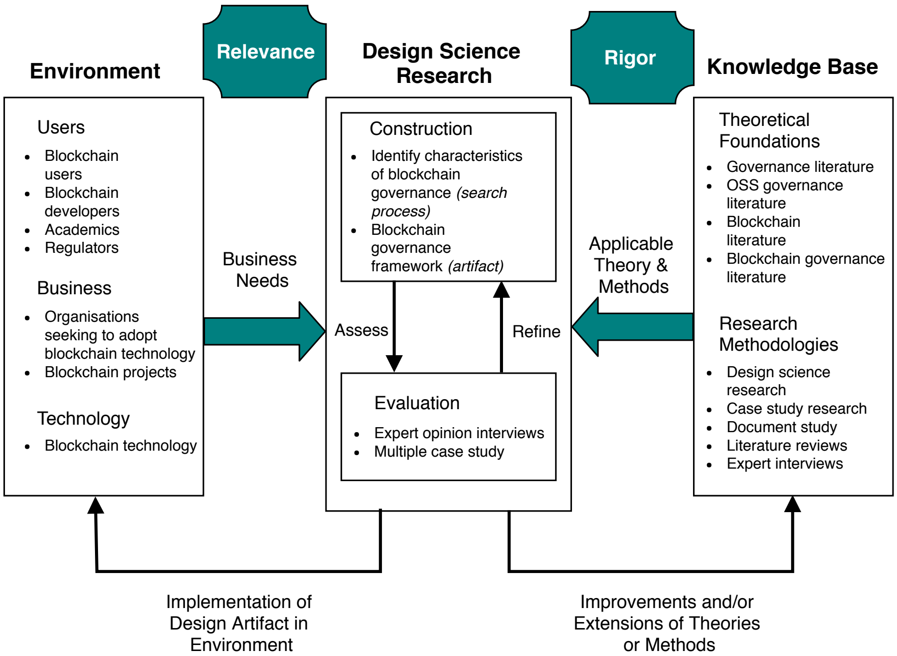


FIGURE 2.1: The Design Science Research Framework applied to this study, adapted from Hevner and Chatterjee (2010)

2.1.1 Artefact design and evaluation

Primarily, Design Science Research can be viewed as a decomposition of two main processes. The first is a process of activities to design a new artefact while the second deals with the process of activities aimed at the evaluation of the created artefact (Gregory, 2011). Initially, these two processes were seen as an episodic process, but later research viewed them as more iterative (Baskerville & Venable, 2009), implying that the processes of design and evaluation are concurrently revisited multiple times until the artefact is considered finite.

Solely focusing on the creation of a new artefact to solve a problem does not directly imply sound research. Therefore, this study adheres to a respected framework proposed by Hevner and Chatterjee (2010). It includes a set of guidelines to conduct and criteria to evaluate Design Science Research. The Design Science Methodology by Wieringa (2014) is used as a secondary source of good practices.

Figure 2.1 illustrates the Design Science Research Framework (Hevner & Chatterjee, 2010) adapted to this study. The theoretical foundations of this research are grounded in literature on blockchain and blockchain governance, but also on governance literature from Open-source Software (OSS).

2.2 Literature study

The first part of this study primarily focuses on the construction of the knowledge base. In order to gain the knowledge necessary for the design of the artefact, the theoretical foundations displayed on the right side of Figure 2.1 are studied using a literature study. The review of literature can be subdivided into three parts: (i) an overview of blockchain technology, (ii) OSS governance, and (iii) blockchain governance. Since each theoretical foundation is different it was decided to follow a tailored approach for each separate literature review. The next few sections describe the methods and techniques followed and the decisions made for these three literature reviews.

2.2.1 Blockchain technology

The goal of the literature review on blockchain technology is to provide the reader with a general overview of the topic and the concepts involved. The resulting basis of understanding is also utilized by the researcher in the remainder of the study. Since blockchain is a fairly recent innovation and given its multidisciplinary nature, a structured literature review was considered to be inapplicable. Instead, a semi-structured literature review was considered more suitable. To find relevant sources, a semi-structured approach of both forward and backward snowballing was executed (Wohlin, 2014). As a starting source for the forward snowballing the white paper of Bitcoin by Nakamoto (2008) was used, while for the backward snowballing it was deemed applicable to use a recently published book by de Filippi and Wright (2018).

Thematic Analysis was used to process the literature. Braun and Clarke (2014) describe it as *"a method for systematically identifying, organizing, and offering insight into patterns of meaning (themes) across a data set"*. This method was used together with an approach of both inductive and deductive reasoning (Braun & Clarke, 2014). First, a set of overarching concepts were identified which were then taken to structure the presentation of results. Concept mapping (Bhattacherjee, 2012) was used to create a concept map of the identified concepts and their underlying relationships.

2.2.2 Open-source Software governance

Blockchain development projects share multiple similarities with traditional OSS projects. Many of the large public blockchains are developed and released as OSS (Porru, Pinna, Marchesi, & Tonelli, 2017). For instance, the earlier examples of Bitcoin and Ethereum were both released as OSS projects (Lindman, 2017). Bian, Mu, and Zhao (2018) state that OSS development has become the dominant platform for doing blockchain technology development.

Another parallel can be observed in regard to the involvement of external parties within these projects. In traditional OSS projects, external parties such as organisations, entrepreneurs and industries became increasingly commercially involved. In the case of blockchain projects, this external interest also arose, if not, a lot quicker than in the case of traditional OSS projects (Lindman, 2017). Furthermore, a similarity lies within the political motivations that stimulated both types of OSS projects. In the case of traditional OSS software, there was a strong debate between free software vs commercial software, while in blockchain projects contributors are similarly motivated by the aspect of decentralisation vs centralisation (Lindman, 2017).

Due to the highlighted similarities, OSS literature provides useful starting points to discuss blockchain Lindman (2017). In this study, the existing OSS literature can offer insights that are useful when looking at the governance of blockchains. The focus of the literature review is conceptual frameworks that can be used to reason about the governance of OSS projects. It was considered that the most suitable method to adopt is a semi-structured approach of both literature database searches and backward snowballing. The search engine used is Google Scholar.

The first step required the identification of an initial set of candidate articles. This was done by performing search strings on the aforementioned search engine. To identify a set of candidate articles the following search strings were used: *"allintitle: framework open source software governance"*, *"allintitle: governance open source software"*, *"allintitle: framework OSS governance"*, *"OSS governance framework"*, *"open-source software governance framework"*.

The most cited articles were used as an initial starting base. Next, a set of articles were pre-selected based on the reading of their titles and abstracts. This candidate set was then thoroughly read through. In some cases, this led to excluding the article from the study. Additional articles were included using a combination of forward and backward snowballing (Wohlin, 2014).

2.2.3 Blockchain governance

As previously outlined in Chapter 1, there is a lack of published research on the topic of blockchain governance. Furthermore, the universal applicability of blockchain technology leads to the research published on blockchain governance to be multidisciplinary. Because of these reasons, it was decided to set broad acceptance criteria for the to-be-included blockchain governance literature and to also consult relevant grey literature sources such as blog posts and conference talks.

Similar to the previous two literature reviews, a semi-structured approach was used. In order to identify the initial set of candidate articles the following search strings were performed on Google Scholar: *"allintitle: blockchain governance"*, *"allintitle: cryptocurrency governance"*, *"allintitle: distributed ledger governance"*. Next, the resulting articles were judged for inclusion based on the reading of their titles and abstracts. Included articles were then thoroughly read through. In some cases, this led to excluding the article from the study. Reasons for exclusion were the lack of presence of a conceptual framework for describing blockchain governance or the article having a different scope of blockchain governance such as regulation. Again, additional articles and grey literature were included using a combination of forward and backward snowballing (Wohlin, 2014).

2.3 Framework design

After completing the literature reviews, we have built a knowledge base regarding the topic of blockchain governance. In the second part of the research, the gained knowledge is used as a foundation to design the blockchain governance framework. In DSR, the artefact design can be viewed as an inherently creative process (Hevner & Chatterjee, 2010; March & Smith, 1995).

First, we start by identifying the relevant governance concepts discussed in the literature review. Then, two synthesis matrices will be created to organize the identified blockchain governance concepts. A synthesis matrix is a table that can help organise theory and support in the analysis and synthesis of key sources (Ramdhani, Ramdhani, & Amin, 2014). The synthesis matrices will be created in Excel. The first synthesis matrix aims at capturing the governance layers that are mentioned in the literature review. The second synthesis matrix will list identified governance dimensions, these are overarching key topics of governance that are important in the context of OSS and blockchains. The listed governance dimensions can possibly contain smaller concepts in the form of governance mechanisms. These will also be listed in the matrix. During the construction of the governance matrices, overlapping and related concepts are grouped together. After this iterative process, the tables will group the most reoccurring governance dimensions and layers. These are then used as a basis to guide the design of the framework.

Further details on the design process, including a rationale behind design decisions, is reported after completing the first iteration of design in Chapter 6.

2.4 Framework evaluation

As previously mentioned in Section 2.1.1, artefact evaluation is one of the two main activities of Design Science Research. Without a strict evaluation of the created artefact, outcomes might remain regarded as unconfirmed propositions (Shrestha, Cater-Steel, & Toleman, 2014). A solid evaluation of the artefact is key in order to answer the question *"how well the artefact performs"* (March & Smith, 1995).

While the Design Science Research Framework by Hevner and Chatterjee (2010) provides useful guidelines that describe how DSR should be conducted and presented as a whole, it lacks depth on how to choose among available evaluation strategies, and how to report on the outcomes. Therefore, to accurately report the artefact evaluation, we follow the DSR evaluation reporting structure proposed by Shrestha et al. (2014). This structure presents a combined overview of: (i) the *inputs* in terms of the artefact to be evaluated and the evaluation strategies followed, (ii) a discussion of *outputs* in terms of the evaluation process, and (iii) the *impacts* from the evaluation including both immediate findings, their discussion and future impacts. An adapted version of the DSR evaluation reporting structure is illustrated in Figure 2.2.

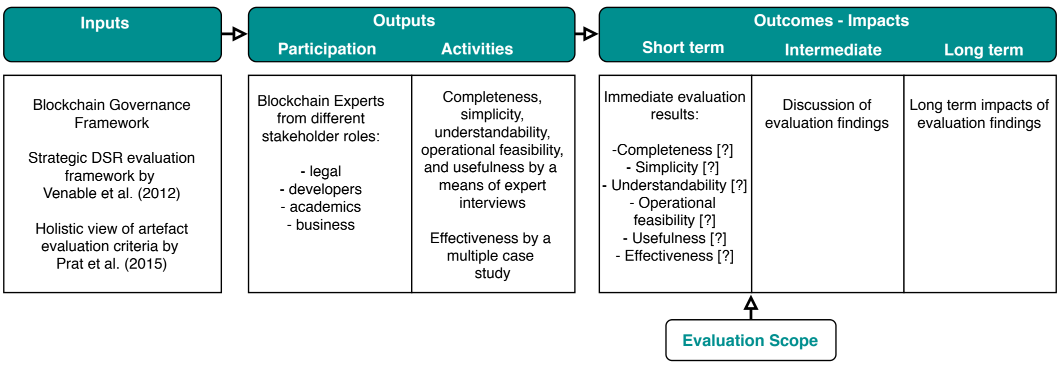


FIGURE 2.2: The DSR Evaluation Reporting Structure applied to the evaluation followed in this study, adapted from Shrestha, Cater-Steel, and Toleman (2014)

An introduction to the artefact to be evaluated has been outlined in Chapters 1 and 6. First, we will introduce our choice of the selected evaluation methods, the criteria considered for evaluation, and a description of the executed evaluation process itself. Finally, the outcomes of the evaluations are reported in Chapter 7 and 9.

Evaluation strategy

The evaluation of the blockchain governance framework was organised based on the strategic DSR evaluation framework by Venable, Pries-Heje, and Baskerville (2012). Besides this, we used the work by Prat, Comyn-Wattiau, and Akoka (2015) as a source for the selection of artefact evaluation criteria. The evaluation strategy makes a distinction between the evaluation of the design product and the design process. In this study, the *design product* is represented by the blockchain governance framework and the *design process* by the DSR methodology (Hevner & Chatterjee, 2010). Furthermore, two aspects that are considered in the evaluation strategy are the timing of the evaluation (*ex-ante* or *ex-post*) and the setting of the evaluation (*natural* or *artificial*). Ex-ante evaluation is formative and takes place before and during artefact design whereas ex-post evaluation is summative and occurs after the artefact is created (Pries-Heje, Baskerville, & Venable, 2008). The evaluation protocol established based on the evaluation strategy is summarised in Table 2.1.

TABLE 2.1: The evaluation protocol established in this study, based on the strategic DSR evaluation framework by Venable, Pries-Heje, and Baskerville (2012)

Evaluation	Evaluation setting	Evaluation method	Evaluation focus	Evaluation instruments
Design product (Artefact)	*Ex-ante*, Artificial	Expert opinion using interviews	Completeness, simplicity, understandability, feasibility, and usefulness of the framework	Evaluation criteria for IS artefacts by Prat, Comyn-Wattiau, and Akoka (2015)
Design product (Artefact)	*Ex-post*, Artificial	Application of artefact in a holistic multiple case study	Effectiveness of the framework in practice	Evaluation criteria for IS artefacts by Prat, Comyn-Wattiau, and Akoka (2015)
Design process (Research method)	*Ex-post*, Artifical	Alignment with DSR guidelines	DSR methodology	Guidelines for conducting DSR by Hevner and Chatterjee (2010)

2.4.1 Expert interviews

According to Wieringa (2014), eliciting expert opinions using interviews is a useful research method in the conceptual stage of artefact evaluation. Interviews can be used as a primary data gathering method to collect information from experts about their own practices, beliefs, experiences or opinions (Harrell & Bradley, 2009). In this study, the goal of conducting expert interviews is to get early information about the completeness, simplicity, understandability, operational feasibility and usefulness of the draft blockchain governance framework.

Semi-structured interviews are conducted in order to collect detailed information in a conversational style and this also enables the researcher to ask follow-up questions (Harrell & Bradley, 2009). A diverse group of potential users of the designed blockchain governance framework is interviewed. These include: (i) businesses looking to utilize an existing blockchain, (ii) blockchain developers, and (iii) researchers with a focus on blockchain technology. More details about the interviewed experts and chosen evaluation characteristics are described later in Section 7.2.

Prior to conducting the interviews, an interview protocol was created. In order to strengthen the reliability of the interview protocol and thereby improve the quality of the obtained data, the Interview Protocol Refinement Framework (Castillo-Montoya, 2016) was followed. The resulting interview protocol can be found in Appendix B.

Using the research information sheet, the interviewees were briefly informed about the purpose of the research, the structure of the interview, the confidentiality of the information discussed and the request of recording the interview. An informed consent form was created based on a template by TUDelft (2019). The first part of the interview focused on the background information of the interviewee and their own perception and considerations on the topic of blockchain governance. In the second part of the interview, the draft blockchain governance framework was introduced and the interviewees were invited to provide feedback. Responses to the questions are used to identify concepts that are possible candidates for removal or change. Furthermore, questions were formulated in order to identify possible extensions to the framework. All interviews lasted between 45 and 75 minutes. The recorded interviews were transcribed within 24 hours and the program *Nvivo* was used to analyse the transcripts. The transcripts were analysed following thematic analysis (Braun & Clarke, 2014), combining an inductive and deductive reasoning approach.

2.4.2 Case studies

A case study is an observational evaluation method which can be used to study the designed artefact in depth in its intended business environment (Hevner & Chatterjee, 2010). This study employs what Yin (1994) considers a *holistic multiple case study*, refering to a design with more than one case but only one unit of analysis. The holistic multiple-case study is conducted to demonstrate application of the blockchain governance framework and to evaluate the effectiveness when applied in the analysis of two blockchains their governance. Following the DSR evaluation framework, case studies are especially suitable to evaluate the effectiveness of a designed artefact (Venable et al., 2012). We decide to conduct a multiple case study because it creates a better understanding of the differences and similarities between the cases (Gustafsson, 2017).

The number of cases is limited to two because it enables the researcher to increase the time and and depth of analysis spent per single case (Gustafsson, 2017). According to Yin (1994), case studies are most appropriate (i) to answer a 'how' or 'why' question, (ii) when the researcher has little or no control over events, and (iii) when the events are contemporary phenomena. The latter two both apply to the governance of a blockchain. Furthermore, we aim to answer SQ4: *How does the created blockchain governance framework influence the comprehension of a blockchain's governance?*

As reported by Yin (2013), a case study design can have multiple validity concerns. In this multiple case study, data source triangulation is used to strengthen validity. The remainder of this section elaborates the relevant decisions related to case selection, data collection and analysis.

Case selection

In the selection of cases it was decided to select Ethereum and EOS.IO. Initially, attention was drawn towards the two largest public permissionless blockchains in terms of market capitalization (Coinmarketcap, 2019), namely Bitcoin and Ethereum. It was decided to select Ethereum as a case over Bitcoin. The rationale behind this decision is twofold. First, out of all the available blockchains, Bitcoin has already been the most researched (Yli-Huumo et al., 2016). Secondly, Bitcoin is primarily developed as a decentralised payment system, while Ethereum describes itself as a decentralised application platform supporting smart contract functionality, supporting more use cases. This difference is explained in more detail later in Chapter 3. Therefore, we expect Ethereum to be of higher interest to businesses, which is one of the primary envisioned end-users of the framework.

EOS.IO (EOSIO, 2019a) is selected as the second case. It is a public permissioned blockchain and, like Ethereum, it is possible to create and deploy decentralised applications upon EOS.IO because of its smart contract functionality. The EOS.IO blockchain is often viewed as a direct competitor of Ethereum and it is therefore useful to analyse the differences and similarities in blockchain governance between the two cases. Furthermore, EOS.IO is chosen because of its significance in market capitalization (Coinmarketcap, 2019) and their self-reported attention towards governance. In the EOS.IO white paper (EOSIO, 2019a), it is stated that prior blockchains rely on *"ad hoc, informal, and often controversial governance processes that result in unpredictable outcomes"*. This is an aspect that EOS.IO claims to have countered by the inclusion of both off-chain and on-chain governance processes.

TABLE 2.2: The two selected blockchains for the multiple case study, market cap and position taken from Coinmarketcap (2019)

Case	Name	Type	Initial Release	Market Cap	Position	Native token
1	Ethereum	Public permissionless	2015	141 billion USD	#2	Ether
2	EOS.IO	Public permissioned	2018	5.8 billion USD	#6	EOS

2.5 Research context

A relevant aspect of conducting research is highlighting the context in which the study took place (Petersen & Wohlin, 2009). A notable contextual factor of this research study is that it was written as part of an internship at the Rabobank's Blockchain Acceleration Lab (BAL).

2.5.1 Blockchain Acceleration Lab

The Blockchain Acceleration Lab is a team of specialists within the Rabobank who have shared expertise on the topic of blockchain technology. The team started with research in 2014 and in the following years grew to over fourteen blockchain experts with various skills and specialised knowledge. The mission of the BAL is to accelerate blockchain projects by being a "Centre of Excellence" for the entire organization. Research is a key activity in playing this role. They are part of various collaborative communities including the Dutch Blockchain Coalition (DBC, 2018), Enterprise Ethereum Alliance (EEA, 2018) and Techruption (TR, 2018). During their existence, the BAL has identified over 200 use-cases where blockchain can be applied in a useful way and created over 40 proofs-of-concept. Two examples of projects include *Sustainable Pay Per Use* (Rabobank, 2017) and *we.trade* (WT, 2018). We.trade is a blockchain-based platform for trade finance developed in a consortium of fourteen banks, which is in production as of June 2018.

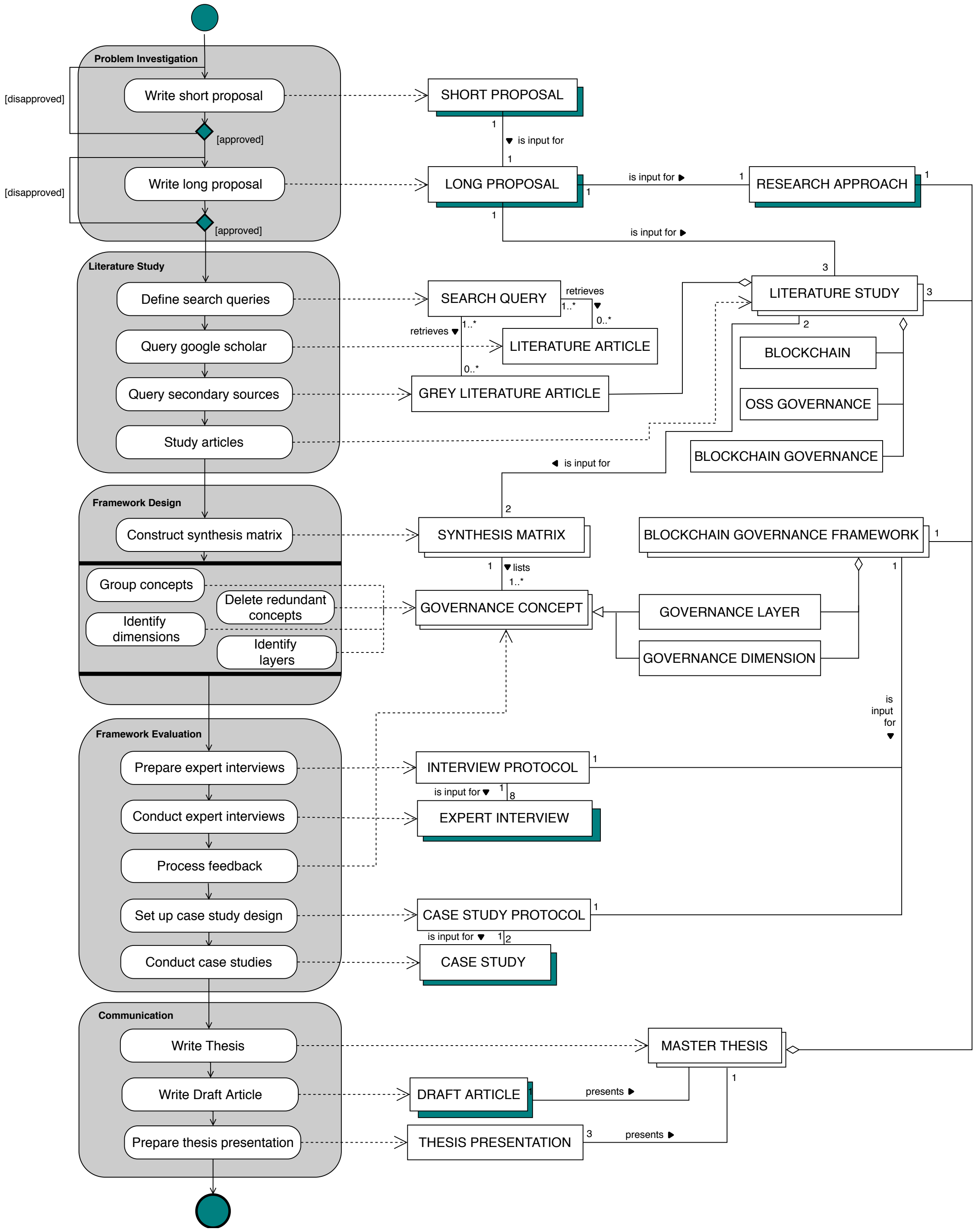


FIGURE 2.3: Process Deliverable Diagram of the described research approach

Chapter 3

Blockchain Technology

3.1 Introduction

In late 2008, an individual or group of individuals by the name of Satoshi Nakamoto published a whitepaper introducing Bitcoin, a decentralized digital payment system designed to operate without the need of a trusted third party (Nakamoto, 2008). Its introduction was a response to the way in which commerce on the internet used to take place. Previously, when a person wanted to make a payment or digitally transfer currency it would require a trusted third party (e.g. a bank or credit card company) to execute this transaction. In Bitcoin, two parties would be able to transact without relying on these types of trusted third parties (Nakamoto, 2008).

In the original paper of Nakamoto, there was no mention of the term *blockchain*. However, the way in which Bitcoin uses a series of time-stamped data *blocks* which are *chained* together is perceived as the source to the phenomenon nowadays known as a blockchain (Mattila, 2016).

3.2 Hashing

Before defining the term blockchain, it is necessary to understand the concept of hashing. Swan (2015) describes hashing as *"running a computing algorithm over any content file, the result which is a compressed string of alphanumeric characters that cannot be back-computed in the original content"*. Hashing in a blockchain involves running so-called *cryptographic hash functions* (Narayanan, Bonneau, Felten, Miller, & Goldfeder, 2016). A general hash function is a mathematical function which can efficiently transform any size of any string into a fixed size output (Narayanan et al., 2016). Cryptographically secure hash functions fulfil three additional properties. First, they are *collision resistant* implying that it is improbable to find two different inputs that hash into the same output. Secondly, they must be *hiding*, meaning that it is also infeasible to back-compute the input string of a given output. Lastly, they are *puzzle friendly*. This represents the idea that there is no efficient way of finding a remaining part of a given input string when also given the output hash. The only option is to randomly try all possible values (Narayanan et al., 2016).

3.3 Blockchain

Simply put, a blockchain consists of blocks of data, where every block of data includes a pointer to the previous block of data (Tschorsch & Scheuermann, 2016). Instead of a normal pointer locating the previous block of data it uses a *hash pointer* (Narayanan et al., 2016). Utilizing the properties of a cryptographic hash function, this pointer enables one to know not only where the data is stored, but also to verify that it has not changed (Narayanan et al., 2016). If any data in a previous block is changed, it will result in a different hash. Because this hash is referenced in the subsequent blocks, these will in turn also be invalid. In this paper, we adopt a definition of blockchain by Yaga, Mell, Roby, and Scarfone (2018), who define it as:

"A distributed digital ledger of cryptographically signed transactions that are grouped into blocks. Each block is cryptographically linked to the previous one after validation and undergoing a consensus decision. As new blocks are added, older blocks become more difficult to modify. New blocks are replicated across copies of the ledger within the network, and any conflicts are resolved automatically using established rules."

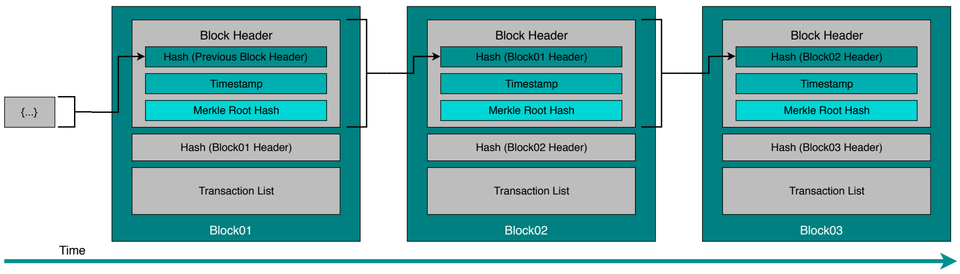


FIGURE 3.1: Simplified visualisation of a blockchain, linked blocks of data chained together using hash pointers, adapted from Yaga, Mell, Roby, and Scarfone (2018)

3.3.1 Asymetric Encryption

Blockchains use Asymetric Encryption (AE), also known as Public Private key encryption, to enable the identification of accounts and the authorization of transactions (Drescher, 2017). AE involves a key pair of a public and private key. The idea is that text encrypted with the private key can only be decrypted with the corresponding public key. Similarly, text encrypted with the public key can only be decrypted with the matching private key.

Public keys are usually treated as identities (Narayanan et al., 2016), serving as the account addresses of users (Drescher, 2017). Likewise, transactions are signed with the corresponding private key (Drescher, 2017). If a sender wants to execute a transaction it can attach its digital signature to a message by combining the message with its private key. The receiver can then verify the authenticity and integrity of the message by decrypting it with the senders public key (de Filippi & Wright, 2018).

3.3.2 Cryptocurrencies

One term that is often used when talking about blockchains is cryptocurrencies. Osterrieder, Lorenz, and Strika (2016) define cryptocurrencies as *"digital assets designed to work as a medium of exchange using cryptography to secure the transactions and to control the creation of additional units of the currency."* Essentially, cryptocurrencies are just one of the many use cases of a blockchain enabling to manage ownership and the creation of digital payments (Drescher, 2017). Since Bitcoin's launch in 2009, many other cryptocurrencies emerged, often referred to as *altcoins* (Tschorsch & Scheuermann, 2016). Due to the open nature of Bitcoin, including the code being open source, many of the early altcoins copied the entire code base of Bitcoin, most only making minor adjustments to the underlying software protocol (Narayanan et al., 2016). In this thesis, the focus does not solely lay on the digital asset use case of blockchains. Therefore, we use the term *blockchain* to refer to a single blockchain platform, its underlying ecosystem of stakeholders, technological features, and protocol.

3.3.3 Smart contracts

As stated before, cryptocurrencies are just a single use case of a blockchain enabling to manage ownership and the creation of digital assets. A Blockchain like Bitcoin is sometimes referred to as first generation blockchain because it mainly focused on this single use case (Swan, 2015). Since Bitcoin's launch, a second generation blockchains has emerged which went one step further by introducing extended smart contract functionality, enabling a new range of possible use cases. The idea of smart contracts originated with Nick Szabo, who described the concept in 1996 (Szabo, 1996). In this context, a smart contract is code that is stored, verified and executed on a blockchain (Christidis & Devetsikiotis, 2016). A well-known example of a second generation blockchain is Ethereum. It functions as a decentralised application platform and has a built-in Turing complete programming language that enables the creation of smart contracts (Buterin, 2013).

3.4 Consensus Mechanisms

The concurrency problem occurs when multiple parties together maintain a single shared database (Mattila, 2016). Instead of having to rely on a trusted third party to decide upon the current version of the database, a blockchain incorporates a *consensus mechanism* into its protocol to solve this issue in a distributed manner (Mattila, 2016).

3.4.1 Proof of Work

One strategy to achieve consensus among nodes in a blockchain network is by using the Proof of Work (PoW) protocol (Tschorsch & Scheuermann, 2016). It is used in many blockchains but is primarily known for being the consensus mechanism used in Bitcoin (Nakamoto, 2008). In PoW, the nodes participating in the network - called miners in Bitcoin - are constantly trying to calculate a target hash of a new block. The block combines the hash of a new set of transactions, a *nonce*, a time stamp and a hash pointer to the previous block (Zheng et al., 2018; Tschorsch & Scheuermann, 2016). By varying the nonce the miners aim to find a winning block which has a hash that meets the criteria of having a number of leading zeros below a specified threshold (Narayanan et al., 2016). Given the puzzle friendliness property of cryptographic hash functions previously described, the only way to succeed in finding a winning block is by varying the nonce randomly (Narayanan et al., 2016). This process of varying the nonce and calculating hashes is a computationally difficult activity (Tschorsch & Scheuermann, 2016). The probability of a node being the first to find a solution is equivalent to the proportion of total computing power compared to the rest of the network the node controls (Narayanan et al., 2016). Because of these properties, PoW assumes it is infeasible for a single entity to control a majority proportion of the computing power, preventing a possible Sybil attack (Douceur, 2002) on the verification of transactions (Tschorsch & Scheuermann, 2016).

When a node finds a solution to the puzzle its block is broadcasted to the rest of the network and given it is valid, the blockchain is eventually updated by extending it with the new block (Tschorsch & Scheuermann, 2016). In Bitcoin, nodes are incentivized to participate in the PoW process because if their block is included they receive rewards in the form of a block reward and transaction fees (Narayanan et al., 2016).

3.4.2 Proof of Stake

Due to its reliance on computing power, PoW has often received negative feedback about its extensive energy consumption (Malone & O'Dwyer, 2014; Zheng et al., 2018). Proof of Stake (PoS) is a consensus mechanism proposed as an energy-saving alternative to PoW (King & Nadal, 2012). Various different flavours of PoS, or sometimes referred to as virtual mining (Narayanan et al., 2016), exist. The key idea of PoS is that the node allowed to propose the next block is selected based on the proportion of staked coins (Tschorsch & Scheuermann, 2016). The underlying assumption here is that stakeholders with a larger proportion of stake are less likely to sabotage the consensus process (Zheng et al., 2018). Saleh (2018) further explains: *"PoS grants authority to update the blockchain to only stake-holders; thus, within PoS, an agent imposes a cost upon herself if she updates the blockchain in a manner that persists disagreement".*

3.4.3 Other mechanisms

Similar to PoW, PoS also imposes several limitations. Examples include the encouragement of coin hoarding and nodes only coming online periodically to collect their rewards (Tschorsch & Scheuermann, 2016). Proof of Activity is a hybrid consensus mechanism combining PoW and PoS to strengthen each other's weaknesses (Bentov, Lee, Mizrahi, & Rosenfeld, 2014). This consensus mechanism only gives online nodes a chance to propose the next block (Bentov et al., 2014). Multiple other consensus mechanisms have been proposed of which some are currently used in blockchains. Examples include Proof of Burn, Proof of Validation, Proof of Elapsed Time, and Proof of Existence (Mattila, 2016).

While most of the aforementioned consensus mechanisms such as PoW and PoS provide strong integrity assurances and protection against attacks, they also come with a cost in terms of performance (Angelis et al., 2018). The next section describes different types of blockchains which do not allow everyone to participate in the consensus mechanism. In these more permissioned blockchain environments, there is an increased level of trust between the nodes of the network (Angelis et al., 2018). As a result, this allows using other types of consensus mechanisms such as Proof of Authority (PoA). In PoA, the achieving consensus relies on a set of nodes which are called Authorities. It is assumed that the majority of these authorities is reliable. At certain time intervals, one of the authorities is selected to lead the creation of a new block (Angelis et al., 2018).

3.5 Different forms of blockchains

Describing the exact characteristics of blockchains is an unrealistic challenge because many different types of properties exist and every blockchain fills in these properties differently (Mattila, 2016). A solution to this problem is to characterise blockchains by focusing on their different types of architectures (Mattila, 2016).

One way in which blockchains can be classified is based on the rights users or nodes are given to read the blockchain data or to process transactions (Bitfury, 2015). In a *public blockchain*, there are no restrictions with respect to the reading of the blockchain data or the submission of transactions (Bitfury, 2015). The opposite of a public blockchain is a *private blockchain* which does restrict the reading of the blockchain data and the submission of transactions to a limited set of users (Bitfury, 2015).

Furthermore, a distinction between *permissionless blockchains* and *permissioned blockchains* indicates whether any restrictions are imposed on the processing of transactions (e.g. writing access by block creation). In a permissionless blockchain, any node is allowed to process transactions while in a permissioned blockchain this right is limited to a chosen set of known nodes (Bitfury, 2015).

TABLE 3.1: The four different forms of blockchains, inspired by Drescher (2017) and (Bitfury, 2015)

Processing of transactions	**Reading and submission of transactions**	
	Everyone	Restricted
Everyone	Public & Permissionless	
Restricted	Public & Permissioned	Private & Permissioned

A different - and often referred to - classification of blockchain forms distinguishes between public, private and consortium blockchains (Vitalik, 2015; Zheng et al., 2018). In this thesis, we stick to the described classification as shown in Table 3.1.

3.5.1 Users and nodes

The previous section about consensus mechanisms explained that nodes are competing for the right to propose the next block, thereby maintaining the state of the blockchain. These nodes are any computers who are running the blockchain's software and its underlying protocol (Yaga et al., 2018). For the remainder of this thesis, it is necessary to make a distinction between nodes and users, of which the latter can be further decomposed into full nodes, mining nodes and lightweight nodes (Yaga et al., 2018). A user is any person, stakeholder, organisation or entity making use of the blockchain in some shape or form. Nodes are the actual computer systems running the blockchain software. Full nodes store a complete version of the blockchain, validate that added blocks are correct and communicate data to other nodes in the network. Mining nodes are full nodes who also participate in the consensus mechanism to publish new blocks. Lightweight nodes do not store a complete version of the blockchain and pass on their data to the full nodes (Yaga et al., 2018). Because of their limited capabilities, they are able to run on lightweight hardware such as smartphones and IoT devices.

Chapter 4

Open-Source Software Governance

4.1 Introduction

Software development holds a long tradition of sharing and cooperation (Lerner & Tirole, 2003). However, along with the history of software development, certain people believed that the major established organizations were failing to produce software in a satisfactory way (de Laat, 2007). As a response to these views, they initiated the development of so-called Open-source Software (OSS) (de Laat, 2007). Typical characteristics of OSS include that the software can be downloaded and spread free of charge (Franck & Jungwirth, 2003) (Lattemann & Stieglitz, 2005) and that the source code is open to being viewed and modified by its users (Lattemann & Stieglitz, 2005). Well known examples of OSS include the Apache HTTP Server, internet browser Mozilla Firefox, and the Linux operating system.

In the first phase of OSS, it was an informal way of cooperative software development (Lerner & Tirole, 2003). Due to this property problems emerged and efforts were put into the formalization of the development of OSS (Lerner & Tirole, 2003). This eventually resulted in new rules and practices including the introduction of a new regulatory framework, the General Public License (GPL) (Lerner & Tirole, 2003; de Laat, 2007). The GPL is a form of copylefting (Lerner & Tirole, 2003). This means that users who use parts of software released under the GPL agree to also release their software following the GPL (Lattemann & Stieglitz, 2005).

OSS is unique because its development usually relies on the contributions of a community of users and developers who participate on a voluntary basis (Shah, 2006; Franck & Jungwirth, 2003). They usually participate either during their regular working hours or purely as a hobby (Hertel, Niedner, & Herrmann, 2003). This distinct organisational model for product development and innovation is sometimes referred to as collective action, community-based innovation or private collective invention (Shah, 2006). de Laat (2007) describes OSS as a movement which can be roughly split up into two camps. A radical camp who mainly believe that developed software is a public good and should, therefore, be openly available and modifiable (de Laat, 2007). And a more moderate camp who focus more on the aspect of transparency. This camp highly values the ability to inspect the source code of software to assure its quality (de Laat, 2007).

4.2 Defining OSS governance

A considerable amount of literature has been published describing the role of governance in OSS. Many different views exist on what the concept exactly involves (Markus, 2007). Examples include people who view it as the process of assigning tasks to developers, communication processes, or institutional mechanisms such as software licenses, structures of roles, and responsibilities (Markus, 2007).

From a higher perspective, there are two ways to look at the purpose of OSS governance (Markus, 2007). One option is to view governance as the solution to the coordination problem of OSS development. This means that the focus lies more on aspects such as how tasks are allocated and code changes are agreed upon. The second perspective is to view OSS governance as the solution to the social aspect of collective action and community establishment. In the latter context, the focal point is the way in which developers and users are incentivized to participate. Markus (2007) himself defines OSS governance as follows:

> *"the means of achieving the direction, control and coordination of wholly or partially autonomous individuals and organizations on behalf of an OSS development project to which they jointly contribute."*

4.3 Conceptual frameworks of OSS governance

4.3.1 Phases in OSS governance

Some authors frame their analysis by identifying different phases of governance in OSS projects. de Laat (2007) distinguishes between three phases of governance within OSS communities. The first phase is *spontaneous governance*. In this phase, the innovation and productivity happening within OSS communities occurred spontaneously. No formal and explicit coordination or control mechanisms were in place. The GPL licensing framework was viewed as the most important governance instrument.

Internal governance is the second phase which is characterised by the increasing size of open source communities. In this phase, communities introduced a collection of governance tools to sustain levels of productivity and innovation. According to de Laat (2007), these tools can be grouped into six categories (see Section 4.3.3).

The third phase captures *governance towards outside parties*. This phase of external governance highlights the institutionalisation within OSS communities. Due to the successes of OSS projects the outside world could no longer be ignored. Challenges such as patenting arose and OSS communities increasingly needed to consciously manage their relations with external parties. As a result, governance mechanisms were introduced at the outside borders of OSS projects. Examples include the introduction of non-profit organisations, official spokespersons, and defined processes on how members can be a part of these new structures.

O'Mahony and Ferraro (2007) examined the evolving governance system of an open source community throughout its lifespan. The authors identified four phases of governance: *de facto*, *designing*, *implementing* and *stabilizing governance*.

The first phase describes the OSS project when operated without formal representations of governance. In this phase the leadership of the project took an autocratic form, indicating that the power was mainly centred in the hands of one person. In the second phase, this existing system of autocratic leadership was challenged. Formalised democratic means were established with the goal to diminish the absolute power of the leader. In the third phase, the designed governance was implemented. Community members elected leaders via explicit democratic processes. In the final phase, the community achieved a stable and shared understanding of the governance system in place.

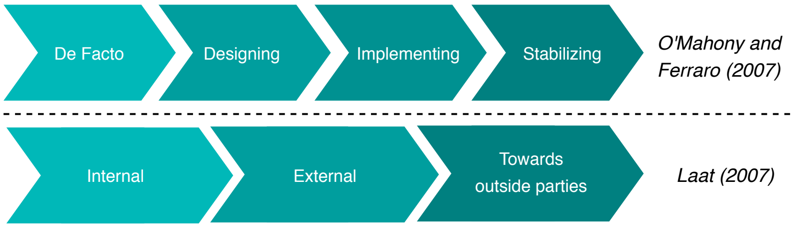


FIGURE 4.1: Comparison of the Different phases of governance in OSS projects by O'Mahony and Ferraro (2007) and de Laat (2007)

4.3.2 Motivational factors of voluntary contribution

For a big part, OSS development relies on the contributions of developers who participate on a voluntary basis. As already mentioned OSS can be downloaded for free and its developers usually do not receive wages. Therefore, multiple attempts have sought to identify what motivates the contributors (developers) in OSS projects (Lerner & Tirole, 2003; Franck & Jungwirth, 2003; Lattemann & Stieglitz, 2005; Shah, 2006).

To describe the motivations of contributors in an OSS project Lerner and Tirole (2003) distinguish between *immediate* and *delayed benefits*. An example of an immediate reward for a contributor is the fun he or she experiences while doing the development work. Simply put, contributing to an OSS project can be experienced as more enjoyable than a routine development task at a regular company. The delayed benefit captures the *career concern incentive* and the *ego gratification incentive*. The first incentive refers to the potential future career opportunities a contributor might receive while doing OSS development work. The latter incentive describes the possibility of eventually receiving some kind of status (e.g. being part of the core development group) within a community, satisfying a personal desire for peer recognition.

Other authors find similar reasons of motivation for contributors in OSS projects. Lattemann and Stieglitz (2005) distinguishes between *extrinsic* (rewards) and *intrinsic* (enjoyment) sources of motivations of contributors. Similarly, Shah (2006) makes a distinction between *need-driven participants* and *hobbyist participants*. Furthermore, the author states that the governance structure of an OSS project is crucial in the motivation of voluntary contributors.

Overlooking the discussion of motivations, Franck and Jungwirth (2003) identify two main patterns of argumentation. *Rent-seeker approaches* highlight that although contributors do not receive direct wages, they expect that their efforts will eventually be converted into a profitable investment. On the other hand, *donator approaches* state that many contributors put their efforts into OSS projects without the expectation to ever receive individual returns.

4.3.3 Dimensions and configurations

Six dimensions of OSS governance tools

de Laat (2007) uses the term governance tools to refer to the collection of explicit and formal tools used to internally coordinate and control an OSS project. The author classified the internal governance tools of OSS projects into six categories:

- *Modularisation*: Modularisation describes the tool of splitting a software program up into different modules. Furthermore, it refers to the distinction between an experimental version (innovation) and a stable version (maintenance) of a software program.
- *Division of roles*: This category describes whether groups of tasks are identified and linked to different levels of access to project files. Examples of roles include developers, observers, project owners and core developers. According to de Laat (2007) an OSS project can vary from three to up to eight different roles.
- *Delegation of decision making*: Many decisions have to be made within OSS projects. Examples include which methods to follow, which modules to integrate into a new release, and which source code is accepted in the stable version of a software program. Variations of decision making in code integration vary from centralised to decentralised designs.
- *Training and indoctrination*: This category describes the entry requirements for people to start contributing to a project. It includes whether or not the contributors must demonstrate certain skillsets or technical competences before they can become developers.
- *Formalisation*: This category captures the tools and procedures invented to enable the globally distributed contributors to work together in an orchestrated manner. Examples include versioning systems, mailing lists, testing procedures, bug reporting procedures and standards to enable better task performance.
- *Autocracy/democracy*: Whether leadership is self-appointed from above (autocracy) or whether leadership is chosen in some sort of democratic way (democracy). Democratic processes involve people selecting their core developer team or a leader elected by the developers.

Six dimensions of OSS governance

Similar to the previous classification by de Laat (2007), Markus (2007) grouped elements of OSS governance in six other dimensions of formal and informal rules:

- *Ownership of assets*: This dimension deals with intellectual property licensing and legal categories of organisations such as foundations.
- *Chartering the project*: Referring to information about the mission and vision of a project, its goals and the ideas on the foreseen features of a product.
- *Community management*: This category captures how the members of a community are managed. Aspects include who can join, which roles are available and how members can join these.
- *Software development processes*: This category describes the operational processes, rules and structures of the actual software development. Examples include release control and task allocation.

– *Conflict resolution and rule changing*: Focusing on how rules are created or modified and the procedures in place to resolve arising conflicts.

– *Use of information and tools*: Highlighting which, and how tools and repositories are used to manage and communicate information.

A micro, meso and macro-level analytical framework

A study by Jensen and Scacchi (2010) introduces a three-level framework to analyse and compare the governance of OSS projects. The authors believe OSS projects can be examined through a micro, meso, and macro-level of analysis. The *micro-level* sets the scope on the individual participants of a project, such as a developer or a user. These individuals are further analysed on two points. Their personal actions and motivations plus the resources and artefacts they use to govern these activities. An example of resources which a developer uses are those helping in the creation and updating of software code. Jensen and Scacchi (2010) highlight these resources and artefacts as coordination mechanisms because *"they help participants communicate, document, maintain awareness and otherwise make sense of how the software is structured or designed"*.

TABLE 4.1: The analytical levels of OSS governance and their emerging themes by Jensen and Scacchi (2010).

Analytical Level	Agents	Emergent Themes
Micro	Individual participants	Individual actions and resources, artefacts and resources as objects of interaction
Meso	Project teams	Collaboraton, leadership, control, conflict resolution
Macro	Inter-project ecosystem	Coordination, leadership, control, conflict resolution

Instead of focusing on individuals, the *meso-level* scopes on the level of project teams involved in an OSS project. At this level, the framework identifies three types of governance elements. The first is *collaboration*, which is further decomposed into *policies and guidelines*, and *separation of concerns*. Examples of policies and guidelines include those in place to define how development tasks are executed, how bug fixes are submitted and how changes of policies are submitted by the community. Overall these type of governance elements enable the developers to work independently and collaborate with others within the project, in line with the expectations of the community. Separation of concerns describes the way in which the project uses modularisation to separate development management efforts and thus foster collaboration. The second element of analysis is *leadership and control*. This element captures the observable hierarchical structures within a project, such as the available roles and their accompanying rights. Two additional components within leadership and control include the *degree of transparency* in the decision making process and whether the decisions are made with *consent* of the rest of the community. The third element emphasizes *conflict resolution*. If a problem arises within the community, this element analyses which formal and informal processes are in place to solve it.

Finally, the analytic *macro level* looks at the governance emerging on the boundary level between the OSS project itself and other projects within the software ecosystem. It includes the same three viewpoints of the meso-level. An overview of the three analytical levels can be observed in Table 4.1.

A multidimensional matrix of OSS governance configurations
de Noni, Ganzaroli, and Orsi (2011) propose a dimensional matrix which captures four identified configurations of OSS governance. The construction of the matrix by de Noni et al. (2011) is based on seven dimensions of OSS governance:

- *Foundation*: Describing whether a foundation is present in the OSS project and what kind of role it takes (e.g. strategic management, legal protection, standardization).
- *Type of license*: Looking at the type of license used in an OSS project and its implications.
- *Membership*: Whether formal or informal procedures are in place before a new individual or firm is considered a member of the project.
- *Changes to source code*: Whether new contributors can directly become involved in the development process. It could be the case that proposed changes are publicly evaluated or submitted to project leaders who have the authority to decide upon implementation.
- *Sub-projects*: Whether sub-projects can be created, who retains the control over these sub-projects and their possible inclusion in the main project.
- *Release authority*: Describing who has the authority to make the final release decisions.
- *Leadership and decision-making*: Whether membership is in place, a board, and how decisions are made with regards to the future of the community and project.
- *Acces to the code and bug reporting*: Highlights whether access to the source code is complex or limited to a certain group of members.

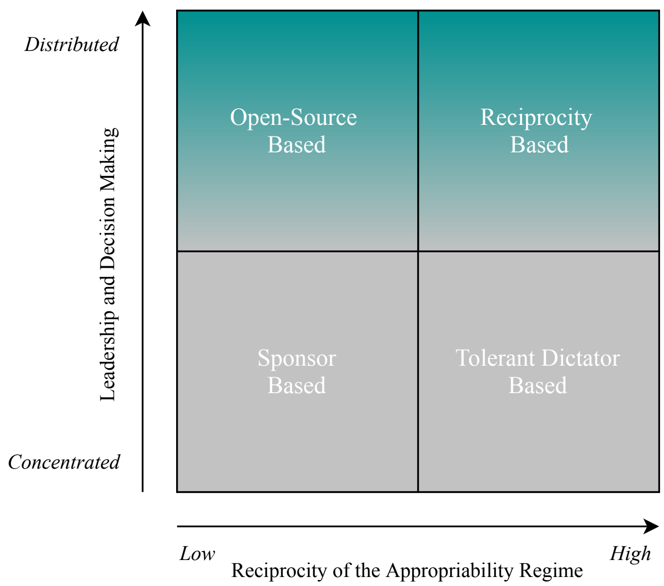


FIGURE 4.2: The OSS Governance Matrix by de Noni, Ganzaroli, and Orsi (2011)

On the horizontal axis, the model differentiates between a low or high *reciprocity of appropriability regime* while the vertical axis varies from concentrated *leadership and decision* making to a distributed variant. The latter axis takes into account the level of concentration or distribution in the membership, the involvement of a foundation, code changing, release authority and leadership. The reciprocity of appropriability regime captures two variables, that of the type of license adopted to distribute the software and the inclusion of sub-projects, indicating whether forms of sub-projects can be set up within the OSS project. An example of an OSS community that can be placed in the Open-Source Based quadrant includes internet browser Mozilla Firefox (de Noni et al., 2011).

The top right quadrant (Reciprocity Based) in Figure 4.2 captures communities with the most traditional model of free development. These communities are characterized by decision making which is highly distributed. Besides this, it is possible for the people involved in a project to set up new sub-projects (de Noni et al., 2011). Communities in the Tolerant Dictator Based quadrant are similar to that of Reciprocity Based but instead of distributed decision making the power is concentrated at one copyright holder who has weak control over the source code. An example of OSS that used to have a tolerant dictator in the early stages includes the Linux operating system and its founder Linus Torvald (de Noni et al., 2011).

Sponsor-based communities are those who are sponsored by one or more companies. In these communities, the founders usually have substantial power, are little led by involvement from the community, and have control over the projects content and development. Open-Source Based communities are those who have found a more balanced way of dealing with the input from other companies (de Noni et al., 2011).

Governance rules framework

Izquierdo and Cabot (2015) analysed how OSS projects are governed by their *governance rules*. For Izquierdo and Cabot (2015), governance rules refer to the set of guidelines and rules which describe how tasks contributing to a project are executed and how the decisions are made with respect to the acceptation or rejection of these contributions. An example of a simple governance rule is a core developer who has the right to decide which development task is next going to be implemented. A more complex example of a governance rule would be that the next task to be implemented is decided upon by a community voting process. According to the authors, the governance rules in place are crucial to the successful continuation of an OSS project. They guide the coordination of developers in a project. Moreover, by modifying the existing governance rules a project can react to environmental changes on how people wish to collaborate (Izquierdo & Cabot, 2015).

However, the authors state that the governance rules of an OSS project are usually not formalized and lack support for their specification and enforcement. To foster this process Izquierdo and Cabot (2015) introduce a nine-dimensional framework which can be used to analyse OSS projects in terms of their governance rules. The framework consists of three viewpoints, namely the organisational, development, and governance rule definition viewpoint (Table 4.2).

The *organisational viewpoint* examines how the developers in an OSS project are organised. Questions to ask in this viewpoint include whether the organisational structure is hierarchical or not, which communication tools are used (e.g. coordination and tracking systems), and whether the project is open for anyone to join

TABLE 4.2: A nine dimensional framework to analyse OSS projects focusing on governance rules by Izquierdo and Cabot (2015)

Viewpoints	Dimensions
Organisational	Organisation Communication Participation
Development	Task review Patch review Release decision
Governance rule definition	Rules definition Rules application Roles

and participate. Examples of coordination systems include forums, mailing lists and blogs.

The *development process viewpoint* focuses on how the review process takes place at three different decision points in the software development process. These decision points include the acceptation or rejection of new development tasks and patches (which are essentially the implemented development tasks). But also a decision made on when to release a new version of the software product and which new features to include.

Finally, *the governance rule definition viewpoint* looks at which roles are involved in the definition of rules, where the new rules are defined, and how they are applied.

Participation and responsibility management

Midha and Bhattacherjee (2012) studied the governance practices of OSS projects in the process of software maintenance. The term software maintenance is used by Midha and Bhattacherjee (2012) to refer to *"the correction of errors, and the implementation of modifications needed to allow an existing system to perform new tasks, and to perform old ones under new conditions"*. In their study, the authors propose a two-dimensional taxonomy of OSS project governance consisting of participation and responsibility management.

Participation management describes the process of deciding and monitoring who is allowed membership in the core development team and maintenance team of an OSS project. Whether a developer is able to join the core development team of an OSS project could be based on the developer's qualities or experience with the project. The main goal of participation management is to oversee the quality control of developers. An example of participation management is observed in Apache (Midha & Bhattacherjee, 2012). Here, new contributors are allowed to work on a project for a certain time period. After that, a panel of the Apache Foundation members judge their work quality and reach a consensus vote on what formal development role the new contributor can take. Overall, participation management can be highly formalized or not at all, without any explicit roles and access rights specified.

Responsibility management describes the way in which the responsibilities of development tasks are assigned among the developers. It looks at whether roles are defined for activities such as bug fixing or documentation. Furthermore, responsibility management can be decomposed into *open* and *delegated responsibility*. These two types indicate whether the responsibility of development is completely left open in a project or whether tasks are allocated to developers. In most OSS projects an online tracking system (e.g. Git) is used to support responsibility management.

Code forking and its effect on governance

Nyman and Lindman (2013) draw our attention to the element of code forking and its effect on the sustainability of OSS. For Nyman and Lindman (2013) code forking refers to the ability to take the source code of an existing OSS project in order to start a separate independent version of the project. The same authors define sustainability as the ability of an OSS project to continue its lifecycle and to keep satisfying the needs of its users and developers. Before, code forking was mainly viewed as a bad thing but nowadays it is referred to in a more broad context (Nyman & Lindman, 2013). While many reasons exist, one of the main reasons to fork a project's source code is the desire to modify an existing product in order to better address the needs of a group of users (Nyman & Lindman, 2013). Another example of code forking includes the experimentation of new ideas and features in a forked project.

According to Nyman and Lindman (2013), the right to fork the source code of an OSS project is embedded in the nature of being an OSS program. This can be observed in one characteristic of OSS previously highlighted stating that the source code of OSS is open to being viewed and modified by its users. The authors introduce a framework which shows the effect of forking on three levels of governance in OSS projects (Table 4.3).

TABLE 4.3: A leveled approach showing the effect of forking on the governance of OSS projects by Nyman and Lindman (2013)

Level	How forking provides sustainability
Software	The right to fork protects against planned obsolescence, versioning and vendor lock-in Disuse due to decay can be countered by forking and updating
Community	Prevents hijacking and other unfavourable actions by project leaders or owners through giving developers the option to continue their own version of the program
Ecosystem	Increases innovative potential by allowing for the combination and modification of open source projects Abandoned (or badly handled) projects can be revived, creating new business opportunities

At the *software level*, any type of project's source code has the ability to be modified or extended, and thus evolve into updated versions of the software (Nyman & Lindman, 2013). Traditional closed software development organisations can use mechanisms such as planned obsolescence, lock-in and versioning to stay relevant for their customers (Nyman & Lindman, 2013). An example of this is a software company who after a certain time period deliberately disables the support for a specific version of an operating system on their old products. As a result, customers of that company are forced to buy new products that do support the usual operating systems. In the case of an OSS project attempting to introduce planned obsolescence, the source code can be forked and modified so that it is still usable by its users. Code forking on a software level, therefore, serves as a governance mechanism contributing to the healthy continuation of an OSS project (Nyman & Lindman, 2013).

The *community level* focuses on the shared ownership of an OSS project. The absolute ownership over an OSS project is not in the hands of a single person or group of persons. Instead, it is usually shared among its community (Nyman & Lindman, 2013). If a split of trust, standpoints or desires occur within the community it can result in the project to be forked off into two versions. These kinds of splits can be prevented by effectively managing the community and the available developer resources. Here, forking provides the community with a way out in case of large issues.

Similar to a community forking an OSS project's source code, the *business-ecosystem level* describes how other companies can do the same thing. A company who forks the source code of a successful commercial product still need to obtain part of the potential customer base. This is related to aspects of *trademarks*, *brand value*, *recognition*, and *the existing user and developer base of the original project* (Nyman & Lindman, 2013). At the business-ecosystem level, forking stimulates competition and innovation.

4.4 Summary

This chapter set out to answer ***SQ1:*** *What artefacts are used to characterise the governance of Open-source software?* Reviewing the available literature on OSS governance, we see that multiple authors focus on a discussion of the motivational factors - also referred to as *incentives* - of the individual participants in OSS (Lerner & Tirole, 2003; Franck & Jungwirth, 2003; Lattemann & Stieglitz, 2005; Shah, 2006). Because a large part of the work in OSS takes place on a voluntary basis, the incentives in place for contributors seem to be a meaningful aspect of their underlying governance.

When taking a closer look at the artefacts used to characterise the governance of OSS, we can make a few observations. While the discussed artefacts cover a wide range of approaches, a few of the authors seem to be using a *three-layered approach* to describe the governance of OSS. Jensen and Scacchi (2010) distinguish between a micro, meso and macro analytical level of OSS governance, where each of the levels takes a wider scope of looking at the agents involved. Similar to these three layers, Nyman and Lindman (2013) also introduce three levels, namely the software level, community level and ecosystem level. Izquierdo and Cabot (2015) divide their nine-dimensional governance rules framework into three viewpoints. Again, this approach can be viewed as a way to subdivide the complex phenomena of governance into a subset of layers.

Besides the importance of incentives, there are other recurring governance themes across the reviewed literature. Various sources highlight *modularisation* as an influential governance mechanism that could be present within an OSS project. The author de Laat (2007) describes modularisation as the act of splitting a software program into a set of smaller submodules. de Noni et al. (2011) refers to this concept by mentioning the possibility to create sub-projects and looking at who retains the control over these sub-projects and their possible inclusion in the main project. Multiple authors highlight the aspect of how the actual *software development* takes place (Markus, 2007; Jensen & Scacchi, 2010; de Noni et al., 2011; Bhattacherjee, 2012; Izquierdo & Cabot, 2015). Lastly, which and how *communication tools* are used within a project is also considered a relevant aspect of their governance (de Laat, 2007; Markus, 2007; Izquierdo & Cabot, 2015).

Chapter 5

Blockchain Governance

5.1 Introduction

The term governance has been omnipresent since the 1980s (Bevir, 2012). Usage of the term has grown rapidly and so are the different contexts in which it is used. According to Bevir (2012), governance refers to:

"all processes of governing, whether undertaken by a government, market, or network, whether over a family, tribe, formal or informal organisation, or territory, and whether through laws, norms, power or language."

Various perspectives on governance exist. Examples include corporate governance (Harford, Mansi, & Maxwell, 2008), public governance (Osborne, 2010) and global governance (Finkelstein, 1995), but also more niche areas such as governance in IT (Weill & Ross, 2004), Software Ecosystems (Alves, Oliveira, & Jansen, 2017) and OSS (see Chapter 4). Each type has its own body of existing theory and literature. In the context of software development organizations, governance is defined as "the way an organization is managed, including its powers, responsibilities and decision-making processes" (Dubinsky & Kruchten, 2009). Jansen, Brinkkemper, Souer, and Luinenburg (2012) extend this definition by stating that it also involves the assignment of roles, decision rights, measures, policies and how much power is left to the community. This chapter will review the existing literature conducted on blockchain governance.

Blockchain governance is a term frequently used in the blockchain ecosystem, however, to date, there is no shared understanding about what the term exactly refers to. There is a degree of uncertainty around the concept because just as with the term governance itself, it is used in many different contexts, at different levels of abstraction and by people from different disciplines. This shows a need to be explicit about what exactly is meant by the term blockchain governance in the rest of this thesis.

5.2 Defining blockchain governance

Before continuing to define blockchain governance, it is important to highlight two different roles that governance can play in the context of blockchain. The authors Ølnes, Ubacht, and Janssen (2017) highlight a distinction between *governance of the blockchain*, and *governance by the blockchain* (Figure 5.1). Firstly, governance *by* the blockchain refers to the use of blockchain technology to more efficiently govern and coordinate existing actions and behaviour. In this context, the technology itself provides a supporting role to improve existing governance processes. An example is when a blockchain is used to implement and automate existing governmental processes. Secondly, governance *of* the blockchain describes the development, adaptation and maintenance of the blockchain technology itself. The latter role of governance is the topic of interest in this study. Throughout this thesis, the term blockchain governance is thus used to refer to the governance *of* the blockchain.

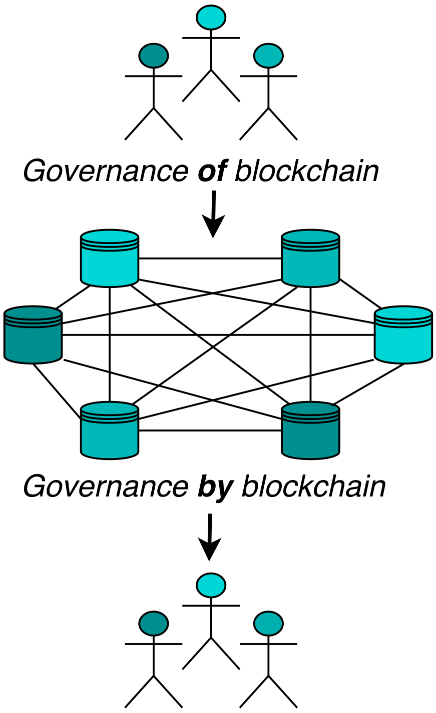


FIGURE 5.1: Two roles of governance in blockchain technology, adapted from Ølnes, Ubacht, and Janssen (2017)

One more term that is often mixed up with blockchain governance is consensus (DiRose & Mansouri, 2018). As previously described in Section 3.4, consensus mechanisms such as PoW and PoS are used in a blockchain so that nodes can achieve agreement on which new blocks are valid. Consensus thus refers to the process of making a decision on the status of the blockchain via a majority agreement (or other specified consensus rules) between nodes. This should not be confused with blockchain governance, which DiRose and Mansouri (2018) define as the process by which new technical features – but also strategies or marketing plans - are proposed, designed, agreed upon and implemented. While a governance decision can be consensus-based (e.g. developers voting on the approval of a new protocol change), both terms have a different meaning.

Another aspect when discussing blockchain governance is the level of analysis. In grey literature, a recently proposed classification distinguishes between five levels of blockchain governance: (i) intra-blockchain governance, (ii) inter-blockchain governance, (iii) pan-blockchain governance, (iv) supra-blockchain governance, and (v) private off-chain governance (CleanApp, 2018). In this classification, each term refers to a different scope of blockchain governance. For example, pan-blockchain governance refers to governance aspects common to every blockchain (e.g. legislation about environmental friendly targets), while private off-chain governance refers to governance elements between blockchain development teams and commercial entities (e.g. Ethereum and their relationship with Amazon). In this thesis, intra-blockchain governance, here referred to as *internal-blockchain governance*, is the level of analysis when discussing blockchain governance. This level refers to the governance matters within the context of a given blockchain project or organisational space (e.g. governance within Bitcoin, governance within Ethereum).

Continuing with the definition of the concept, Ziolkowski et al. (2018) simply describe blockchain governance as the placement and enactment of decision rights. Nic Carter defines it as "the way in which public blockchain communities and key stakeholders arrive at collective action, specifically with respect to protocol change" (Carter, 2018), while Finck (2019) states that in a blockchain context, governance refers to "the processes, rules and procedures relied on to maintain the protocol".

In this thesis, the definition of OSS governance by Markus (2007) is adapted to define **blockchain governance** as:

"the means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute."

5.3 Conceptual frameworks of blockchain governance

5.3.1 An IT governance perspective

Beck et al. (2018) propose a research framework for governance in what they describe as the 'blockchain economy'. Drawing from IT governance literature, they derive three key dimensions of governance that are applied to a blockchain case study. The first dimension is (i) **decision rights**, concerned with the rights that enable one to govern control. Decision rights are further split up into *decision management rights*, dealing with aspects such as the generation of decision proposals and the execution or implementation of decisions, and *decision control rights*, concerning the approval, monitoring and measurement of decisions. The second dimension is (ii) **accountability**, which captures to which degree actors are and can be held accountable for their actions. The third and last dimension is (iii) **incentives**, highlighting what motivates actors to take actions. Incentives include monetary and non-monetary rewards, but also incentive alignment, standing for incentives that enable actors to behave freely, and yet, promote the correct behaviour.

Building upon these dimensions, the authors propose an extended IT governance framework. Following this framework, the governance of a blockchain is a combination between the extent of incentive alignment, the degree of centralization in decision rights, and the level to which accountability is either technically enacted or institutionally enacted (Figure 5.2).

Using the block size debate of Bitcoin as a case study, Filippi and Loveluck (2016) investigated the social and technical governance of Bitcoin. The authors make a clear distinction between two coordination mechanisms: (i) **governance by the infrastructure** (via the protocol) and (ii) **governance of the infrastructure** (by the community of developers and other stakeholders). This distinction shows similarities with the separation of Ølnes et al. (2017) outlined earlier in Section 5.2. Drawing from IT governance literature, Filippi and Loveluck (2016) identify the following three dimensions to further analyse Bitcoin's governance: (i) *definition and protection of community borders*, (ii) *establishment of incentives for participation and acknowledgement of the status of contributors* and (iii) *mechanisms of conflict resolution*. Furthermore, the

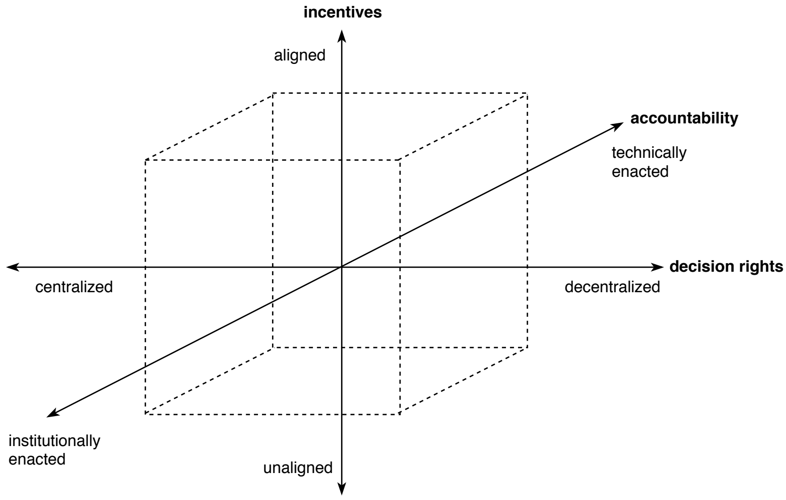


FIGURE 5.2: An extended IT governance framework by Beck, Müller-Bloch, and Leslie King (2018)

authors state that the Bitcoin project consists of two different types of communities, namely (i) *the community of nodes within the network*, which can be subdivided into *passive users* and *active users* (miners) and (ii) *the community of developers*.

Building upon the previous work by Filippi and Loveluck (2016), the author Carter (2017) conducted an empirical study that attempts to classify and highlight the differences in organisational structures of fifty blockchain projects. Of interest here are the various variables defined by the author to analyse the governance structures of these blockchain projects. These variables include: a blockchain its (i) *consensus mechanism*, (ii) the *launch style of a project* (e.g. ICO or hardfork), (iii) *the number of coins generated at launch*, (iv) *the founder reserve*, (v) *whether a project has support from corporates*, (vi) how *developers are funded*, (vii) *if a foundation is present*, and (viii) *whether the project is open source*.

In a conference presentation by the same author, a layered model is outlined making a separation on-chain and off-chain governance (Carter, 2018). Regarding on-chain governance, a distinction is made between (i) *non-binding votes*, (ii) *direct on-chain votes*, and (iii) *delegative on-chain votes* (Figure 5.3). An example of non-binding votes is when miners in Bitcoin voluntary signal their preference in newly mined blocks

TABLE 5.1: Summary of the governance dimensions applied to the Bitcoin project by Filippi and Loveluck (2016)

Dimension	Governance by the infrastructure	Governance of the infrastructure
Community borders	Flexible and open, technical solutions to protect against attacks	Copyleft license, clear line between developers and community members, pull requests, BIP process
Legitimacy and status recognition	Trustless infrastructure, mining run by ologopolostic mining pools	Decision making delegated to small number of people, users and miners decide whether to support the protocol
Conflict resolution	Protocol specifies the longest chain wins after a fork	Forking as a last resort solution

for or against a particular decision. The results of signalling remain non-binding. This is different in the case of direct on-chain votes and delegative on-chain votes, where the results of a vote are binding. Delegative on-chain votes are a special form of direct on-chain votes. In these, stakeholders can vote for a representative, who then, in turn, votes on behalf of his followers.

FIGURE 5.3: Three types of on-chain governance and examples of projects that utilize these, adopted from Carter (2018)

Regarding off-chain governance, a distinction is made between mechanisms on (i) *the implementational level* and (ii) *the community level* (Carter, 2018). The former level captures how the software is built. It includes the development processes and tools such as Bitcoin and Ethereum Improvement Proposals (BIPs/EIPs), mailing lists and software version control tools such as Github. The implementation level describes how actual changes are made, while the community level captures how an agreement is achieved between the community of a project at large. According to the author, off-chain governance at the community level is given insufficient attention and is, therefore, less understood than governance at the implementation level. The community level includes conferences, but also discussion on tools such as Slack, Reddit and Twitter.

5.3.2 A corporate governance perspective

The authors Hsieh et al. (2017) draw from theory on organisational and corporate governance to examine the governance of public blockchains. Following corporate governance literature, a distinction is made between internal and external governance. This discrepancy is similar to the one outlined in Chapter 5.2 by CleanApp (2018). In the model of Hsieh et al. (2017), external governance refers to the influence of external stakeholders such as the community, media, and general public over the organisation, in this case, a blockchain. Their model of looking at internal governance is described here. Considering internal governance, the authors identify three levels: (i) owner control on **the blockchain level**, (ii) formal voting on **the protocol level**, and (iii) centralized funding at the **organisational level**.

On *the blockchain level*, miners are considered the key stakeholder group whose actions are guided by the rules and incentives in the underlying protocol. Miners hold power to decide which transactions are included in the next block and to agree upon the current state of the blockchain. This level looks at the consensus mechanism in place, whether coins on the blockchain are pre-mined, and whether nodes can nominate other nodes in order to faster achieve consensus.

On *the protocol level*, developers are considered as the key stakeholder group because they are the one writing the 'rulebook' of the blockchain. Central is the decision making of core developers, whether other users can voice their views via voting, and the presence of formal voting mechanisms for miners to vote on protocol changes.

Finally, *the organisational level* looks at the formative ideology behind a blockchain. In most cases, the origins lie in a decentralised control of coin distribution, network participation and openness. Yet, differences can exist and this level aims to highlight the management strategies present in a blockchain to attract external funding and grow. Examples include developers that are hired as formal employees and paid via a centrally managed foundation or trusted nodes that are only allowed to participate in the network upon approval.

In another paper by Hacker (2017), blockchain governance is also framed through a corporate governance perspective. The author states that uncertainty in blockchain based organisations can be reduced, and elements of stability and order strengthened, by applying a corporate governance framework. Before proposing such a framework, the author looks at a few specific cases of forks in the blockchain ecosystem.

The first example outlined is the bitcoin hard fork of 2013, an unintended fork which was the result of the slow updating of miners to the newly released version of the protocol. The blockchain fork persisted for several hours until the core developers convinced the majority of mining pools to continue mining on the shorter chain. A second example is the Ethereum hard fork of 2016, when an exploited vulnerability in the source code of the DAO, an application built on top of the Ethereum blockchain, led to a hack of over 50 million dollars. After consulting a vote with the users and miners of Ethereum, the core developers eventually decided to proceed with a controversial solution of returning the stolen Ether via a hard fork. Not everyone agreed with this decision, forking the Ethereum blockchain in two different versions.

Similar to Hsieh et al. (2017) a framework is proposed based upon corporate governance literature, distinguishing between external governance (exit) and internal governance (voice). Regarding external governance, Hacker (2017) adds that as of now there is no formal way for a takeover, or in other words, to overthrow the core development team of a blockchain. Available exit strategies that Hacker (2017) highlights include users selling off their tokens simultaneously to put pressure on developers, and the option to fork off a project at any time.

5.3.3 Other perspectives

An OSS governance perspective

Garagol and Nilsson (2018) adopted the six-dimensional governance mechanism framework by de Laat (2007), as described in Section 4.3.3. The authors use Ethereum as a case study to investigate whether these six mechanisms are also present in a blockchain project. The results indicated that the first five dimensions of OSS governance were too present in the case of Ethereum. However, the sixth dimension of *autocracy versus democracy* was experienced to be different, with leadership being difficult to define in the case of Ethereum. Furthermore, the authors identified a seventh governance dimension, namely that of *initiative-based progress*. This new dimension states that contributors to a blockchain project are stimulated because they have the freedom to decide where in the project to contribute and to start new subprojects.

Multistakeholder governance groups
The authors Gasser, Budish, and West (2015) used Bitcoin in a twelve-part case study to examine the real-world governance structures of multistakeholder governance groups. According to the authors, multistakeholder governance implies ''the incorporation of representatives from multiple groups in discussions and decision making". The aim of their research was to inform the current and future evolution of the internet governance ecosystem. In the case study of Bitcoin, they examined the process that was followed to update its source code with the new feature of multisignature transactions. To analyse the governance of a multistakeholder group such as Bitcoin, an analytical framework was used that distinguished between four main dimensions and several sub-dimensions.

The first dimension is (i) **the purpose and context** of a multistakeholder group. This dimension looks at the motivations that drove the formation of the governance group. For example, in the case of Bitcoin, the group wanted to create a new digital currency that was not dependent on trusted third parties. Besides the *purpose* of the governance group, the first dimension also aims to highlight its *cultural and contextual factors* and its *types of legitimacy*. The cultural and contextual factors include geopolitical factors, the already existing relationships between stakeholders, the allocation of resources, and the relations of the group with governmental institutions. Types of legitimacy aim to explain why certain decisions are adopted even without any formal enforcement instruments in place. The second dimension is called (ii) **formation**. This dimension considers the architectural composition of the multi-stakeholder group, the *inclusion criteria* of participants versus stakeholders, and lastly, its *structures* including divisions and working groups.

TABLE 5.2: An analytical framework used by Gasser, Budish, and West (2015) to examine the governance of multistakeholder groups

Dimension	Sub-dimension
(i) Purpose and context	Purposes of governance groups Cultural and contextual factors Types of legitimacy
(ii) Formation	Inclusion criteria Architectural structures
(iii) Operation	Decision making procedures Conflict resolution Interfacing and coupling management Knowledge and memory management Motivational issues Communication
(iv) Outcomes	Outputs, outcomes and impact Unintended consequences Operational continuity

The third dimension focuses on the (iii) **operation** of the multi-stakeholder group. As Gasser et al. (2015) express ''it describes the operational systems and tools that they use in order to reach the agreement necessary to create its outputs and address the issue at hand." This dimension is decomposed into six sub-dimensions which include: *decision-making procedures*, *conflict resolution*, *interfacing and coupling management*, *knowledge and memory management*, *motivational issues*, and *communication*. As an example, knowledge and memory management deals with the ways in which knowledge is built and stored within the group, e.g. Bitcoin uses Github to log discussions and states. Finally, the fourth dimension (iv) **outcomes** highlights the outputs of multistakeholder initiatives, their *impact*, *unintended consequences* and *operational continuity*. Table 5.2 summarizes the framework with its four dimensions and corresponding sub-dimensions.

As a result of the twelve-part case study, including that of Bitcoin, the authors conclude that there is no single best-fit solution for multistakeholder governance groups that is applicable to every situation. Instead, the authors believe that there are a series of governance instruments available for both the formation and operation of multistakeholder groups. Whether a multi-stakeholder governance group is successful depends on the careful selection, deployment, and management of these instruments.

Layouts of self-governance

Tasca and Tessone (2018) conducted a comparative study across some of the most well-known blockchains in order to create a taxonomy of blockchain technologies. Using a reverse engineering approach, the authors deconstructed existing blockchains into several building blocks, which in turn are hierarchically subdivided into main, sub, and sub-subcomponents. For the different subcomponents, the authors identified several different layouts. While in total seven main components were identified such as *consensus*, *transaction capabilities*, and *identity management*, only the fourth component *extensibility*, and more specifically, its sub-component ***governance*** are of interest here.

Regarding a blockchain its governance, the authors identified two types of governance rules: (i) **technical rules of self-governance defined by the participants** and (ii) **regulatory rules defined by external regulatory bodies**. Similar to what we have seen before, this distinction shows resemblance with the concepts of internal and external governance outlined by Hsieh et al. (2017), CleanApp (2018) and Hacker (2017). According to Tasca and Tessone (2018), the technical rules of self-governance include *software*, *procedures*, *protocols*, *algorithms*, *supporting facilities* and other technical elements. On the other hand, the regulatory rules refer to *regulatory frameworks*, *provisions*, *industry policies*, and other components. The regulatory governance rules lay outside the scope of their taxonomy, similar to the governance scope defined in this thesis.

The authors identified three possible layouts of self-governance:

i **Open source community:** This describes blockchains that have open communities of developers. This layout follows the principles of OSS. Usually, a foundation is present that helps coordinate changes to the protocol together with the miners and core developers.

ii **Technical:** This layout relates to enterprises with a strong technical background that have proposed themselves as a solution provider for a blockchain (e.g. IBM and Microsoft). In this governance layout, the technical governance rules of a blockchain are influenced by these enterprises. The authors highlight Microsoft as an example who partnered with ConsenSys in 2015 to offer Ethereum Blockchain as a Service for Microsoft Azure Enterprise clients and developers. Another characteristic of these enterprises is that they usually apply for patents.

iii **Alliance:** This third layout highlights a governance model proposed by industry consortia (e.g. R3). Industry consortia are associations of several companies with similar interests and demands in business and technological advancements. They join forces under the goal of mutual benefit and common contribution, sharing a technological platform and building standards. Only those companies that fulfil certain criteria are eligible to be part of the consortia and are thereby also legitimized to provide input on the technical rules of the blockchain governance.

In an article by ListedReserve (2018), a distinction is made between two models of governance in blockchains. The first model refers to the situation of having a (i) *centralised development team*. In this model, the community of a project can provide input and suggestions, while the final say on a protocol change remains with the development team. The second model describes an (ii) *on-chain voting system*. In this model, stakeholders can cast votes based on certain criteria, with the voting results binding the future path of the blockchain.

In another report, researchers provide an analysis of existing blockchain technologies from the perspective of their business model and governance (van Deventer et al., 2017). The latter perspective is of interest to this study. In terms of governance, the authors make a distinction between technology governance and network governance. **Technology governance** here refers to the governance of the blockchain technology, i.e. the actual source code development of a blockchain project. A few examples given of technology governance include: (i) a blockchain its licensing model, (ii) development roles (iii) presence of a foundation and (iii) how to contribute code. On the other hand, **network governance** implies the governance of the associated blockchain networks. Examples of network governance derived include (i) a blockchain its consensus mechanism, (ii) the roles and type of participants in the network and (iii) the process to allow new members or roles to join the network.

Six dimensions of decision making

Ziolkowski et al. (2018) explored the governance decisions made in fifteen existing blockchains from four different application domains. Their work outlines six core decisions that have to be made in the governance of a blockchain. These six core decisions include:

i *Demand Management:* Who makes decisions when new business requirements emerge and how are these decisions made (e.g. decisions on standards the API and business requirements).

ii *Data Authenticity:* Who can write data to the blockchain, how are transactions validated and how is data preserved (e.g. the consensus mechanism used).

iii *System Architecture development:* Who decides upon the requirements and functionalities of the initial and future blockchain.

iv *Membership:* How are decisions made upon granting new actors reading or writing access in the network (this is not applicable to public permissionless blockchains).

v *Ownership disputes:* How are conflicts resolved when multiple users claim the same property (e.g. when a dispute occurs over the ownership of assets).

vi *Transaction reversal:* Decisions that have to be made about whether an unintended transaction can be reversed or corrected.

Three branches of blockchain governance

Maddrey (2018) proposes a three branch model to look at blockchain governance. In an analogy, the author compares the three traditional branches of government with stakeholder groups in blockchain governance. This comparison is illustrated in Figure 5.4.

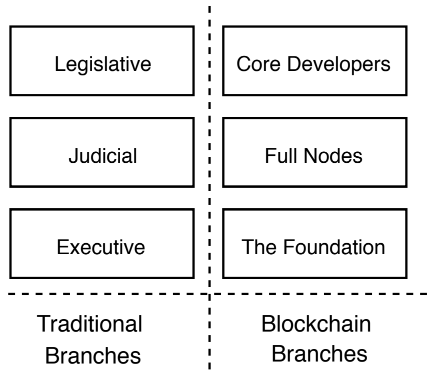


FIGURE 5.4: A three branch model of looking at blockchain governance by Maddrey (2018)

The first group includes (i) the *core developers*. They manage the software repository in a blockchain project and follow a process to update the source code. The core developers are compared to the legislative branch because they have the power to add new code, yet they do not have the power to enforce its usage. The second group are (ii) the *full nodes*. In order for the updated source code to take effect, these nodes must run the new software. For this group, a comparison is made with the judicial branch, who can decide to decline a new law if they disagree with it. The third group is (iii) the *foundation*. Maddrey highlights that most blockchains have a (non-profit) foundation or organisation that manages funds and backs core developers. The foundation is comparable with the executive branch in the sense that it might have direct control over the hiring of core developers. Following this distinction, blockchain governance is a balance between a blockchain its core developers, full nodes and foundation. Finally, the users of a blockchain can be viewed as 'the people', a fourth branch of influence.

Governance mechanisms in Bitcoin and Dash
The authors DiRose and Mansouri (2018) evaluated the governance mechanisms present in Bitcoin and Dash. In order to do so, the authors looked at how these two different blockchains approached the block size scalability problem. For their analysis, the Governance Analytical Framework Hufty (2011) was used. This framework distinguishes between two types of social norms. One type being (i) **first level norms**, describing the rules of the game. In the case study of DiRose and Mansouri (2018) this maps to the block size as written in the blockchain protocol. The other type being (ii) **second level norms**. This captures meta-governance, or in other words, the rules that establish how the first level norms are established. In their case study, this deals with how the decision is made to change the block size.

The authors describe the initial governance of Bitcoin as a benevolent dictatorship. When Satoshi Nakamoto disappeared and the network's usage increased, a governance mechanism was introduced via the Bitcoin Improvement Process (BIP). The BIP is used to propose new protocol changes and to signal those changes that are accepted by the network. No mechanisms are in place to enforce a change, instead, the adoption rate of the network determines whether a change is accepted. In Bitcoin, miners hold governance power to vote upon BIPs. The voting power of a miner is equal to their total amount of computing power. The approach of Bitcoin is non-binding and dependent upon the adoption by the market.

In contrast to Bitcoin, Dash uses the Decentralised Governance Blockchain Budget (DGBB) system. In the DGBB, there are not only users and miners but also master nodes. Instead of giving the full mining rewards to miners, certain percentages are also divided among supernodes and the Dash Budget System (DBS). The DBS is then used to back the implementation of changes. In Dash, there is a distinction between those who can mine (the miners) and those who are eligible to vote on proposals (the master nodes). A new proposal is accepted when a majority of the master nodes votes in favour of a change. The proposal is then implemented because development is backed by the DBS. Furthermore, the authors highlight that in the Bitcoin community discussion takes place on a different platform (Reddit) than were the BIPs can be found (Github), while Dash directly integrated community discussion into the DGBB system and its proposals.

5.4 Summary

While Chapter 4 presented the available literature on OSS governance, this chapter outlined what has been discussed in the primary and grey literature about the governance of blockchains. In this chapter, we set out to answer ***SQ2:*** *What concepts and structures does the governance of blockchains encompass?* First, attention is drawn towards the different meanings the concept of blockchain governance can have. Where one group of people uses the term to refer to the use of blockchain technology to support existing governance processes, the focus in this thesis lays on the governance of existing blockchain technology itself (Ølnes et al., 2017). Furthermore, layers to look at blockchain governance include governance matters between the development teams of different blockchains and governance aspects such as regulation that apply to all blockchains. In this thesis, the focus lies on the intra-blockchain governance layer (CleanApp, 2018), defining blockchain governance as: *"the means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute."*

Furthermore, the literature study shows a diverse set of conceptual models to discuss blockchain governance from different theoretical perspectives. Where one group of authors builds on an IT governance perspective (Filippi & Loveluck, 2016; Beck et al., 2018) others approach the concept from a corporate governance background (Hsieh et al., 2017; Hacker, 2017). Yet, similar as with OSS governance, multiple authors use a layered approach (Hsieh et al., 2017; Carter, 2018) and the identification of governance dimensions (Filippi & Loveluck, 2016; Gasser et al., 2015; Ziolkowski et al., 2018) to examine the governance of blockchains. *Incentives*, or more specific the question *how developers are funded* is again one of the recurring governance themes across the set of reviewed literature (Beck et al., 2018; Carter, 2017; Hsieh et al., 2017). Moreover, multiple authors highlight the relevance of a blockchain its *consensus mechanism* (Beck et al., 2018; van Deventer et al., 2017; Filippi & Loveluck, 2016; Hsieh et al., 2017) and the governance aspect of *forking* (Beck et al., 2018; Filippi & Loveluck, 2016; Hacker, 2017).

Chapter 6

Blockchain Governance Framework Design

In the previous chapters, we have outlined the concepts and structures that are used to describe the governance of Open-source software and blockchain in literature. In the next chapters, we will make use of those concepts and structures to design a blockchain governance (BG) framework that captures the main dimensions and layers of blockchain governance. Complementary to the literature reviews, we will draw from insights gathered during events covering blockchain and discussions with people participating in the blockchain ecosystem. Examples include a *panel discussion* about blockchain governance, a full day organised by the Dutch Blockchain Coaliation about *the governance of Distributed Ledger Technology* and the *Ethereum Community Conference* where the draft BG framework was discussed with interested people from the community. An overview of attended events related to blockchain governance is highlighted in Table A.1 of Appendix A.

In Chapter 2 we described the design science research approach of this study. According to Baskerville and Venable (2009): "*the search for the design solution and the evaluation of the design solution are activities that take place in the abstract world of design thinking*". Design thinking is the process which besides analysis also involves creativity. In DSR, the artefact design can be viewed as an inherently creative process (Hevner & Chatterjee, 2010; March & Smith, 1995). This chapter describes the process that led to the creation of the first version of the BG framework. First, the process of identifying the blockchain governance dimensions is described. Next, the identification of the governance layers is elaborated upon. Finally, the resulting draft BG framework is described.

6.1 Blockchain governance dimensions

In the literature review it became evident that multiple authors subdivided the complex phenomena of governance into several distinct dimensions. In the remainder of this study, blockchain governance dimensions are defined as overarching key themes of governance that are relevant in the context of blockchains. The first step during the design of the framework was the creation of a synthesis matrix. As described earlier in Chapter 2.3, a synthesis matrix is a table that can help organise theory and support the analysis and synthesis of key sources (Ramdhani et al., 2014). In order to identify the dimensions needed to create the BG framework, we create a synthesis matrix including all individual governance concepts identified during the literature reviews. In this stage, no attention is paid to the granularity of the concepts. For example, both the concept *software release decision* and *decision making* *processes* could be identified as governance concepts during this process, with the latter probably being a larger concept.

After a first iteration of identifying governance concepts, the dimensions synthesis matrix contained approximately 122 governance concepts. Some examples of listed concepts in the synthesis matrix included: *rule changing* (Markus, 2007), *demand management* (Ziolkowski et al., 2018), *division of roles* (de Laat, 2007) and *type of license* (de Noni et al., 2011). Next, several iterations of clustering were performed in order to group similar and related concepts. Because the goal is to identify dimensions which comprise multiple governance concepts, individual concepts which could not be grouped to other concepts or which were not mentioned in more than one literature source were dropped from the list.

The result of this iterative process was a list of 15 clusters of governance concepts. An example of a cluster of governance concepts included:

– Foundation: present and which role? (de Noni et al., 2011)

– Foundation (van Deventer et al., 2017)

– Whether a foundation is present (Carter, 2018)

– The foundation (Maddrey, 2018)

The next step was concerned with the definition of each cluster using one label. Labelled clusters could then be used as input for the selection of governance dimensions. After defining each group of concepts, the 15 clusters were referred to as follows:

- Incentives
- Software development
- Forking
- Decision making
- Community
- Conflict resolution
- Context and formation
- Modularisation
- Roles
- Communication
- Foundation
- License
- Membership
- Consensus mechanism
- Voting mechanisms

The result was a list of 15 clusters of related governance concepts. The next step dealt with selecting the relevant clusters which could form the main dimensions in the BG framework. For each cluster of governance concepts, questions such as the following were asked: (i) is this an overarching key theme of governance? (ii) could this be a subconcept of one of the other dimensions? (iii) does it overlap with one of the pre-defined layers? After asking these questions, several clusters were not considered candidates for having their own separate governance dimension:

– **Software development** was considered to be in line with the later identified governance layer *off-chain development* and therefore did not earn its own individual dimension.

– **Forking** was not considered as a dimension because of its different level of granularity. For example, forking could be viewed as a sub-concept of conflict resolution, as hard forks are used in the blockchain ecosystem to solve conflicts when two camps within the community disagree.

- **Consensus mechanism** was also considered to be a too small concept in order to be a candidate for a dimension. At this stage, it was already thought of as a subconcept of decision making, namely on the blockchain itself.
- **Voting mechanism** was viewed as a subconcept of decision making. It is a mechanism in order to support decision making and was therefore not considered as a candidate dimension.
- **Modularisation** was also not considered as a candidate dimension because of its different level of granularity. Modularisation is highly related to software development and was viewed as a subconcept of it.
- **Community** was considered to be in line with the later identified governance layer *off-chain community*, therefore not having its own individual dimension.

The remaining 9 dimensions included *formation and context*, *roles*, *foundation*, *license*, *incentives*, *membership*, *communication*, *decision making* and *conflict resolution*. As described in the following sections these were used as direct input for the draft BG framework. License and foundation were eventually grouped together as one dimension. A full description of each dimension including the sources from which they are inspired is listed below in Table 6.1.

TABLE 6.1: The eight identified governance dimensions of blockchain governance and their foundations in the literature

Governance dimension	Description	Inspired by
Formation and context	This dimension highlights the relevant background information of a blockchain. Examples of aspects to look into include the purpose of a blockchain, its launch style and formative ideology.	(Markus, 2007; Gasser, Budish, & West, 2015; Hsieh, Vergne, & Wang, 2017; Carter, 2017)
License and foundation	This dimension describes the type of license used by a blockchain and its implications. Furthermore, it looks at whether a foundation is present and its role within the project.	(de Noni, Ganzaroli, & Orsi, 2011; Filippi & Loveluck, 2016; van Deventer, Brewster, & Everts, 2017; Carter, 2017; Maddrey, 2018)
Roles	This dimension identifies the different roles present on each of the three layers of governance. Furthermore, it aims to describe the hierarchical structures between them.	(de Laat, 2007; van Deventer, Brewster, & Everts, 2017; Jensen & Scacchi, 2010; Izquierdo & Cabot, 2015)
Incentives	This dimension captures the motivational factors involved for the roles specified in the roles dimension. This is done by looking at the incentives present on the three layers of governance. It includes questions such as what the intrinsic sources of motivation are and how developers are funded.	(Lerner & Tirole, 2003; Lattemann & Stieglitz, 2005; Jensen & Scacchi, 2010; Gasser, Budish, & West, 2015; Hsieh, Vergne, & Wang, 2017)
Membership	This dimension focuses on the way participation and membership are managed for the available roles. It captures whether a blockchain is open for anyone to join and participate. Questions asked here include the process to enable new members to join the network and whether new contributors can directly become involved in the development process.	(de Laat, 2007; de Noni, Ganzaroli, & Orsi, 2011; Midha & Bhattacherjee, 2012; Izquierdo & Cabot, 2015; Hsieh, Vergne, & Wang, 2017; van Deventer, Brewster, & Everts, 2017; Ziolkowski, Parangi, Miscione, & Schwabe, 2018)
Communication	This dimension captures the formal and informal ways of communication between the stakeholders of a blockchain. It includes the available communication tools such as coordination systems and tracking systems, but also looks at discussions done in the open, such as meetings and working groups.	(de Laat, 2007; Markus, 2007; Izquierdo & Cabot, 2015; Gasser, Budish, & West, 2015; van Deventer, Brewster, & Everts, 2017)
Decision making	This dimension highlights how decisions are made, monitored and agreed upon on the three layers of governance. Furthermore, it looks at the way in which the decision making processes are set in place.	(de Laat, 2007; Markus, 2007; Jensen & Scacchi, 2010; de Noni, Ganzaroli, & Orsi, 2011; Izquierdo & Cabot, 2015; Gasser, Budish, & West, 2015; Filippi & Loveluck, 2016; Hsieh, Vergne, & Wang, 2017; Ziolkowski, Parangi, Miscione, & Schwabe, 2018; Beck, Müller-Bloch, & Leslie King, 2018; DiRose & Mansouri, 2018)
Conflict resolution	Disagreement can arise on all three layers of governance, when such a dispute arises, certain actions are taken to resolve the disagreement. This dimension focuses on the processes in place to solve arising conflicts.	(Markus, 2007; Filippi & Loveluck, 2016; Carter, 2017; DiRose & Mansouri, 2018)

6.2 Blockchain governance layers

The second building block needed during the design of the BG framework consists of a series of blockchain governance layers. The results from the literature review highlighted multiple authors who used a three-layered approach to describe either the governance of OSS or blockchain. Distinguishing between analytical levels or layers is viewed as a way to subdivide governance into more comprehensible subcomponents. In order to distinguish between governance layers in our framework, we draw from a layered structure described by Carter (2018). This author distinguishes between governance on the *off-chain community*, *off-chain implementational* and *on-chain* level. Further inspired by more sources, we adapt these levels and identify them as the (i) **off-chain community layer** (ii) **off-chain development layer** and (iii) **on-chain protocol layer**. Descriptions of the layers and an overview of the sources in which they are grounded can be found in Table 6.2.

TABLE 6.2: The three identified layers of blockchain governance and their relation to the literature sources in which they are grounded

Governance layer	**Description**	**Inspired by**
Off-chain community	As the highest of the three layers, the off-chain community layer encompasses the governance matters taking place in the real world with a focus on the wider community of a project. It highlights how a project is defined more generally and captures the ties of the community to the governance layers below.	Off-chain community level (Carter, 2018), Organisational level (Hsieh, Vergne, & Wang, 2017), Off-chain (Finck, 2019; Reijers et al., 2018)
Off-chain development	The off-chain development layer encompasses the governance matters taking place in the real world with an explicit focus on the software development process. For example, it looks at how roles related to development interact and decisions are made in the maintenance of the protocol.	Off-chain implementational level (Carter, 2018), Individual participants and project teams (Jensen & Scacchi, 2010), Off-chain (Finck, 2019; Reijers et al., 2018)
On-chain protocol	The on-chain protocol layer comprises all the governance matters taking place on the blockchain through its underlying protocol. Examples include the decision making processes, voting mechanisms and rules of interaction encoded directly into the infrastructure of the blockchain.	On-chain (Carter, 2018; Finck, 2019; Reijers et al., 2018), Blockchain and protocol levels (Hsieh, Vergne, & Wang, 2017)

6.3 Combining governance dimensions and layers

The next step was to combine the governance dimensions and layers into one framework. It was discovered that the dimensions could be laid on top of the layers. Two exceptions were found during this approach. First, the *formation and context* dimension was considered to be placed at the edge of the framework. The reasoning behind this decision was that the context of how a blockchain was formed over time is applicable to all three layers. Having an understanding of the formation and context of a blockchain should be the logical first step of a stakeholder wishing to retrieve insights in the governance of a blockchain, therefore this dimension is placed on top of the framework. The *foundation and license* dimension was also placed at the edge of the framework because it did not seem logical to lay it on top of the three layers.

As a result of this approach, smaller governance concepts relevant to the cells where a dimension and layer crossed could now be listed in the framework. The list of governance concepts identified during the identification of the governance dimensions was used as input for the selection of the smaller governance mechanisms. Based on the blockchain governance concepts from literature, questions were identified for each respective cell in the framework. The list of included governance mechanisms and their sources is highlighted in Table A.2 of Appendix A. The resulting draft BG framework is illustrated in Figure 6.1.

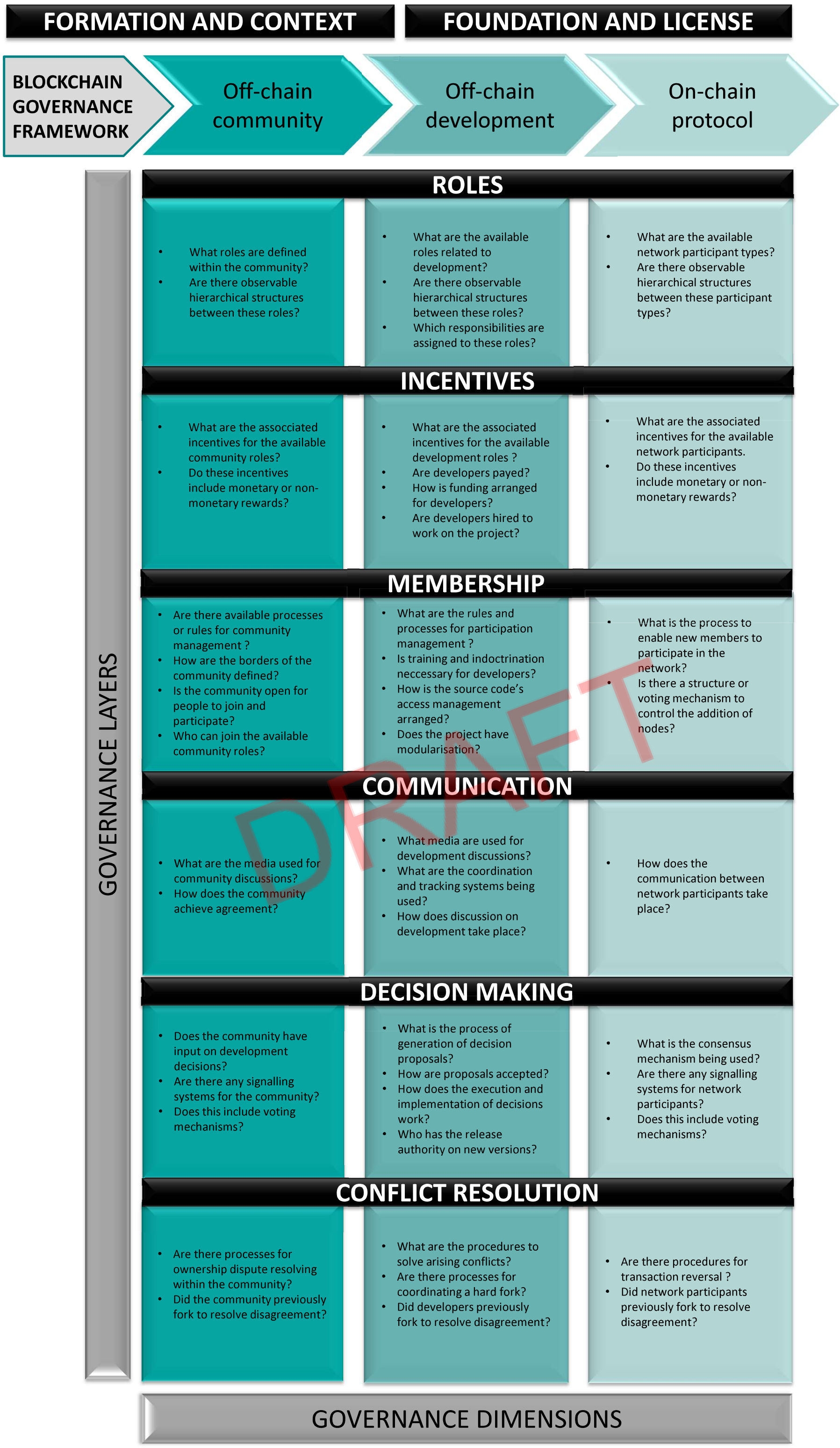


FIGURE 6.1: The resulting draft version of the BG framework

Chapter 7

Expert interviews

The previous chapter described the draft version of the blockchain governance (BG) framework based on inputs from the literature review. In this section, we present the results of the *ex-ante* design product evaluation, following the evaluation strategy as defined in Section 2.4. This initial evaluation is based on expert opinions elicited from a series of semi-structured interviews. The interviews were conducted following the interview protocol included in Appendix B.

In order to evaluate the draft BG framework, several characteristics have been predefined as the primary evaluation characteristics. The following section further explains the rationale behind the chosen evaluation characteristics and their operational definition in this study.

7.1 Ex-ante evaluation objectives

By conducting an ex-ante evaluation through expert interviews we aim to evaluate five criteria of the draft BG framework. The draft BG framework was designed with the intention to *"capture the dimensions and layers of blockchain governance in a comprehensible manner in order to guide blockchain stakeholders to analyse the governance of blockchains in a structured way"* (Section 1.1.1). From this goal, three envisioned qualities of the framework were derived: (i) it should at least include the main dimensions and layers of blockchain governance, (ii) it should do so in a comprehensible manner for its users and (iii) it should positively impact the users during the analysis of a blockchain's governance. Taking these three qualities in mind and drawing from the evaluation criteria hierarchy by Prat et al. (2015), we consider five criteria relevant during the ex-ante BG framework evaluation: completeness, simplicity, understandability, operational feasibility and usefulness.

The five characteristics which were evaluated during the expert interviews are summarised in Table 7.1. The standard definitions from Prat et al. (2015) were translated to operational definitions, implying the specific context in which they are used to evaluate the BG framework.

7.2 Interviewed experts

In this study, we used a *purposive sampling* approach. Purposive sampling has been described as: "*the deliberate choice of a participant due to the qualities the participant possesses*" (Etikan, Musa, & Sunusi, 2015). To be more specific we combine *expert*

TABLE 7.1: The operationalised evaluation characteristics

Characteristic	Definition by Prat, Comyn-Wattiau, and Akoka (2015)	Adapted operational definition
Completeness	The degree to which the structure of the artefact contains all necessary elements and relationships between elements.	Whether the BG framework includes all necessary dimensions, layers and sub-questions.
Simplicity	The degree to which the structure of the artefact contains the minimal number of elements and relationships between elements.	Whether the BG framework contains the minimal number of layers, dimensions and sub-questions.
Understandability	The degree to which the artefact can be comprehended, both at a global level and at the detailed level of the elements and relationships in the artefact.	Whether the BG framework is comprehensible, especially from a general level on the dimensions and layers.
Operational feasibility	The degree to which management, employees and other stakeholders will support, operate and integrate the proposed artefact it into their daily practice.	Whether the interviewed experts see themselves using the BG framework in future situations.
Usefulness	The degree to which the artefact positively impacts the task performance of individuals.	Whether the BG framework is perceived as an added value to stakeholders dealing with blockchain governance.

sampling and *maximum variation sampling*. In this study we decide to use these techniques because we want to select information-rich cases of individuals who are well-informed and experienced on the topic of blockchain (governance) but as a group represent different viewpoints of stakeholders for whom the framework can be relevant. Another benefit of purposive sampling includes the willingness of individuals to participate and the "*ability to communicate experiences and opinions in an articulate, expressive, and reflective manner*" (Etikan et al., 2015). Furthermore, the goal of the expert interviews is not to get results that enable generalisations to an entire population. Instead, the intention is to receive insightful feedback from experts early in the design process in order to improve the BG framework as much as possible.

Criteria used for selection were as follows. First, the candidate should have a minimum three years of experience in the blockchain ecosystem. Secondly, the interviewee fulfils a function as one of the potential stakeholders for whom the BG framework is considered to be relevant. As previously mentioned these include developers, researchers, business stakeholders, and legal professionals in the blockchain ecosystem. In total, eight blockchain experts were interviewed.

TABLE 7.2: An overview of the conducted evaluation interviews

Interview	Type of stakeholder	Organisation	Identifier
1	Developer	Freelancer	IE-1
2	Developer	Financial institution	IE-2
3	Developer, researcher	University and research institute	IE-3
4	Researcher	University	IE-4
5	Researcher	University	IE-5
6	Researcher, business	University and consultancy firm	IE-6
7	Business	Blockchain company	IE-7
8	Business	Software company	IE-8

Semi-structured interviews were conducted with eight experts from different types of backgrounds which can be viewed in Table 7.2. For example, one of the experts included the CEO of an international company developing blockchain solutions, while two interviewees were writing a PhD on the topic of blockchain governance at the time of being interviewed. To maintain the privacy of the individuals, the participants have been coded according to their interview number from Table 7.2. The identifiers will be used in the remainder of this chapter to refer to the corresponding experts and their opinions.

7.3 Results

7.3.1 Perception of blockchain governance

From the interviews, it became clear that most of the experts have a slightly different perception when asked about the term blockchain governance. For example, the following definitions of blockchain governance were given by four of the experts.

– *"How to steer the direction of a public open blockchain without an owner, that is the basis."* (IE-1)

– *"The laws and regulations which apply within a particular blockchain sphere, the sphere can be both on-chain and off-chain."* (IE-2)

– *"All the factors that influence the decision making of the future of a [block] chain."* (IE-8)

– *"The set of technical and non-technical agreements which can help parties to decide whether they want to participate in a blockchain or not."* (IE-3)

Where the first definition (IE-1) focuses on public blockchains, the other definitions (IE-2, IE-8, IE-3) are applicable to private blockchains too. The definitions by IE-2 and IE-8 are wide in their scope. In both of these definitions, external regulations by governments are also taken into account. Furthermore, different from the others, IE-3 looks at the concept from the perspective of a party looking to participate in a blockchain.

Unsurprisingly, this brief comparison shows that even experts in the blockchain ecosystem have a different frame of reference when they think of blockchain governance. However, one aspect of blockchain governance that was mentioned by all experts was decision making: "*it's about decision making*" (IE-4), "*mainly decision making and how to ensure that information needed for decision-making ends up with the right people*" (IE-5), "*when you have a decentralised network, with an application on top of it, how do you make decisions together such as a change to one of the front-end buttons*" (IE-7). Another aspect that was mentioned by three experts included the forking mechanism (IE-1, IE-2, IE-4). Regarding forks, one expert stated: "*If people don't agree with the new rules within a blockchain you can get a hard fork. As a result, a new blockchain sphere exists with its own new governance*" (IE-2). Other themes mentioned more than once included smart contract upgradeability (IE-1, IE-3), on-chain and off-chain governance (IE-2, IE-3) and regulation (IE-2, IE-6).

7.3.2 Considerations of blockchain governance

The experts mentioned various reasons why the governance of a blockchain is a key aspect which needs to be understood by stakeholders in the blockchain ecosystem. As an organisation looking to build a blockchain application you must decide on which blockchain you are going to build. In those cases, it is necessary to have a certain level of trust in the continuity of that blockchain (IE-8). In line with this reasoning, another expert stated that: "*while a developer will probably mostly care about* *features, a description of governance is important when you need to convince other stakeholders within your organisation to decide for a particular blockchain*" (IE-3). Once you are building on a blockchain infrastructure a dependency exists on its underlying governance. Because you are storing or building value on top of it you should know who has possible influence over it (IE-2). Similarly, IE-6 described that the blockchain infrastructure you chose to build your application on top is a fundamental choice in which governance is an important factor. He made an analogy with companies deciding whether to build an application specifically for Apple, Microsoft or Linux: "*this choice heavily influences factors such as the available programming languages and how deployment is arranged. In the case of a blockchain in an even heavier form*" (IE-6).

The same expert described how he experiences that companies and startups are not paying enough attention to the environment in which they are deploying. Governance, risk and compliance are important factors when choosing to develop on top of a specific blockchain. As an example, he pointed out a startup called Affect.AI who have recently decided to migrate their application from the NEO blockchain to that of EOS. The expert explained that it is better to make an informed decision right at the start of a project: "*when you are already developing on top of a blockchain for two years, switching from blockchain can have quite a lot of impact*" (IE-6).

A different expert explained that as soon as he starts developing on top of a blockchain, he is influenced by what happens with the underlying infrastructure (IE-1). Therefore, he wants to remain up to date with how that blockchain is further developing. He indicated that for him to keep faith in the underlying infrastructure, he needs to perceive that the governance works well (IE-1). IE-7 described that governance is one of the reasons most companies currently do not touch public blockchains, as they are still scared to lose control: "*where people currently have trust in using a Microsoft solution, trust still has to grow for the adoption of decentralised networks*" (IE-7).

One expert noted that the relevancy of blockchain governance is not going away anytime soon: "*I think that governance is going to become a unique selling point.. when I have to decide between platform A or B, then I will pick the one with the better governance*" (IE-4). Finally, two experts mentioned that because of the immutable and unstoppable nature of blockchains, governance is especially important when something goes wrong (IE-3, IE-6). For example, when you deploy a smart contract that includes a mistake, it is crucial to know what possibilities exist to deal with the issue.

7.3.3 Draft framework evaluation

The results of the five qualitative evaluation characteristics are presented according to the communication structure used by Shrestha et al. (2014). These authors highlight that the use of a matrix is a useful way to analyse qualitative evaluation criteria. The opinions gathered during the semi-structured interviews are reported as either positive ☑ for strong evidence of support on one of the evaluation criteria or negative ☒ if there is evidence of a strong negative comment on the evaluation criteria. A summary of the evaluation results of the draft BG framework is presented in Table 7.3.

TABLE 7.3: Summary of the draft BG framework evaluation results

Evaluation characteristic	Case evidence (No. comments)	Prominent comments
Completeness	☑ × 5 ☒ × 7	☑ *IE-6: "I believe it [the framework] is rather complete, there are some details but the question is whether you can fit all of those in this model. . . "* ☒ *IE-5: "Accountability currently misses . . . I would definitely add it [to the framework]. "*
Simplicity	☑ × 6 ☒ × 9	☒ *IE-6: "I would merge these two [conflict resolution and decision making], because conflict resolution is about making a decision."* ☒ *IE-8: "Membership and roles I find duplicates. I do understand you make the distinction but maybe you can combine them in some way."*
Understandability	☑ × 8 ☒ × 7	☑ *IE-2: "I would like to see some examples but the framework itself looks reasonably logical."* ☒ *IE-1: ". . . it [the framework] is not simple enough to be understood by somebody who knows nothing about software development in the domain of blockchain . . . it would only work if somebody explains the difference between off-chain and on-chain."*
Operational feasibility	☑ × 7 ☒ × 1	☑ *IE-3: "When you share this framework I would definitely look back at it in future situations. This is a great starting point for when people ask me questions about governance and to help them think about it."* ☑ *IE-8: "When I deal with blockchain governance [in the future] I would definitely check whether I have not forgotten something."*
Usefulness	☑ × 11 ☒ × 3	☑ *IE-1: "I think it [the framework] is of added value for stakeholders who are looking at the governance of projects. . . many aspects exist to look at and this [the framework] offers a thread on many levels because it asks questions you might not thought about."* ☑ *IE-6: "I do think it really helps people think of things like. . . what are the roles in our community? who has a saying in what? Even if you have already made a choice for a particular blockchain, this [framework] can be very useful."*

☑ indicates the evaluation characteristic was strongly supported in a comment
☒ indicates the evaluation characteristic was strongly opposed in a comment

Completeness and simplicity

In terms of completeness and simplicity, there were slightly more negative than positive comments. Multiple experts noted aspects that they felt were currently missing in the framework. In particular, accountability was reported multiple times to be missing. IE-6 stated that in every governance structure accountability is one of the most important aspects: "*you can easily capture it in your current framework, for example by mentioning it in the roles dimension*". Three experts indicated that they miss a certain value judgement that shows from the framework. For example, IE-4 misses governance values such as the degree of transparency and whether there is a balance of power in a blockchain's governance.

On the other hand, comments were also present which demonstrated appreciation for the completeness of the framework. IE-1 described that from a higher level the framework covers blockchain governance quite well. One expert explained that he thought a lot of governance aspects were included in the framework but that he would need more time to study the framework in order to fully determine the completeness.

Regarding simplicity, there were three reoccurring comments by the experts. First, there seemed to be a wide agreement that the dimension foundation should be incorporated into the roles dimension as a single question: "*instead of a separate dimension I think that foundation is an answer to one of the questions in off-chain community roles*" (IE-8). Secondly, multiple experts expressed that the dimensions conflict resolution and decision making were tightly coupled: *"actually, conflict resolution is just making a decision"* (IE-3), *"these two have a lot in common, decision making and conflict resolution. You can make the distinction but conflict resolution is actually done through decision making"* (IE-2). Thirdly, experts indicated that the dimensions membership and roles seemed to overlap. However, they did understand that the distinction was made: *"you could merge roles and membership but if you have defined membership from the standpoint of accessibility I would not do it because then it certainly is something different"* (IE-6).

Understandability
Overall, the experts understood the main structure of the framework quite well: *"I think it is a nice set-up to place all the dimensions over the three different layers"* (IE-1), *"it is clear to use the structure of a model"* (IE-5), *"your explanation was helpful but I think if I looked at it myself I would also quickly have understood it"* (IE-8). Still, certain parts of the framework were not clear immediately. Two experts were confused by the labels indicating that the columns are the layers and the rows are the dimensions. They noted that they interpreted them the other way around, and recommended to switch them: *"I would change these two axes. I see this more as the layers.. the community layer, the development layer, those visual bars. I see this more as the dimensions.. the roles, the incentives"* (IE-6). Moreover, one expert recommended being more clear about the subject of the on-chain governance layer: *"what is the subject? Is it the transaction over which you place governance or is it about the evolvement of the source code?"* (IE-4). Another expert expressed his doubts about whether the framework would be simple enough for people who do not know a lot about blockchain software development. In order for them to understand it, the expert recommended accompanying the framework with a clear business introduction or even a website with video lectures for each dimension accompanied by examples.

Operational feasibility and usefulness
In terms of operational feasibility and usefulness, there was wide support from the experts. In respect to both characteristics around 80% of the comments were positive.

The experts widely perceived an added value of the framework for stakeholders dealing with blockchain governance: *"personally I have it globally in my head where I should look when the topic is blockchain governance. However, at the same time I think that when you look at a new project, and you have everything textually written down, categorised, that it is really of added value for everyone involved"* (IE-1), "*It definitely gives a grip on the different aspects of governance*" (IE-3), "*the fact that you let them think about the relevant questions is an important step... so I definitely think there is an added value*" (IE-6).

There was one particularly interesting comment about not being able to draw conclusions when using the BG framework: *"I do think that drawing conclusions is left to the interpretation of the person using this framework. Somebody could fill this in for a blockchain... but then the next question is whether the governance is actually good?" (IE-8)* Related to this comment another expert stated: *"when the goal is to help people ask the right questions ... to get a better understanding [of the governance of a blockchain], then this [framework] is quite smart. Attaching values to these questions would be a nice follow-up study"* (IE-6).

The experts indicated to see themselves coming back to the framework when they deal with blockchain governance in the future. They described three situations in which they saw themselves using the framework:

i As a **starting point** for discussion in new blockchain projects. For example, when they have to think about how to set up the governance of a project.

ii As a **testing framework** to analyse the governance of an already set up blockchain. For example, to compare the governance of Bitcoin to that of Ethereum.

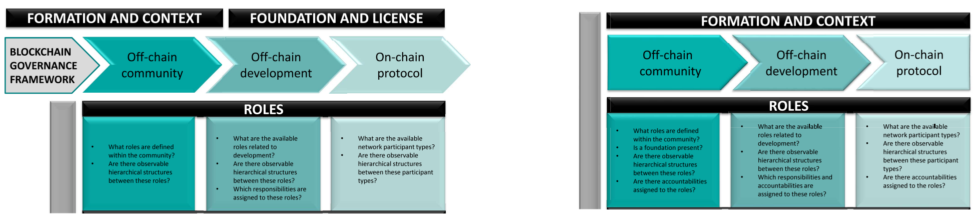
iii As a **checklist** at the end of a situation in which they are dealing with something blockchain governance-related. For example, to check whether an aspect of governance has not been forgotten.

One expert was a bit more sceptical about the usefulness of the framework: *"beginners do not understand everything that is in here [the framework] while experienced people have all the knowledge in their head, so then they won't use it either"* (IE-4).

7.3.4 Adjustments to the draft framework

Considering the feedback of the experts, we make several adjustments to the framework. Tips not directly related to changes of the framework are also kept in mind during the remainder of the study. Adjustments such as fixing a spelling mistake are considered too minor to be mentioned here.

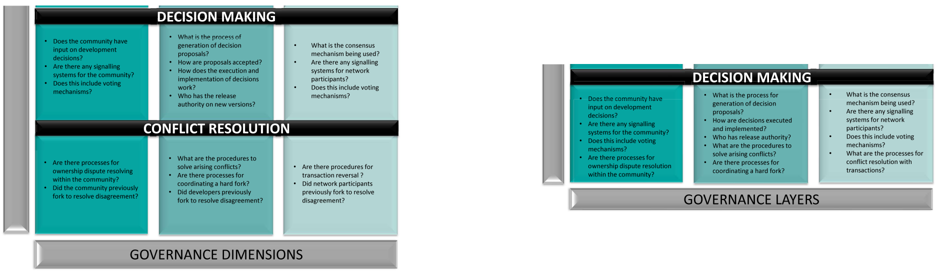
- **Including accountability in the roles dimension.** Based on the feedback from several experts it became clear that accountability should be included in the framework. While *responsibilities* is already present in the roles dimension, *accountability* goes one step further by asking whether someone is to be held accountable for everything that happens as a result of fulfilling their responsibilities. By including accountability the goal is to contribute to the completeness of the framework.
- **Including foundation in off-chain community roles.** In the draft version of the framework, foundation and license were a separate dimension outside the layers of the framework. After feedback from the experts, it became clear that information about a possible foundation should be included as a question in off-chain community roles. Questions about the type of license of the blockchain can be asked during the initial formation and context analysis. The goal of this adjustment is to improve the understandability of the framework.



(A) Before (B) After

FIGURE 7.1: Including of accountability in the roles dimension and foundation in off-chain community roles

- **Combining decision making and conflict resolution.** From the feedback, it became clear that the simplicity of the framework could be improved. Two candidates for a merger that were mentioned most often by the experts were the decision making and conflict resolution dimension. We decided to include conflict resolution as a question in the decision making dimension. The rationale behind this decision is that, as indicated by several experts, conflict resolution essentially is about making a decision. The goal of this adjustment is to improve the simplicity of the framework and possibly also contribute to its understandability.
- **Switch of labels indicating the dimensions and layers.** Based upon feedback from the experts it became clear that two labels in the framework should be switched. At the bottom of the framework was a horizontal label pointing out that the rows represent the dimensions. Similarly, there was a vertical label indicating that the columns represent the layers. The experts misinterpreted these labels and suggested to switch them. The goal of this adjustment is to improve the understandability of the framework.



(A) Before (B) After

FIGURE 7.2: Merging of conflict resolution into decision making and the switch of labels indicating the dimensions/layers

Chapter 8

The Blockchain Governance Framework

The previous chapter described the results of the expert interviews and concluded with several adjustments to the draft blockchain governance (BG) framework. This part of the thesis incorporates these adjustments by introducing an improved version of the framework. Building on the theoretical roots and insights from experts, the BG framework for stakeholders in the blockchain ecosystem comprises 6 governance dimensions (Table 8.1) and 3 governance layers (Table 8.2). The BG framework is illustrated in Figure 8.1. The dimensions make up the rows in the framework while the layers are indicated by the columns. For each combination of a dimension and layer several governance mechanisms are identified. These are the questions a stakeholder needs to ask in order to retrieve insights into the governance of a blockchain.

TABLE 8.1: Six blockchain governance dimensions

Governance dimension	Description	Inspired by
Formation and context	This dimension captures the relevant background information of a blockchain. Examples of aspects to look into include the purpose of a blockchain, its launch style, formative ideology and the type of license used.	(Markus, 2007; Gasser, Budish, & West, 2015; Hsieh, Vergne, & Wang, 2017; Carter, 2017)
Roles	This dimension identifies the different roles present on each of the three layers of governance. Examples of roles on the three different layers include a foundation, developers and miners. Furthermore, the aim is to describe observable hierarchical structures between them. Other aspects to look into include responsibilities assigned to the roles and whether they are held accountable for their actions.	(de Laat, 2007; van Deventer, Brewster, & Everts, 2017; Jensen & Scacchi, 2010; Beck, Müller-Bloch, & Leslie King, 2018; Izquierdo & Cabot, 2015)
Incentives	This dimension captures the motivational factors involved for the roles specified in the roles dimension. This is done by looking at the incentives present on the three layers of governance. Examples of questions include what the intrinsic sources of motivation are for community members, how developers are funded, and why node operators want to participate.	(Lerner & Tirole, 2003; Lattemann & Stieglitz, 2005; Jensen & Scacchi, 2010; Gasser, Budish, & West, 2015; Hsieh, Vergne, & Wang, 2017)
Membership	This dimension focuses on the way participation and membership are managed for the available roles. It captures whether a blockchain is open for anyone to join and participate. Questions asked here include the process to enable new members to join the network and whether new contributors can directly become involved in the development process.	(de Laat, 2007; de Noni, Ganzaroli, & Orsi, 2011; Midha & Bhattacherjee, 2012; Izquierdo & Cabot, 2015; Hsieh, Vergne, & Wang, 2017; van Deventer, Brewster, & Everts, 2017; Ziolkowski, Parangi, Miscione, & Schwabe, 2018)
Communication	This dimension captures the formal and informal ways of communication between the stakeholders of a blockchain. It includes the available communication tools such as coordination systems and tracking systems, but also looks at discussions done in the open, such as meetings and working groups.	(de Laat, 2007; Markus, 2007; Izquierdo & Cabot, 2015; Gasser, Budish, & West, 2015; van Deventer, Brewster, & Everts, 2017)
Decision making	This dimension highlights how decisions are made, monitored and agreed upon on the three layers of governance. Furthermore, it looks at the way in which the decision making processes are set in place. Relevant aspects to look at include available voting mechanisms, release decision processes, the consensus mechanism used and procedures to solve arising conflicts.	(de Laat, 2007; Markus, 2007; Jensen & Scacchi, 2010; de Noni, Ganzaroli, & Orsi, 2011; Izquierdo & Cabot, 2015; Gasser, Budish, & West, 2015; Filippi & Loveluck, 2016; Hsieh, Vergne, & Wang, 2017; Carter, 2017; Ziolkowski, Parangi, Miscione, & Schwabe, 2018; Beck, Müller-Bloch, & Leslie King, 2018; DiRose & Mansouri, 2018)

TABLE 8.2: Three layers of blockchain governance

Governance layer	Description	Inspired by
Off-chain community	As the highest of the three layers, the off-chain community layer encompasses the governance matters taking place in the real world with a focus on the wider community of a project. It highlights how a project is defined more generally and captures the ties of the community to the governance layers below.	Off-chain community level (Carter, 2018), Organisational level (Hsieh, Vergne, & Wang, 2017), Off-chain (Finck, 2019; Reijers et al., 2018)
Off-chain development	The off-chain development layer encompasses the governance matters taking place in the real world with an explicit focus on the software development process. For example, it looks at how roles related to development interact and decisions are made in the maintenance of the protocol.	Off-chain implementational level (Carter, 2018), Individual participants and project teams (Jensen & Scacchi, 2010), Off-chain (Finck, 2019; Reijers et al., 2018)
On-chain protocol	The on-chain protocol layer comprises all the governance matters taking place on the blockchain through its underlying protocol. Examples include the decision making processes, voting mechanisms and rules of interaction encoded directly into the infrastructure of the blockchain.	On-chain (Carter, 2018; Finck, 2019; Reijers et al., 2018), Blockchain and protocol levels (Hsieh, Vergne, & Wang, 2017)

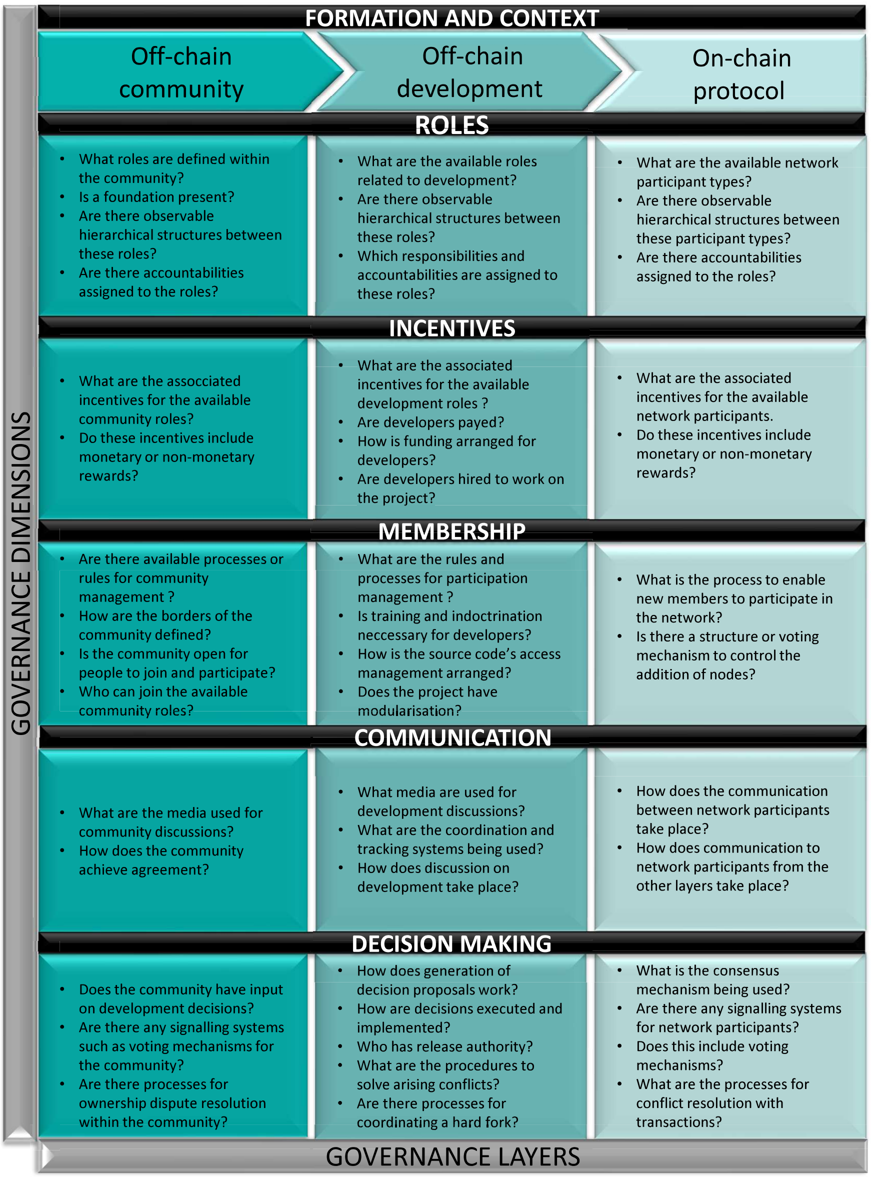


FIGURE 8.1: The blockchain governance framework

Chapter 9

Case studies

The previous chapter described the improved version of the BG framework based on the results of the expert interview evaluation. In this chapter, we present the outcomes of the *ex-post* design product evaluation, following the evaluation strategy as defined in Section 2.4. This second evaluation is structured around the application of the BG framework in a holistic multiple case study. The next sections further define the objectives and followed process.

9.1 Ex-post evaluation objectives

The process of evaluation can be divided into two activities, namely demonstration and evaluation (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). A demonstration is a light version of evaluation that demonstrates the use of the artefact to solve an instance of the problem. The evaluation activity is more formal and evaluates how well the artefact performs. By means of an ex-post evaluation we aim to evaluate the effectiveness of the BG framework. Prat, Comyn-Wattiau, and Akoka (2014) define effectiveness as "*the degree to which the artefact achieves its goal in a real situation*". In our ex-post evaluation the researcher takes the role of a user of the BG framework and therefore it is executed in an artificial setting. However, we apply the artefact to real cases and in a realistic illustrative situation to closely resemble a naturalistic setting. Summarised, the objectives of the ex-post evaluation are twofold: (i) *demonstrating* the application of the BG framework to a problem situation and (ii) *evaluating* the effectiveness of the BG framework when doing so. To support our objectives we introduce a running example in the form of a scenario:

> **Running scenario:** *Bob is the CEO of a successful London based software startup. He and his team have come up with the idea for a new decentralised application (dApp). They believe the dApp will be a success in the long term and are expecting over 100.000 users by the end of 2020. Before starting on development, they now need to decide the blockchain platform which they are going to build the dApp upon. In terms of costs and features, they have selected two blockchains that fulfil their requirements, namely Ethereum and EOS.IO. Because they find it important that the dApp will run steadily for the next few years, they also want to consider the governance of both blockchains in their final decision. Having to migrate the dApp at a later moment in time from one blockchain to the other is something they want to avoid at all costs. However, Bob and his team lack knowledge about how both blockchains are governed. They decide to use the BG framework to understand and compare both blockchains in terms of governance, highlighting their potential strengths and weaknesses.*

9.1.1 Data collection and analysis

The BG framework outlined in Chapter 8 is used as a basis for the relevant questions and criteria for data collection. The data collected is mainly of qualitative nature and from different type of sources. All data is derived from publicly available sources related to the case of interest. Examples of data sources include: *Project documentation published on the projects official web pages*, *blog posts*, *academic papers and reports* but also *social networking posts* and *videos*. For each case, an Excel sheet is kept listing the included data sources. Detailed information will be gathered for each data source such as: the data of publication, the author, the type of source, and why it is considered relevant. An overview of the consulted data sources is provided in Table 9.1.

TABLE 9.1: An overview of the consulted type of data sources for writing the case studies, data collection took place between 2019-05-20 and 2019-06-14

Consulted data sources	Ethereum	EOS.IO
Academic papers and reports	3	2
Blog posts	21	14
Books	2	0
News and magazine articles	10	7
Project documentation	9	7
Social networking posts	7	4
Videos	6	8
Wikis	3	2
Other	7	6
Total	68	50

The collected data is analysed following thematic analysis (Braun & Clarke, 2014). Using a deductive reasoning approach, the themes for data analyses emerge from the blockchain governance framework. The designed artefact is thus used as a thread to conduct and report on the analysis, demonstrating its practical use. Where applicable we aim to provide tables and figures as they provide the reader with a rich presentation of evidence, making the case more reliable (Gustafsson, 2017).

9.2 Case 1: Ethereum

9.2.1 Formation and context

Ethereum is a public permissionless blockchain that went live in 2015. The idea for Ethereum originated with Vitalik Buterin who was inspired by the shortcomings he experienced while doing Bitcoin related development. He believed blockchain applications were not only limited to financial applications and therefore envisioned a fully Turing-complete programming language supporting the launch of smart contracts on a blockchain. The original development team of Ethereum included Vitalik himself, Mihai Aisie, Anthony di Lorio and Charles Hoskinson. Another key figure is Gavin Woods, who published the Ethereum Yellow Paper in 2014 which served as the blueprint for later efforts of implementing the system.

At the start of Ethereum, slightly more than 72 million coins of the native currency Ether (ETH) were pre-mined. The current total supply is about 106 million Ether. The percentage of pre-mined coins therefore represents 67% of the current total supply. Out of the 72 million coins, 60 million coins were part of the crowdsale held by the Ethereum Foundation. This was done via a crowdsale in which investors could exchange bitcoin in change for Ether. The other 12 million coins were put into the Ethereum foundation to support marketing and development efforts.

After the crowdsale, headquarters were founded in Zug, Berlin and London. The initial development process of Ethereum was subdivided into four phases of milestones. The first phase was called Frontier and led to the first minimalistic release version of Ethereum on 30 July 2015. This could be viewed as a beta release which gave developers the ability to learn and experiment with building decentralised applications. For example, it included a command line for uploading and executing smart contracts, sending Ethers and the ability for miners to configure and start their mining operations. The ability of smart contract functionality in Ethereum enabled others to create new tokens on top of the platform. Since its launch, Ethereum hosted many crowd sales, sometimes also referred to as Initial Coin Offerings (ICOs) or token sales. Augur, a decentralised prediction market platform, was the first ICO launched on Ethereum.

9.2.2 Roles

Off-chain community roles

At the off-chain community level, a multitude of roles could be identified at several levels of granularity. To our understanding, the most significant community roles can be grouped into the following categories: investors and token-holders, the Ethereum Foundation, industry organisations, fellowships, community figureheads and online moderators.

- **Token-holders:** The most obvious role in the Ethereum community is probably that of being a token-holder. Once an individual has bought some Ether he/she could now be considered to be part of the Ethereum community. Token-holders do not hold any responsibilities, they can decide to buy more or sell their Ethers at any moment in time.
- **The Ethereum Foundation (EF):** The EF is a Swiss non-profit organisation established in Switzerland in June 2014. Their initial role was to help start up the network of Ethereum and to coordinate the crowdsale. From the pre-mined coins, 12 million were given to the EF to support marketing and development efforts. From the start of the project until early 2015 most of the client and development tools were developed by the EF. The EF also holds the trademark over the Ethereum brand. Other activities include them running the yearly developer conference (DevCon), investing in research and ecosystem support, for example via the EF Grant program. Furthermore, the EF maintains a majority of the major Ethereum software clients. According to their executive director, the role of the EF is currently shifting. Where the people of the EF used to be heavily involved in building Ethereum, the EF is moving towards a more communicative role for the public, informing them about the development and progress of the Ethereum platform.
- **Industry organisations:** Another important group of stakeholders within the Ethereum community are the major industry organisations associated. Two examples of organisations who have been driving institutional engagement with Ethereum include the Ethereum Enterprise Alliance (EEA) and ConsenSys. The EEA, launched in February 2017, describe themselves as a member-led industry organization with the objective to drive the use of Ethereum as

an open-standard to improve all enterprises. In simple terms, they are an organization compromising many companies of different shapes and sizes, such as startups, academic institutions, enterprises, and technology vendors. They host events, publish material such as webinars, newsletters and technical specifications for an enterprise version of Ethereum. ConsenSys is one of the founding members of EEA, who have also made a large contribution to the development of Ethereum. They were founded a year after the initial idea of starting Ethereum and have contributed to building an infrastructure that is critical for the Ethereum ecosystem.

- **Fellowships:** Another prominent stakeholder group within the Ethereum community are fellowships. These are groups of individuals who organise themselves in a semi-formal way among a shared interest. Examples include the Ethereum Cat Herders (ECH), the Fellowship of Ethereum Magicians and the Department of Decentralisation. The ECH describe themselves as a group of independent contributors serving the Ethereum community. They support Ethereum core developer teams by coordinating hard forks, monitoring EIPs, creating project management processes, creating retroactive reports, taking notes during Core Developer Calls and more. Where the CH specifically focuses on improving governance and project management processe, the FEM has a more technical focus aiming to norture community consensus on the technical direction and specification of Ethereum. The DoD is a group of individuals that aim to support the Ethereum Open-source community by raising awareness on the benefits and challenges of decentralisation and open source software. They do this by organising events, connecting people from the community with jobs and so forth.
- **Community figureheads:** An informal role that includes members in the community with larger influence than other individuals based on their recognition, status or social media following base. A few examples include Vitalik Buterin (founder of Ethereum), Hudson Jameson (developer, member of the EF and editor for the ECH), Gavin Wood (co-founder of Ethereum) and Vlad Zamfir (researcher in the EF).
- **Online moderators:** A formal role giving a limited group of individuals within the community extra responsibilities and powers on their respective forums, chat systems or websites. For example, the official Reddit of Ethereum currently has 9 moderators with full permissions. They are responsible for checking whether new posts are in line with the defined rules and guidelines of the community.

Off-chain development roles

Considering the roles on the off-chain development layer we can start by making a distinction between two types of Ethereum developers. The first type being the Ethereum Infrastructure Developers. These are the developers that are working on improving the Ethereum infrastructure. The second type of Ethereum developer includes Ethereum Software Developers who are building software and dApps on top of the Ethereum infrastructure. The first type of developers is of interest here.

It is important to note that Ethereum Infrastructure Development is spread among more than 200 different repositories, each dedicated to different aspects of the infrastructure such as the Ethereum clients, the devp2p peer communications protocol, and the Ethereum Virtual Machine (EVM). Each repository has its own way of working which also translates into different development roles with unique responsibilities. Furthermore, there is a repository dedicated to Ethereum Improvement Proposals (EIPs), which are used to propose, define and agree on standards. Standards describe specifications which can be implemented by clients. Anyone can create open or closed source code implementing such a specification without being tied to a particular repository or language. When multiple clients correctly implement a specification they are interoperable. Overall we identify three main roles closely related to development.

- **Contributors:** A contributor can essentially be anyone who decides to contribute towards one of the repositories related to Ethereum. This is somebody who comments on existing issues or pull requests, creates new issues or pull requests, writes codes or organizes events.
- **Maintainers:** The maintainers make up the Core Developers of Ethereum, they have commit rights (writing access) to the code repository and have additional rights to manage the issue backlog of their own repository. The maintainers play an important role in conducting a critical examination of new proposals. For example, they have to judge whether they are technically sound in terms of implementation details and implications. In a sense, they are stewards of the project because they collectively have a veto over new technical proposals. They merge pull requests into the main branch of code. Following a report of the development activity in Ethereum, there are on average 216 active core developers contributing to the Ethereum repositories per month. Within certain repositories, maintainers can be assigned as a reviewer to new pull requests, making them responsible for reviewing the difference between the old and new code. Maintainers can be given commit rights to a repository by the owners, who have the ability to add members, add or delete repositories, and change member status.
- **Editors:** Finally, with regards to EIPs there is a formal group of editors. The responsibilities of these EIP editors are for example reading the EIPs to check whether they are ready in terms of soundness and completeness, making an initial judgement on whether a proposal technically makes sense, checking whether the title accurately describes the content of the proposal and whether the code style, language and markup match the requirements of an EIP. Summarised, they are responsible for the administrative and editorial part of new proposals. Currently, there are eight EIP editors.

On-chain protocol roles

The nodes in Ethereum are also known as clients. The clients are the devices or computer programs that communicate with the Ethereum network. The leading software clients of Ethereum are go-ethereum and Parity. In Ethereum there have been multiple client implementations since the beginning of the project. These vary over different types of operating systems and are written in different languages (e.g. Go, Rust, C++ and Python). Usually, a client also offers wallet functionality, enabling its user to perform transactions on the Ethereum blockchain.

In general, a distinction can be made between three different network participant types. These include full nodes, lightweight nodes, and miners.

- **Full nodes:** Full nodes are Ethereum clients connected to the peer to peer network verifying new blocks broadcasted to the network. For each new block, they check whether the block and its included transactions follow the rules defined in the Ethereum specifications. They store a complete version of the Ethereum blockchain on disk and validate that added blocks are correct. Furthermore, they communicate data to other nodes in the network.

- **Miners:** Miners are nodes that participate in the consensus mechanism to propose new blocks. Apart from usually running a full node, they are connected to a specific software which enables them to invest energy into finding the solution to a cryptographic problem in order to be the one to propose the next block.
  - **Mining pools:** The computational power needed to compete in mining has increased over the years. To increase the chance of successfully mining a block, miners often pool their resources together in so-called mining pools. Miners can commit their hash power to such organised pools to assure a more stable income of frequent payouts from block rewards which is often based on their share of input.
- **Lightweight nodes:** Lightweight nodes do not store a complete version of the Ethereum blockchain. Furthermore, they also do not verify every block or transaction that is broadcasted to the network. Instead, they only verify information from the blockchain that they need for their own activities. Lightweight nodes are dependent on full nodes for extended details. Because of their limited capabilities, they synchronise quicker with the network and are able to run on lightweight devices such as smartphones, for example, because it requires less storage on the device. Lightweight nodes use full nodes as intermediaries. For example, they could rely on full nodes for requesting the balance of an account or for retrieving the latest block headers.

9.2.3 Incentives

Off-chain community incentives
On the off-chain community layer, we identified five categories of stakeholders. For each of these stakeholder groups, incentives slightly differ. Most of the stakeholders on the off-chain community level are incentivised by speculating on Ethereum to become more successful in the future. If this is the case, their token-holdings are likely to increase in value. Although the community figureheads are indicated as a separate group of stakeholders, they probably have similar incentives as token-holders. Usually, community figureheads are people who have put much effort into Ethereum to succeed, for example by programming, marketing or community management efforts. They believe in the project and usually hold a significant number of Ether as well. By contributing to the project, they aim to increase the value of Ethereum.

Industry organisations are incentivised by Ethereum to grow in features and user adoption. They want to improve their current business processes using the benefits of blockchain technology, in this case using Ethereum. The EEA aims to accelerate the use of Ethereum as an open-standard to improve all enterprises. They are funded by license fees from the organisations that join the alliance. The industry organisation ConsenSys is largely funded by the personal fortune of owner Joseph Lubin, who is reportedly one of the top ETH holders in the ecosystem. The EF wants to do supporting and coordination work for Ethereum for it to succeed in the long term. Their value is directly depending on the value of Ethereum because a large portion of their fundings are in Ether. This aligns their incentives with the incentives of the Ethereum protocol and of the ecosystem. Lastly, fellowships such as the ECH are also supporting the Ethereum ecosystem because they want it to succeed. The ECH is incentivised by improving the governance processes within Ethereum because they believe this will increase the sustainability of Ethereum moving forward. The ECH operates on the contributions of volunteers and collects funds via donations and grants.

Off-chain development incentives
Similar to the off-chain community incentives, developers are also incentivised by a potential future value increase of their holdings in Ether. However, in contrast to some of the more passive users in the off-chain community, they are actively contributing to development in order to improve the Ethereum protocol and achieve an increase in value. A few intrinsic motivations for developers include social recognition from other peers in the Ethereum ecosystem, a sense of power to make decisions and the ability to have a certain level of control over the direction of the network. Lane Rettig, one of the core developers of Ethereum stated in 2018 that being a core developer requires a good deal of intrinsic motivation: *"If solving complex, fundamental problems, writing good, maintainable code, and building a platform that millions of people may someday use sounds like your idea of fun, that's a good start."*

For a large part, Ethereum developers contribute on a voluntary basis, this especially accounts for the contributors as described in Section 9.2.2. However, the EF plays an important role in the funding of development. For example, maintainers and editors get paid via the EF and other individual organisations sponsoring their projects. In 2019, the EF announced to allocate 30 million dollars over the next year to fund the ongoing development of the Ethereum platform. However, funding of development has also been one of the reoccurring challenges within the Ethereum community. Core developers have indicated multiple times that they are not paid enough or do not have the funds to leave their day jobs in order to fully concentrate on the Ethereum project. New initiatives such as Gitcoin have emerged to address these issues. Gitcoin is a distributed software development platform that enables contributors in open source software to receive payment for their efforts.

On-chain protocol incentives
Miners in Ethereum have similar incentives to those in Bitcoin, as described in Section 3.4.1. They have a monetary incentive in the form of block rewards and transactions fees. When a miner is the first to successfully broadcast a new block of validated transactions to the network, it will receive a 3 ETH block reward along with the transaction fees part of the newly found block. The expected revenue of a miner is equivalent to the proportion of its own computing power to the total computing power of the entire network.

Except for mining, there is no built-in incentive to run a full node. This makes the incentive to run a full or lightweight node different. An incentive for these type of network participants includes the intrinsic motivation to contribute towards securing the Ethereum network or just to interact with the blockchain. Furthermore, businesses and individuals decide to operate a full node because they need it for their activities (e.g. block explorers and exchanges). Another incentive for individuals to run a full node is that it is a secure way to interact with the blockchain. It enables them to validate blocks themselves instead of relying on a third party. An incentive to run lightweight nodes is the ability to interact with the blockchain on smaller devices such as smartphones and embedded machines.

9.2.4 Membership

Off-chain community membership
Overall the Ethereum community is very open to new participants. Anyone can join the ecosystem by buying some Ether, taking part in community discussions, transferring Ether, attending meetups or trying out dApps. Most of the online forums where community discussions take place such as Reddit only require a simple registration before one can participate in conversations. Given the multitude of different stakeholders in the Ethereum community, its boundaries are relatively wide. If a company wants to become a member of the EEA it has to go through an application process. This involves signing a membership agreement and paying an annual license fee based on the number of employees your company has. After a company has joined the EEA its employees are able to log in on the website of EEA and to access all kinds of resources such as webinars, F2F events and industry working group.

No formal processes seem to exist to become part of the EF. Individuals that wish to join the EF can apply by contacting current members through different channels, for example by submitting their cv via a twitter thread. It is also expected that new members get asked to work full time for the EF based on their activity, recognition and efforts within the community. Similarly, becoming a community figurehead is solely based on your achievements and following base within the community.

Off-chain development membership
There is no formal application process in place to become a contributor of Ethereum. As Ethereum is fully open-source, anybody can directly start by contributing to the development of Ethereum. To become a contributor, it is useful to have mastered a couple of general aspects of software engineering such as comprehensive design, testing and documentation. First, one would need to find a project to contribute to one of Ethereum's repositories. Examples include geth, ethreumjs or sharding. To contribute code, somebody can go to one of the repositories of Ethereum and then (i) fork, (ii) fix, (iii) commit and finally (iv) send a pull request (PR) to the maintainers for review. To do this you need a GitHub account. The same goes for the EIP repository where everyone can submit new proposals.

To our understanding, there are no formal processes in place to receive additional commit rights on GitHub and to become a maintainer. It is likely that active contributors are either approached by a project team to become a maintainer or that they request this themselves. Maintainers should have demonstrated enough competency to take this role based on their previous contributions. This is not a formal process but highly visible due to the nature of Open-source software. Similarly, no information is available on how to become an EIP editor. These seem to be respected developers in the community who have been approached after multiple years of contribution efforts. As previously mentioned the development of Ethereum is spread among more than 200 different repositories. Every repository or project has slightly different guidelines and rules for development.

On-chain protocol membership
Ethereum is a public permissionless blockchain. As described in Chapter 3.5, this means that reading, submission and processing of transactions is open to anyone. Anybody in Ethereum is allowed to run a full node. To do so, one should have at least a consumer-grade laptop. This means that most people are able to participate in the validation process of new transactions and blocks. Two common clients that

can be used to run a node include Geth and Parity. The same openness counts for people that want to do mining. However, in order for new miners to have a realistic chance in succeeding to find a new block, a significant amount of money needs to be invested into mining hardware, forming a certain barrier for entry. To our understanding, no mechanisms are in place to control the addition of extra nodes.

9.2.5 Communication

Off-chain community communication
Most of the communication between the community of Ethereum take place online. The official Ethereum Community Forum and the Ether Forum are examples of forums where discussions are held daily. Another example includes Reddit, a place with online conversations, general information and a starting guide for newcomers. The official Reddit of Ethereum has over 400k subscribers at present. Furthermore, many discussions takes place on dedicated Slack, Discord and Gitter channels. These are team-oriented chat platforms that also enable file sharing. Real-time discussions sometimes also take place on Twitter, where community figureheads such as Vitalik Buterin or the official twitter account of Ethereum share new information or thoughts. Furthermore, information is exchanged via local meetups, podcasts and events. An example of a large event is the Ethereum Community Conference. Two editions of this event have been held with the aim to bring together all kinds of stakeholders from the Ethereum Community in workshops and talks.

Off-chain development communication
We identified five channels through which developers communicate within Ethereum. This list is not exhaustive but is expected to include the ways of communication which are most used. They include discussion threads on Github, calls, online forums, chat platforms and real-life meetings. Most of the discussions related to development occurs out in the open on Github. For example, all EIPs including their status and discussion threads are visible to everyone on the Ethereum repositories. Besides Github, another significant channel includes the Core Developer Calls. These are virtual calls that according to its moderator Hudson Jameson feel like you are in person talking to the other people. The All Core Developers Call is scheduled every two weeks and represents most of the people working on the low-level protocol or infrastructure of Ethereum. Furthermore, every client is represented on the Core Developer Call. During these calls, new proposals are brought up and the core developers coordinate whether they are going to approve and implement the proposal. All meetings are audio recorded and these recordings including notes are openly published on a dedicated project management repository on Github by the moderator of the calls. Other calls dedicated to specific projects exist too, examples are the Ethereum Implementators 2.0 call, the EWASM Community Call and the Plasma Implementers Call.

The communication channels of developers have overlap with those of the wider community. Development challenges and new proposals are also discussed in online forums such as the FEM forum and Reddit. Furthermore, development teams often use dedicated Slack, Gitter or Discord channels for communication. Finally, it is important to note that developers also meet in person. For example, the EF has organised four editions of the Ethereum Developer's Conference (DevCon). This is an annual event dedicated to bringing together developers and representatives of all projects within the Ethereum ecosystem. Examples of more informal meetings also exist. For example, in 2018 a group of stakeholders met up in Toronto to talk

FIGURE 9.1: Informal off-chain development communication in action at EthCC in Paris 2018 (Rettig, 2018)

about governance issues within Ethereum and to sign a document stating their intentions to improve the situation. This meeting led to noise within the community as Vitalik Buterin later expressed on Twitter that the meeting was organised without his awareness or permission and that he did not know what was discussed. An example of an informal meeting of developers is illustrated in Figure 9.1, illustrating a developer discussion in action during the Ethereum Community Conference 2018.

On-chain protocol communication
Ethereum uses a universal data diffusion model. This means that data is shared between all nodes in the network. The nodes in Ethereum communicate via a peer-to-peer communication network. This enables them to communicate without going through a central entity. Every node can request data from other nodes in the network such as the balance of an account or the latest verified block. To be more specific Ethereum uses JSON RPC middleware to retrieve data from and send data out of nodes. For data transfer, the RLPx Node Discovery Protocol is used, which is based on a protocol called Kademlia DHT. Lightweight nodes need a connection to a full node before they can receive information about the blockchain.

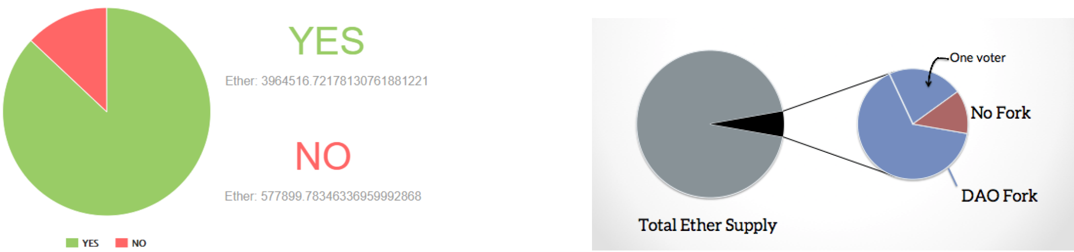
9.2.6 Decision making

Off-chain community decision making
Because of the Open-source nature of Ethereum, developers can fork the project at any time. The community of Ethereum can support a fork and enable the developers to start such a version with a new community. This forking mechanism was previously described in Section 4.3.3. Furthermore, token-holders in the community can always sell their Ether to voice their exit. Another way is to stop using a client that implemented a certain change into the protocol. The influence of community figureheads on decision making should also not be underestimated. In the past, it has been noted that the founder of Ethereum (Vitalik Buterin) still has a strong influence on decision making. Due to his experience with the technology and status

within the community, many people follow his recommendations and he has often been referred to as the 'benevolent dictator' of Ethereum.

There are a few formalised ways in which the community of Ethereum can influence development decisions. Within the Ethereum community, these are known as signalling systems. They enable the community to signal their opinion about contentious decisions. Two of the signalling systems available today include Carbon Votes and Twitter Polls.

- **Carbon Votes:** During a Carbon Vote, two Ethereum addresses are created. One being 'YES' in favour of a standpoint and one being 'NO' representing the opposite opinion. Token-holders of Ethereum can cast their vote by sending 0 ETH to one of the two addresses. The cost of a vote is the minimal transaction fee of 0.0006 ETH. The weight of their vote is based on the number of Ether they hold. Where the transaction itself serves as the message of the vote, the ETH under the account of the sender is counted as ballots. It is important to note that this is only a coordination tool, decisions are not automatically enforced based on the results of the Carbon Vote. Like an advisory referendum in politics. While the votes are cast over the blockchain, it is not a built-in feature of the protocol. An example of a Carbon Vote was the one held during the governance crisis of the DAO. One group of developers wanted to rewrite the history of the blockchain but not all developers agreed. A Carbon Vote was held to measure the opinion of token-holders, the results are illustrated in Figure 9.2a. There have been many critics pointing out the disadvantages of a Carbon Vote. Examples include (i) low voter participation, (ii) non-distributed wealth of Ether, (iii) low legitimacy (Figure 9.2) and (iv) the danger of bribing.



(A) Results of the DAO Carbon Vote (CarbonVote, 2019)

(B) A Disadvantage of Carbon Votes pointed out by a critic, adopted from (Buterin, 2017)

FIGURE 9.2: Illustrations of the DAO Carbon Vote

- **Twitter Polls:** Organised by different people within the community, they represent another way in which stakeholders can voice their opinion. Like Carbon Votes, they also suffer from several weaknesses including low voter participation and low legitimacy. An example of a Twitter Poll is illustrated in Figure 9.3. This was a poll organised by the Ethereum Cat Herders to gauge consensus from the community about their stance on ProgPow, a proposal aimed at reducing the efficiencies of specialised mining hardware.

The lack of representative and relevant signalling systems has been recognised as a problem within the Ethereum community. Community figureheads like Vitalik Buterin have suggested introducing more signalling systems that can then be aggregated together for input. This is also an active area of research for the ECH. With

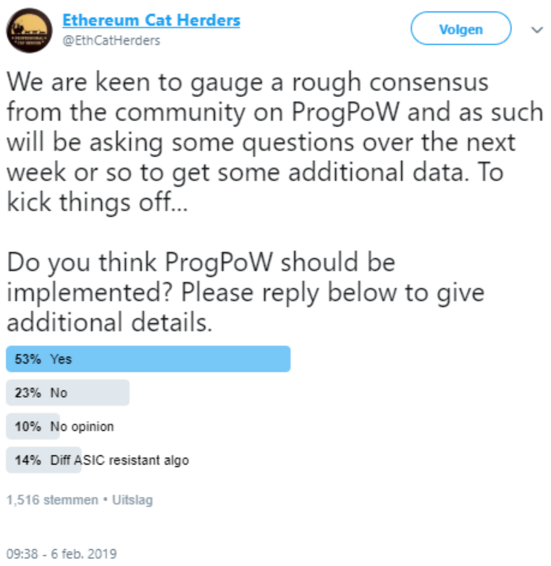


FIGURE 9.3: Example of a Twitter Poll within the Ethereum Community (Twitter, 2019)

regards to conflict resolution, the ECH play a coordinative role around protocol updates. During the latest network upgrade, the ECH contacted major stakeholders such as mining pools and exchanges to make sure they were prepared for the upgrade. Furthermore, they follow a hard fork checklist and create retroactive reports. More processes and roadmaps are currently being developed by the ECH to support network upgrades.

Off-chain development decision making

There are two formal mechanisms through which the developers of Ethereum make decisions: (i) Etherereum Improvement Proposals (EIPs) and (ii) Core Developer Calls.

i **EIPs:** These are used to propose, define and agree on standards for Ethereum. The rules and procedures of the EIP process are described in EIP-1, serving as a sort of constitution. The process of a new EIP starts with an individual filling out a predefined template. The template includes mandatory information such as a preamble, simple summary, motivation, rationale, specification and test cases. When every part of the template has been filled out, the individual can submit a pull request. From that moment onwards, the pull request must be 'pulled' through several phases, indicated by a status attached to the pull request:

- **Work in progress (WIP):** These are draft EIPs that have just been submitted. One of the EIP editors will check whether the proposal includes all relevant information and is correctly formatted according to the template. Furthermore, the EIP editor will check if the proposal is technically sound, in line with the Ethereum philosophy and not a duplication of effort. If the proposal passes these checks the EIP editor will assign a number to the EIP and it is moved to the next status.
- **Draft:** During this phase, new pull requests can be submitted to improve the draft. They are open for consideration and undergoing rapid iteration

and changes. When no further changes are expected the EIP editor will assign the Last Call status and set a review end date.

- **Last call:** In this phase, the EIP is reviewed by a wider audience. Substantial technical complaints will result in the EIP to be reverted to draft. The author of the EIP can then address these technical complaints. When a successful last call is made, the EIP is moved towards Accepted.
- **Accepted:** EIPs in this status are dependent on the decision making of the Ethereum core developers. They must decide whether they want to implement the changes in their clients. This decision making process is not part of the EIPs and occurs mainly through the Core Developer Calls. If the core developers and the community adopt the implementation, the status of the EIP is changed to Final.
- **Final:** These include EIPs that have already been released in an update or are planned to be released in a future update.

ii **Core Developer Calls:** Previously highlighted in the section about off-chain development communication, the Core Developer Calls are virtual calls scheduled every two weeks. They represent most of the people working on the low-level protocol or infrastructure of Ethereum. Furthermore, every client is represented in the Core Developer Calls. During these calls, EIPs are brought up and discussed. The Core Developers use the call to coordinate whether new EIPs are going to be approved and implemented in future updates. During this informal coordination process, the opinion of the community is also tried to be weight in. However, according to reports in the community, this informal process also has some drawbacks. In some cases, controversial EIPs turn out into highly political debates distracting away from technical decision making. This can put a lot of pressure on the Core Developers who do not want to be involved in such political debates. This is where unresolved conflicts about major updates can result in the Ethereum project to fork into two separate projects, as previously seen in the case of Ethereum and Ethereum Classic.

On-chain protocol decision making

Before protocol updates implemented by developers have an effect, nodes and miners must first decide to run the new software. Also, an on-chain voting mechanism exists for miners to vote on the gas limit per block. This determines the maximum number of transactions that can be included in one block. The network capacity is dynamically adjusted based on the results of the voting. Like the Carbon Votes and Twitter Polls, miners are also able to signal their preference in the case of contentious development updates. When miners broadcast a new block, there is an extra data field in the block where they can put whatever information they want. This data field can be used to signal their opinion on future protocol updates. For example, during the DAO crisis, 65% of miners voted against rewriting the history of the blockchain.

PoW is used to achieve consensus about the state of the blockchain at the on-chain protocol layer. The PoW consensus mechanism has been described in more detail in Section 3.4.1. When forks occur during the execution of the consensus mechanism, the longest valid chain rule is applied. This rule indicates that the valid chain to continue mining on is chosen based on the highest number of cumulative PoW. Related to PoW, mining pools have sometimes been criticised because of introducing centralisation at the on-chain protocol layer. For Ethereum, it has been reported that the top 3 mining pools account for more than 50% of the total hashrate.

9.2.7 Summary

TABLE 9.2: Summary of Ethereum's Governance

Off-chain community	**Off-chain development**	**On-chain protocol**
Roles		
• Token-holders • Ethereum Foundation • Industry organisations • Fellowships • Community figureheads • Online moderators	• Contributors • Maintainers • EIP editors	• Miners • Full nodes • Lightweight nodes
Incentives		
Most of the community is incentivised by speculating on the increase of value of Ether, the EF received 12 million Ether from the ICO, industry organisations are seeking the benefits of Ethereum's applications in the long term, support from the community towards development by fellowships.	Developers are incentivised by a potential value increase of Ether from their contributions, contributors usually work on a voluntary basis for fun and social recognition, maintainers are paid through and sometimes hired by the EF.	Miners have a monetary incentive in block rewards (3ETH) including transaction fees. Full nodes can be necessary to run for a business' activities. Other incentives to run full nodes include network support and security reasons. Lightweight nodes are ran to interact with the blockchain on light devices.
Membership		
Overall a very open community. Anybody can become a token-holder. Joining industry organisation groups such as the EEA requires an application process and license fee. No clear process exists to become a community figurehead or online moderator, this requires recognised contributions and trust from other community members.	Anybody can start contributing to the development of Ethereum. No formal processes are in place to become a maintainer. It is likely an informal process through recognition for contributor efforts. The same reasoning applies for becoming an EIP editor.	Anybody is allowed to run a mining node, a full node or lightweight node. Running a full node requires a consumer-grade laptop. However, becoming a miner who actively proposes new blocks has a high barrier of entry due to the expensive set up costs of hardware.
Communication		
Communication takes place via Reddit, Twitter, Slack, Discord, Gitter, The Ethereum Community Forum, the Ether Forum, local meetups, podcasts and events (e.g. the Ethereum Community Conference). Large width of channels.	Developers mostly communicate via the comment system in Github and scheduled developer calls. Core developer calls are recorded, summarised in notes and publicly available. Informal communication occurs during meetups and events.	Nodes communicate using a universal data difussion model. Data is shared between all nodes in the network. Lightweight nodes need a connection to a full node to retrieve information about the blockchain.
Decision making		
Signalling systems for the community exist in the form of **Carbon votes** and **twitter polls**. Furthermore, they can voice their opinion through posting in the communication channels, selling their Ether and supporting potential hard forks of developers.	The two formal mechanisms through which developers in Ethereum make decisions are the **EIP process** on Github and **core developer calls** every other week. Community signalling systems serve as input during the calls.	The consensus mechanism in Ethereum is **Proof-of-Work**. Miners can signal their preference on contentious development decisions using an optional data field in blocks. Network capacity can be automatically adjusted by a miner gas vote.

9.3 Case 2: EOS.IO

9.3.1 Formation and context

EOS.IO is a public permissioned blockchain that went live in January 2018. Similar to Ethereum, it operates as a smart contract platform and decentralised operating system that enables the deployment of dApps by other developers. However, the EOS.IO platform was designed with the aim to address some of the scalability and governance issues experienced by Ethereum. The realised EOS.IO blockchain is based on a White Paper published in 2017 by Daniel Larimer. He is a software programmer and blockchain entrepreneur who prior to the creation of EOS.IO founded BitShares (a decentralised exchange) and co-founded Steem (a decentralized social media platform). Currently, he is the CTO of the software startup block.one. This startup, registered in the Cayman Islands, was responsible for the initial development of EOS.IO. They released it as Open-source Software in June 2018.

To fund the development of EOS.IO, block.one held a year-long ICO without a maximum limit of raised funding. When the ICO of EOS.IO ended, block.one had raised over 4 billion dollars worth of Ether. To date, this is the highest funded crowdfunding project of all time. One billion tokens of the platform's native currency EOS were minted and distributed during the ICO to promote initial engagement and activity. Ninety per cent of the one billion tokens were sold for Ether during the ICO. The other ten per cent were held by block.one to fund the development of the platform.

9.3.2 Roles

Off-chain community roles
At the off-chain community level of EOS.IO, we have identified five main categories of community roles. These include token-holders, the EOS Alliance, Block Producer teams, block.one and online moderators. These roles all have their own extend of influence within the community.

- **Token-holders:** Like Ethereum, the largest part of the EOS.IO community consists of token-holders. However, in contrast to Ethereum, token-holders in the EOS.IO community have two responsibilities, namely that they are entitled to participate in the selection process of block producers and the setting of policy in via the EOS Referendum system. Block producers eventually get to mine new blocks as described later in Section 9.3.6. Token-holders are expected to stake their EOS tokens to vote for one or up to thirty candidate block producers. The EOS referendum system is also explained in more detail in Section 9.3.6.
- **EOS Alliance:** This is a group of individuals that want to give EOS.IO community stakeholders a voice in the direction of the development of the EOS.IO protocol. According to their mission they "*Serve the EOS community by facilitating communication and providing the focal point that the decentralized community needs in order to self-organize, reach decisions, and carry them out*". They are currently led by an interim board which is said to be replaced in September 2019 following new elections by token-holders. Responsibilities include driving awareness and adoption of EOS.IO, communication and representation of the EOS.IO community.

- **Block Producer Teams:** Usually, a full team is involved to operate a Block Producer as a network participant type at the on-chain protocol level. These can be viewed as full nodes being a candidate for participation in the mining process of EOS. Besides their on-chain task of safely, securely and reliably producing blocks, they also have an off-chain community task of bringing value to the community and earning their votes. They grow small communities within their local area and campaign to get elected. They support the community by onboarding new users, facilitating discussions and education. The Block Producer Teams operate similar to an independent company that is hired to provide infrastructure.
- **Block.one:** As introduced earlier, block.one was responsible for the initial development of EOS.IO before it was released as an Open-source software project. The core team of block.one consists of Dan Larimer (CTO), Thomas Cox (VP of Product) and Brendan Blumer (CEO). Given their significant effort in the founding and development of EOS.IO the block.one company is also viewed as an important stakeholder within the wider EOS.IO community.
- **Online moderators:** Identical to the community role present in Ethereum, moderators in the EOS.IO community have extra responsibilities and permission rights on the websites, chat systems and forums that are used.
- **Voter proxies:** If token-holders do not have the time or knowledge to research which block producers to vote for, they can also use the option to delegate their vote towards a voter proxy. Voter proxies thus have the responsibility to vote on behalf of the token-voters that delegated their vote to them. An example of a proxy is EOS Watchdogs who also share information about the quality and activities of block producers for others to make a better-informed decision.

Off-chain development roles
Like Ethereum, a first distinction is made between EOS.IO Infrastructure Developers who are working on the EOS.IO Mainnet and Ethereum Software Developers who are building dApps that run on top of the EOS.IO Mainnet. The development of the EOS.IO Mainnet is of interest here. The development of EOS.IO is spread among 89 repositories on Github to support the separation of concerns and achieve more maintainable code. Most of these repositories can be viewed as independent projects that for example focus on tooling for developers, privacy-focused side chains or decentralised exchanges. Again we make a distinction between contributors and maintainers. However, unlike Ethereum, no detailed improvement proposal process exists and the majority of protocol-level work is done by developers of block.one.

- **Contributors:** A contributor can be any individual on Github who decides to contribute towards one of the repositories of EOS.IO. This is somebody who reports issues (bugs, change requests or feature requests) or directly contributes code by submitting pull requests, fixing bugs and getting involved in testing activities.
- **Maintainers:** The maintainers can be viewed as the Core Developers of EOS.IO. As already mentioned, the majority, if not all, Core Developers of EOS.IO are part of the block.one team. They own the extra rights to manage the issue backlog of the repositories and the ability to merge pull requests into the main branch of the code. Following a report of the development activity in EOS.IO, there are on average 30 active developers contributing code to the EOS.IO

repositories per month. To our understanding, the block.one team has full ownership of the main EOS.IO repository.

On-chain protocol roles
Two main network participant types are identified on the on-chain protocol layer to run the EOS.IO Network.

- **Block producers (BPs):** These are full-nodes that are allowed to actively participate in the verification and producing of new blocks. There are exactly 21 BPs who have retrieved the most votes from token-holders. The BPs have many responsibilities such as: block creation and confirmation, file hosting, community support and engagement, financial support for EOS dApps, account freezing, acting on misbehaving contracts, staying up to date with development updates, and maintaining a block time of 0.5 seconds. Together, the 21 BPs make up the EOS.IO Core Network infrastructure.
- **Non-producing nodes:** These are full-nodes that are only watching and verifying new blocks for themselves. They also maintain a full history copy of the blockchain. To become a block producer they first need to become part of the standby pool of non-producing nodes. Nodes in the standby pool have indicated the desire to become a BP, furthermore, they have demonstrated to be capable of handling the responsibilities of a BP. If they receive enough votes from token-holders, they automatically become an active BP. Together, the non-producing nodes make up the EOS.IO Access Network. With regards to non-producing nodes, a further distinction can be made between API nodes and Seed nodes. This distinction is based on the primary role which the non-producing node takes.
  - **API Node:** These nodes are responsible for the pre-processing of faulty transactions. They filter out the first batch of transactions and relay the good transactions to one or multiple active BPs.
  - **Seed Node:** These nodes communicate with all the other nodes to maintain synchronisation of the network. Their main task is to serve other nodes and to maintain synchronisation with active BPs. By doing so they want to demonstrate their ability to also become a BP, waiting to get voted in by the token-holders.

9.3.3 Incentives

Off-chain community incentives
On the off-chain community layer, we identified six categories of stakeholders. Differences in incentives exist per stakeholder group. Like token-holders in the Ethereum community, the token-holders in the EOS.IO community also are incentivised by speculating on a positive return on capital investment. They hope to achieve a consistent return on investment by leasing their resources (EOS tokens) in the network to profitable dApps. The EOS Alliance is independently funded by early token-holders of EOS. It is not exactly clear who these early token-holders are but it is expected that block.one also plays a role in its funding. The incentives of block.one are mainly intrinsic. Their team has started the EOS.IO project and would like to see it succeed. Also, they currently still hold a large number of EOS tokens.

The individuals part of a BP Team support the efforts needed for a BP to get selected for block production. Besides them wanting the EOS.IO project to succeed, there is a clear monetary incentive involved, as they are likely to split rewards coming from the BP rewards. Finally, online moderators and voter proxies are mainly driven by intrinsic motivations of supporting the EOS.IO community in order for it to succeed. Another motivation could be the recognition and status that comes from being a popular voter proxy, online moderator or block producer team member.

Off-chain development incentives
The maintainers at the off-chain development layer are mostly incentivised by monetary compensation from block.one. They are hired to work on the project by block.one and are financially compensated in return for their work. Contributors, however, participate mostly on a voluntary basis. It could be that they are incentivised to also become hired, for EOS.IO to succeed and their personal token-holdings to increase in value, or solely because they like developing on such a project.

During the ICO of EOS.IO, block.one raised over 4 million dollars worth of Ether. Besides this, the company held 10 per cent of the initial one billion distribution of EOS tokens to fund development. Considering the record amount of money raised, funding of the development in EOS.IO is not considered a challenge. Furthermore, the EOS system is programmed to have an inflation of 5% every year, 4% is directed to a Worker Proposal Fund (WPF). This translates to over 40 million EOS being allocated every year. The WPF is a system which was proposed in the EOS whitepaper. However, to date it has not yet been fully implemented. It was envisioned to become a portal where developers or community members could create worker proposals in exchange for a small fee. The proposals would include ideas and tasks that represent community needs, development work, educational efforts and marketing. Token-holders would then be able to vote on the proposals using their EOS tokens and based on the voting results the authors of winning proposals would receive their requested funding from the WPF. One of the reasons the WPF has not yet been activated includes sceptical feedback from individuals within the community who are afraid large token-holders will vote on their own proposals without the actual intent of fulfilling them.

On-chain protocol incentives
Like Miners in Ethereum, BPs in EOS.IO have a monetary incentive in the form of BP rewards. Instead of receiving a fixed number of EOS tokens per mined block, the rewards are based on two factors: (i) whether a BP is in the top 21, therefore being an active BP and (2) the percentage of received votes. As already mentioned, the EOS.IO system is programmed to have an inflation of 5% every year. This means that per year about 50 million EOS tokens are minted. Out of this 5%, 1% is used to reward the BPs. A quarter of the 1% inflation is spread among the top 21 (active) BPs. The other 75% of the 1% is spread among the standby nodes based on their percentage of the votes. The standby nodes include both the top 21 BPs as the non-producing nodes.

9.3.4 Membership

Off-chain community membership
Membership at the off-chain community layer is comparable to that of Ethereum. The community is very open to new participants. Anybody can create an EOS account and buy some tokens. Furthermore, the platforms where community discussions take place are also open to welcome new people. With regards to the EOS Alliance, it is a little bit harder to become a member. The EOS Alliance is currently

led by an interim board. New elections are expected to be held in September 2019. According to their website, everybody can fill out an application form to be a candidate for the EOS Alliance board elections. Exact details on how the elections are going to take place are not yet decided. For now, it is only clear that one of seven seats will be elected by the EOS token-holders, based on a selection of candidates selected by the current board.

Off-chain development membership
Similar to the case of Ethereum, there is no formal application process in place to become a contributor of EOS.IO. The software of EOS.IO has been developed by Block.one and was released as Open-source Software in June 2018. Anybody with an account on Github is able to start contributing by raising issues or submitting Pull Requests. However, with regards to maintainers it is not clear how additional commit rights can be obtained. From the activity on Github it seems that a small group of developers from Block.one are the ones with additional permissions to accept Pull Requests and to push updates. However, it is likely that active contributors are either approached by staff from Block.one to become a maintainer or that they request this themselves.

On-chain protocol membership
In theory, anybody can become a BP, in practice however, it is not that simple. First, it is important to understand that a BP is entitled the responsibility to facilitate the proper functioning and scaling of the EOS network. Therefore, to become a BP, one needs to fulfil demanding requirements. Only those with the required technical and monetary resources are able to compete and to properly set up the environment for becoming a BP. Therefore, BPs tend to be big parties such as EOS New York and EOS Bejing or major crypto exchanges such as Bitfinex.

Besides having the right technical infrastructure to become a BP, it is also necessary to continuously campaign for votes of the token-holders from the community. Only the top 21 BP candidates who have received the most votes are chosen as actual BPs. Votes on BPs in the EOS.IO network are counted every 60 seconds.

9.3.5 Communication

Off-chain community communication
Large parts of the communication within the EOS.IO community take place online. The most popular channel for communication seems to be Telegram groups. Telegram is a cross-platform mobile messaging application. An extensive list of channels exists, varying from channels dedicated to specific Block Producers, EOS.IO Governance, test networks, trading, news and wallets. Another popular communication channel includes the official Reddit of EOS which currently has over 65k subscribers. Furthermore, the BP teams around the world regularly organise local meetups in order to educate individuals about EOS.IO and to build a community around their BP candidacy. Finally, two community-wide online events have been organised in the past. These include the EOS Summit and the Webcast Conference EOS Ignite in 2018.

Off-chain development communication
We have identified three main channels through which communication at the off-chain development layer takes place. Public discussions related to development either take place on Github and a Telegram group dedicated to development. Github is the development tracking system that is being used. Furthermore, development

updates, news and releases are mostly communicated towards the rest of the community via the official channels of block.one, which include their Twitter account with over 190k followers, their website, and their blogging account on Medium. After our analysis, it remains unclear whether the maintainers of EOS.IO also communicate in person or via calls as is done in Ethereum. If so, this communication is not available to the public. Block.one did release a public roadmap in the past but it contains no plans for 2019. It has also not been updated since its publication in 2018.

On-chain protocol communication
For clarity purposes, the EOS.IO Network can be conceptually depicted as a set of layered circles. The innermost circle represents the EOS.IO Core Network, which is located within the EOSIO Access Network. In turn, the latter is accessed by the consumers of EOSIO (e.g. token-holders). This conceptual representation is illustrated in Figure 9.4.

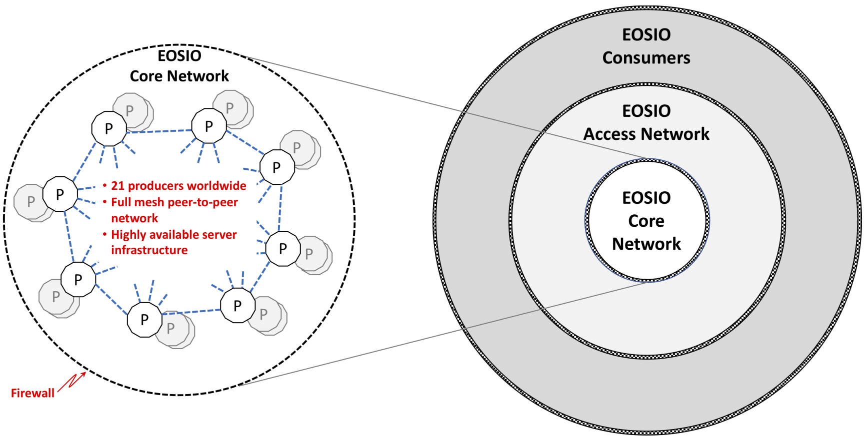


FIGURE 9.4: The network communication layers within EOS.IO (EOSIO, 2019b)

The Core Network is consists of the 21 active BPs and their accompanying server infrastructure. The active BPs are voted for by the community and connected together in a full-mesh peer-to-peer network. In this network, every active BP can communicate directly with the other active BPs. The idea of this architecture is that the active BPs only have to focus on the process of reaching consensus and producing new blocks. The Access Network serves as a filter between the Consumers layer and the Core Network. The non-producing nodes in this layer also have significant processing, memory and network capabilities, however, their main goal is to reduce the number of traffic that needs to be processed by the Core Network.

9.3.6 Decision making

Off-chain community decision making
Like Ethereum, the community of EOS.IO can play an important role in the case of a fork initiated by the developers. This forking mechanism has been previously described in Section X. Similarly, token-holders can always sell their EOS tokens to voice their exit. They could potentially do this when they disagree with decisions made by the developers and block.one to show their opinion and decline the value

of EOS. Furthermore, there are two formal voting mechanisms in place for the community of EOS.IO. These include (i) BP Voting and (ii) the EOS Referendum.

- **BP Votes:** Token-holders are able to use their staked EOS tokens in order to vote on the BPs that they believe are the best candidates. This mechanism is based on a continuous approval voting system. At any moment in time, a token-holder can change its votes, the voting results are counted every 60 seconds. Each token-holder can vote for up to 30 BPs. By doing so they are lending the total voting power of their EOS tokens to the candidates they elect. For example, if a token-holder has 50 EOS tokens, he or she can vote for 30 different candidate BPs and they will all receive 50 votes. As mentioned before, token-holders can also delegate their voting power towards a proxy, who then vote on their behalf. The process of registering the votes and selection of BPs occurs entirely automated on-chain and is embedded in the protocol.

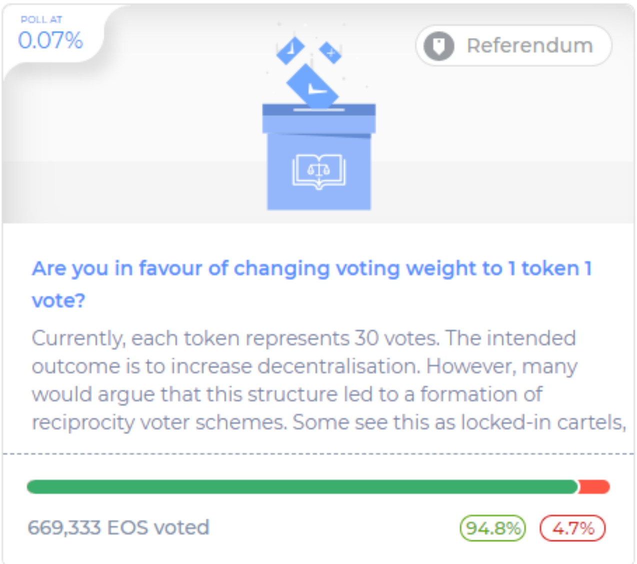


FIGURE 9.5: Example of an active proposal on the EOS Referendum System (EOSAuthority, 2019)

- **EOS Referendum:** The EOS Referendum went live in January 2019. Its goal was to enable token-holders to voice their opinion on matters that they wanted to have a say in. Casting a vote does not cost any fee and its weight is equal to the amount of EOS tokens an individual possesses. A referendum is considered to be officially passed based on a few requirements, for example a minimum threshold of 15% vote participation sustained for 30 continuous days within a 120 day period. These requirements were described in the EOS Interim Constitution. When a referendum proposal is successfully passed, it is not automatically enforced by code on the chain. Instead, the top 21 BPs still have to take action and implement the proposal. An example proposal is illustrated in Figure 9.5.

With regards to the EOS Referendum, we observe that it has been functioning far from the way it was intended. To date, voter turnout is very low, with no proposal having come close towards the threshold of 15% participation. In April 2019, Block Producers decided to sign a new proposed EOS User Agreement which replaced the EOS Interim Constitution. The new User Agreement was proposed in the EOS

Referendum System. While in the proposal about 99% of voters voted in favour of overthrowing the EOS Interim Constitution, voter turnout never reached significant numbers. By implementing the new User Agreement anyway, Block Producers put the up until that moment active EOS Core Arbitration Forum (ECAF) out of play. The ECAF was a juridical entity part of the EOS ecosystem responsible for ruling on conflicts and disputes on the blockchain. The ECAF had a perceived authority over decision making on the blockchain, based on the EOS interim constitution, they could instruct Block Producers to enforce certain actions. For example, if a user had lost its coins because of a hack, the ECAF could rule on the case and instruct the Block Producers to freeze the account. By signing the new EOS User Agreement, the Block Producers have made the ECAF obsolete.

Off-chain development decision making
From our understanding, not much information is available about how development decisions are made in EOS.IO. The only formal mechanism that is publicly visible is the Pull Request process. On Github, it states that it is up to the individual submitting a New Pull Request to convince the project's leaders of the necessity of the feature. Similar to Ethereum, A new request is pulled through several phases, from *Draft* to *Review required* and finally *Approved*. Discussions regarding a PR moving towards the next phase are viewable in Github. However, most of the development decision making is not public information and happens between the group of the maintainers from block.one. As mentioned before, Block.one did release a public roadmap in the past but it contains no plans for 2019. It has also not been updated since its publication in 2018. Release authority lies with the development team of Block.one.

On-chain protocol decision making
EOS.IO uses a Delegated-Proof-of-Stake (DPoS) consensus mechanism. This is an extension of PoS as described earlier in Section 3.4.2. With DPoS, the BPs are selected based on a token-holder vote previously described as a decision making mechanism at the off-chain community layer. Based on the results of the BP votes, 21 BPs are selected to participate in the process of proposing new blocks. They are encouraged to do so following the rules of the protocol, if not, they risk to get voted out by the token-holders. The BPs do not compete directly, instead, they take turns producing blocks. In the case of conflicts, for example because of a malicious or malfunctioning BP, the longest valid chain rule is applied. Besides block producing, the 21 BPs also have extra powers which can be used to carry out policy and enforce certain actions. For example, a specific user account can be black-listed or a new set of rules adopted. This is done via the eosio.prods account which basically is a multisig wallet that can perform certain actions when 15 out of 21 BPs agree to do so.

When the Mainnet of EOS.IO went live, the decision making rules were tried to be formalised within a so-called EOS interim constitution. This document served a similar role as constitutions used in real political jurisdictions. It consisted of a set of rules that everyone who wishes to become a part of the EOS.IO platform accepted to act in accordance with. The original idea in the EOS.IO whitepaper was to reference the constitution via a hash in every transaction executed on the network. However, this idea was never implemented. The EOS constitution was never successfully ratified by the community in a referendum. Furthermore, not everyone agreed with all the contents of the constitution, especially with regards to the role and scope of the

ECAF. As previously mentioned, in April 2019, 21 of the network's top 30 block producers signed an on-chain vote in favour of replacing the interim constitution with a new EOS user agreement, putting the ECAF out of play.

Block Producers   Vote For Producers

Rank	BP Name	Status	Location	Links	Votes %	Total Votes	Rewards Per Day
1	eoshuobipool	Top 21	China		2.029 %	148,574,476 -2,171	773.4860
2	starteosiobp	producing	China		1.965 %	143,840,130 +86,534	759.1279
3	eoslaomaocom	Top 21	Japan		1.925 %	140,927,470 +69,316	750.2946
4	zbeosbp11111	Top 21	China		1.745 %	127,800,325 -144,714	710.4832
5 ↑6	eosiomeetone	Top 21	Singapore		1.735 %	127,007,139 +3,997,804	708.0777
6 ↓1	atticlabeosb	Top 21	Ukraine		1.718 %	125,765,897 -53,478	704.3133
7 ↓1	helloeoscnbp	Top 21	China		1.717 %	125,699,345 +15,781	704.1115
8	cochainworld	Top 21	China		1.699 %	124,393,560 +1,438	700.1514
9	eosflytomars	Top 21	China		1.694 %	124,069,536 -18,645	699.1687
10 ↑3	eosasia11111	Top 21	Hong Kong		1.693 %	123,929,542 +1,409,332	698.7441

FIGURE 9.6: Snapshot of the top 10 Block Producers in EOS as per 05/06/2019 (Bloks.io, 2019)

In the past, individuals from the EOS community have been issuing criticism against the current way in which the BP voting process operates. According to them, the top 21 BPs are becoming increasingly geographically centralised. They state that there are signals of collusion and mutual voting among the top 21 BPs. A snapshot of the top 10 BPs in terms of total votes is illustrated in Figure 9.6.

9.3.7 Summary

TABLE 9.3: Summary of EOS.IO's Governance

Off-chain community	**Off-chain development**	**On-chain protocol**
	Roles	
• Token-holders • EOS Alliance • Block producer teams • Block.one • Online moderators • Voter proxies	• Contributors • Maintainers	• Block producers • Non-producing nodes – API Nodes – Seed Nodes
	Incentives	
Token holders speculate on positive returns on investment, the EOS alliance is independently funded by token-holders, block.one holds a large number of EOS tokens and state willingness to make EOS a success, block producer teams have a monetary incentive from split block producing rewards.	Maintainers have a monetary incentive as they are paid by block.one, contributors mainly participate on a voluntary basis. They might also want to be hired or increase the value of EOS by contributing. An untouched controversiall Worker Proposal Fund exists of about 40 million USD.	Block producers are incentivised by block producer rewards. The top 21 BPs is paid the most, 1% inflation per year spread among BPs, a quarter to active BPs and the rest to non-producing stand by nodes. The standby nodes also include the top 21 BPs.
	Membership	
Community overall very open to new participants. Anybody can become a token-holder of EOS by creating an account and buying tokens. EOS Alliance was initially self-appointed. New elections take place in September but exact details are not available. Anybody can become a voter proxy.	Anybody can become a contributor for EOS.IO. It is unclear how an individual can become a maintainer. All maintainers seem to work for block.one and they are the ones with additional permissions for accepting Pull Requests and pushing updates.	Anybody can become a block producer, however, the barrier for entry is very high. Besides technical and monetary resources it also involves the ability to continiously campaign in order to receive and sustain enough votes to become a top 21 block producer. Votes are counted every 60 seconds.
	Communication	
Most communication takes place via Telegram groups, filtered with dedicated channels per topic. Other popular ways include Reddit, local meetups of block producer teams and events (e.g. EOS Summit and Webcast Conference).	Two pucblic communication channels include Github discussions and dedicated developer channels on Telegram. Development updates shared via the official channels of bock.one (e.g. Twitter and Medium).	The top 21 block producers form the core who communicate via full mesh peer-to-peer network. At the edges of this network, non-producing nodes serve as a filter between the consumers of the network and the block producers.
	Decision making	
Token-holders are expected to use their staked EOS tokens to **vote on block producers**. Each token-holder can vote for up to 30 block producers. Proxy nodes can vote on behalf of a token-holder. Token-holders can also vote on new policy proposals via the **EOS Referendum**. To date, voter turnout has been to low for any proposal to pass.	The **Pull Requests process** visible on Github is the only available information about developer decision making. Block.one controls the direction of development. A public roadmap was published in the past but contains no items for 2019 and has not been updated since publication in 2018.	EOS.IO uses the **Delegated-Proof-of-Stake** consensus mechanism. Block producers are elected by token-holders and the top 21 take turns in proposing new blocks. The longest valid chain rule is applied in conflict situations. Via a multisig account, the top 21 block producers have extra powers to carry out policy and enforce actions such as the freezing of accounts. Reports of collusion and mutual voting by block producers exist.

9.4 Comparing the Governance of Ethereum and EOS.IO

Before progressing, the running scenario is continued:

> **Running scenario:** *The team of Bob has finished documenting the governance of Ethereum and EOS.IO according to the BG framework. Furthermore, they have summarised the governance of both blockchains in Tables 9.2 and 9.3. Next, they want to make a decision based on the obtained information and understanding. There are three aspects that they value primarily, these include: (i) a transparency in decision making, (ii) a sustainable balance of power and (iii) the ability for the community to participate in decision making. Based on their analysis, they try to directly compare both blockchains in terms of their general governance and the aforementioned requirements.*

Overall the governance of Ethereum can be summarised as a *technocracy*, implying that the decision making and direction of the project is publicly decided by a group of core developers/maintainers. Looking at the *decision making* dimension of Ethereum, development updates are accepted into the protocol at the *off-chain development* layer. Although everyone within the community can raise a new EIP, the EIP Editors function as an important gatekeeper role. Next, if an EIP does make it through the phases of the EIP process, the maintainers are going to decide together whether they want to implement the changes in their clients. This is essentially a technocracy where the core developer calls function as an important channel through which decisions are made.

In EOS.IO on the other hand, the governance can be summarised as *organisational capture*. Basically, the *block.one* organisation decides the direction and future of the project on the *decision making* dimension. Not much information is available about how development decisions are made, the information that is available points towards developers working for block.one making the final decisions. Similar as in Ethereum, Pull Requests can be submitted by anyone, but the maintainers have the extra permissions to accept new changes. EOS.IO also still holds a significant portion of EOS tokens that are used for the funding of development. In Ethereum, it is the Ethereum Foundation who funds development, they initially held 12 million ETH and also hire developers through an informal process.

At the *on-chain protocol* layer, both blockchains have extra power in the hands of the entities maintaining the state of the blockchain. In Ethereum, there is extra power in the hands of large mining pools. Together these pools control a large portion of the hashing power and therefore form an important voice of input for decision making at the *off-chain development* layer. In EOS.IO, extra power lies in the hands of the top-21 block producers, besides having a voice, they also have the ability to perform extra actions such as block-listing of accounts. In EOS.IO, there is an increasing concern about mutual voting and collusion between the top-21 block producers.

In terms of transparency, the decision making processes of Ethereum seem more transparent. The entire *EIP process* is publicly documented on Github and furthermore the *Core Developer Calls* are publicly available to tune into and are recorded and summarised for publication. Also, various public roadmaps of Ethereum and its sub-projects are available. In the case of EOS.IO however, there seems to be less transparency around decision-making processes. Besides discussions on Github, there is not much information about how the core developers in EOS.IO make their decisions. Furthermore, a public roadmap of EOS.IO is not available. There is one roadmap published but it does not contain any information from 2019 onwards.

To analyse the ability for the community to participate in decision making, attention is drawn towards the *decision making* dimension on the *off-chain community layer*. Both blockchains are currently experiencing the same challenge: *How do you accurately measure community sentiment on contentious decisions?* In EOS.IO a formal mechanism is built into the protocol in the form of the EOS Referendum. However, while the intention was there, it currently only functions as a signalling system. Voter turnout has never come close towards the set threshold of 15% participation. Similarly, Ethereum also has signalling systems in the form of *carbon votes* and *twitter polls*. These only serve as consideration for decision makers at the *off-chain development* layer. The lack of representativeness of signalling systems has been recognised as a problem within both the Ethereum and EOS.IO community and are still active areas of research.

The identified points of interest related to transparency in decision making, a sustainable balance of power and the ability for the community to participate in decision making are summarised in Table 9.4. Next, the running scenario is wrapped up.

TABLE 9.4: Summary of the brief comparison between EOS.IO and Ethereum

Ethereum	**EOS.IO**
• A *technocracy*, decision making and direction of the project decided publicly by a group of core developers (maintainers). • Mostly transparent decision making processes (EIPs, public Core Developer Calls), public roadmap available. • Funding of development by the EF who initially held 12 million ETH and also hire developers through an informal process. • Informal signalling systems for the community on contentious decisions: carbon votes, twitter polls. • Medium barriers of entry to become a competitive miner (mostly hardware), possibility to join mining pools. • At the on-chain protocol level, extra power lies in the hands of large mining pools, they form a competitive market but also have shared interests.	• *Captured by an organisation*, decision making and direction decided privately by block.one and their maintainers. • Less transparency around decision-making processes, no public roadmap available. • Funding of development by block.one, held 10% of EOS tokens and raised a record of capital during the ICO. • Formal EOS Referendum built into the protocol but only functioning as a signalling system. • High barriers of entry (hardware, knowledge and campaigning) for becoming a top 21 block producer. • At the on-chain protocol level, extra power lies in the hands of the top-21 block producers as they have the ability to perform extra actions such as black-listing of accounts, signs have been reported of mutual voting and collusion.

Running scenario: *After conducting their comparative analysis of the governance of EOS.IO and Ethereum, the team of Bob decides to choose Ethereum as the blockchain platform to build their dApp upon. The decision is based on the gained information during the initial analysis and follow-up comparison. Based on the results, Bob and his team believe Ethereum is a more suitable option in their situation. This is the case because of (i) perceived higher transparency in decision making and (ii) a more sustainable balance of power. In particular, Bob and his team are concerned about the power of the top-21 BPs in EOS.IO and the additional reports of collusion and mutual voting. In terms of (iii) the ability for the community to participate in decision making, the analysis showed this aspect is equally present in both blockchain platforms.*

9.5 Evaluation findings

The ex-post evaluation through a holistic multiple case study had two objectives: (i) a *demonstration* of the artefact in practice and (ii) an *evaluation* of how well the artefact performed. Where the previous section demonstrated the BG framework in practice, this section reflects upon its *effectiveness* through a series of findings.

- **Finding: The BG framework facilitates a structured thread for analysis of the governance of a blockchain.** This is a logical finding, the application of the BG framework to the Ethereum and EOS case has demonstrated that the dimensions and layers of the artefact are distinctive and applicable. It is important to note that the application of the BG framework is flexible. In this case, it was used as a thread to describe the governance of two blockchains in detail. Essentially, the BG framework was used as a frame of reference when discussing the governance of both blockchains.

- **Finding: Application of the BG framework in a full analysis can be time-consuming.** During the application in both cases, we found that the process of analysis can be time-consuming. The BG framework consists of 15 subtopics to look at (combinations of dimensions and layers). Finding the required information per subtopic and writing it down according to the structure of the framework can be a time consuming process. However, the time spent when applying the framework also depends on the scope and background knowledge of its user. We expect application by practitioners in the blockchain ecosystem to be more flexible and lightweight. The time of application could be greatly reduced if its user is already familiar with the blockchain of interest, a condition that was not the case in our demonstration.

- **Finding: The BG framework leaves interpretation of the findings in the hands of the user.** Application of the BG framework on the cases of EOS and Ethereum increased our understanding of their governance. However, the illustrative scenario also demonstrated that the framework does not directly produce a value judgement about how well the governance of these blockchains performs. Comparison between two blockchains is possible using the given dimensions and layers but no metrics are involved to draw conclusions. While the dimensions and layers are perceived as a helpful way of framing the discussion and analysis of blockchain governance, interpretation of the findings are left in the hands of the user of the artefact. Incorporating metrics in the framework could be possible through new iterations of the framework and is discussed as an opportunity for new research in Section 11.2.

Chapter 10

Discussion

This chapter is divided into two parts. In Section 10.1, we start with a formal evaluation of the design process according to the DSR guidelines by Hevner and Chatterjee (2010). Next, the chapter continues with a general discussion about the implications of this study, the research process followed and encountered challenges in Section 10.2. Throughout both sections, we also provide a discussion of identified limitations.

10.1 Alignment with DSR guidelines

In chapter 2, we described our evaluation strategy adopted from Venable et al. (2012). Part of the predefined strategy is an evaluation of the design process using the guidelines for DSR (Hevner & Chatterjee, 2010). We use them in an ex-post, artificial setting to evaluate the design process followed in this thesis which took an iterative approach. Where applicable, we discuss threats to to the validity of this research according to an overview by Wohlin et al. (2012).

Design as an artefact. This research has resulted in the development of a framework which supports stakeholders in the blockchain ecosystem with understanding and analysing the governance of blockchains. The BG framework is a conceptual framework describing three layers and six dimensions of blockchain governance.

Problem relevance. The BG framework is a response to the call for new research on the topic of blockchain governance (Bodo et al., 2018). Despite its importance, blockchain governance is still poorly understood and insufficiently researched (Hsieh et al., 2017; Finck, 2019). Moreover, we have identified a lack of artefacts and tools that can be used by stakeholders in the blockchain ecosystem to understand blockchain governance. The governance of a blockchain influences a blockchain's ongoing development and sustainability and is therefore of paramount importance for stakeholders relying on them (Lyons et al., 2019). The BG framework is, therefore, addressing a relevant business problem and research gap.

Design evaluation. To evaluate the designed BG framework, we created an evaluation strategy based on the work by Venable et al. (2012). The evaluation of the artefact consisted of an ex-ante evaluation with blockchain experts via semi-structured interviews and a demonstration of the application of the framework in an ex-post multiple case study. During the evaluations, we focused on several quality attributes including the framework its completeness, simplicity, understandability, operational feasibility, usefulness and effectiveness. In line with the objectives of the framework, these criteria were selected from the holistic view of artefact evaluation criteria (Prat et al., 2015).

Various validity threats were identified for the design evaluation. *Interaction of selection and treatment* is a possible threat to the expert interviews as the subject population is not representative of the population that we want to generalise to. The framework was evaluated by experts who have much knowledge about blockchain technology and in some cases also governance. The envisioned users of the framework also include blockchain stakeholders who are less informed about the topic. We tried to mitigate this threat by interviewing experts from different types of stakeholder groups (developers, researchers, business) and indicating during the interviews who the envisioned end users of the framework are. The threats of *evaluation apprehension* and *selection* could also have influenced the results. Due to the experts participating voluntary, and knowing that their answers are used as input for analysis, it could be possible that they generally responded more positive due to politeness or because they were more motivated by the subject. We tried to mitigate the threat of *experimenter expectancies* by having multiple people validate the evaluation protocol beforehand.

Research Contributions. The outcomes of this research have both scientific as well as societal contributions. The *scientific contributions* include (i) the definition of a conceptual framework providing an overview of three governance layers and six governance dimensions related to blockchain governance based on foundations in literature (ii) the ability for researchers to categorise and identify areas of research related to blockchain governance using the BG framework (iii) a definition of the term blockchain governance and overview of related literature (iv) contributions to the domain of OSS research by providing an overview of artefacts used to discuss OSS governance and (v) documentation of the design process for creating the conceptual framework which can be useful for other researchers interested in the design of conceptual frameworks and artefacts.

Furthermore, the *societal contributions* include (i) indications that the introduced BG framework provides added value for stakeholders in the blockchain ecosystem who want to obtain a better understanding of blockchain governance. Outcomes of the expert interviews highlighted a strong perceived usefulness of the framework and the experts indicated positive reactions towards them returning to the framework in future situations. Finally, (ii) this study serves as a direct response to the request of Bodo et al. (2018) for new research on the topic of blockchain governance.

Research rigour. The input for the designed BG framework is based on prior literature about OSS governance and blockchain governance. Furthermore, most of the research process has been structured around established research frameworks such as DSR and evaluation methods such as semi-structured interviews and case studies. The execution of the literature studies suffered from *mono-operation bias* because only the search engine Google Scholar was used to identify relevant literature. However, we have reviewed the impact to be limited as additional searches on other databases did not retrieve many new results, especially with regards to blockchain governance. To increase the *reliability* of this study, we have aimed to provide extensive documentation where possible, for example by giving a thorough documentation of the research approach in Chapter 2 and additional reporting in Appendix A and B. All expert interviews were recorded and transcribed for later analysis. However, because the interviews were conducted in Dutch, information might have been wrongly interpreted or lost during translation.

Design as a search process. The design of the BG framework followed an iterative approach of constant evaluation with fellow researchers and colleagues. The framework was compared to the current developments in the blockchain ecosystem on a daily basis. Moreover, by attending external events and discussions with people active in the blockchain ecosystem served as extra insights and input for the design and evaluation of the framework. As highlighted in Chapter 6, examples include a conference organised by the Dutch Blockchain Coalition about the governance of Distributed Ledger Technology and the Ethereum Community Conference where the draft framework was discussed with people from the community.

Communication of research. The findings of our study are communicated extensively through this thesis. The BG framework was designed with the goal in mind to be of added value for different stakeholders including technical audiences such as developers but also businesses and regulators An introduction to blockchain technology has been included in Chapter 3 to provide an overview of the concepts involved and to extend the accessibility of this thesis to a broader audience. Finally,the DSR evaluation reporting structure (Shrestha et al., 2014) was used as a template to communicate the evaluation results.

10.2 Further discussion

Many scopes of blockchain governance

Prior to starting this research, our knowledge of the topics blockchain and governance was limited. It was experienced first-hand how complex both topics are and how research about blockchain is still in its early stages. As highlighted in the introduction, most of the research that has been done is often focused on the technical features and legal considerations of blockchains or solely aimed at the Bitcoin blockchain. At the beginning of this study, the idea was to focus on everything blockchain governance-related. While progressing and getting a better idea of the range of the topic it was decided to further scope our research.

In this study, it meant that the focus would lie on an *internal* governance perspective of mostly *public* blockchain platforms. This left out other interesting areas of research such as the way in which governance is set up within a private consortium led blockchain or the effect of laws and regulation (*external* governance) on a blockchain. Besides this, we also decided to focus on the governance of a blockchain its underlying infrastructure. Other levels where governance also plays a crucial role include the governance of blockchain applications that run on top of a particular blockchain platform and the governance of smart contracts that are deployed within these applications. While these are interesting areas for research they were decided to be out of scope.

Innovation in the blockchain ecosystem is very fast which leads to research in the academic world seeming to constantly lack behind developments in practice. The role of academic research in this domain is possibly not to advance real-life developments, instead, the role can be to capture what is happening in practice and define theory to create standards and a shared understanding of the phenomenon. This is also the role that we see for this study and in particular the BG framework that has been proposed. Our study provides an extensive introduction into the the topic of blockchain governance for interested stakeholders. Furthermore, the created BG framework gives them a tool to to use when needing to understand blockchain governance in future situations.

The strength of the framework is also its limitation

One of the major strengths of the proposed BG framework is directly also one of its limitations. From the beginning of this study, we envisioned a wide set of blockchain stakeholders for whom the BG framework should be of added value. This has resulted in a generic conceptual framework without a single specific use case. During the design, multiple applications of the framework were thought of. The flexible nature of the designed artefact directly introduces limitations. When an artefact is more generic, it becomes more difficult to validate that it has fulfilled the outlined objectives. This is why this study primarily focused on an *evaluation* of the proposed artefact instead of a *validation*. Furthermore, it is important to note that the BG framework does not produce a value judgment and leaves interpretations in the hands of the user of the framework. For example, as demonstrated in the illustrative scenario in Chapter 9, the framework might be used to directly compare the governance structures of two blockchains but deciding which governance structure is more effective depends on the context and interpretation of the user.

Impact of the BG framework

As highlighted in the conclusions in Chapter 11, we recommend future validation studies to confirm our initial findings. However, we strongly believe that the proposed BG framework already has a solid basis upon which future research can be carried out. The artefact outlined in this thesis combines findings from OSS governance literature, blockchain governance literature and interviews with blockchain stakeholders into one unified framework.

As an example, we hypothesise a similar role of the framework to the work of Markus (2007) who defined six dimensions of OSS governance which served a reference in many later studies investigating the governance of OSS. His results were used in new case study research and comparisons of OSS governance. It would be equally interesting to apply the BG framework in future single and multiple, in-depth case studies (Yin, 1994). These case studies could be constructed based on the BG framework as was the case with the work of Markus (2007).

We envision the BG framework as a reference framework in the establishment of a shared understanding and discussion surrounding the topic of blockchain governance. Two other examples of frameworks which played a similar role in their own domain include the SPM framework (de Weerd, Brinkkemper, Nieuwenhuis, Versendaal, & Bijlsma, 2006) as a reference framework for software product management and the business model framework (Schief & Buxmann, 2012) for the software industry.

While finalizing this thesis, there has been worldwide attention for the announcement of the Libra blockchain (Libra, 2019), introduced as a *"decentralized, programmable database designed to support a low-volatility cryptocurrency that will have the ability to serve as an efficient medium of exchange for billions of people around the world"* (Amsden et al., 2019). Given the large corporations involved and its potential impact, Libra has already resulted in many discussions, for example, related to the way the blockchain is going to be governed. While Libra will launch as a permissioned blockchain, they have stated that they *"aspire to make the Libra Blockchain fully permissionless"* (Amsden et al., 2019). Investigating the governance structures of the Libra blockchain through an analysis of the BG framework would be an example of a relevant single, in-depth case study.

Chapter 11

Conclusion and outlook

The objectives that were set out for this study were to improve the lack of understanding and tools available on the topic of blockchain governance. The preceding chapters reported on the design of a conceptual framework that aimed to capture the main dimensions and layers of blockchain governance in a comprehensible manner in order to guide blockchain stakeholders to analyse the governance of blockchains in a structured way. The study was organised around the following research question:

RQ *How can the governance structures of blockchains be defined and compared?*

The main research question has been studied on the basis of five subquestions. This chapter concludes the study by answering the research questions in Section 11.1. Finally, directions for future research are presented in Section 11.2.

11.1 Conclusion

Subquestions
This section concludes the main findings for each subquestion (SQ).

SQ1 *What artefacts are used to characterise the governance of Open-source software?*

In Chapter 4 we reported on the results of a semi-structured review of the available literature on OSS governance. The results showed that the artefacts used to describe OSS governance cover a wide range of approaches. Examples include *the phases of OSS* by Lattemann and Stieglitz (2005) and the *six OSS governance categories* by Markus (2007). Multiple artefacts follow a *three-layered* approach to reason about OSS governance (e.g. software- community- and ecosystem level), where each layer has a different scope of looking at the stakeholders involved. These perspectives are viewed as a way to subdivide the complex phenomena of governance in a subset of layers. Furthermore, the available studies often highlight the *incentives*, *communication tools*, *modularisation* and *software development* of OSS governance.

SQ2 *What concepts and structures does the governance of blockchains encompass?*

In Chapter 5 we presented the results of a semi-structured review of the available academic and grey literature on OSS governance. First, we discussed various scopes of blockchain governance. These include the distinction between governance *by* vs governance *of* the blockchain, *on-chain* vs *off-chain* governance and *intra* vs *internal* blockchain governance. Furthermore, the literature study showed a diverse set of theoretical perspectives that are used to approach blockchain governance. Recurring themes that were used across the literature to discuss blockchain governance were *incentives*, *funding of developers*, *consensus mechanisms* and *forking*.

SQ3 *What are the perceptions of stakeholders regarding blockchain governance?*

In Chapter 7 we discussed the outcomes of interviews with eight experts from the blockchain ecosystem. The results indicated that stakeholders in the blockchain ecosystem have no shared understanding of what the term blockchain governance entails. Common themes brought up by the interviewees included *forking*, *decision making*, *on-chain* vs *off-chain* governance and *regulation*. Overall, the experts indicated that understanding blockchain governance is of high importance for stakeholders in the blockchain ecosystem. The selection of a blockchain platform can be a fundamental choice, where understanding the governance is a necessity to keep faith in its continuity. Moreover, the interviews served as an evaluation of the draft BG framework that was designed based on the theoretical foundations of answering SQ1&2. The evaluation led to valuable improvements and the experts widely perceived an added value of the framework for stakeholders in the blockchain ecosystem.

SQ4 *How does the created blockchain governance framework influence the comprehension of a blockchain's governance?*

In Chapter 9, we demonstrated the application of the improved BG framework in a holistic multiple-case study. The case studies showed that the BG framework facilitates a structured thread to analyse the governance of a blockchain. However, it was also highlighted that the application of the BG framework in a full analysis can be time-consuming and leaves interpretations of findings in the hands of the user. Overall, the BG framework facilitated the discussion of the governance of Ethereum and EOS.IO and increased our understanding of how both blockchains are governed.

Main research question

Drawing from insights and knowledge gained from answering the subquestions, we formulate an answer to our main research question:

RQ *How can the governance structures of blockchains be defined and compared?*

To define and compare the governance structures of blockchains this study proposes a blockchain governance (BG) framework. Building on OSS governance and blockchain governance foundations in literature and insights from blockchain experts, the BG framework defines the governance structure of a blockchain as a combination between 6 governance dimensions, the *history and context*, ***roles***, ***incentives***, ***membership***, ***communication*** and ***decision making*** dimension and 3 governance layers, the ***off-chain community***, ***off-chain development*** and ***on-chain protocol*** layer. The BG framework is described in detail in Chapter 8.

While further validation studies are recommended, the BG framework is a solid basis upon which future research can be carried out. The strength of the framework is that it combines insights from literature into OSS governance, blockchain governance and opinions from blockchain experts into a framework that can be of added value for various stakeholders in different situations. For example, the framework can be used to describe, analyse, categorise and compare the governance of blockchains. However, it is important to highlight that the BG framework does not produce a value judgement and leaves interpretation in the hands of the user. We hypothesise that the BG framework can act as a reference framework in the establishment of a shared understanding and discussion surrounding the topic of blockchain governance.

11.2 Future directions

This research has opened interesting new areas for further research.

Emperical validation
The current study evaluated the proposed BG framework through a series of expert interviews and application in a multiple case study. While the first evaluation results look promising, further empirical validation is necessary to further confirm our exploratory findings. Ideas for validation research include technical action research, surveys, interviews and focus groups. Preferably, these techniques are triangulated to form a complete picture of the validity of the BG framework. Resulting feedback can be used as input to incrementally refine the BG framework.

What entails good blockchain governance
The current study has only examined how to define and capture blockchain governance inside a conceptual framework. An interesting area of research to pursue would be to define what good governance entails for a blockchain. Defining good blockchain governance could be context specific and highlight different quality properties such as the degree of transparency, efficiency and balance of power. Prior literature discussing what constitutes good governance in other domains could be used as a starting point, e.g. a study by Weiss (2000). Next, it would be interesting to explore whether the BG framework presented in this study could be linked to a measure of good governance. An extended version of the framework connecting to a direct value judgement or used for performance analysis would be a promising next step.

Configurations of blockchain governance
The BG framework can be applied to many more cases with the aim of identifying configurations of governance. Ethereum and EOS are just two cases out of a large list of available blockchains. By using the BG framework as a thread, patterns of governance could be identified among different cases. A promising step would be to replace the current questions inside the dimensions and layers of the BG framework with actual examples of configurations. For example, if all on-chain protocol roles are identified among a large set of blockchains, these could potentially be categorised into several reoccurring configurations. In turn, the BG framework can be extended by offering pre-defined choices per dimension and layer.

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Appendix A

Extra sources draft BG Framework

A.1 Events

TABLE A.1: An overview of attended events and workshops that also covered the topic of blockchain governance and served as inspiration during the design and evaluation of the BG framework

Event name	Organisation	Location	Date	Topics
Utrecht Blockchain Congres	Hogeschool Utrecht	Utrecht	17-10-2018	Blockchain & testing, blockchain in production, governance for blockchain
Smart Contract Governance Workshop #1	Techruption	Utrecht	8-11-2018	Smart contract governance
Smart Contract Governance Workshop #2	Techruption	The Hague	25-1-2019	Smart contract governance
Bitcoin Wednesday	Pikapay	Amsterdam	6-2-2019	Decentralised Exchanges, security audits in Smart Contracts, Blockchain technology sustainability
Blockbar Panel: Governance, FTW	Blockbar	Den Haag	22-2-2019	State of play around blockchain governance, governance in EOS, challenges, best practices
Ethereum Community Conference	Ethereum	Paris	5/6/7-3-2019	Blockchain governance
Smart Contract Governance Workshop #3	Techruption	Utrecht	14-3-2019	Smart contract governance, Ricardian Contracts
Deep Dive into Governance of DLT	Dutch Blockchain Coalition	Delft	18-3-2019	Challenges and opportunities of DLT Governance, governance processes in public DLT core teams, governance in Consortium Blockchains, building and governing business ecosystems
Corda Amsterdam Launch event	Corda Netherlands	Amsterdam	21-3-2019	Corda, Corda network
Blockchain Innovation Conference	BIC	Amsterdam	7-6-2019	Blockchain, governance, regulation, alliances, business cases

A.2 Governance Mechanisms from Literature

TABLE A.2: Overview of governance mechanisms identified from the literature studies of OSS governance and blockchain governance

Off-chain community	**Off-chain development**	**On-chain protocol**
	Roles	
Community roles (Markus, 2007)	Development roles (de Laat, 2007; van Deventer, Brewster, & Everts, 2017)	Network participant types (van Deventer, Brewster, & Everts, 2017)
Observable hierarchical structures (Jensen & Scacchi, 2010)	Observable hierarchical structures ((Jensen & Scacchi, 2010)	Observable hierarchical structures (Jensen & Scacchi, 2010)
	Incentives	
Monetary and non-monetary rewards (Gasser, Budish, & West, 2015)	Funding of development (Carter, 2017)	Monetary and non-monetary rewards (Gasser, Budish, & West, 2015)
	Hiring of developers (Hsieh, Vergne, & Wang, 2017)	
	Membership	
Community management (Markus, 2007)	Participation management (Midha & Bhattacherjee, 2012)	Network participation (Hsieh, Vergne, & Wang, 2017; van Deventer, Brewster, & Everts, 2017)
Community borders (Filippi & Loveluck, 2016)	Training and indoctrination (de Laat, 2007)	Nodes control (van Deventer, Brewster, & Everts, 2017)
	Source code access management (de Noni, Ganzaroli, & Orsi, 2011)	
	Modularisation (de Laat, 2007; Jensen & Scacchi, 2010; de Noni, Ganzaroli, & Orsi, 2011; van Deventer, Brewster, & Everts, 2017)	
	Communication	
Community discussion (DiRose & Mansouri, 2018)	Development discussion media (van Deventer, Brewster, & Everts, 2017)	Communication between network participants (Gasser, Budish, & West, 2015)
Community agreement (Carter, 2017)	Coordination and tracking systems (Izquierdo & Cabot, 2015)	
	Decision making	
Voting mechanisms (ListedReserve, 2018; DiRose & Mansouri, 2018; Carter, 2017; Hsieh, Vergne, & Wang, 2017)	Generation of decision proposals (DiRose & Mansouri, 2018; Beck, Müller-Bloch, & Leslie King, 2018)	Voting mechanisms (ListedReserve, 2018; DiRose & Mansouri, 2018; Carter, 2017; Hsieh, Vergne, & Wang, 2017)
	Execution and implementation of decisions (Beck, Müller-Bloch, & Leslie King, 2018)	Consensus mechanism (Beck, Müller-Bloch, & Leslie King, 2018; van Deventer, Brewster, & Everts, 2017; de Filippi & Wright, 2018; Carter, 2017; Hsieh, Vergne, & Wang, 2017)
	Release authority (de Noni, Ganzaroli, & Orsi, 2011; Izquierdo & Cabot, 2015)	
	Conflict resolution	
Ownership disputes (Ziolkowski, Parangi, Miscione, & Schwabe, 2018)	Procedures to solve arising conflicts (Markus, 2007)	Transaction reversal (Ziolkowski, Parangi, Miscione, & Schwabe, 2018)
Forking to resolve disagreement (Beck, Müller-Bloch, & Leslie King, 2018; Filippi & Loveluck, 2016; Hacker, 2017; Nyman & Lindman, 2013)	Forking to resolve disagreement (Beck, Müller-Bloch, & Leslie King, 2018; Filippi & Loveluck, 2016; Hacker, 2017; Nyman & Lindman, 2013)	Forking to resolve disagreement (Beck, Müller-Bloch, & Leslie King, 2018; Filippi & Loveluck, 2016; Hacker, 2017; Nyman & Lindman, 2013)

Appendix B

Interview protocol

B.1 Informed consent

Taking part in the study

- ☐ The research information sheet dated 29/03/2019 has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
- ☐ I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.
- ☐ I understand that taking part in the study involves an audio-recorded interview, or if I don't agree with the interviewer recording the interview, an interview in which information is captured by written notes.

Use of the information in the study

- ☐ I understand that information I provide will be used in the master thesis of *Rowan van Pelt*, more specifically in the chapter that deals with the evaluation of his created artefact (a Blockchain Governance Framework).
- ☐ I understand that personal information collected about me that can identify me, such as my name or function, will not be shared beyond the study team.
- ☐ I agree that my information can be anonymously quoted in research output.

Signatures

Name of participant: ________________________________

Signature: ____________________ Date: ____________________

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Researcher name: ________________________________

Signature: ____________________ Date: ____________________

B.2 Research information sheet

Version 1.0, Date: 29/03/2019

Context and purpose of the research
You have been asked to participate in an interview as part of a research project about Blockchain Governance. This research is executed as a master thesis project in the programme Business Informatics of Utrecht University, under the supervision of Slinger Jansen and Sietse Overbeek. Furthermore, the project is conducted in combination with an internship at the Blockchain Acceleration Lab of the Rabobank, under the supervision of Djuri Baars.

In this research, we have created a draft Blockchain Governance Framework. It is aimed at capturing the main dimensions and layers of blockchain governance in a comprehensible manner. The goal of the framework is to guide businesses, regulators, developers, and other stakeholders with the understanding or analysis of a blockchain its governance. For example, by helping them with the identification of those questions that are relevant to ask when looking at the governance of a particular blockchain.

This interview consists of two parts. In the first part, we want to explore your relationship with blockchain. Furthermore, we are interested in your own understanding of the concept blockchain governance, and which aspects related to it are in particular of interest to you. In the second part of the interview we want to share our own definition of blockchain governance. Next we want to introduce to you a draft version of the aforementioned blockchain governance framework, which we want to evaluate with you. We are interested in your initial opinion of the framework, especially with regards to perceived usefulness, completeness, and simplicity.

Usage of data and personal information
You can withdraw from the interview at any time by simply letting me know. If you wish to withdrawal from the study at a later moment in time, you can let us know via e-mail. Any of the information provided during the interview will then be deleted and not included within the research output. The latter request should occur within 21 days after the interview took place. The master thesis is expected to be publicly available in the thesis archive of Utrecht University.

During the interview, I will take notes. If you agree, the interview will also be audio-recorded. Relevant parts of the audio-recording will be transcribed for further analyses. You also have the right to request access to, and rectification or erasure of the interview recordings and note takings. The information captured, either by note-taking or transcribing of the interview recording, will be anonymized before serving as input for the master thesis. Personal information regarding the interviewees will not be shared beyond the study team. The study team consists of me (Rowan van Pelt), my internal supervisors (Slinger Jansen and Sietse Overbeek), and external supervisor (Djuri Baars).

Additional questions
Do you have any unanswered questions about the interview?

Contact details of the researchers
Name: *Rowan van Pelt*, mail: *r.l.vanpelt@students.uu.nl*
Supervisor: *Slinger Jansen*, mail: *slinger@slingerjansen.nl*

B.3 Questions

Introduction
The interview is planned to last no longer than 60 minutes. As already mentioned there are multiple questions that I would like to cover. If time begins to run short, it may be necessary to interrupt you in order to complete the line of questioning.

[Start audio-recording]

Background information interviewee

- Can you briefly tell me about your affinity with blockchain technology?
  - First experience
  - Function and activities *Prompts*
  - Years active

Perception of blockchain governance interviewee
The next few questions seek to explore what you think about when you hear the concept of blockchain governance. There is no right answer here, I am solely interested in whatever comes to mind when you think about the topic.

- What do you think about when you hear the concept of blockchain governance?
- In your context, how would you define blockchain governance?
- Following this definition, is blockchain governance relevant in your activities related to blockchain?
  - In what way?
  - Why (not)? *Prompts*
  - To others in your environment?

Defining blockchain governance
Since you have just described your own thoughts on the topic of blockchain governance, I would now like to continue by explaining some of the different types of roles blockchain governance can have. Followed by the scope of blockchain governance that I'm focusing on in my thesis.

[Explain governance ***by*** *vs.* ***of*** *blockchain]*

[Explain layers of blockchain governance]

The way I define blockchain governance in my thesis is: *"the means of achieving the direction, control and coordination of stakeholders within the context of a given blockchain project to which they jointly contribute."*

- To what extent is my scope different to yours?
- Is this scope of blockchain governance relevant for your blockchain related activities?
- Did you previously look into how the governance of a particular blockchain works?
  - What for?
  - Did you use any artefacts? *Prompts*
  - Approach used?

Evaluation of Blockchain Governance Framework
I would now like to continue by introducing the draft version of my Blockchain Governance Framework.

[Introduce Blockchain Governance Framework]

- Do you find this framework easy to understand?
- On a first impression, do you think it could be beneficial for stakeholders that are looking into the governance of a particular blockchain?
  - Why (not)?
  - If yes, could you describe such a situation? *Prompts*
  - What about the comparison of blockchains?
  - Which type of stakeholders?
- Did this framework expand your views on the topic of blockchain governance?

[Point out feedback indicators]

- Are there any aspects you would like to change to the framework?
  - Additions
  - Duplicates *Prompts*
  - Removals

Closing thoughts
You have seen this framework for the first time today.

- Would you see yourself coming back to it in the future when you are dealing with blockchain governance?
- Are there any final things you would like to add this interview?

[Stop audio-recording]