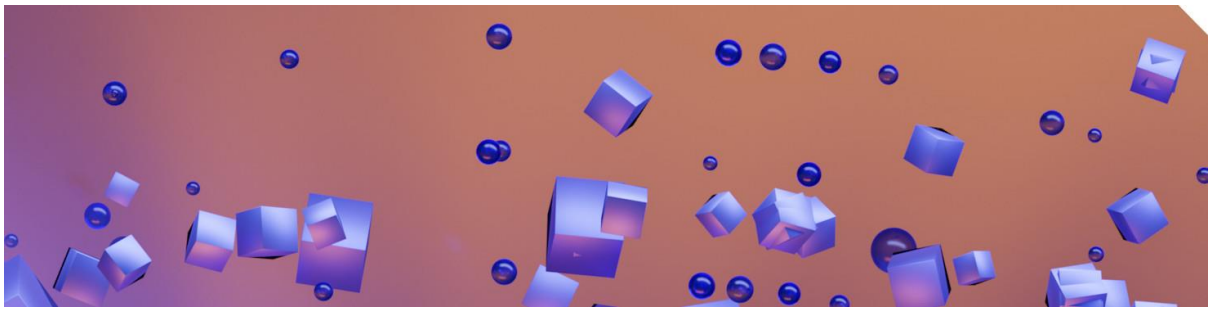
The Relevance of Blockchain in Commons Governance



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Summary

In the last five years the rapid development in blockchain technology is witnessed, where this technology has not been spared by mainstream attention. Rapid development in (decentralized) financial frameworks are engulfed traditional markets, institutions, and consumers. A parallel trend can be seen in academic canons, such as the exploration of potential decentralized and autonomous markets with decentralized stateless governance, promising the advent of a revolution. The main research however is predominantly based on digital worlds and infrastructures, which have different design considerations. Little substantiated attention has been given to the subject of blockchain governance in physical worlds, specifically physical commons governance. Not engulfing a holistic understanding of how to combine these two worlds, actors cannot make informed design decisions. Therefore understanding how a digital framework can be used to govern a physical commons is of vital importance.

This thesis proposes a theoretical framework based on blockchain, for an implementation within a neighbourhood commons, to elevate governance effectiveness. The framework is grounded by the synthesis of pre-existing theoretical reflections, reviewing key academic literature and 10 expert interviews. The framework serves as a "conceptual tool", combining previously disconnected worlds of blockchain and commons governance. Extensive use is made of Ostrom's (1990) work of commons governance, for the subsequent creation or principles for self-governance. Furthermore, this thesis indebted by Rozas et al. (2021) exploration of affordances, or congruences, between principles for self-governance and inherent blockchain characteristics. After to the establishment of this synthetic framework, thesis attempts to conclude if the main research question: *What potentials does a blockchain application hold to improve governance of a neighbourhood commons?*

Findings and reflection of expert interviews highlight how there is a possible benefit and usefulness for the implementation of blockchain in a physical commons. However, current technical challenges greatly hinder the implementation process. Dilemmas and mismatches between digital and physical worlds raise critical concerns on the "actual" benefits of such an implementation. These design dilemmas revolve around fundamental and philosophical considerations, potentially requiring a re-evaluation of how current societies are designed. The implementation of a blockchain governance framework dynamically holds potential, especially wthin digital commons. However, the implementation thereof within physical commons, requires extreme considerations in design with benefits being wholly dependent on context specific variables.

Although this analysis and proposed framework serves as a solid starting point, the conduction of extensive future research is highly recommended to further understand and possibly optimize its potential. The technical nature, novelty, and abstraction of this research, perhaps some simplifications and assumptions. Nevertheless, this thesis highlights vital design considerations, finding strength in critically exploring these considerations and potential comprises. These identified critical reflections are urged to be taken into consideration, when designing blockchain frameworks.

Acknowledgements

This thesis is a conglomeration of events, decisions, and countless hours of studying and marking the end of my academic career at Utrecht University. In the second half of 2021, my understanding of blockchain technology and commons governance was quite limited. Months of researching, brainstorming, writing and pondering have broadened my horizons in both disciplines. It seemed as if the more I delved into this research, the less I knew and the more questioned I had. It has been a very challenging journey from start to end. Beginning from idealistic dreams of developing a blockchain app, to coming to the realization of the complexity of the topic, I chose to ground a theoretical reflection. Doing so I was able to dive into fundamental questions regarding the use of blockchain for complex social and human decisions. As challenging as it was, this thesis has allowed me to subsume new knowledge, for the academic canon but also as an outlook in my professional career.

None of this would have been possible without the support and encouragement of my supervisor Frank van Laerhoven. In the initial thesis orientation phase, I approached him with a research proposal and after a discussion, where he encouraged me to pursue my thesis proposal. Exciting and motivating feedback from Frank encouraged me to go start this blockchain adventure. His critical feedback and concerned face during feedback sessions continuously motivated me. The subsequent positive feedback and recognition of work done, was always a reward for me.

Next, I would like to thank my parents and my sisters, for their continuous support, encouragement, interest, and help in writing this thesis. Furthermore, I would like to thank my friends for being critical, and asking challenging questions and second guessing my research decisions.

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1 Introduction

1.1 The potential of blockchain for the governance of commons

All, if not most, of natural resources that humans rely on are prone to be overexploited through the tragedy of the commons (Hardin, 1968; Telemo, 2015). Tragedy of the commons occurs when a collective of rational individuals act in their own self-interest, creating a situation that is suboptimal for everyone involved (Hardin, 1968; Ostrom, 1990; Telemo, 2015). Conventional approaches in avoiding the tragedy within commons-setting, boils down to privatization and government control. Traditionally it is believed that self-governance is difficult, especially in absence of a central authority or institution. Even more challenging is crafting and imposing rules (on oneself and collectively), regulations, and institutions, especially when collective action and collective agreement is required (Baerlein, 2015; Hardin, 1968; Osmundsen et al., 2021). Yet Ostrom's (1990) work empirically describes a successful third alternative, where self-governance is formulated through eight design principles. Ostrom substantiates how individuals can manage and collaborate within their local community, to properly govern scares resources and facilitate long-term sustainable uses (Ostrom, 1990). When orienting towards the principles of self-governance delineated by Ostrom, one can formalize suitable forms of governance with regards to common pool resources (CPR's).

In a self-governance approach, individual actors can organize themselves to deal with CPR challenges, which are derived from the inherent "free access" characteristic of commons. Such challenges can be overexploitation, low profits, trust issues, poor management, pollution, and destruction (Dipierri & Zikos, 2020; Ostrom, 1990; Saunders, 2014). This requires an effective and coordinated approach. It can be argued that so-called rational resource users struggle to provide a clear and meaningful description of local norms, values, objectives, and interests in CPR projects, with personal difference playing a conflicting role (Saunders, 2014). Most theoretical analysis of CPR cases fail to take into consideration how local conditions are defined by social relations at different levels, further complicating social dynamics, norms, and values (Saunders, 2014). What becomes important in these situations is trust and transparency, to facilitate clear objectives, common norms, and commons enforcement (Baggio et al., 2016; Cox et al., 2010; DeMotts et al., 2009; Fisher et al., 2010; Ostrom, 1990; Tang et al., 2014; Wendel, 2004). Not only is clear understanding and communication necessary, but also facilitation of building of trust between actors. This conditions the ability in clearly defining objectives, boundaries, and decision-making processes in self-organization. Thus transparency and trust are essential in tackling the challenges found in CPR governance, as well as defining and communicating social relations.

The binary rift in the paradigm, of needing or not needing a central authority for self-governance, remains a heated debate. A potential and largely unexplored approach to this challenge is the use of blockchain. Blockchain technology appears to have the potential of making and enforcing rules in absence of a central authority, through the introduction of a decentralized, "trust-less", and transparent system. Blockchain can be defined as follows;

"… a distributed database that is shared among the nodes [users] *of a computer network. As a database, a blockchain stores information electronically in digital format*." (Investopedia, 2016).

Essentially this entails that there is no need for trust: all information is held publicly and in the hands of every actor. This creates somewhat of an oxymoron, as trust is created from not needing any trust. Blockchain as a system records information in such a way that it makes it difficult, some say impossible, to hack, change, or cheat, given that everyone holds an identical record of transactions (Rozas et al., 2021). The inability to alter any entry in the database, unless complete consensus is held, inherently

creates trust in the system, as power is decentralized and all information is public. 'Trust-lessness' is derived from this characteristic, as there is no need to trust anyone, given that all power and information is distributed evenly in a decentralized manner. Henceforth this thesis examines in what ways blockchain might alleviate challenges identified with regards to the management of commons.

All Ostrom's (1990) 8 design principles can be applied within a blockchain-based governance approach, where some design principles are more salient than others (Rozas et al., 2021; Shackelford & Myers, 2017). Additionally, a framework developed by Rozas et al. (2021) highlights similarities, or *affordances*, within Ostrom's (1990) design principles and blockchain characteristics. Synthesizing these establishes the theoretical backbone of this thesis. Rozas's (2021) theory on blockchain affordances, examines how similarities and positively influencing effects can be seen in principles for self-governance and blockchain characteristics. Follows, is a brief overview of these synergies.

The initial synergies between inherent blockchain characteristics, through Ostrom's (1990) design principles and Rozas's (2021) theory of blockchain governance, highlight a potential approach to a new form of commons management. Identifying what interactions are deterministic between commons, self-governance principles, and blockchain, shed light on how fitting this approach could be. Rozas (2021) has developed a theoretical framework, which conceptualizes blockchain characteristics, or "affordances", which could be used for governance frameworks (Rozas et al., 2021). These characteristics are developed in response to Ostrom's (1990) eight design principles, for self-governance of the commons (Ostrom, 1990). This thesis aims to operationalize these "*affordances*" together with Ostrom's (1990) design principles into a theoretical framework. Essentially this brings together two disconnected theoretical worlds, to assess how effective blockchain-based governance could be. Follows is a brief reflection on the two theories.

Defining boundaries (1) revolves around who has the power to participate in the CPR case but it also denotes the trustworthiness and cooperation of others. Blockchain can facilitate this in different forms depending on the design used, may it be fully public, transparently distributed, or a private blockchain (Rozas et al., 2021; Shackelford & Myers, 2017). In a transparent distributed design, the collective has equal power in any decision making process. Blockchains dimension in *proportionality (2)* can be seen as an encouraging mechanic for greater equity. This is achieved through the use of transparency, user participation, and giving out rewards for contributions (Hassan & De Filippi, 2021; Rozas et al., 2021; Shackelford & Myers, 2017). This approach achieves this through a decentralized public ledger and rewards system, incentivizing does who participate to do so according to communal rules and norms, incentivizing collective behaviour (Rozas et al., 2021). Blockchains fundamental success stems from its multi-stakeholder approach, where the continuous development and maintenance is performed by various actors as well as a decentralized and public authentication mechanism (Shackelford & Myers, 2017). A *collective-choice approach (3)* magnifies how similar approaches are taken in the development of any blockchain-based governance approach, by relying on multi-stakeholder participation and active involvement in all rule and boundary setting moments (Rozas et al., 2021; Shackelford & Myers, 2017).

In order to delineate this research further, a specific focus will be given to urban commons, more specifically city neighbourhoods as a commons. A focus will be given to neighbourhood commons situated in developing/ developed cities, in which existing infrastructure can support the implementation of advanced technologies such as blockchain. A city neighbourhood commons has quite a fluid definition but can generally be described as;

A concept based on the idea that public spaces, urban grounds, and urban infrastructure in a neighbourhood should and must be accessible for the urban communities. The utilizations of these

concepts should support and produce a range of sustainable values beneficial for the longevity and health of the community (S. Foster & Iaione, 2018).

Examples of neighbourhood commons can be found everywhere, from your local neighbourhood watch to community gardens, housing collectives, neighbourhood groups; these are dependent on the boundaries used. Somewhat infamous examples can be found all over the world, ranging from *Fristaden Christiania* (Free City Christania in Copenhagen), to *Ruigoord* (Amsterdam), to *Metelkova* (Ljubljana), or *Nimbim* (Australia).

This thesis is a theoretical analysis using a theoretical lens in exploring a blockchain based governance approaches through in the implementation of a neighbourhood commons. This approach underlines how this thesis is a theoretical reflection of two previously disconnected-from-each-other academic worlds, thus the focus is on the theoretical implications of a blockchain based approach for neighbourhood commons governance. The aim of this research, is to understand and evaluate what the implications are of blockchain governance implementations in a neighbourhood commons setting. Given the theoretical nature of this thesis, the novelty of the technology, as well as the difficulties of implementing such a system, the results are based on academic assumptions and theories. Therefore, this thesis should be considered as a critical and theoretical reflection.

In the exploration of this thesis, the following propositions will guide this research into main- and sub-research questions (MRQ &SRQ);

What potentials does a blockchain application hold to improve governance of a neighbourhood commons?

1. *What main neighbourhood CPR governance challenges can be identified?*
2. *What advantages does blockchain-based governance approach present?*
3. *How could blockchain advantages alleviate neighbourhood CPR challenges?*
4. *What are the main blockchain implementation challenges?*
5. *What recommendations for the implementation of a blockchain based neighbourhood commons approach can be formulated?*

The following conceptual framework will be used to lend structure and direction to the thesis and research process:

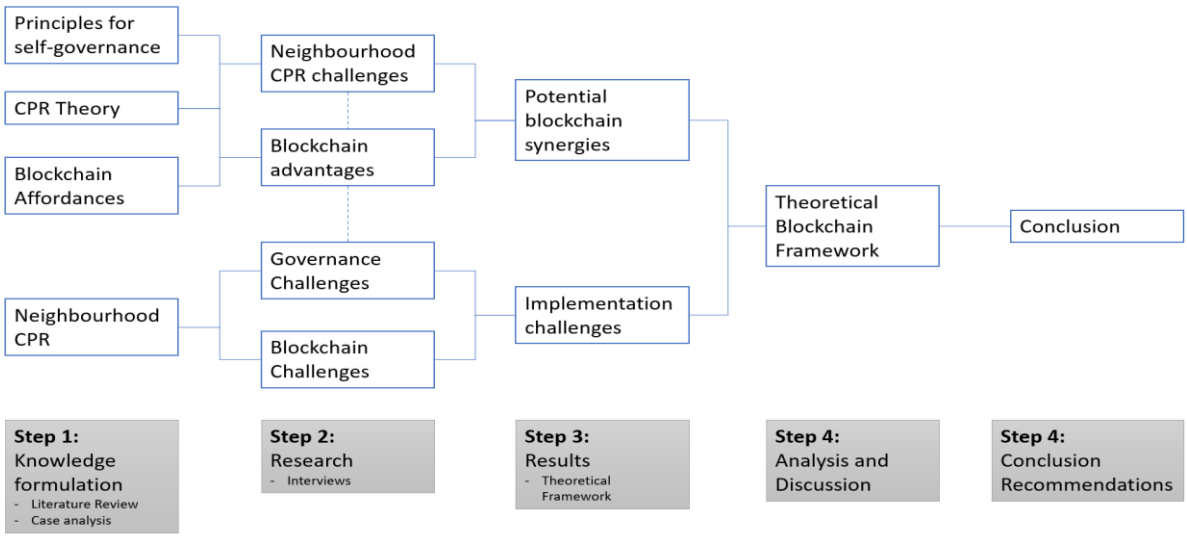


Figure 1 Research Framework

Step four of this research grounds the conceptualization of a theoretical blockchain-based into a governance framework. This framework includes basic principles found in this research needed for the implementation in a neighbourhood commons, and should be regarded as a theoretical blockchain framework incorporating both theoretical frameworks. This theoretical blockchain-based application later is assessed, for the benefits and implementation challenges faced in a neighbourhood commons setting through also relating these to real life examples of commons . The conclusion elaborates on the effectiveness of a blockchain-based governance application and what should be considered for future research.

1.2 Scientific and Societal Relevance

This thesis references the literary body on governance of CPRs and commons (Fisher et al., 2010; Gardner et al., 1990; Hardin, 1968; Ostrom, 1990; Rozas et al., 2021; Steins & Edwards, 1999; Van Laerhoven & Barnes, 2014; van Laerhoven & Ostrom, 2007). Challenges that arise in this field are often complex, multi-dimensional, and unpredictable in nature. Since Hardin's (1968) initial mentioning of the *tragedy of commons,* many approaches and theories have been presented that discuss possible solutions to this "phenomenon" and commons governance in general. Furthermore, this thesis aims to connect blockchain and decentralized governance to the existing literature on CPR and commons management (Cerf et al., 2020; Clavin et al., 2020; Hassan & De Filippi, 2021; Risius & Spohrer, 2017; Rozas et al., 2021; Shackelford & Myers, 2017).

The fusion of these totally disconnected theoretical worlds has not been explored and can potentially lead the emergence of a new niche-theory within the research and new forms of governance. Additionally, research connecting these two worlds will shed light on the knowledge gap that exists with regards to blockchain-based governance. Currently, little is known about the intricate interactions between commons, CPR's, blockchain, and decentralized governance approaches. Potentially, a multitude of variables exist that hinder or promote the synthesis of blockchain-based governance. The scientific contributions this thesis will deliver are multiple: i) defining and creating a theoretical blockchain governance framework for a neighbourhood commons, ii) identifying implementation barriers and opportunities, iii) initial definitions on blockchain governance standards, and lastly v) identifying important consideration for future research. Possibly, there is no room in the future in the realm of governance for blockchain-based governance. However, it remains trivial to explore and highlight the interactions, synergies, and challenges of blockchain-based governance within the use in commons and CPR management.

Understanding what potentialities exist in blockchain-based governance could pave a road towards a new and improved form of CPR management or decentralized governance. On a societal scale this could mean more efficient, equitable, and transparent commons management. Any successful implementations in commons or CPR settings could be seen as proof-of-work for future research in global blockchain-based governance. The importance of a decentralized and blockchain-based governance approaches can be traced to the equitable distribution of power, wealth, and decision-making strength for actors. Furthermore, societal value can be found in creating a more transparent and "trusting" governance system, which does not rely on centralized, bureaucratic, and non-transparent proceedings. The creation of this potentially more equitable form of governance and commons management approach, could lead to a reduction in inequality gaps. Societally speaking, this would lead to a more equitable commons structure.

2 Theory

The following section highlights major theoretical views and frameworks used in both, blockchain and commons governance fields of research. Furthermore, driving forces in the dissemination of blockchain based applications will be discussed, specifically in the context of governance and collective action. This section will conclude with a newly synthesized theoretical framework, proposing a conceptual blockchain-based governance application.

2.1 Theoretical Background

2.1.1 Common pool resources & tragedy of the commons

In simple terms CPR can be defined as: *any good consisting of a natural or human-made resource system. Of which its size or inherent characteristic makes it costly, but not impossible to exclude others from harvesting benefits from its use* (Ostrom, 1990, 2008b). In more technical terms, a CPR typically has a core resource (such as oceans, air, forestry), with a defined stock variable, and a limited quantity of extractable units. CPR's face the issue of congestion or overuse, as its inherent nature means resources are subtractable. Therefore the value of CPR's can be reduced through overuse. This is especially true if individuals pursue their own self-interests, above collective gain.

The term CPR can be explored in two ways, namely *commons* and *pool resources.* In academic literature the concept of "*commons*" is generally understood to be an environment or domain that is characterized by an open access problem, being difficult to bar others for accessing the resource (Fennell, 2011; Hess & Ostrom, 2008; Ostrom, 2008b). Ostrom describes commons as "*long enduring, self-organized, and self-governed system*" (Ostrom, 1990, p. 58). These differing definitions should be used in unison when describing and understanding what commons are. This contrast with CPR's, as one person's use subtracts from another's use, given the physical nature of natural commons. Thus, CPRs are "open" in such a way that it becomes difficult, but not impossible, to define and exclude users. As Ostrom & Hess (2008) illustrate, "*each person's use of such resources subtracts benefits that others might enjoy"* (Hess & Ostrom, 2008, p. 11). Overuse of a CPR, or the reduction of another person's benefit, has generally been termed as *tragedy of the commons.*

Due to the inherent characteristics of CPR's, especially *the commons* aspect, arise concerns with regards to the effectiveness of governance and sustainability. The most common and subsequently influential theory as to why users are left to their own devices and fail to manage CPR's sustainably, comes from Garrett Hardin idea on *tragedy of the commons* (Hardin, 1968). Hardin illustrates a situation where pasture land is being used by shepherds to heard sheep. In order to maximize individual benefits each shepherd decides to introduce more sheep to the pasture, leading to overexploitation and depletion of pasture lands, ultimately reducing everyone's benefit. The issue arises due to the fact that each shepherd acts on an individual rational basis, and does not consider a collective (sub-optimal) approach.

Hardin's *tragedy of the commons* can be compared to the prisoner's dilemma and the concept of free riding (Bravo & Marelli, 2008). An important aspect that needs to be taken into consideration is how trust and transparency play a role in this dynamic. With increased transparency in a CPR setting, there is increased trust, and increased trust could lead to more effective, equitable, and streamlined commons management (Baggio et al., 2016; Cox et al., 2010; DeMotts et al., 2009; Fisher et al., 2010; Ostrom, 1990; Tang et al., 2014; Wendel, 2004). Hardin's depiction of the commons issue applies to a vast amount of different situations, especially for the case of open-access resources (Bravo & Marelli, 2008). Furthermore, Hardin's theory is a compelling explanation as to the underlying reason of overuse in CPR's by rational individuals (Bravo & Marelli, 2008; Hardin, 1968). Subsequently, Hardin

argues that public management of CPR's is a necessity to prevent any form of tragedy of the commons. (Castillo, 2013)

2.1.2 Principles of self-governance

CPR's can be managed by a multitude of different mechanisms, from combinations of government interventions, to market driven mechanics, and communal/local unofficial agreements. In smaller CPR cases, unofficial honour systems are used by involved parties, whilst other times this is done by local agreements. In more complex and larger CPR cases, government intervention and government institutions are the norm and CPR's are partially controlled and managed by local authorities (Ostrom, 2008b; Van Laerhoven & Barnes, 2014). What these different forms of management have in common is that each agreement (formal or informal) specifies physical boundaries of the resource, actors involved, allocation of resources, time constraints, authoritative body, sanctions, and enforcement means (amongst other mechanisms) (Ostrom, 1990). Thus, these different fruitions of CPR's and management mechanisms highlight the diverse and complex nature of CPR management. Here the question arises, as to which mechanisms or forms of management are best suited for CPR's?

1. **Clearly defined boundaries**
   Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.
2. **Congruence between appropriation and provision rules and local conditions**
   Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labour, material, and/or money.
3. **Collective-choice arrangements**
   Most individuals affected by the operational rules can participate in modifying the operational rules
4. **Monitoring**
   Monitors, who actively audit CPR conditions and appropriator behaviour, are accountable to the appropriators or are the appropriators.
5. **Graduated sanctions**
   Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.
6. **Conflict-resolution mechanisms**
   Appropriators and their officials have rapid access to low-cost arenas to resolve conflicts among appropriators or between appropriators and officials.
7. **Minimal recognition of rights to organize**
   The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8. **Nested enterprises**
   Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

(Ostrom, 1990, p. 90)

Ostrom (1990; 2008) has made observations that many CPR's are governed effectively by common property protocols based on local self-governed initiatives, pointing towards a possible candidate to the aforementioned question. Ostrom (1990; 2008) believes that CPR's should be managed locally, which counters traditional belief that states that CPR's should be privatized or institutionalized to prevent overexploitation self-interested behaviour, and thus tragedy of the commons (Hess & Ostrom, 2008; Ostrom, 1990; Partelow et al., 2019). To aid the development of local and endogenous management principles, Ostrom (1990) identifies eight design principles, which are seen as cornerstone characteristics for stable CPR management protocols.

The creation of these eight design principles was Ostrom's response to the challenges in the processes of developing institutions for self-governance (Ostrom, 1990). Given the complex and dynamic nature of CPR's, developing comprehensive common property protocols can be challenging. Firstly, common

sets of rules have to be developed for the management of CPR's and who bears the costs of the new institution. An important observation that must be stated is that user agreement on coordination do not inherently imply common agreement on rules.

2.1.3 Neighbourhood as a commons

Foster & Iaione (2018), similarly to Ostrom's (1990) work, have conducted a meta-analysis of 100+ cities and 200+ urban commons to test whether Ostrom's (1990) design principles for self-governance hold up for a modern commons setting. Foster & Iaione (2018) propose that a different approach is necessary to bridge commons and urban studies, hence they propose a new set of design principles for self-governance. Using a neighbourhood as a commons example, Foster & Iaione (2018) propose a new sub set of design principles for commons governance. In the paper written by Foster & Iaione (2018) the design principles of a "*Co-City*" are proposed, with supplementary design principles for improved self-governance effectiveness. Examining a different modern CPR setting, such as outer space, research illustrates that factors such as boundary setting, monitoring, and conflict-resolution are indispensable, requiring a specific sub set of design principles (Aoki, 2018; Goehring, 2021; Lal & Nightingale, 2014; Venkatesan et al., 2020). This new sub set would build upon Ostrom's (1990) existing work.

Traditionally speaking, commons settings are thought of as meadows, fisheries, or forestry's and usually have had an agricultural element associated with it (Berge & Laerhoven, 2011; Gardner et al., 1990; Hardin, 1968). Since this development, new commons have been developed, introducing multiple complex social dynamics, as well as new resource characteristics and resource dependency (Berge & Laerhoven, 2011; Mantilla, 2018; Sestáková & Plichtová, 2019). These developments are not limited to only agricultural settings, but also far newer settings (F. A. Foster, 2016; S. Foster & Iaione, 2018; Huron, 2015; Sestáková & Plichtová, 2019; Spiliakos, 2019). Neighbourhood commons differ greatly from the more traditional commons in distinct ways. City commons can be thought of as urban assets such as: community gardens, parks, shared/ community managed neighbourhoods, and urban infrastructure (S. Foster & Iaione, 2018, 2020; Ostrom, 2005). Neighbourhood commons are spaces that are increasingly more urbanized or digitalized, creating a whole new interplay between principles for self-governance designed by Ostrom (1990) (S. Foster & Iaione, 2018; Huron, 2015; Sestáková & Plichtová, 2019). Especially within the increasingly developed city landscapes, communication, awareness, and monitoring are reliant and facilitated my technological means. Whereas decision-making processes, policy development, and implementation are still done in an analogous manner (S. Foster & Iaione, 2018; Sestáková & Plichtová, 2019). This discrepancy in approaches for whole systems leads to inefficiencies and incompatibilities; these can be avoided. An important aspect in this development, is that globalization and the interconnected society modern humans live in has resulted in an increasingly nested commons setting (S. Foster & Iaione, 2018, 2020; Sestáková & Plichtová, 2019). This trend in urban-/digitalization has created new challenges for commons neighbourhood governance and potential opportunities for blockchain implementation.

What these new digitalized and urbanized neighbourhood commons have is something that needs to be capitalized on: they offer rooms for "public entrepreneurship" (S. Foster & Iaione, 2018; Gardner et al., 1990; Ostrom, 2005; Sestáková & Plichtová, 2019). In Ostrom's work (2005), public entrepreneurship stems from a highly polycentric commons setting. Opening up of the public sector has led to innovation in facilitating, creating, and promoting cooperation and co-production of CPR specific goods (S. Foster & Iaione, 2018; Ostrom, 2005). Especially in a neighbourhood commons setting, public entrepreneurship is enhanced due to the increasingly polycentric dynamics of modern cities. This leads to more nested enterprises within this commons settings (Carlisle & Gruby, 2019; Ostrom, 2012; Sestáková & Plichtová, 2019). In a cities commons, polycentricity is usually very high,

with multiple and semiautonomous decision making centres present. These centres can range from different segments of society, to different floors of an apartment building, or different municipality departments (Carlisle & Gruby, 2019; S. Foster & Iaione, 2018, 2020; Sestáková & Plichtová, 2019). If the various decision making centres, such as in a complex and multiple dimensional city system, take each other into consideration and facilitate competitive and productive relationships, it can be said that the system is polycentric (Carlisle & Gruby, 2019).

It is important to understand the plurality of commons as seen within city commons, as they require a different sub-set of design principles for self-governance. Factors such as spatial mismatch, multiple jurisdictions, temporal mismatches, and the need for interdisciplinary action become important factors. In larger and more complex systems, cooperation and communication of knowledge become an important consideration, especially when communicating boundaries. Boundaries, in large complex systems, need to address the resource dynamic as well as the human social dynamic. It is a given that larger systems include more social dynamics. In a neighbourhood commons setting, shared spaces and city goods are used by a multitude of different actors. This requires clear delineation of access rights, distribution and allocation of resources, and how these resources are used (S. Foster & Iaione, 2018; Sestáková & Plichtová, 2019). However, the larger the city commons becomes, the more human dynamics and variations in preferences that have to be included. Hence it is important to recognize that in a neighbourhood commons setting there are a multitude of different (in)tangible resources at play, on which differently situated and thinking individuals depend (S. Foster & Iaione, 2018; Nagendra & Ostrom, 2014; Sestáková & Plichtová, 2019). These differing relations and dependencies introduce Ostrom's (1990) concept of polycentricity and raises the question, what is needed to manage a city commons?

These basic empirical observations of theoretical neighbourhood commons setting can be boiled down to a few important characteristics. The characteristics are the determining factors in defining the nature of a neighbourhood commons and thus play an important role in what challenges can be expected in such a setting. According to Hess (2008) & Feinberg (2021) neighbourhood commons can be delineated into smaller segments. Figure 2 illustrates a possible division in neighbourhood sub-commons:

Figure 2 Neighbourhood commons (Feinberg et al., 2021)

The division in neighbourhood commons typologies is a specificity in what sub-divisions can exist, rather than characteristics defining and describing a neighbourhood commons setting. However, these sub-divisions do play an important role when taking the neighbourhood level approach for a

commons setting, rather than the individual sub-division approach. It therefore is important to examine the characteristics of these individual sub-divisions and incorporate them into the greater neighbourhood commons setting. As these factors will comprise the larger and overarching neighbourhood commons setting.

2.1.4 Blockchain & commons

Blockchain technologies share an inherent characteristic with CPR's, namely an open or free nature. This technology could not exist without free software, i.e. free and open source software abbreviated as FOSS (CryptoCommons, 2019; Nofer et al., 2017; Rozas et al., 2021; Yaga et al., 2018). Exact definitions of blockchain differ slightly across various fields. Another captivating definition postulates:

"*blockchains are tamper evident and tamper resistant digital ledgers implemented in a distributed* [multi-nodal] *fashion (i.e. without a central repository) and usually without central authority (i.e. a bank, company or government".* (Yaga et al., 2018, p. 4)

Here Yaga continues to further expand on this definition by stating that, in essence blockchain technology allows communities to record transactions, votes, rules, and regulations on a shared ledger (within the community) (Nofer et al., 2017; Yaga et al., 2018). Under normal functioning of the blockchain, these commitments and decisions cannot be changed by any single individual once published, given the decentralized and multi-nodal properties of blockchain (unless consensus on the blockchain leads to collective change, collectively termed "reaching consensus") (Nofer et al., 2017; Rozas et al., 2021; Yaga et al., 2018). Any application developed on blockchain is independently maintained and managed by a decentralized and distributed group of actors (Nofer et al., 2017). This mechanism makes the blockchain application resilient, and all notes on the ledger, to attempts of alterations or tampering (Nofer et al., 2017; Yaga et al., 2018). Given that the decentralized nature of any developed app on blockchain requires an exact blueprint to be held by each user or node, makes a single altered blueprint stand out and thus not synchronous with the rest of the network (Nofer et al., 2017; Yaga et al., 2018). With the use of FOSS, trust is placed within all users, unlike with proprietary or non-FOSS systems (CryptoCommons, 2019). FOSS has become the standard for any application developed on the blockchain, as more eyes (people) on the source code leads increased chances in finding flaws and tamper attempts. As trust and transparency are essential for any forms of CPR management, blockchain based applications are an ideal platforms for developing new forms of governance mechanisms on (CryptoCommons, 2019; Nofer et al., 2017; Rozas et al., 2021; Yaga et al., 2018).

Blockchain-based governance of CPR's can offer a powerful network, backed by a coordinated number of nodes/users, which transmits and notes the value of a system, and is inherently resistant to censorship and corruption. Working with blockchain on the open commons also implies that it should be harder for any entity controlling the release of the software, rules, or contracts to include malicious applications such as, backdoors, unjust rulings, or resources allocation (CryptoCommons, 2019; Nofer et al., 2017). This would disallow them to target specific users or exploit the CPR, enabling transparent commons management.

Blockchain's capacity to function depends on the manner the network incentivizes users to follow the rules defined in the code and social contracts, as well as acting in the best interest of the network. Acting in accordance with the network results in rewards or *tokens*, which can be used to vote and decide on new developments. This is relatively easy with regards to non-tangible goods, such as data, internet or digital currencies. A challenge is trying to superpose this on natural and physical goods with CPR properties. A possible solution to this issue can be found with the realm of Decentralized Autonomous Organizations (DAO's).

2.1.5 Decentralized autonomous organizations

A DAO is defined as: "*A DAO is a blockchain-based system that enables people to coordinate and govern themselves mediated by a set of self-executing rules deployed on a public blockchain, and whose governance is decentralized (i.e., independent from central control)*" (Hassan & De Filippi, 2021, p. 3). DAO's are open for interpretation, but the main characteristics DAO's tend to adhere to are as follows:

- DAO's smart contract code specifies rules for interaction among people – other governance mechanisms can be present
- Since these rules are defined using smart contracts, they are self-executed independently of the will of the parties
- DAO governance should remain independent from central control

(Hassan & De Filippi, 2021)

A smart contract in essence is a section of code that contains a specified set of rules in programming logic. A smart contract does not necessarily reflect an actual contract between two actors or entities. Rather, a smart contract validates transactions and it validates execution of code (predefined rules) and automates various tasks. In practice, the implementation of smart contracts have the following characteristics (Nartey et al., 2021):

- Atomicity: the smart contract will run entirely, independent of external circumstances
- Immortality: code is only able to be removed if a self-destruct option is executed, removing the whole code
- Availability: whatever has been coded and the associated data is available for all to read
- Agency: code and data is always traceable to the coder
- Synchronous: code is continuously and synchronously executed, in tandem with other smart contracts

Academic literature on DAO's is fairly limited, where the majority of literature coming from computer science journals, focusing on blockchain technology as a technical platform for new blockchain-based applications (Hassan & De Filippi, 2021; Rozas et al., 2021; Yaga et al., 2018). DAO's can fulfil the role of decentralized exchanges, market-based platforms, or decentralized organizations with autonomous decision making processes (Hassan & De Filippi, 2021). This variation in application highlights the novelty of this technology. A DAO can be used to fulfil many different types of functions and should not be seen as a particular type of approach for anyone industry (Hassan & De Filippi, 2021). In its most simple and distilled form, a DAO is a network of stakeholders with no central governing body, is regulated by a set of automatically enforced rules on a public blockchain (Hassan & De Filippi, 2021).

The use of a DAO could enable the automatization of various commons governance processes. Any activity, decision-making process, or physical input into the CPR can be tracked. Tracking would subsequently allow for automatic allocation of rewards, rule enforcement, or sanctions. A DAO could potentially also allow for more efficient and transparent governance procedures. However, a cautious approach needs to be taken towards DAO's, as they are dependent on the intentions of the authors who wrote the code. The role of DAO's in decentralized governance still needs to be explored.

2.1.6 Six qualities of blockchain governance

Rozas (2021) introduces six fundamental "*affordances*" or characteristics in his paper, understood as "*the potential uses and applications these technologies enable*" (Rozas et al., 2021, p. 4). The creation of these *affordances* are situated within common governance contexts, making use of aforementioned

eight design principles of Ostrom's (1990). Rozas et al. (2021) synthesizes these affordances, basing them on the existing blockchain literature, with a focus on literature relevant to the organizational process of communities and governance (Rozas et al., 2021). Frequent keywords and important characteristics of blockchain governance found during the literature review include immutability, transparency, persistency, resilience, and openness (Rozas et al., 2021, p. 5). This framework is used as fundamental research element for this thesis. The six affordances are juxtaposed to Ostrom's designs principles as follows:

Table 1. Summary of the Relationships Between the Identified Affordances of Blockchain Technologies for Governance and Ostrom's (1990) Principles.

Affordance\principle	Tokenization	Self-enforcement and formalization	Autonomous automatization	Decentralization of power over infrastructure	Increasing transparency	Codification of trust
1. Clearly defined community boundaries	✓					
2. Congruence between rules and local conditions	✓	✓		✓		
3. Collective choice arrangements	✓			✓		
4. Monitoring		✓	✓	✓	✓	
5. Graduated sanctions		✓	✓			
6. Conflict resolution mechanisms			✓		✓	
7. Local enforcement of local rules		✓		✓		✓
8. Multiple layers of nested enterprises			✓			✓

(Rozas et al., 2021)

Rozas (2021) defines the six affordances as follows;

1. **Tokenization:** How the blockchain facilitates the creation and management of tokens. Tokenization refers to the process of transforming the rights to perform an action on as asset into a transferable data element (token) on the blockchain.
2. **Self-enforcement & formalization:** Refers to the self-enforcing capacities of smart contracts, which facilitate formalizing rules as code
3. **Autonomous automatization:** How DAO's present new capabilities and challenges. Ensures continuous functioning
4. **Decentralization of power over infrastructure:** How decentralized technologies enable new power dynamics between social and technical power. This affordance refers to the process of communalizing the ownership and control of the technological elements employed by the community through the decentralization of the infrastructure they rely on.
5. **Increasing transparency:** relying on the persistency and immutability properties which enable all users to access the blockchain data. Increasing transparency refers to the process of opening the organizational process and the associated data by relying on the persistency and immutability properties of blockchain technologies.
6. **Codification of trust:** one of the most cited properties of blockchain, which supposedly enables "trust less" systems. Trust less systems are those which enable participants to enter into an agreement, without requiring a third party to provide a certain degree of trust between them.

(Rozas et al., 2021)

The conceptual nature of these six affordances leaves room for interpretation. What follows is a more practical explanation of each affordance.

- A *token* in essence is an abstract form of a *coin*, that is given out or earned. This *token* can be used not only as a monetary tool, but may also represent equity, decision-making power, property ownership, or labour certificates (Rozas et al., 2021). *Tokens* are a conceptual

manifestation and reflection of defined boundaries and norms in a given CPR, earned/received through supply inputs (physical labour, being part of a deliberation process, voting, etc) (Rozas et al., 2021).

- *Self-enforcement* refers to how the rules and sanctions defined are enforced in the commons context. In a blockchain-based context this refers to how the process of smart contracts and automated decisions are defined (how communities defined certain rules regarding the allocation of common resources).
- *Autonomous automatizations* ties into *self-enforcement* and examines the finer details of each rule, law, regulation, sanction, penalty and how these interact as well as how to create a series of triggers that come into action when community objectives are ignored.
- *Decentralization of power infrastructure* refers to the process of distributing power equally in the CPR setting, through decentralizing the decision-making, voting, and rule setting mechanics (in essence through decentralizing the "infrastructure" used to set the boundaries.
- *Codification of trust* occurs due to the public and decentralized nature of blockchain. All the information is held collectively and publicly, and any alteration requires that each user agrees. There is no need for an independent third party to verify or oversee an operation, as this is controlled and managed collectively by the users on the blockchain.

Two theoretical frameworks are subsumed within this section, that of Ostrom (1990) & Rozas (2021); these ground the fundamental theories within this thesis. Synthesizing these into a conceptual framework allows this thesis to expand on and create a new research avenue. Insights gained from Ostrom's (1990) allows for a better understanding of the strengths and challenges in commons management. Furthermore, this theory illustrates a clearer picture of the complex dynamic trust and transparency has in a CPR setting. Rozas (2021) framework allows for better insights within the relation of blockchain based capabilities in a governance application, as well as what implication challenges arise. Ultimately, the combination of these frameworks should propose a theoretical blockchain-based governance application.

2.2 Conceptual framework

To empirically understand what effects a blockchain based application can have on self-governance principles for CPR's, it is important to understand what challenges neighbourhood commons governance faces. This thesis proposes a two-pronged approach in designing a new form of a blockchain based governance approach. Firstly, commons governance in general and neighbourhoods as a commons are analysed in order to identify governance challenges, where section of research aims to answer SRQ 1. Secondly, a theoretical analysis will be conducted to gain a better understanding on how blockchain governance might complement Ostrom's (1990) principles for self-governance. For this, Rozas's (2021) framework is used to discuss affordances between blockchain and Ostrom's (1990) principles. These affordances, supported by research findings, aim to illustrate how blockchain governance can alleviate neighbourhood commons challenges, answering SRQ 3. After this, the emergence of this thesis's theoretical DAO framework (the synthesis of Rozas's (2021) and Ostrom's (1990) theories) is used to follow-up on SRQ 4. The theoretical framework transposes the theoretical neighbourhood, where subsequently this is analysed on the operationalization of governance modes. These differences are assessed, with the goal to propose a working conceptual recommendations for a new and improved blockchain based governance approach. The following page presents the conceptual framework:

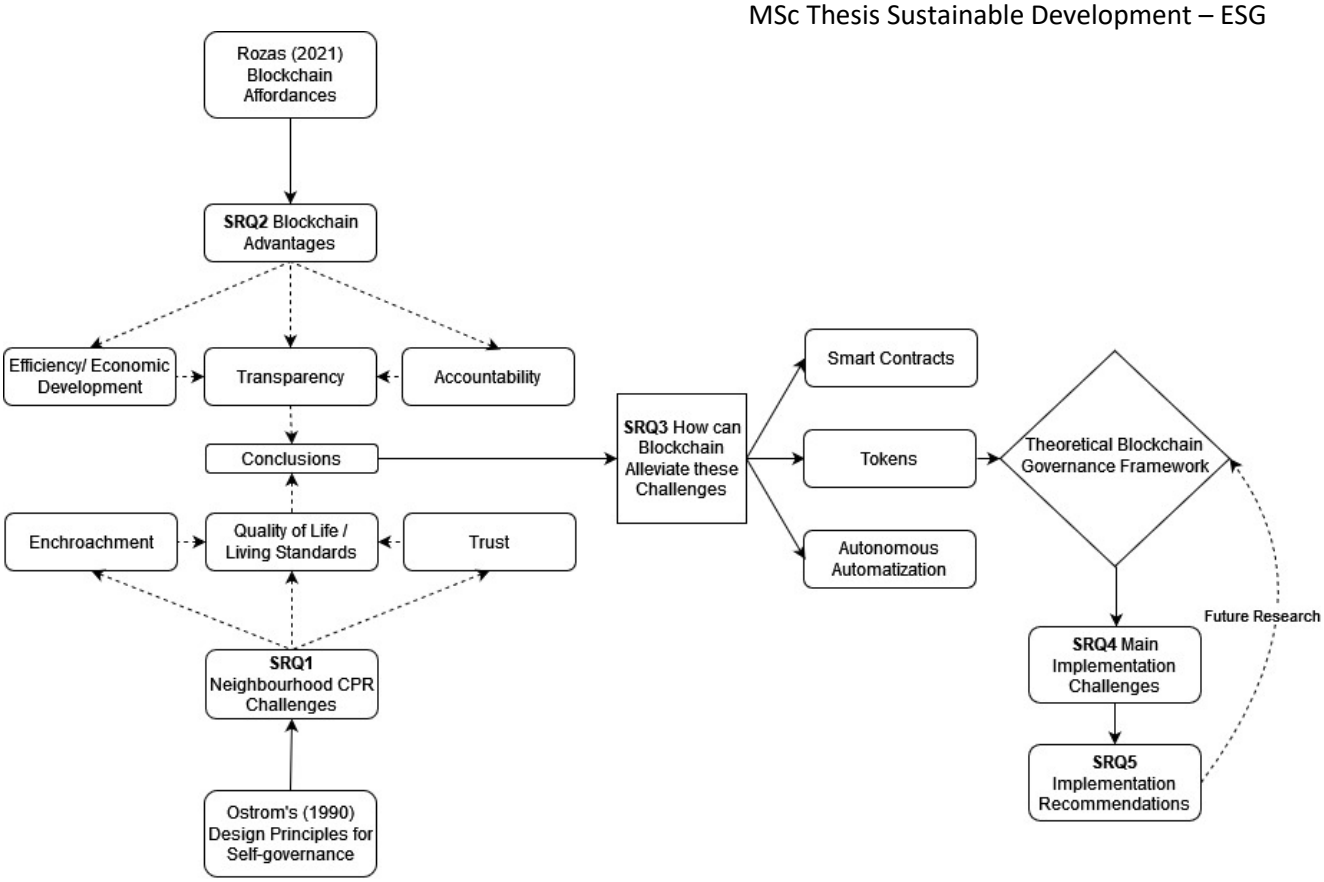


Figure 3: Conceptual Framework

The conceptual framework is derived from the research questions that focus this thesis. The research questions stems from two fundamental pieces of literature, namely a paper written by Ostrom (1990) and one written by Rozas et al. (2021). Ostrom (1990) introduces and defines the concept self-governance, exploring different types of commons and commons settings. Ostrom (1990) further explores general characteristics of various commons formulating principles for self-governance. These principles of self-governance are used as the main analytical framework for exploring what challenges are presented in a neighbourhood commons.

Complimenting to Ostrom's (1990) work, extensive use was made of two papers written by Foster & Laione (2018, 2020), to set a clear understanding of a neighbourhood commons. Other supplementary literature on commons is also used in formulating sub-research question 1 & 3. Rozas et al. (2021) research is the second fundamental literature that this thesis is indebted to. This is because Rozas (2021) explores the similarities found between principles for self-governance and inherent blockchain characteristics. Rozas (2021) describes these similarities as *affordances* and is the basis for sub-research question 2 & 3. This is essential to the understanding what blockchain based governance benefits are, as well as understanding what neighbourhood commons challenges are present. The decision to start with a tow pronged approach, namely sub-research questions 1&2, is made to have a clear and well defined understanding of two different theoretical worlds.

Sub-research question 3 is a summation of two previously disconnected academic worlds, namely blockchain and neighbourhood commons governance. This sub-research questions functions as crossroad, where blockchain, commons governance, and neighbourhood as a commons meet. The challenges identified in sub-research question 1 are compared to benefits identified in sub-research

question 2. After the comparison of benefits and challenges, sub-research question 3 delivers a theoretical analysis of how these challenges are alleviated through the implementation of a blockchain based governance approach.

The decision to conduct a theoretical analysis for sub-research question 3, stems from the current difficulties in implementing such a framework in real life. To add legitimacy to this theoretical analysis, supporting findings in similar academic papers, as well as later interviews, were used to substantiate findings. To further add depth to the findings of sub-research question 3, a proposed framework is enticed, highlighting how a potential blockchain framework might be established and what role it will have in a neighbourhood commons. This theoretical blockchain framework should not be seen as "the go-to approach/solution". Rather as a framework, it can be used to analyse how affective this blockchain approach is in alleviating neighbourhood commons challenges for a specific occurrence. Furthermore, this theoretical framework also functions as a tool to analyse what implementation challenges exist in this specific occurrence.

Sub-research question 4 presents findings on what implementation challenges occur. These implementation challenges are challenges identified when introducing a blockchain based governance approach for a neighbourhood commons setting, specifically for a setting as described in the theoretical framework presented in sub-research question 3. The identified implementation challenges are evaluated on their impact for successful implementation of a blockchain based approach.

Sub-research question 5 summarizes the identified implementation challenges and presents possible solutions and recommendations in order to alleviate these implementation challenges. Furthermore, sub-research question 5 presents points for further research, which can be used to improve findings in sub-research question 4. Following thereafter is a brief overview of the most important sources per sub-research question and the role these sources played in shaping this thesis (additional unlisted academic sources have been used to substantiate and corroborate the following sources):

Sub-research question 1

The sources mentioned below are cornerstone papers used for this research question. These sources critically explore commons and principles for self-governance, as well as, introduced urban settings/ cities as a commons. Through this literature, a definition and scope for this thesis is created, namely a neighbourhood commons settings. This is managed by specifically focusing on neighbourhood commons challenges such as encroachment quality of life, and socio-economic development.

(Baggio et al., 2016; Cox et al., 2010; Feinberg et al., 2021; Foster & Iaione, 2020; Gardner et al., 1990; Ostrom, 1990; Schlager, 2016; Teck et al., 2014)

Sub-research question 2

Sources used for this research question aid in shaping an improved understanding of the fundamentals of blockchain functionality, as well as, what potential benefits a blockchain based governance approach holds. Important characteristics such as transparency accountability, automatization and decentralization are identified.

(Ali et al., 2021; Barnes & Xiao, 2019; Calcaterra, 2018; Rikken et al., 2019; Rozas et al., 2021; Shackelford & Myers, 2017; Tan et al., 2022)

Sub-research question 3

Combining the results and sources of the two previous research questions, conclude important considerations to be missing, in how blockchain can alleviate neighbourhood commons challenges. The following sources are used to fill in this gap, with many of these papers analysing relevant blockchain commons settings (albeit not neighbourhood level related). It is here where this thesis introduces possible positive effects of blockchain implementation such as incentives, accountability, efficiency, and agency.

(Allessie et al., 2019; Attaran, 2022; Cerf et al., 2020; Cila et al., 2020; Deshpande et al., 2017; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021; Tan et al., 2022)

Sub-research question 5

The sources for this research question are used due to their analysis of existing blockchain based governance projects around the world. Significant design dilemmas are identified in various social governance settings, generalizable across all cases. Transparency vs privacy, automatization vs human interpretation, and incentives vs manipulation are just a few of the design dilemmas identified. Furthermore, these academic papers highlight technical difficulties, which are also found in a neighbourhood commons.

(Allessie et al., 2019; Attaran, 2022; Battah et al., 2021; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Nartey et al., 2021; van Pelt et al., 2021)

Sub-research question 6

The following papers analyse various blockchain governance policy directives and their effectiveness. These papers presented recommendations for improved future blockchain implementation, and are generalizable for a neighbourhood commons. Most recommendations revolve around technical and design issues, rather than actual implementation issues.

(Alam, 2020; Allessie et al., 2019; Lustenberger et al., 2021)

3 Methods

3.1 Research Aim

This thesis aims to gain an enhanced understanding of the potentialities blockchain can offer with regards to managing a neighbourhood commons. Furthermore, the identification of governance challenges within blockchain applications is a major component of this thesis. These are dependent on the variation of blockchain framework and the characteristics of the neighbourhood. Besides these foci, this thesis intends to shed more light on challenges faced by neighbourhood CPR settings, the applicability of blockchain to solve these challenges, and the challenges blockchain presents with regards to commons governance. The ultimate goal of this thesis is to introduce and connect the two theoretical worlds of commons governance in tandem with blockchain, introducing thereby a blockchain-based governance approach for commons management. The implementation of blockchain technologies will be conducted on a hypothetical neighbourhood and any challenges in operationalization or governance will be analysed and assessed. This thesis aims to deliver three components: firstly, in identifying governance challenges in a neighbourhood commons. Secondly, the different forms of decentralized governance applications for CPR governance. Thirdly, a classification of challenges faced when implementing blockchain technologies as a novel form of commons governance.

3.1.1 Research methods

This thesis makes uses of a mixed methods approach, in a combination of interviews and literary synthesis. The additional use of interviews is expected to lead to more in-depth and richer outcomes. Interviews are conducted with PhD authors, Dutch blockchain & commons organizations, and DAO developers. Additional information is gathered through literary synthesis, desk research, and debates with my supervisor and colleagues.

The semi-structured interviews expect to answer SRQ 1,2,3, and 4. The semi-structured interviews supply information regarding expert's views (both experts on commons management and blockchain) on the applicability and effectiveness of a blockchain-based governance approach. The semi-structured interviews will consist of open-ended questions, to allow for a nuanced and fluid responses. However, the same open-ended questions are asked to all interviewees. Furthermore, an interview guide is used, based on merged SRQs and the theoretical framework. This approach allows for both explorative evaluation and theory testing, with answers of to these questions helping to solve the theoretical SRQs. The interviews will be used to validate/disprove preliminary findings regarding blockchain opportunities and neighbourhood commons challenges. The first planned in interviews are predominantly with commons experts, which helps with the discussion and formulation of a neighbourhood commons setting. Later interviews are mainly with blockchain experts and help with regards to implementation considerations. The interviews will be used to discuss initial findings of this thesis and how these findings compare to thoughts and previous experts research. Interviews with blockchain experts will be used to discuss possible theoretical frameworks for a blockchain based governance approach in a neighbourhood commons setting.

This thesis is a critical theoretical reflection, using a neighbourhood commons lens, to better understand the implications of a blockchain governance approach for a commons setting. Thus, the majority of this thesis is based on theoretical assumptions, derived from an extensive academic basis corroborated by expert interviews. The benefits and challenges identified are based on theoretical assumptions, thus these should be considered as theoretical and academic reflections. The choice for this approach is due to the technical and temporal difficulties. Blockchain as technology and the development of a DAO for a whole new approach requires extensive technical knowledge and financial

capabilities. This is beyond the scope of this thesis, hence the focus on a theoretical reflection and analysis.

Common pool resources research is focused on Ostrom's work, the prisoner's dilemma, and tragedy of the commons (as well as other supporting theories). Blockchain technology will be seen as a tool which can mitigate loss-aversion, facilitate democratic elections, better reflect public opinion, enabling group decision mechanisms, enhancing transparency, and the creation of trust. This necessitates a nuanced approach; these subjective concepts are open to interpretation. The use of interviews is an attempt at objectifying these interpretations into a "standard" definition. A conceptual blockchain framework will be developed for a hypothetical neighbourhood commons, and will be assessed in its capabilities in offering improved common pool resource management tools. The aforementioned theoretical application adds another dimension to this research, illustrating a potential approach design choices for DAO framework. This allows for the operalization of SRQ 5 and see first-hand what implementation challenges arise, adding depth and a critical reflection to this research.

3.1.2 Types of data & sources

Collected data will be split between primary and secondary data points. Primary data points will consist of interviews and discussions. Secondary data sources will be derived from media, journals, and academic literature. A heavy reliance will be put on Nexis Uni, Google Scholar, peer recommended papers, and recommendations from interviews. Interviews will also be used as a source for future references, and will make use of the *snowball* effect.

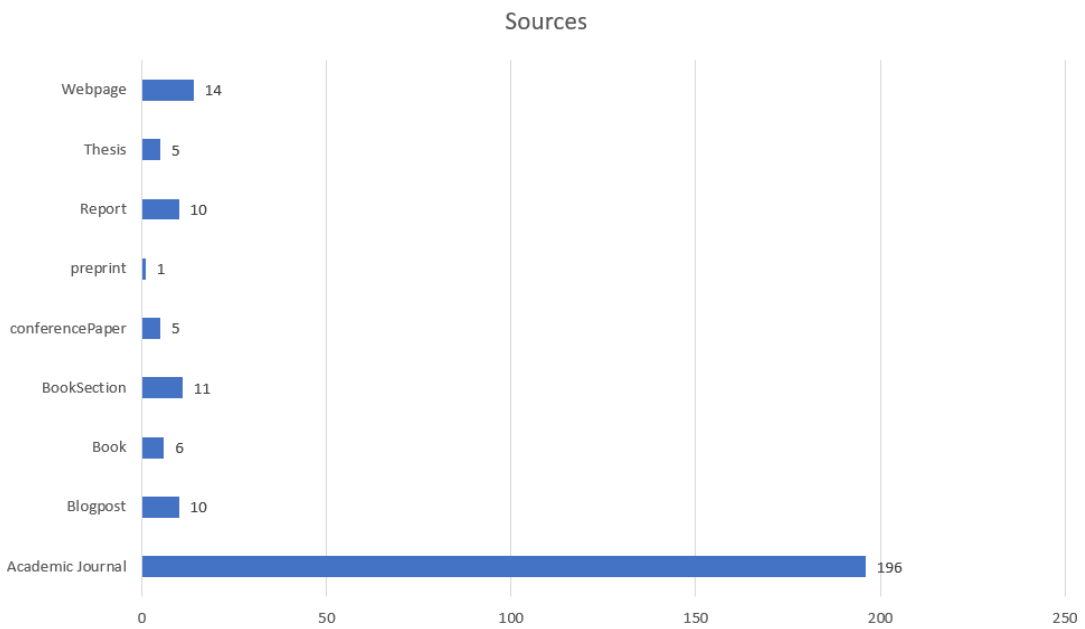


Figure 4 Amount of sources distribution

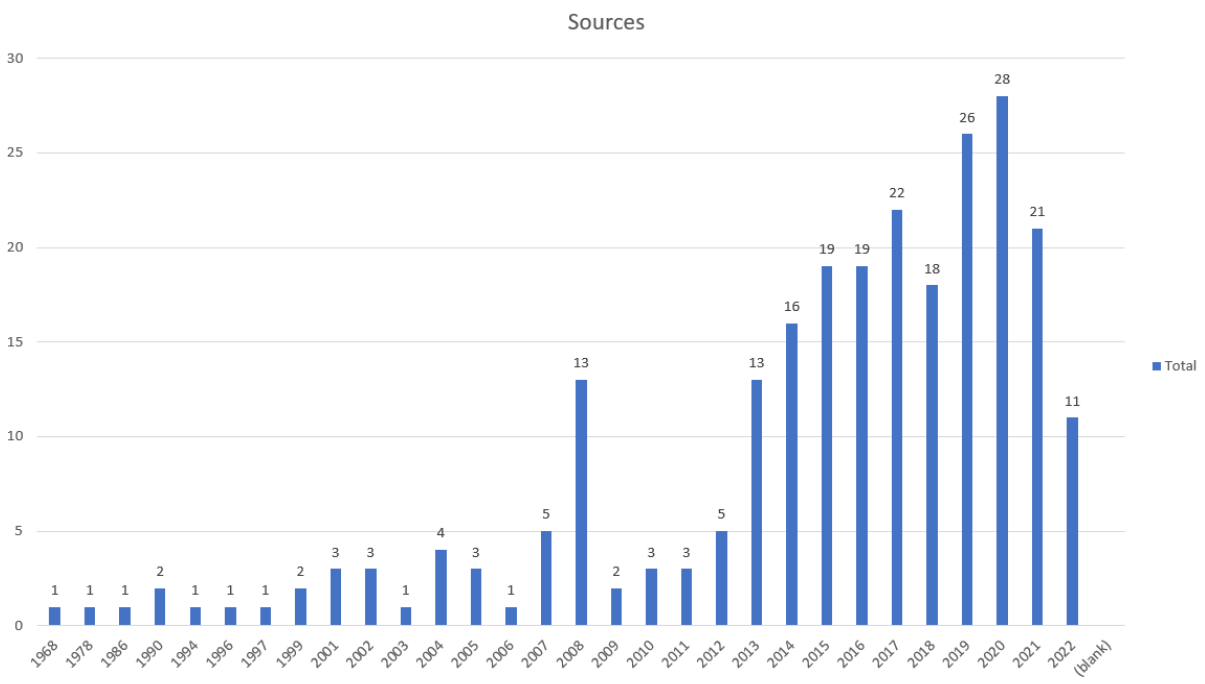


Figure 5 Sources distribution by year published

This thesis also includes an extensive literary analysis consisting of approximately 200 academic peer reviewed articles. These academic journals and the findings distilled there from are supported by 10 expert interviews, of which five interviewees are commons experts and the other five are blockchain experts. To ensure relevancy of this research, a reliance was put on academic sources from within the last 10 years, reflecting the development timeline of blockchain as a concept.

3.1.3 Data measurement

Interviews will be conducted in a semi-structured manner, with consistent and standard questions and sub-questions. However, in order to gain context specific, and research specific information, open ended questions will be used, as well as discussions at the end of interviews (for unfiltered data). The structured questions remain the same throughout all interviews, enabling a meaningful comparison of qualitative data over multiple data sources. Open-ended questions and discussions at the end of interviews will be synthesized into a few returning critical points. Thereafter the project of theoretical blockchain-based framework/application is developed.

3.1.4 Analysis of data

Data is analysed according to the two frameworks developed by Ostrom (1990) and Rozas (2021). This thesis is a qualitative and normative analysis. Theory dealing with commons and CPR management will be further broken down into sub-categories. These categories are further examined for a neighbourhood commons and are used to develop a theoretical blockchain-based governance application. Theories dealing with blockchain and decentralized governance are to be analysed on a conceptual level. Later these are fused together with the theory on commons to create a theoretical blockchain-based governance application.

The interviews will be held using an interview guide, with specific questions objectives per SRQ. This purpose of this interview guide is to ensure consistency in the questions asked. Furthermore,

consistency in the questions asked, will allow for a meaningful comparison of answers. The research guide will consist of both close and open-ended questions with room for exploratory and "free" questions, depending on how the interview develops. This is to ensure that possible unthought information and/ or questions are answered.

3.1.5 Ethical issues related to data collection

Interviews are to be conducted according to the highest standards of academic research, with audio recordings (if allowed by interviewee), transcriptions, and secure storage. No interviews or data gathered will be shared, hosted, or sent to any individual or organization. Any sensitive materials will be left out of any final or public product (if required, all necessary NDA's will be signed). All work, research, and information will be saved on a private Google Drive Account, personal laptop, and a personal external hard disk (used for frequent backups).

3.1.6 Reliability of methods

This research and its results aim to offer valuable insights into the factors influencing CPR governance. Questions such as what governance challenges are most frequent, or what form of governance works best for a specific common, are posed. This requires a nuanced approach, leaving room for interpretation and bias. As this might occur, future replication of this research will likely differ. However, it is believed that the operationalization of Ostrom's (1990) and Rozas's (2021) frameworks into a theoretical application warrants a solid staging point for future research. Furthermore, a qualitative approach is desirable in this research situation, as actual empirical testing is not feasible. The use of nearly 200 academic sources, as well as 10 interviews, underline the effort taken in ensuring bias is removed. The use of such a large set of data points also ensures that a holistic approach is taken in understanding interactions between two disconnected academic worlds. Given the novelty of this research, it is deemed that a qualitative approach is best suited for a theoretical reflection.

3.1.7 Relation to main research question

The aim of the aforementioned steps, methods, and theories, is to pave a possible pathway for the implementation of blockchain in the realm of common governance and the management of CPR's. The expected results are core characteristics of blockchain commons governance, in accordance with Rozas's (2021) framework of *six affordances.* These findings are derived from this methodological section and augmented with Rozas's (2021) framework to create a theoretical framework for blockchain commons governance.

4 Results

The theoretical framework used in this thesis and the five steps of the research framework summate an analysis of challenges in neighbourhood CPR governance, (dis)advantages of blockchain based governance, implementation challenges, and suitability of implementation. In this section, all five SRQs are answered and discussed. More specifically, these results and findings of the SRQ's will present opportunities and challenges faced in the implementation process of a blockchain based governance framework for a neighbourhood commons setting. Finally, a theoretical blockchain framework is presented and discussed. These results are based off the 10 expert interviews conducted throughout the research, as well as literary findings. This theoretical framework will reflect and integrate the findings presented in this chapter.

Concluding this thesis, a brief summary is presented on the findings, possible biases, and points for future research. These findings should be seen as a theoretical reflection of the implementations factors for a blockchain based governance approach to neighbourhood commons.

4.1 What main neighbourhood CPR governance challenges can be identified?

The following section delineates a theoretical analysis of the challenges faced for a neighbourhood commons setting.

The appropriation of a CPR usually leads to a suboptimal outcome, given that characteristic of a CPRs are non-excludability and rivalrous (Mantilla, 2018). When all else is equal, the only variable creating uncertainty in collective management of a resource are social dynamics (Hardin, 1968; Mantilla, 2018). Moreover, a fluid and dynamic environment brings additional problems in a CPR governance setting. Imperfect information symmetries add an additional layer of complexity to the social dynamics of a CPR (Mantilla, 2018). In these dynamic settings, communication and norm-crafting (Ostrom, 2008b, 2015) cannot always adequately reduce the uncertainty in these scenarios (Mantilla, 2018). This is especially true in complex social settings, such as in a neighbourhood. Neighbourhoods are usually comprised of multiple societal layers, containing wide a wide range of ages, educational backgrounds, and social preferences. Furthermore, household composition (alone vs couple vs family) play a deterministic role in defining preferences for neighbourhood development. Information asymmetries can be attributed to the (ir)rationale of human nature and thus is difficult to mitigate in a neighbourhood CPR settings (Gardner et al., 1990; Mantilla, 2018; Ostrom, 1990; Sestáková & Plichtová, 2019). The issue of complex social dynamics is that the irrational action of an individual is based on outcomes which are dependent on the actions of others (Berge & Laerhoven, 2011; Hardin, 1968). In essence, the predominant issue of commons management and CPRs is the social dynamic that are at play, were collective action can result in unpredictable and adverse collective outcome (Mantilla, 2018; Sestáková & Plichtová, 2019). A neighbourhood as a commons setting encapsulates such a complex social dynamic.

Ostrom's design principles for self-governance revolve around actions, which are to be taken collectively. Accordingly, a neighbourhood working towards a preferred outcome, should work collectively to achieve said optimal outcome. Ostrom's work on commons and her meta-analysis on a wide range of different resource commons conclude that the most successful CPR settings were the ones with the most effective and balanced social dynamics (Gardner et al., 1990; Ostrom, 1990, 2010). Hence, depending on how interconnected a neighbourhood is and the quality of these connections, this defines how successful collective action will be. And necessarily, strong interactions within neighbourhood setting are desired. Whereas the interactions with external actors, such as non-resident policy developers or actors, generally lead to reduced success in managing a commons (Berge & Laerhoven, 2011; Gardner et al., 1990; Ostrom, 1990).

Challenges faced in CPR governance, and thus in a neighbourhood commons setting, tend to be of a similar overarching nature. This chapter delves deeper into what this means specifically for a neighbourhood setting. Furthermore, during interviews held with experts a reoccurring challenge was identified specific to this thesis; how to convince communities and actor groups to start using a new commons governance mechanism, e.g. based on blockchain technology. Questions such as: why would a neighbourhood community suddenly implement a blockchain based governance model? Or, how does one sanction a user on a digital platform? Explicitly speaking, a blockchain based governance approach needs to enhance and improve an existing process. It is believed that through a blockchain based approach transparency, efficiency, and decision making power can all be enhanced. This would incentives actors within a neighbourhood commons setting to start using such a blockchain based governance approach. The potential benefits of a blockchain based approach will be highlighted at the end of each sub-chapter.

4.1.1 Socio-economic challenges

Encroachment challenges

Economic growth plays a central role in most economically motivated cities, were international financial interests replace social interests (Harvey, 2012; Simpson, 2014). This economic focus in cities greatly affects neighbourhood commons through; encroaching on open space, privatization/ commodification of pool resources, displacement of social identity and displacement of peoples (Bresnihan & Byrne, 2015; Hodkinson, 2012; Kalb, 2017; Newman, 2013; Petrescu et al., 2016). Due to encroachment there is a higher chance for ***social exclusion*** from the system (Colding et al., 2013; Cooke et al., 2020; Di Feliciantonio, 2017a, 2017b; Gilmore, 2017; Mundoli et al., 2017; Williams, 2018). Thus, there is a need for an exclusion rule in commons management, which can arise from the actors themselves or from a governmental institution, to safeguard quality and the usage of said commons. This exclusion is simple for a physical and extractable commons, such as a tree, fishes, or a meadow. However, for a neighbourhood commons with more abstract resources social exclusion becomes a bit complicated.

Furthermore, social preferences and identity play a central role. Personal preferences can change over time and in such a setting, interests and preferences can and will change. This subsequently might not be in line with what the commons setting originally set out to be. This redevelopment of social identities/ preferences over time can eventually lead to ***social exclusion*** (Colding et al., 2013; Feinberg et al., 2021; Nagendra & Ostrom, 2014; Williams, 2018). International cities further exacerbate this potentiality, where existing and new divergent cultures collide, with different views potentially causing conflict (Di Feliciantonio, 2017b; D'Souza & Nagendra, 2011; Gilmore, 2017; Grabkowska, 2018; Huron, 2015; Rao, 2013). However, Han & Imamasa (2015) argues that ***social exclusion*** being a challenge is false, as a commons do not belong only to the commoners but also its future users and guests (Han & Imamasa, 2015). This can be argued, as there is a difference between more traditional commons and neighbourhood commons, as the latter is relatively porous and loosely defined (Bresnihan & Byrne, 2015; Hess & Ostrom, 2008; Huron, 2017; Zapata & Zapata Campos, 2019).

Challenges in values

Challenges in values are defined as challenges with regards to differing perspectives of value, or worth, of a neighbourhood commons by individual actors. Neighbourhood commons can have a ***lack of incentives*** in prospects or be unable to maintain interest from the community. This stems largely from the socio-economic challenges, with different social ideas and preferences being present. Factors which can influence ***lack of incentives:*** lacking experience in commons "life", general lack of interest, no perceived benefit, not interest in specific neighbourhood/ neighbourhood resource, not

recognizing the commons value (Blomley, 2008; Correa et al., 2018; Feinberg et al., 2021; Ghorbani et al., 2012; Grabkowska, 2018; Hameed et al., 2019; Huron, 2015; Lang, 2014; Łapniewska, 2017; McShane, 2010; O'Brien, 2012; Rocha et al., 2016; Schauppenlehner-Kloyber & Penker, 2016; Teck et al., 2014; Teli et al., 2015).

Financial viability

Distrust, mismanagement, or lacking (financial) support are frequently reasons for commons to distance themselves from governmental bodies or governmental approaches to commons management (Follmann & Viehoff, 2015; Radywyl & Biggs, 2013; Sancho, 2014; Scharf et al., 2019). This increases the difficulty in cooperation with state and commons, which can negatively affect subsidy attainment. Furthermore, self-organized and self-governend commons tend to rely on participating actor input and support. (Aernouts & Ryckewaert, 2018; Bresnihan & Byrne, 2015; Correa et al., 2018; Huron, 2015; Noterman, 2016). However, the effects of social distance between commons and state and the resulting effects it has on **financial support** still needs to be further researched. A potential increase in financial support from a governmental body, sans increased governmental control, could improve the effectiveness of neighbourhood commons management. This is especially relevant for the implementation of an advanced technology, and subsequent support of, as blockchain based governance approach.

Knowledge

Knowledge in whichever form, whether it be digital, science, or practical will, support a neighbourhood commons (Feinberg et al., 2021; S. Foster & Iaione, 2020; Sestáková & Plichtová, 2019). An important factor to take into consideration is how the local/ commons knowledge is used and retained. Issues with missing **knowledge** or biases threaten how the commons actors act with each other and how the commons might interact with external organizations (Becker et al., 2015; Schauppenlehner-Kloyber & Penker, 2016; Teli et al., 2015; Tornaghi, 2017; Unnikrishnan et al., 2016; Unteidig et al., 2017; Wise, 2013). Furthermore, misinterpretation of data or misuse of data can lead to detrimental outcomes when deciding on neighbourhood policy developments.

Neighbourhood communities could fight with the issue of **knowledge re-appropriation**, misuse of DIY technology, or ineffective urban food producing facilities (Tornaghi, 2017; Unnikrishnan et al., 2016; Unteidig et al., 2017; Wise, 2013). An important factor to take into consideration for this thesis, is that the implementation of a blockchain based governance approach requires authentic and accurate data transactions. This presents a second challenge, data mismanagement. Data management could become insufficient, which would lead to non-use of the blockchain application. This requires that the implementation, ledger, and record process are created in such a manner that it adds value to the governing process (Artopoulos et al., 2019; Camps-Calvet et al., 2015; Łapniewska, 2017; Teli et al., 2015). **Communication challenges** can also occur, taking the form of too many superficial users, too many interactive moments, too little physical interactions, and unequal opportunity to access IT infrastructure (Batliboi et al., 2022; Chiu & Giamarino, 2019; Durusoy, 2016; Feinberg et al., 2021; Rao, 2013).

4.1.2 Institutional challenges

Governance

Different commons studies have identified that lacking institutional support leads to less effective commons approaches, which can be distilled to lacking cooperation and lacking polycentricity (Feinberg et al., 2021; Radywyl & Biggs, 2013). Multiple institutional settings can affect how a neighbourhood commons is managed, ranging from lose to rigid institutional support, level of local

governmental autonomy, sanctioning, or perceived security issues. A lose or weak commons infrastructure can make the system more vulnerable to changes in local political settings, deeming it **institutionally ineffective** in the long run (Feinberg et al., 2021; Giannini & Pirone, 2019; Jiménez, 2014; Radywyl & Biggs, 2013). On the other hand, a rigid institution in the commons can lead to **irresponsive** behaviors, requiring extensive time to pass (Arora, 2015; Chatterton, 2016; Grabkowska, 2018; Teck et al., 2014, 2014). This can potentially occur through static neighbourhood design or neighbourhood bureaucratic stalling, requiring a fine balance between a loose and rigid institutional design. **Ineffective institutions** can also be found in too young or to democratic systems, or have inadequate co-government implementation plans safeguarding property rights and social stability (Goldman, 2015; Grabkowska, 2018; Mundoli et al., 2017; Safransky, 2017; Sevilla-Buitrago, 2014; Teck et al., 2014). **Boundaries** are important factors to take into consideration, and should be "fluid or open" enough to allow participation at different levels of the common, being especially true for a neighbourhood commons (Borch & Kornberger, 2015; Feinberg et al., 2021; Radywyl & Biggs, 2013; Schauppenlehner-Kloyber & Penker, 2016; Sestáková & Plichtová, 2019). Extreme cultural, social, or institutional enforcement of boundaries can lead to the creation of "imaginary" walls, which will deter people from joining or participating in the commons (Borch & Kornberger, 2015, 2015; Feinberg et al., 2021). An additional consideration to take into account is the level of autonomy the neighbourhood commons has (Feinberg et al., 2021; Scharf et al., 2019; Unnikrishnan et al., 2016). A neighbourhood commons with very high autonomy might fail to attract **formal** or **legal recognition** from the municipality, which can lead to regulatory issues down the road (Cooke et al., 2020; Feinberg et al., 2021; S. Foster & Iaione, 2020; Scharf et al., 2019; Sestáková & Plichtová, 2019; Unnikrishnan et al., 2016). However, to little autonomy (i.e. extensive integration with the municipality) can lead to the aggravation of political agendas and inequalities, leading to a loss of **recognition** from the public (Bresnihan & Byrne, 2015; Bunce, 2016; Camps-Calvet et al., 2015; Łapniewska, 2017). Both of these examples are extreme case scenarios, however remain important to take into consideration.

Land accessibility

Neighbourhood commons are usually located within densely populated cities, with existing pressures on land availability. Increasing land development pressures such as encroachment of open spaces through commercial commodification of open spaces, commercialization of neighbourhood property, increasing legal regulations, and competition between commons all lead to a reduction in land **accessibility** and **availability** (Feinberg et al., 2021; Huron, 2015; Jain & Moraglio, 2014; Petrescu et al., 2016). It thus becomes important to address these issues when creating a blockchain based governance approach for the management of a neighbourhood commons. Facilitating equitable and "open" access to the neighbourhood and all property it contains has to be balanced out with local municipalities and other non-state actors (Blomley, 2008; Colding et al., 2013; Nagendra & Ostrom, 2014; Safransky, 2017; Tornaghi, 2017).

4.1.3 Physical challenges

Neighbourhood commons are increasingly experiencing expansion and densification of property and shared spaces, leading to unwanted land use changes, degradation of shared spaces, and **encroachment** of shared spaces (Chiu & Giamarino, 2019; Derkzen et al., 2017; Feinberg et al., 2021; Rao, 2013; Shah & Garg, 2017; Webster, 2007). A major issue identified during interviews with regards to neighbourhood commons management is the fact that current city societies are dependent lead by technocratic, corporate drive, and capitalistic driven ideologies, leading to frequent **commercialization** CPRs (either **privatization** or **commercialization**) (Di Feliciantonio, 2017b; Goldman, 2015; Huron, 2015; Nagendra & Ostrom, 2014; Petrescu et al., 2016; Rao, 2013; Teli et al., 2015; Unnikrishnan et al., 2016). A neighbourhood example would be the "smart-ification" of cities,

were city municipalities increasingly connect and transform shared spaces, for the purpose of urban recreational zones, special economic zones, or enhanced transport infrastructure leading to transformed "smart cities" (Feinberg et al., 2021; Goldman, 2015; Rao, 2013; Unnikrishnan et al., 2016). This increase in space saturation, leads to increased competition for land, harming urban infrastructure, leading to adverse effects for neighbourhood commons.

4.1.4 What these challenges means for a blockchain based approach

Increasingly so, neighbourhood spaces are being encroached upon by economically driven plans, through commodification and centralization of shared spaces. This conflicts with an emerging social unit and value, one based on collective socio-economic development and integration into a broader sense of a community, such as a neighbourhood commons. This commons is based on values of accessible and communal social and financial infrastructure, which facilitates repeated continuous development of social capital and trust. For such a commons to function properly, it requires available and shared infrastructure facilitating and promoting collective action through reliance on local businesses, creating an auxiliary civil economy focused on supporting social initiatives (Thunder, 2022). Such a commons would not necessarily be independent from a government, but rather co-govern with a relative high degree of autonomy, whilst being accountable to its users and the municipality. Tackling the aforementioned challenges found in neighbourhood commons, requires a collective and active community based approach, of which all actors proactively want to govern in such a manner. Decision making power is deferred from municipality to individuals, and a new form of co-governance is facilitated. What this means for a blockchain based approach, is that the system must facilitate accountability and traceability, but must also reward proactive behaviour and responsive decision making processes from actors. Only when this decentralized transparent power is fully realized and traceable, will effective collective action be facilitated. Follows is a brief overview of the afore mentioned challenges:

Table 1 Overview of urban commons challenges

Socio-economic Challenges	**Encroachment** **Challenges in Values** **Financial Viability** **Knowledge**	Social exclusion
		Lack of Incentives
		Financial Support
		Knowledge Re-appropriation
		Knowledge
		Communication Challenges
Institutional Challenges	**Governance** **Land Accessibility**	Institutionally Effective
		Irresponsive
		Boundaries
		Legal Recognition
		Accessibility
		Availability
Physical Challenges	**Physical**	Encroachment
		Privatization
		Nationalization

4.2 What advantages does blockchain-based governance approach present?

The collective benefits of a blockchain based governance approach can be broken down into two important characteristics, namely: the distributed ledger aspect and the blockchain technology itself (Allessie et al., 2019).

4.2.1 Distributed ledger technology

In simple terms a distributed ledger (DLT), is a technology, which enables and maintains a list of "transactions", which are chronologically and cryptographically signed and unalterable records, shared and held by all participants of the network/system (Allessie et al., 2019; Poux & Ramos, 2022; Rozas et al., 2021; Tan et al., 2022; van Pelt, 2019; van Pelt et al., 2021). In the semantics of blockchain governance, a transaction on the network does not necessarily define a monetary or fiscal events, but rather a "movement or action". All actors within the network are able to trace any transactional record, irrespective of time, user, or participant. This allows for records to be stored in a decentralized manner, resulting in verification on a consensual collective manner (Allessie et al., 2019). This is achieved through the implementation of smart contracts and algorithms, allowing for responsive decision-making.

"Double counting" is an issue faced when translating physical resources into a digital world. This phenomenon refers to the important consideration that information, as everything else on that is digital and on the internet can be copied by anyone (Allessie et al., 2019). Meaning, in a neighbourhood commons setting people could keep digital ownership over an asset such as a *token*, reputation, or property documents whilst sending an exact copy to a different actor in the network, in essence creating two copies. In the physical world this is traditionally done through third party operators, such as banks or mediators, who act as centralized authorities in charge of keeping track and validating all transactions (Allessie et al., 2019; Poux & Ramos, 2022; van Pelt et al., 2021). DLT change this, by shifting the responsibility of validation to the whole network, eliminating the requirement for a centralized database. Meaning, all network users / actors holds a copy of the ledger, requiring any change in ownership in digital assets to be validated by all users. Simple exchanges can be automated using smart contracts, with predefined and collective imposed rules and thresholds for actionable triggers. This enables increased transparency, monitoring and traceability capabilities and enhances efficiency through decentralization and the omission of third party actors.

4.2.2 Blockchain technology

Essentially blockchain is a DLT, a system or network were value associated exchanges are serially grouped into blocks. Every block carries with it a signature, which links each previous block to one another (Allessie et al., 2019). What sets blockchain apart from previous forms of governing, is that it guarantees, or removes the need for, trust. Currently, any transaction or record in a public domain such as in a commons, requires trust, monitoring, reputation checks, and third party mediation. Blockchain inherently supplies basic benefit's which reduce costs and increase efficiency, namely;

1. The DLT nature of blockchain forces records and data to be held by all users. This makes monitoring and traceability fully disclosable, even for large polycentric systems.
2. The decentralized approach for storage of information and transaction details delivers integrated security into the blockchain based framework. It mitigates potential single point of failures, with no single node being critical for the network to function. No matter the circumstances, the ledger will always be accessible.
3. Any new transaction or record can only be written in an append-only form, being directly linked to a previous transaction (linking the signatures of each block together, forming a blockchain). This means that previous transactions cannot be altered, as the ledger and its

containing information is decentralized. Requiring a change to the appended information is to be approved by all users. This ensures integrity of the system, as no single individual is able to change any entry in the system.

4. Peer-to-peer consensus ensures that transactions are verified collectively, ensuring an authentic and consensually built ledger. There is no need for a centralized third party actor, improving speed and efficiency. This leads to decentralization, shifting power away from an intermediary to the ecosystem. This establishes a power and control mechanism for actors, ingraining a checks and balances system into the technology itself. This can be stacked on multiple levels, depending on the design of the blockchain based framework.
5. Decentralization, append-only, and consensus features remove the need for third party middlemen and any associated costs, complications, and bureaucracy. This decentralization shifts the balance of power, increasing ownership and control over actions and developments. In other words, the implementation of blockchain gives more power to the users of the system, rather than a governmental organization.
6. Leveraging smart contracts and autonomous automatization could increase economic and efficiency benefits. Through defining predetermined triggers, parameters, rules, and action sequences, transactions can be automated. This allows for automatic management of energy, financial payments, monitoring, and sanctioning. In more technical terms, smart contracts implement autonomous algorithms that facilitate a protected framework for digital collaboration, which is not dependent on a central authority. These autonomous algorithms or scripts represent verifiable application logic which helps automates system rules and streamlines decision making processes.
7. Complex multiple and anonymous relationships of modern neighbourhood s impede Ostrom's (1990) condition and design principle of clearly defined boundaries, resulting in increased chances for tragedy of the commons. DLTs ensure that all aspects of a system a registered and recorded, facilitating trust and clearly defined boundaries through technological implementation. This reduces any potentialities of tragedy of the commons occurring in a neighbourhood.

(Allessie et al., 2019; Andersson et al., 2004; Arora, 2015; Carlisle & Gruby, 2019; Cila et al., 2020; Clavin et al., 2020; Huckle & White, 2016; Poux & Ramos, 2022; Rozas et al., 2021; Shackelford & Myers, 2017; Tan et al., 2022; van Pelt, 2019; van Pelt et al., 2021; Zwitter & Hazenberg, 2020)

Overall a major value proposition of blockchain and a cornerstone for the concept presented in this thesis is the idea of decentralization. Blockchain enables disintermediation, as the necessity for independent verification and authority is no longer needed, allowing for increased efficiency and more direct control over policy developments and implementation (Andersson et al., 2004; van Pelt et al., 2021; Zwitter & Hazenberg, 2020). Trust, some say the "lack of trust (trustless)", and consensus rules replace the need for intermediaries. This approach is argued to introduce several technical, social, and economic improvements. Firstly, increased transparency, consistency, and performance of policy mechanisms is expected (Allessie et al., 2019; Cila et al., 2020; Poux & Ramos, 2022). Secondly, reduced bureaucracy is expected facilitated through the decentralization of decision making processes. This decentralization of power leads to increased discretionary power for the actors in the commons. This increased control over direct governance can be coupled with automatization through smart contracts and autonomous organizations, to streamline decision making processes (smart contracts, in essence are automatic and autonomous triggered events imbedded as code into the blockchain system, based on predefined commons rules). Thirdly, accountability is expected to

increase, as direct power is vested in the actors themselves and the inherent characteristics of blockchain facilitate immediate distribution of burdens and responsibility.

Naturally, these efficiency gains are only as attainable as the design of the system, meaning a tailored approach is required. Many examples exist of fraudulent or ill-designed blockchain systems, are always leading to the demise of said system. However, it is expected that with a well-designed and tailored blockchain based system, efficiency can be increased. As mentioned afore, this is achieved through the removal of redundancy, streamlined processes (no middlemen), increased security, lower auditing burdens, and effective data storage (Allessie et al., 2019; Cila et al., 2020; Rozas et al., 2021; Shackelford & Myers, 2017; Zwitter & Hazenberg, 2020). This additionally ensures consistency, with the automatization and streamlining of decision making processes, removing human bias and error.

Thus in a decentralized system, people collectively decide on neighbourhood developments. The absence of any physical settings or rule making frameworks and the decentralized digital nature of blockchain, allowing a direct democracy to be established. Historically speaking, direct democracies have been less efficient, as it required all participants to be physically present to cast a majority vote. However, in a digital domain, such as a blockchain based governance approach, this issue is eliminated to a large degree. It can even be argued that a direct democracy is not as effective or even desirable for (inter)national policy deliberation. Nevertheless, this is beyond the scope of this thesis, with this thesis focusing on a local neighbourhood level of governance. These findings can be summarized into seven overarching benefits:

- Promote local capital development
- Shared space responsibility
- Local financial autonomy
- Local strategic decision making
- Recognizing reputation
- Monitoring & Transparency
- Sanctioning

4.2.3 Promoting local capital development

Promotion of local capital development occurs through the incentivization of commons actors, which is facilitated by the use of *tokens* and increased responsibility and control over the commons. The proposed blockchain governance system will promote meaningful and active participation in the neighbourhood commons, resulting in local social and economic development (Allessie et al., 2019; Becker et al., 2015; Di Feliciantonio, 2017b; Giannini & Pirone, 2019; Grabkowska, 2018; Mundoli et al., 2017; Poux & Ramos, 2022).

The system envisioned for this thesis introduces the concept of blockchain *tokens,* which are generated through various mechanisms in the commons setting. A blockchain based approach enables actors of a neighbourhood commons to directly reinvest and thus develop their local community, through the use of the aforementioned *tokens* (both monetarily and socially). For this to be achieved, a decentralized approach and the *Tokenization* of activities in the local neighbourhood is needed. In essence, a *token* is an abstraction of a coin or a right to perform an action (Rozas et al., 2021). The implementation of *tokens* is not only meant as a digital form of monetary representation, but also holds value as a representation of equity, decision making power, ownership, reputation or as a recognized and certified actionable input (Huckle & White, 2016; Rozas et al., 2021). The ability to *tokenize* actions in a neighbourhood commons provide *affordances* to Ostrom's (1990) design principles and facilitates a new form of governance (Rozas et al., 2021). One of the first principles Ostrom (1990) discusses, is the principle of community boundaries. In a blockchain based governance

approach, *tokens* form new boundaries, especially when using the *tokens* as a form of "action" or ownership (Rozas et al., 2021).

The use of *tokens* should be seen as a construct tool, allowing for granular definitions regarding participation rights, voting, and reputation characteristics. For example, in a neighbourhood commons *tokens* can grant extra privileges to commons services, access to specific infrastructure (neighbourhood parking, botanic garden, library, etc.). More specifically, *tokens* can be used to propose or vote on new commons policy development (Allessie et al., 2019; Rozas et al., 2021). The use of *tokens* in such a manner directly reflects on Ostrom's (1990) second and third principles, namely congruence in local conditions and collective choice arrangements (tokens and the blockchain system allow any actor to initiate or discuss change). Promotion of local capital development is facilitated through the cooperative approach between residents and the local commercial property owners, as both stand to gain *tokens* through local participation. Increased participation in the neighbourhood commons, instead of outside of the commons, encourages value to stay within the local system. Value is defined as monetary value, such as monetary growth and as commons infrastructural development or maintenance. Additionally, value also describes an intangible aspect, one of social connections and community participation. Thus, value remaining in the system means that both economic and social value stay within the neighbourhood commons, rather than leaving the commons and city.

4.2.4. Shared space responsibility / Monitoring & transparency / Sanctioning

The three benefits of shared space responsibility; monitoring, transparency, and sanctioning. These all share many overlapping similarities, hence these are grouped together into one sub-chapter. Shared space responsibility, or shared responsibility, is naturally engrained within the characteristics of a blockchain based system. Unwavering transparency and accountability are accompanied by the distribution nature of blockchain, and somewhat forcibly it hold all actors accountable in managing and checking the system. Increasing the responsibility that actors have increases the degree for self-governance of the neighbourhood commons (Poux & Ramos, 2022; Rozas et al., 2021; Tan et al., 2022). The benefit of implementing a blockchain based approach, automatically enforces accountability, monitoring, and traceability on all actors. The common responsibilities, shares affordances with self-enforcement and formalization of rules, intertwining with Ostrom's (1990) principles for self-governance, namely monitoring and graduated sanctions (Ostrom, 1990; Rozas et al., 2021). The concept of shared responsibility is described by self-enforcement, graduated sanctions, and monitoring. And thus the use of a blockchain based governance approach can integrate and automate principles of monitoring and graduated sanctions into the system itself; in essence embedding self-enforcement into the commons without any room for deviation. This integration can be implemented in a modern manner, through the inherent DLT characteristics of blockchain (as aforementioned).

Blockchain technology, as any other machine, requires unambiguous and clearly defined rules. This requires, tying back to the previous points, detailed and specific formalization of local and collective governance rules (Rozas et al., 2021). The process of collectively, clearly, and explicitly defining governance regulations for the implementation of smart contracts provides an opportunity. The increased attention to rules makes that these rules are more visible and available for deliberation (Rozas et al., 2021). Thus the formalization of rules in greater detail, in combination with self-enforcing blockchain frameworks leads to increased enforcement of local rules and monitoring (Ostrom, 1990; Rozas et al., 2021). This approach, in explicitly defining rules thus requires a holistic and detailed understanding of local needs, forcing commons actors to take more shared responsibility and control.

Neighbourhood commons settings can introduce frameworks of DAOs and smart contracts to create triggered and automated rule enforcements (Rozas et al., 2021; van Pelt, 2019). For example, a

capping of a resource (garden access, commons service funds, solar energy etc.) agreed by on the community, can be automatically enforced when a certain threshold is reached. This prevents overuse of a resource, or warns of forecasted depletion of a resource. Sanctioning misconduct can also be automated, however this is a sensitive topic. Unambiguity of a machine cannot always properly assess intricate details of social interactions, and thus caution must be taken with the automatization of sanctioning frameworks (Rozas et al., 2021). An example would be the automatic distribution of locally produced green energy. Energy could be proportionally distributed, relevant to the amount of action put into the commons per actor can (i.e. more input in the system leads to a greater allocation of locally produced green energy). Another option would be to redistribute commons resources to those most in need, dependant on what the commons wants and how the system is designed. This automatic distribution, recognition, and measurement is facilitated through the inherent ease of monitoring and traceability on a blockchain system (Poux & Ramos, 2022; Tan et al., 2022; van Pelt, 2019; Zwitter & Hazenberg, 2020). As these examples illustrate, a multitude of options and applications are possible, being dependant on local needs and contexts. The use of smart contracts can improve monitoring and accountability through automated and autonomous rules and governance frameworks. Hence this intensification of responsibility through increased accountability and monitoring, allows for more equitable use and distribution of commons resources. Through a DLT, monitoring is encoded into all aspects of the neighbourhood commons system, and in the hands of all actors. And this does not require individuals to monitor each other.

4.2.5 Local financial autonomy / Local strategic decision making

Through the implementation of *tokens*, and the incentivizing effects they have on the actors of the neighbourhood commons, it is expected that control over social, political, and economic developments will grow (Allessie et al., 2019; Poux & Ramos, 2022; Tan et al., 2022; van Pelt et al., 2021; Zwitter & Hazenberg, 2020). Being able to formalize governance rules and reward payoffs for social actions, as well as defining *token* allocation for commercial activities enables increased financial autonomy (Drasch et al., 2020; Kim & Chung, 2018; Uzsoki & Guerdat, 2019). The use of *tokens* can allow for the creation of new systems which enable novel governance mechanisms, such as a system which incentivizes common objectives (Drasch et al., 2020; Rozas et al., 2021; Uzsoki & Guerdat, 2019). Furthermore, *tokens* allow for passive work to be *token*ized and used on the blockchain as a bargaining tool (Uzsoki & Guerdat, 2019). The introduction of *tokens* leads to new revenue streams for actors, improving a new cash flow and reducing any need for a central authority validating transactions. This can potentially introduce new business models to the commons, diversifying the neighbourhood. The use of tokens creates room for peer-to-peer transactions and can kickstart a "sharing economy" (Deshpande et al., 2017).

All financial transactions occur, to a certain extent, within the neighbourhood commons. This recenters fiscal power to neighbourhood levels. Residents and commercial properties with the neighbourhood commons contribute funds to the *neighbourhood finance fund.* The use of *tokens* allows tax spending to be more responsive to local requirements and increases accountability of actors within the system (Drasch et al., 2020; Freni et al., 2022; Hulsemann & Tumasjan, 2019; Kim & Chung, 2018; Uzsoki & Guerdat, 2019; Voshmgir, 2020). A use case for *tokens* can be specific tax *tokens:* these can be assigned to wallet holders. These specific tax *tokens* are to be used for more sensitive public service decisions such as healthcare, education, security (Allessie et al., 2019; Feinberg et al., 2021; Poux & Ramos, 2022; van Pelt et al., 2021). Consequentially, the benefits for local financial autonomy are derived from increased say over developments in the system and the commons. This incentivizes to purchase and act locally, eventually creating a resilient commons (Fraga-Lamas & Fernández-Caramés, 2020; Work, 2018). The implementation of a blockchain based governance system for a

neighbourhood commons setting also allows for the introduction of a "Time Bank" (TimeBank, 2013). A relatively old framework, which essentially registers work done by an individual per hour as a currency, which can be exchanged for other services or products. It is defined as "*A time bank is a reciprocity-based work trading system in which hours are the currency*" (TechTarget, n.d.). Through the use of *tokens,* this time based currency adds to financial autonomy and possibilities of a commons system, through diversification of socio-economic opportunities (Anderson et al., 2002; Brunette et al., 2020; Mitchell, 2013; OECD & World Trade Organization, 2019).

An important factor for increased local strategic decision making, is transparency and trust. As with financial autonomy, the use of *tokens* and decentralized governance allows for more direct collective control of the neighbourhood commons. A blockchain based governance approach has the potential to foster a social framework to be established, wherein social actions and operations are tracked and rewarded (Rozas et al., 2021). This tracking would allow for the development of a *Reputation* framework, indicating of the degree of participation in the commons (Rozas et al., 2021). Increasing transparency and recognition of actions by individuals in a community is useful, as this increases the legitimacy of the blockchain process and create a positive sphere of accountability for the actors in the commons (Allessie et al., 2019; Fraga-Lamas & Fernández-Caramés, 2020; Rozas et al., 2021; Uzsoki & Guerdat, 2019). This increased trust in local actors, coupled with increased financial autonomy, eventually leads to improved local strategic decision making, as policies and decision implementations are initiated, curated, and introduced by local actors.

4.2.6 Recognizing reputation

Input in the neighbourhood (communal service, conflict resolution, etc.) can be rewarded by commons users, through allocating reputation to the specific user. The level of reputation does not offer any tangible benefit, but rather it certifies the level of participation of an individual actor. It identifies the level of expertise/ seniority an actor has (or the degree of trust the community has in the actor) (Dennis & Owen, 2015; Hasan et al., 2022; Rozas et al., 2021; Wang et al., 2021). Binding trust to reputation, through automated entries in the DLT, forces actors to behave honestly in the commons (Dennis & Owen, 2015). The purpose of measuring and having reputation is to ensure that accountability of actors in a decentralized sphere is ensured. Using a reputation system also increases the level of trust in the blockchain system (Battah et al., 2021; Huang et al., 2020; Tamang, 2018; Unalan & Ozcan, 2020).

All transactions, regulations, records, policy, and boundaries are discussed and implemented on the blockchain, allowing everyone to hold a copy of the DLT. This is especially vital for the public fund held by the neighbourhood commons, to ensure financial records are not altered. People can easily vote, propose, mediate, and resolve on the blockchain and decisions are done collectively on relatively short timeframe (e.g. 8 hours). This approach only requires a wallet/ device connected to the blockchain based neighbourhood commons framework. Reputation plays an auxiliary role in describing the worth of a proposal. The neighbourhood commons cannot be completely independent from state or country, in essence being a rogue state. There is a need for a representative neighbourhood commons body, which works together with the municipality on a more global level. Having a commons neighbourhood body functions as the liaising body to the municipality, but also as a curator for new commons proposals and mediator in conflict situations. This is because a committee membership is fluid and flexible but also it is based on reputation. The neighbourhood committee is funded by neighbourhood taxes, and presents a platform for discussion, debate, and proposal setting.

4.3 How could blockchain advantages alleviate neighbourhood CPR challenges?

This following chapter delves into more detail on how the afore mentioned solutions can alleviate neighbourhood commons governance challenges, and how the solutions can potentially add value to a neighbourhood commons setting.

As introduced in the conceptual framework, SRQ3 is a figurative crossroad where two theories collide. In Rozas's (2021) work, he identifies *affordances* blockchain shares with Ostrom's (1990) design principles for self-governance. These affordances highlight that there are potential successes in implementing a blockchain based governance approach for a commons, such as a neighbourhood. To better understand how these affordances and potential success might translate, requires careful consideration of what a neighbourhood commons is, and what challenges such a commons usually faces. Through the analysis of urban, city, and neighbourhood commons, various challenges are identified. These challenges are grouped into three overarching themes of challenges:

- Socio-economic
- Institutional
- Physical

After the identification of these afore mentioned challenges, an in-depth examination is conducted on potential benefits a blockchain based governance approach can have in a commons setting. Additionally, reflections from one expert interview are included in the design of this framework. These benefits are based on benefits identified in various similar studies, and are used to corroborate Rozas's (2021) findings and *affordance*. These findings are based on existing functional blockchain products and characteristics and are synthesized into overarching themes:

- Increased financial autonomy
- Promoting local development
- Shared responsibility
- Recognizing reputation and input

To gain a better understanding of the dynamics between these challenges and opportunities, requires the creation of a theoretical neighbourhood with a theoretical blockchain based governance framework in place. What follows is a theoretical creation, with a blockchain based framework illustrated in simplified terms, and how certain aspects are implemented in the neighbourhood commons. The following framework should not be seen as a definitive solution, or best-in-case approach, but rather as one of many possible solutions. Thus the following findings, interpretations, and recommendations are specific to the design presented in this chapter.

The following framework theoretical blockchain framework stems from the identified neighbourhood commons governance challenges. These challenges revolve around agency, socio-economic prosperity, and recognition. In developing this theoretical blockchain framework, it is specifically designed to around the afore mentioned challenges. Special considerations are given to these challenges, in order to design a theoretical framework that positively influences neighbourhood commons challenges. Thus this framework is designed for a specific setting and specific challenges, whereas a different commons might require a different approach and different design. After the introduction of the proposed technical blockchain model, an in-depth analysis will be conducted on how exactly the framework implements the solutions and how these solutions address the challenges.

4.3.1 Theoretical blockchain based governance design

Principally, blockchain based governance frameworks create space for digital commons management and digital governance. This approach to digital governance focuses on facilitating user centred, responsive, and innovative public services (Allessie et al., 2019). This user centric form of governance is aligned with Ostrom's (1990) principles for self-governance, focusing on responsive and local approaches to commons management. Decentralization is a key component, especially in a neighbourhood blockchain based approach, reshaping how actors in the neighbourhood interact with one another. It would enable the transfer of administrative responsibilities from municipality to commons, allowing the municipality to have a supervisory role with regards to transactions, policy, and infrastructure development. This approach would allow for more direct control of actors over the neighbourhood they reside in, leading to more responsive policy and neighbourhood development.

However, none of this matters if there is no congruence between blockchains characteristics, the aforementioned benefits and the challenges identified specifically for neighbourhood commons. What follows is an illustration and explanation on how such a blockchain based governance system could function. This framework is over simplified, with many important mechanisms, numbers and proportions left out, as these values are very context specific. This theoretical framework will be referred back to throughout the results section. Follows are technical considerations and decisions made, in order to design a blockchain governance framework, which addresses neighbourhood commons challenges;

Table 2 Important framework definitions

Purpose	To collectively manage the neighbourhood commons, through a decentralized approach. Enabling direct control and ownership of the commons, actions, and future developments. This is achieved through increasing responsibility and participation in the commons using a blockchain based governance approach.
Voting Mechanism	Quadratic voting, with a cap (Ray, 2021). *Tokens* can be used to vote on a proposal(s), with each consecutive vote costing more to vote (with a hard cap). A hard cap will ensure that holders of many *tokens* cannot abuse the system/ overpower a vote through monetary advantage (to a certain extent minimizing the formation of an aristocracy). Quadratic Voting formula: **Cost to the voter = (Number of votes)^2** I.e. one vote costs 1 *token*, two votes cost 4 *tokens*, three votes cost 9 *tokens*, 4 votes cost 16 *tokens*, etc.. This allows for actors to not only state their preference for a proposal, but also their intensity in their preference.

	Higher intensity votes weigh more in the voting process. Voting cap ensures not one person can "buyout" all other participants.
Governance *Token*(s)	**Blue** *token*(s) for voting (asset token) **Red** *token*(s) for reputation (utility token) *Tokens* can collectively be named after the specific neighbourhood, e.g. *Lombok Neighbourhood Token – LNT token* Blue *tokens* are earned through social and economic activity in the neighbourhood system. Red *tokens* are earned through active participation in policy, policy development, and voting. Reputation slowly dilutes, with longer inactivity in the commons speeding up this dilution process. This is to prevent reputation being skewered towards actors with old age (i.e. accumulating reputation over the years). This dilution promotes active participation in the commons, as participation halts the dilution process. A further differentiation could be made, and naming the blue *token*, coin(s). This would reflect the associated monetary dimension more clearly.
Community (network)	All residents and commercial actors in the neighbourhood. The neighbourhood can be defined in whichever way is deemed reasonable. e.g. one block, a historical neighbourhood, one square kilometre, etc. Outside actors can buy from local stores, interact with residential services, but will not receive any *tokens* and thus cannot participate in the commons. *Tokens* and reputation are commons specific. All actors within the blockchain commons have a unique blockchain address aka. wallet. e.g. 0x05C6fE645A05b7b66ea1c59F2C760d685185df95

	An extremely simplified explanation; this unique string of characters is a specific chain of blocks, i.e. blockchain, defining a unique wallet only accessible to one person. A wallet can be transformed into a QR code or into a chip carrying object (i.e. credit card) or remain as is. The blockchain based governance system would be hosted on a local/private network, based on Ethereum infrastructure. This private network would be disconnected from the main-net of Ethereum removing any current associated infrastructural issues. This network would be solely independent and not require any support from nodes on the main-net. This is, amongst other factors, beneficial for efficiency and security. (Hiremath, 2019)
Fund Management	Neighbourhood Finance Fund is only accessible on consensus basis and used to finance proposals and commons budget services. Is managed by the neighbourhood committee and is essentially a decentralized treasury. The fund is cryptographically secured and the funds ledger is held by each actor of the network. This prevents any misappropriation of funds without network consensus. The fund is “locked” using multi-sig, i.e. multiple signatures (unique blockchain addresses). A predefined set of unique keys i.e. signatures is needed, which through a smart contract activate/ open the neighbourhood fund. In this theoretical framework, the required signatures would be held by individuals from the neighbourhood committee. To access the fund would require a majority vote, i.e. 4/5 committee members.

Table 3 Theoretical illustration of blockchain based governance framework

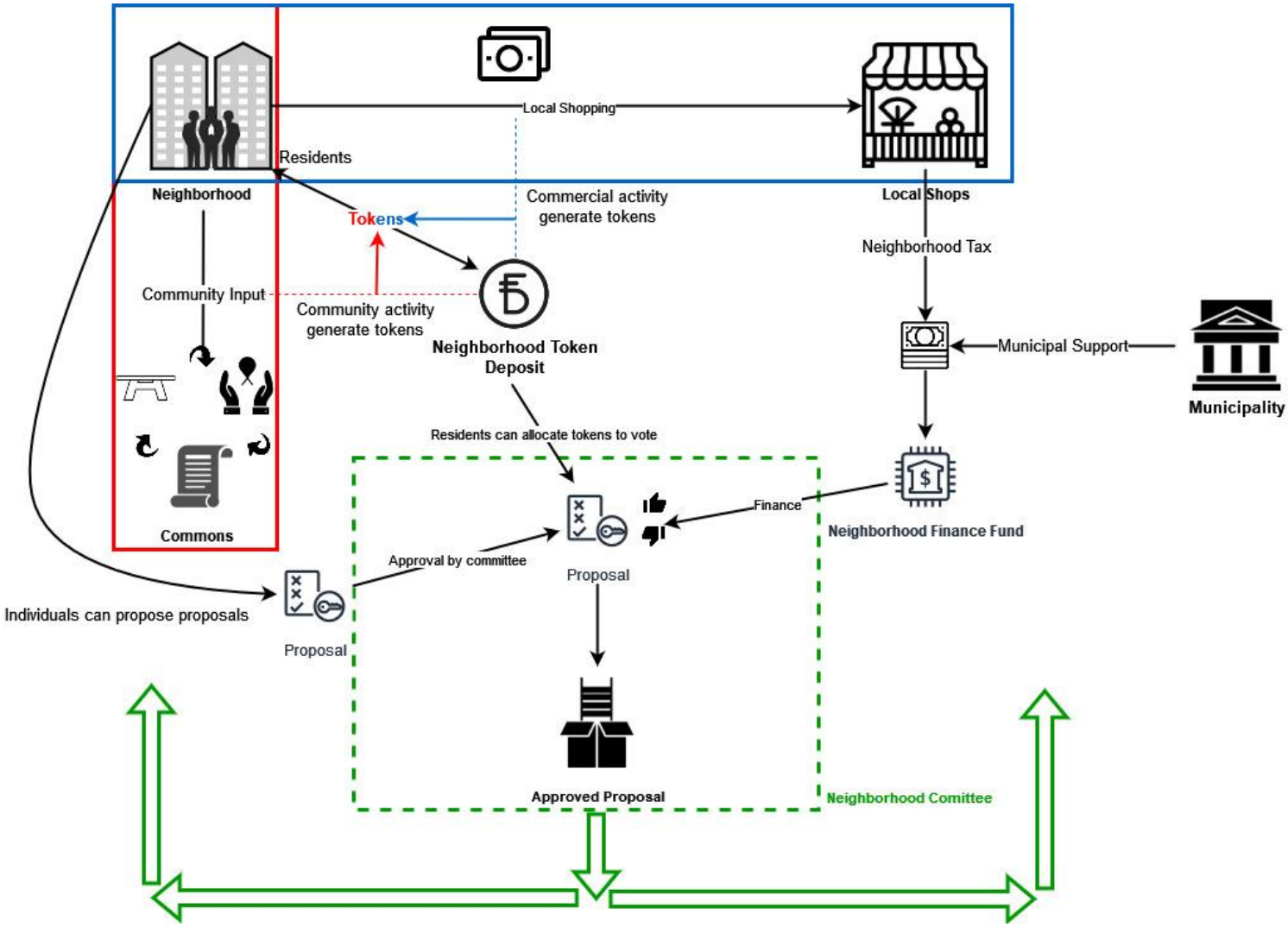


Table 3 illustrates a theoretical blockchain governance framework and how this would conceptually be implemented in a neighbourhood setting. This theoretical framework is designed in a manner to fully utilizes blockchain benefits, whilst addressing the identified commons challenges. Given the digital nature of blockchain, this governance system is transposed on existing neighbourhood frameworks and infrastructure. Existing functions, such as an actor performing work in the commons or purchasing from a local shop remain. These actions get digitally augmented through the implementation of said blockchain governance framework. Given the neighbourhood commons challenge of agency and socio-economic development, has led to the implementation and use of *tokens* (as can be seen above). The use of commercial and reputation *tokens* tries to address the challenges of agency and socio-economic development. Follows is a simplified description of how various interactions, mechanisms, and tools function.

All transactions occur through the local blockchain, using digital payments with any chip baring device linked with a unique blockchain wallet (key fob, mobile, debit card etc). This wallet has a unique address on the blockchain and can be seen as an extension of a social security number (thus is specific to one person). Local business operators should reside within the neighbourhood for neighbourhood *tokens* to be allocated. Purchases done with locally residing business operators or other organizations, result in the creation of neighbourhood "*tokens*", received both for seller/ buyer. For reasons of simplicity, these are the *tokens* generated in the **blue field**, and are **blue** *tokens*. Action into the

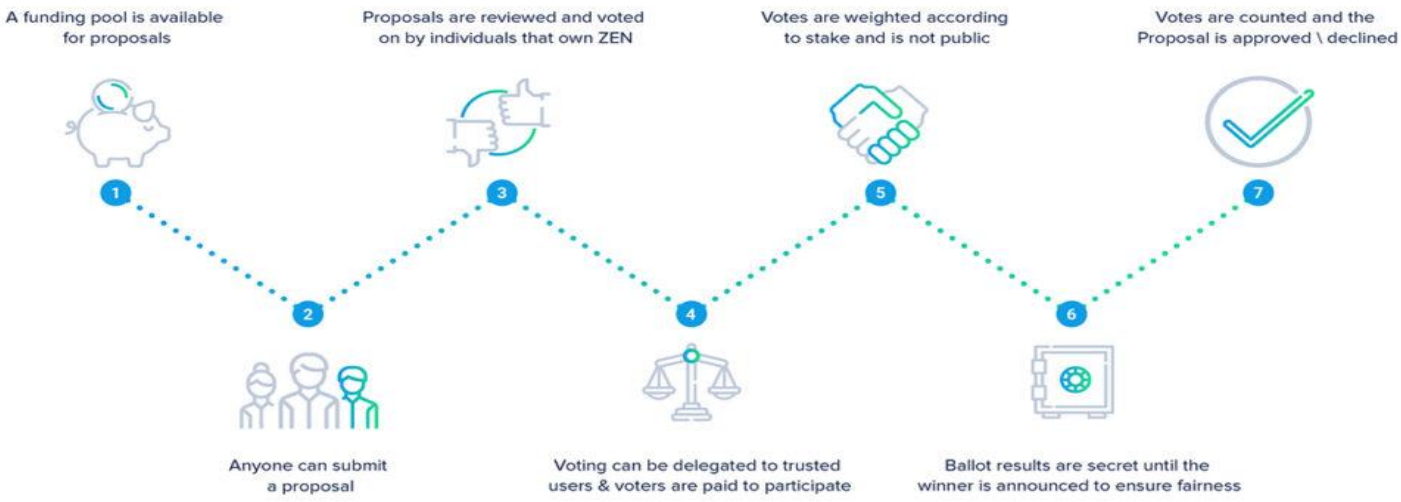
commons, such as gardening, trash removal, volunteer work, event organization, public space maintenance, mediation, etc. also leads to *token* generation for the participating residents. These **red** *tokens* add to a reputation based system, with increased activity in the commons leading to increased reputation for the specific actor. These *tokens* are generated in the **red field**, and are **red** *tokens*. Both **blue** and **red** *tokens* have a use in the neighbourhood blockchain system.

Table 4 Comparison of tokens

Blue *Tokens* (commercial)	**Red *Tokens*** (service)
- Proposal submission - Voting (for / against) - Appeal/ dispute - Neighbourhood committee assignment - Can be collected or spent, specific to one person	- Reputation - Access to commons services - Neighbourhood committee role Cumulative, specific to one person, depreciates over time

Red *tokens* lead to reputation and are used for receiving access for specific commons services, such as elevated/ increased access to a community garden, community tool shed or roles that can be assigned in the neighbourhood committee for the individual. These reputation *tokens* are also earned, at a diminished rate, through voting on proposals. This incentivizes people to vote and participate in the system. Higher reputation equals to more participation in the commons and more potential responsibilities. **Red** *tokens* are collected continuously and are bound to one individuals unique wallet. These reputation *tokens* are not tradeable and unique to each resident, this is to ensure that there is no perversion of reputation rights. **Blue** *tokens* are used to vote on various proposals and can be spent however a person wants. **Blue** *tokens* can be used to propose new proposals on which citizens have to vote or they can be used to vote on existing proposals. Proposals which reach the predetermined *token* staking level, i.e. minimum amount of *tokens* allocated to the voting process, are approved and introduced into the commons setting, financed through the neighbourhood business tax. The **green** field represents the neighbourhood committee, which is elected by the residents of the neighbourhood commons. The tasks of the neighbourhood committee varies from deciding on which proposals to host too communicating with the municipality. Figure 6 illustrates a possible form of voting and what steps have to occur.

Figure 6 Simplified voting process of a blockchain that uses ZEN *tokens* (Smith, 2022)



Business's pay a small neighbourhood fee, which goes into the "*Neighbourhood Finance Fund*". *Tokens* received for citizens are automatically placed in citizen specific wallets, which can later be used for various activities in the community. *Tokens* can be used for commons activities, resources, access rights, or for proposal submission and voting. The municipality supplies a small fee to the blockchain network to supplement business tax, in order to finance commons activities and new proposals.

All residents will be able to see proposal submissions and voting results on their devices, through a dedicated neighbourhood application. Actors will be able to see how many *tokens* they have collected, what their reputation level is, as well as fund levels in the *Neighbourhood Finance Fund*. Furthermore, all residents will be able to view all current proposals awaiting votes, what levels the vote is at, and how long the voting period will last. The application is accessible on all devices, allowing for citizens to vote and propose where and whenever they want.

Follows is an explanation of specific solutions, how these function, and how these are implemented in the framework.

4.3.2 Socio-economic solutions

As Table 4 illustrates, the use of a blockchain based governance systems significantly improves socio economic challenges faced within a neighbourhood commons. Neighbourhood commons, just as any other commons, requires continues development with regards to collective choice agreements and boundary setting (Ostrom, 1990; Rozas et al., 2021; Shah & Garg, 2017; Teck et al., 2014). The development of these boundaries, rules, and policies are all based on local conditions and delineate the form of participation an actor can experience in the commons setting. The implementation of *tokens* and the non-monetary value each *token* holds is stipulated by the neighbourhood and their local needs. Thus, negotiations, access, mediation, and ownership are facilitated by blockchain based governance *tokens* and are designed by the community, in essence defining boundaries through the use of *tokens*. This implicitly implies that the neighbourhood community defines relevant tasks, responsibilities, and communal boundaries to be made visible and interactive through the allocation of *tokens* (Allessie et al., 2019; Fraga-Lamas & Fernández-Caramés, 2020; Rozas et al., 2021; Uzsoki & Guerdat, 2019). Tasks such as commercial activity, (in)tangible labour, mediation, social activity, and

sanctioning will generate specific *tokens*, allocated by collective agreement or recognition (Freni et al., 2022; Hulsemann & Tumasjan, 2019; Voshmgir, 2020).

Tokens add a complementary stream of socio-economic value to the actors of the commons (Drasch et al., 2020; Freni et al., 2022; Hulsemann & Tumasjan, 2019; Rozas et al., 2021; Voshmgir, 2020). This can be automated through the implementation of smart contracts and DAOs, which trigger with specific requirements and fulfilments (as mentioned earlier, smart contracts allow the automatization of predefined rules and triggers in policy contexts and rules to be triggered autonomously through embedded code). T*okens* facilitate a reimagining of power dynamics and boundary setting for neighbourhood commons, through local collective agreements, which define boundaries and operations of the commons, and the addition of a new dimension to the governance structure. Additionally, encouraging actors (residents or commercial properties) to perform work within the commons, such as gardening, building maintenance, volunteer work, etc., by the use of *token* incentives, ensures non-monetary value is added to the neighbourhood. In essence, increased participation in the commons setting leads to more influence in commons developments, ultimately leading to improved socio-economic levels (Freni et al., 2022; Hulsemann & Tumasjan, 2019; Rozas et al., 2021; Thunder, 2022; Uzsoki & Guerdat, 2019). This can lead to improved living standards and quality of life for the residents of the commons.

Incentivization for socio-economic developments stems from various sources, for residents the increase in value in local developments is relatively self-evident. Blockchain based governance system facilitates increased resident power over developments in the neighbourhood commons, increasing connections with other actors and meaningfully rewards for actionable inputs into the system through *tokens* (Allessie et al., 2019; S. Foster & Iaione, 2018; Freni et al., 2022; Hulsemann & Tumasjan, 2019; Voshmgir, 2020). The use of *tokens* affects how actors see and value the system, changing the perceived **challenges in values**. Business benefit from this approach as it can promote increased sales, similarly through the distribution of neighbourhood *tokens*. Instead of purchasing goods online, residents are incentivized through *tokens* to buy locally. This not only increase sales, and local value retention but also fosters greater interactions and possible connections between business and resident. As mentioned earlier, it is expected that citizen participation will increase in the system, resulting in an energetic city. A energetic city in turn attracts more opportunity and is a center for innovation and cooperative value production through cooperative spaces, which in turn makes it more attractive for businesses to settle in the neighbourhood (Castelnovo et al., n.d.; Cortés-Cediel et al., 2021; Ju et al., 2019; Leclercq & Rijshouwer, 2022). Furthermore, through the use of *tokens* and time/reputation based currency, adds to financial autonomy and possibilities an actor has in the commons system. This is achieved through diversification of socio-economic opportunities, addressing further **challenges in values** views. Often times external financial support leads to questions of concern, regarding the **financial viability** of a commons. However, it is expected that the implementation of this blockchain based system, capitalizes on the participatory nature of tokens and decentralized power dynamics. This increase in participation, and the accompanying internal value it creates should lead to more financial stability for the commons, improving the **financial viability** of the commons.

The issue with **social exclusion** is that it can be relatively subjective, especially when diverging beliefs or ideologies collide. Social exclusion in the setting of neighbourhood commons either occurs through commercial displacement, or social exclusion (Colding et al., 2013; Cooke et al., 2020; Di Feliciantonio, 2017a, 2017b; Mundoli et al., 2017). Commercial displacement is the gradual fading of local traditions and an increase in generic enterprises, resulting in a negative effect on local entrepreneurship and inclusion, eventually alienating locals from the neighbourhood (Di Feliciantonio, 2017b; Pastak et al.,

2019; Thunder, 2022). Which means that the generic commercialization of a neighbourhood leads to exclusion of its citizen, through removing the ability to participate in economic and social activity (Pastak et al., 2019). Through the implementation of the blockchain system, citizens retain and foster social and economic value, giving the citizens increased political and economic capabilities to fight against unwanted commercial encroachment. This is enabled through the use of decentralized finance and *token* incentives. This direct financial approach allows citizens to participate and integrate into the commons, reducing the effects of **social exclusion**. Preventing **social exclusion** from happening, whether it be through encroachment or through changing personal preferences, requires strong local support and high perceived value. Through the *promotion of local capital development* **social exclusion** can effectively be addressed. It is expected that with a blockchain based governance approach, autonomy and control is placed within the system and is accessible and affected by all users. The aspect of **knowledge** somewhat benefits from the implementation, requiring constant relay between physical and digital domains. However, **knowledge** present on the blockchain enjoys transparency and traceability, being accessible to any actor on the system. Overall, it is expected that this blockchain based governance framework will effectively improve socio-economic conditions in the neighbourhood commons, if implemented correctly.

Overall, the implementation of a blockchain based governance approach presents a suite of opportunities. Firstly, the automatization of processes and the removal of middlemen has the potential to introduce measurable efficiency gains and cost saving measures. It potentially introduces a new socio-economic revenue stream through the introduction of *tokens*, diversifying the neighbourhood. The introduction of this new socio-economic development can result in the creation of new businesses and economic frameworks, such as a sharing economy (Cila et al., 2020; Deshpande et al., 2017; Gloerich et al., 2020).

4.3.3 Institutional solutions

Referring back to the effectiveness matrix we can see that the implementation of this blockchain based governance framework, leads to a relative high score of 3,9 for success in alleviating institutional challenges. Institutional challenges refer to the form and recognition of governance, as well as access and ownership of land. A Challenge with the implementation of this blockchain based governance approach is, achieving municipal/ government support for the initiative. The implementation of this blockchain approach, or the proposal of implementation does not guarantee success, which is also why **institutionally effective** scores relatively mediocre with 3. Implementing this blockchain approach essentially means that a neighbourhood to some extent detaches from the reach and realm of influence of the municipality, likely resulting in little to no support from the municipality. For a commons to effectively function and prosper, it requires both the commons actors as well as the local municipality to work cooperatively (Feinberg et al., 2021; Giannini & Pirone, 2019; Jiménez, 2014; Mundoli et al., 2017; Ostrom, 1990; Radywyl & Biggs, 2013; Schauppenlehner-Kloyber & Penker, 2016; Sestáková & Plichtová, 2019; Teck et al., 2014). This ties together with **legal recognition**, which is also determined by the state, with increasing neighbourhood autonomy likely resulting in less **legal recognition**.

The implementation of this blockchain based governance framework would institutionally function and add value as an administrative ledger (in this case a DLT). This blockchain framework will automatically and transparently register resource production, usage, account balances, identity, ownership, votes, policies, and rights (Cila et al., 2020; Gloerich et al., 2020; Martín & Smith, 2021; Rozas et al., 2021). A cooperative approach between commons and municipality is needed, which would result in increased autonomy and value of a neighbourhood. The benefit for the municipality would be reduced costs and management resources needed, as this administrative tasks is taken up

by the commons and the blockchain governance framework. This blockchain based governance approach is not applicable to every city and would require proactive participation of a municipality wishing to modernize its neighbourhood districts. Nonetheless, examples do exist were complete or partial autonomy is granted to a neighbourhood with regards to policy and control (e.g. Freetown Christiania, Madrid, Barcelona), resulting in effective commons management of neighbourhoods and public policy development (Bae, 2013; Díaz-Lanchas & Mulder, 2021; Foldvary, 2001; Gomà & Brugué, 1994; Ishii et al., 2007; Martín & Smith, 2021; UNDP, 2014; Wu et al., 2018). Thus, a tailored and cooperatively (commons & municipality) implemented version of this blockchain governance framework would be expected to be **institutionally effective**. Given the monitoring and consensus based algorithmic approach results in a transparent and non-repudiable framework, contributing to fundamental trust in the system (Gloerich et al., 2020). It is expected that cities focused on driving innovation and sustainability will initially test this blockchain based governance system, being more receptive and capable of granting a neighbourhood increased autonomy. A city in which the implementation of a blockchain based governance approach would likely find success in implementation, could be Utrecht (Jiang, 2021; Koster, 2016; Nijland, 2020; Otten, 2015; Tomor et al., 2021; Zuijdam, 2019). Nonetheless, the implementation of this blockchain based governance system could lead to an **institutionally effective** approach, improving local democracy, governance transparency, decentralization of power, and subsequently citizen empowerment (Díaz-Lanchas & Mulder, 2021; Foldvary, 2001; Gloerich et al., 2020; Gomà & Brugué, 1994; Ishii et al., 2007).

Boundaries, as used in the neighbourhood challenges chapter, refer to the degree of participation at different levels of the commons. The implementation of this blockchain framework has a two sided effect on **boundaries**, it quite thoroughly excludes actors who are not directly part of the commons. Whilst, on the other hand, it enables all actors within the commons to participate at any level (Foldvary, 2001; Gloerich et al., 2020; Rozas et al., 2021). Actors are able to participate, propose, and vote on any policy. The use of *tokens* and the reputation system, allows actors of the neighbourhood commons to effectively cross any socio-economic borders (Dennis & Owen, 2015; Huang et al., 2020; Wang et al., 2021). A reoccurring theme in this thesis, are the concepts of transparency and decentralization, similarly coming into effect for **boundaries**. The reputation system allows people to exemplify behaviour, and use active participation in the neighbourhood commons as a means to end. Whether this is to be part of the *neighbourhood committee* or just a sign of recognition or as a tool to gain more access to common resources, is up to the individual actor themselves. Thus, the implementation of this blockchain system builds upon reputation to overcome socio-economic **boundaries,** were reputation is seen as an effective mechanism for creating trust and solving social commons problems (Goetzmann, 2021; Milinski et al., 2002; Ostrom, 2008a; Ostrom & Walker, 2005). It is expected that socio-cultural and politics factors, experience little change by the implementation of this blockchain framework. Existing socio-political **boundaries** will remain, and will be unaffected by the implementation. Overall, the implementation of this blockchain framework is expected to positively affect how **boundaries** are addressed.

An area in which the implementation of this blockchain framework scores low (2), is addressing the challenges of **accessibility** and **availability**. Naturally the whole blockchain based governance system and its resulting benefits are based on digital infrastructure. Any actor, institution, or organization which outside of the commons setting is not bound by any communal boundaries or rules. If an external party wants to purchase land, demolish a building, etc., which is not wholly owned by the commons, they can do so. Furthermore, if the relation between the commons is non-existent or bad, the municipality can decide to undertake similar actions. In essence, anyone acting outside of the commons and with the means to do so, can alter physical aspects of the neighbourhood with little to

no opposition. Thus, the issue is a principle of disconnection between the physical and digital world, poses a significant challenge. To combat this would require extreme collective action in the commons, as well as extensive cooperation and support of the municipality. If the commons can successfully gather enough monetary and political capital (both internally & externally) it can potentially prevent external interference. The municipality has to see the neighbourhood commons as a recognized and independent socio-political body, with equitable power in municipal decision making processes.

Overall, the effects that the implementation of this blockchain framework will have on institutional challenges, is debatably effective. Challenges remain or are even intensified if there is no cooperation between neighbourhood commons and the municipality. Cooperative work on boundary setting and equity is needed. Clear rules on the position of the neighbourhood commons within the sphere of the municipality is needed, as well as the relation between the municipality and neighbourhood commons. If effectively designed and implemented, the introduction of blockchain based governance framework would positively affect how a neighbourhood is governed and functions. The decentralized nature of this system and thus the lack of one central point, could prevent central system failures, facilitating a more resilient and secure system (Deshpande et al., 2017). Furthermore, this blockchain system can empower neighbourhood actors, through putting control directly in the actors hands, increasing trust in the system (Cila et al., 2020; Deshpande et al., 2017; Gloerich et al., 2020).

4.3.4 Physical solutions

Physical challenges link up with some of the aforementioned points, and scores the lowest of all challenges. Many of the same issues facing **accessibility** and **availability** effect **physical challenges**. Issues of **privatization, encroachment,** and **nationalisation** still exist. The implementation of a blockchain governance framework does little to prevent external commons interference, and would require the commons to be in possession and own all physical aspects of the commons. This can cause conflicts with the municipality, as questions of ownership arise. Who is responsible for plumbing, roads, public infrastructure, etc. This is the main shortcoming of a blockchain implementation and a major challenge in successfully and effectively implementing such a governance approach (Allessie et al., 2019; Cila et al., 2020; Clavin et al., 2020; Poux & Ramos, 2022; Rikken et al., 2019; Tan et al., 2022). This disconnect between digital and physical worlds is a major obstacle, potentially disqualifying the concept of blockchain based commons governance. Only if the commons is able to collectively gain ownership of non-governmental property and infrastructure would the actors of the neighbourhood commons be able to address **physical challenges**. The exact implications and limitations are discussed in the following chapter.

4.3.5 Blockchain solutions & summary of results

The following interpretation of the aforementioned research results, challenges, as well as the applicability of a blockchain approach in overcoming these challenges and the expected success in alleviating these challenges:

Table 5 Average success in addressing neighbourhood CPR challenges

(A detailed matrix overview can be found in appendix 8.3)

	Challenge	Average Alleviation
Encroachment	Social exclusion	0
Challenges in Values	Lack of Incentives	+
Financial Viability	Financial Support	+
	Knowledge Re-appropriation	0
Knowledge	Knowledge	0
	Communication Challenges	+
Governance	Institutionally Effective	+
	Irresponsive	++
	Boundaries	+
	Legal Recognition	0
Land Accessibility	Accessibility	- -
	Availability	-
Physical	Encroachment	-
	Privatization	0
	Nationalization	0

This matrix is based on findings and interpretations from literature, interviews, and independent observations. This means researcher bias can be present. These rankings are based on and distilled from a conglomeration of secondary sources of results and findings. Thus these findings are not only based on the researcher's interpretation but are also deduced from supporting academic statements. No quantitative research was done to present these results, and should be seen as a qualitative and normative statement, open to interpretation. Numbers presented in these matrices are based on conclusions and data presented in related academic papers.

The **challenges** identified in the previous chapter are represented on the left side of the table. The **green** boxes represent **socio-economic** challenges, the **blue** represent **institutional** challenges, and **orange** represent **physical** challenges. The scale ranges from - - to ++, with - - being the lowest fulfilment, 0 being neutral fulfilment, and ++ being the highest fulfilment (fulfilment = effectiveness in combating the challenge). A detailed explanation of each individual finding will be presented in the following chapter.

This normative evaluation is based of a larger set of interpretations, found in appendix 8.3, and represent theoretical values. The findings represent perceived success in addressing the identified neighbourhood commons challenges through the approach of the afore mentioned blockchain framework and blockchain opportunities. The findings are based of success and failures identified in other empirically backed research papers, such as *Ali et al. (2021), Allessie et al. (2019), Attaran et al. (2022), Poux & Ramos (2022),* and others used in this thesis. Findings in these afore mentioned papers are extrapolated to similar challenges identified in a neighbourhood commons. The above presented

findings are created to better illustrate identified strengths of a blockchain implementation and in which areas blockchain succeeds the most, which have been identified in previous chapters. Thus these findings should be viewed as a summary synthesis of the previous chapters, illustrated using normative descriptors.

As table 5 illustrates, the implementation of based governance approach in a neighbourhood commons settings has a moderately perceived positive effect in addressing socio-economic challenges identified in a neighbourhood commons setting. This can be seen back in the theoretical framework through the use of *tokens* and the creation of a secondary "artificial" economy in the commons, for the actors to use in commons settings.

Looking at Table 6, institutional challenges, one would assume that the implementation of a blockchain based governance would result in negligible perceived gain in benefits. However, this is not completely the case, as the implementation of a blockchain based approach would fail at addressing certain challenges (**availability** & **accessibility**), and be neutral for **legal recognition**. However, other identified challenges in the institutional category score quite high, with regards to perceived effectiveness of a blockchain approach. The increase over agency and decision making power through a decentralized approach is a fundamental basis of a blockchain based approach and can be traced back to the use of smart contracts and voting mechanisms.

Unfortunately, the perceived effectiveness in addressing physical challenges is low and is a major challenge for the use of a blockchain based governance approach. The following sub-chapters will explain, in greater detail, how these challenges are (not) addressed through a blockchain approach, and which blockchain characteristics have the most potential in positively affecting a neighbourhood commons.

The presented solutions are built upon Rozas's (2021) framework on blockchain *affordances* and incorporate Ostrom's (1990) design principles for self-governance. Furthermore, an attempt is made to illustrate how these solutions are implemented in a theoretical blockchain based governance approach, specific for a neighbourhood commons. The findings are presented as theoretical assumptions and outcomes, given as implementing a blockchain based system for neighbourhood commons governance is beyond the scope of this thesis and requires extensive further research and technical expertise. Table 6 is a summary of the effectiveness of the proposed solutions in alleviating the identified neighbourhood governance challenges (detailed version can be found in appendix 8.3).

Table 6 Summary of success per overarching challenge

Socio-Economic Challenges	+
Institutional Challenges	-/+
Physical Challenges	-

Having discussed how a blockchain approach might introduce opportunities and solutions, it now becomes important to address what implementation challenges need to be addressed. The following chapter sheds more light on various implementation challenges and design dilemmas hinted at in this chapter.

4.4 What are the main blockchain implementation challenges?

As with most emerging technologies, people claim radical changes and improvements or they claim insignificant and counterproductive futures. The same can be said for blockchain, as it has garnered an extremely polarized debate on use cases and effectiveness. Blockchain as a technology is relatively new, and rapidly growing. This brings along a lot of unexplored issues, challenges, and developments. Extensive future research is needed to better understand exactly how and if blockchain could be beneficial as a governance tool. The following chapter attempts to highlight overarching implementation challenges, which will be faced in any commons context. These same challenges are just as applicable to a neighbourhood commons setting as any other setting. Unfortunately, there is no "correct" approach in addressing these challenges. Each commons setting has their unique contexts and requirements, calling for different solutions or approaches. Furthermore, each commons setting will have to address the following challenges in ways best suited to them. Therefore the following challenges do not only serve as implementation challenges for a neighbourhood commons setting, but can also be regarded as general blockchain commons governance challenges. The main implementation challenges for a blockchain based governance approach for a neighbourhood commons are:

- Transparency vs privacy
- Economic vs social value
- Quantified vs qualified values
- Incentives vs manipulation
- Private vs collective interests
- Human vs machine

(Attaran, 2022; Cila et al., 2020; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Poux & Ramos, 2022)

4.4.1 Transparency vs privacy

Transparency has been a fundamental aspect throughout this thesis as well as in other blockchain discussions. As much as it does in promising benefits and solutions, it also poses a major implementation challenge. Blockchains transparency is built on its inherent automatic and autonomous capabilities for monitoring. As with blockchain, commons settings place great importance on monitoring; without it there will likely be no commons to manage. Thus there is a need to monitor users of a commons, not only to ensure over exploitation is avoided, but also to reward input into the commons (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). Although blockchains monitoring could play a key role in commons monitoring, registering data, measuring resource levels, distributing rewards, etc.. The theoretical blockchain based governance framework illustrated in this thesis would measure *token* levels, votes, identities, fund levels, energy production, preferences, how *tokens* are spent, reputation, etc., resulting in high levels of transparency in all aspects of the commons. This allows the commons to see who contributes the most, who to recognize, and who to punish. It also holds all actors and committee members accountable, ensuring boundaries and rules are respected.

However, with such an extensive degree of monitoring and transparency, questions of privacy arise. Patterns, lifestyles, views can all be deuced from data, which all actors hold. Personal concerns, family developments, social orientations are presented in an uncomplicated and naked form (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). Besides private concerns, there are also concerns of health and safety. Even if a commons decide to share information, individuals might refrain from disclosing health details. This can be problematic for energy smart contracts, as

with the omission of certain (health) details the smart contract might distribute energy in a different manner (Cila et al., 2020). Take for example smart contracts regulating energy supply in the commons, and the dependency of certain actors needing consistent energy, for healthcare reasons (i.e. dialysis, breathing mask, etc.). To what extent will this smart contract allocate and prioritize energy during peak moments, i.e. during a block party, as well to actors with greater needs. Besides this situational example, smart contracts function on data and the more data these contracts have the better they function. Challenges arise, when data is left out and certain smart contract thresholds are triggered, irrelevant of what information is missing. A balance needs to be set in the amount of information that is shared and the extent to which smart contracts run the system. Furthermore, *tokens* presented in this system are to a certain extent an abstract reflection of an actor. Whether it be an actors reputation level, or the amount of *tokens* he/she holds. This reflects certain economic and social behaviour, behaviour which an actor might want to keep private. *Tokens* do not necessarily require personal data, rather *tokens* become personal data, and are thus viewable by any actor of the system, as they reflect certain socio-economic levels (Attaran, 2022; Dasaklis et al., 2022; Deshpande et al., 2017; Poux & Ramos, 2022).

Transparency and privacy are sensitive topics, and depending on the need for the commons require different approaches. The implications for a blockchain based governance framework for a neighbourhood commons, is that an actor must be willing to share extensive levels of information, to ensure smart contracts operate equitably. Omission of information would defy the purpose of implementing a blockchain based approach, as data on transactions, ownership, etc. must be known. Furthermore, not using smart contracts diminishes promised efficiency gains. Will actors refrain from joining, if there is a disagreement in the neighbourhood on the extent of information which has to be shared? Eventually this reduces the effectiveness and legitimacy of a blockchain based governance approach for a neighbourhood commons. All of these aforementioned issues can be resolved through the use of a private network blockchain (as in this theoretical framework). However, this requires a central authority or actor, to verify identities of its users and transactions, begging the question of why such a technical framework should be implemented in the first place. This private network also requires that a whole governance structure, database, infrastructure, is created from scratch. This creates a challenge of, who decides on what rules and how they are implemented (Attaran, 2022; Deshpande et al., 2017; Gloerich et al., 2020).

4.4.2 Economic vs social value

In this thesis much value has been placed onto the concept of *tokenization* and the resulting benefits it could bring. Besides the implications *tokens* might have on privacy, they also raise a question of intrinsic value. Outside of a neighbourhood commons and the digital realm, money has a specified value. Products consumers buy in stores have a value, almost everything in our physical world has a defined monetary value, or can be expressed in a monetary value. This is not always the case in a commons setting, especially in a neighbourhood commons, were social actions can be performed as a favour or as a non-monetary form of payment. Furthermore, *tokens* received through commercial activity in the commons system have a specified value/ exchange rate. However, this value is altered through *tokens* received in governance activities or in peer-to-peer transactions. The reputation *tokens* hold different values depending on the actor, as reputation can be perceived to hold different personal value. A challenge arises when defining tasks, and to what extent are tasks measured and valued. Decisions must be made of, whether reputation is based on social or monetary input. Furthermore, how *tokens* are gained through participation in policy development valued. The *tokenization* of various activities in the commons transforms social value into economic value, and

vice versa, which can potentially weaken the meaning of social bonds and activities (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021).

This implementation challenge requires that actors in the neighbourhood commons quantify activities which might not be quantifiable, potentially resulting into a warped view of commons resources, leading to the mismanagement of the neighbourhood. The use of blockchain inevitably brings along the commodification of social aspects, especially when working with *tokens* and reputation. How this is addressed is dependent on local contexts and needs. This commodification of social actions can result in irrational market driven behaviour, defying the purpose of the neighbourhood commons. Actors can collectively decide what value to ascribe to which action or *token*. However, what occurs when there is disagreement in the valuation of an action. This can potentially result in the system coming to a halt, as without a clear definition the smart contracts cannot operate.

4.4.3 Quantified vs qualified values

Ostrom highlights that too much formalization is counterproductive in commons settings (Congleton & Ostrom, 2005). Meaning, that too much formalization, rules, contracts, and code would defy what a commons attains to be and thus would be counterproductive for the commons setting. To many rules does not allow space for human ambiguity and ingenuity. However, a blockchain based governance system requires quantifiable and clear sets of rules (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). Blockchain facilitates the omission of middlemen, through cryptography and transparency. Explicit code, rule pathways, triggers, and regulations need to be defined in a blockchain system. This entails having a formalization of social aspects, which were previously defined in informal and fluid ways (Cila et al., 2020; Poux & Ramos, 2022). Requiring all aspects of the commons to be quantifiable devaluates many social aspects, removing social concepts such as altruism, idealism, and morals (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022). Questions have to be addressed such as, does the quantification of quantified values disrupt existing social and knowledge values, removing concepts of sharing, cooperation, and volunteering. For the benefits of a blockchain system to function, necessarily requires the quantification and coding of almost all aspects of the commons, which stands in contrast to what Ostrom maintains (Attaran, 2022; Deshpande et al., 2017; Ostrom & Walker, 2005). If certain activities are quantified whilst others are not, i.e. garden work is quantified but cleaning the sidewalk is not, do these actions lose meaning and/ or value? This makes certain actions, no matter how qualified in value they are, less valuable or meaningless (Cila et al., 2020; Gloerich et al., 2020). This ultimately incentivizes innovation and creativity, defying the purpose of a commons. It becomes more problematic when public values and informal social relationships are at stake, as these are not easily converted into measurable units. If they are, the risk is that these objectified quantifications obscure their underlying values and dynamics, with citizens internalizing the logic of the quantified system, rather than expressing social preferences (Cila et al., 2020).

Actors in the neighbourhood commons need to examine and understand what role quantification plays, especially in regarding qualified (intangible) social dynamics. *Tokens* can be used to incentivize social participation, but they can also lead to commodification of social actions, with decisions being driven by monetary value rather than social value. Instead of having common sense and social interactions govern policy development, a market driven force will take over and define policy, favouring developments with greater economic returns (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). It is important to understand how a neighbourhood functions, what the neighbourhood values, and what the actors value in the commons. The quantification of “things” that cannot be quantified potentially forces certain standards which do not accurately reflect the nature of an action or the role it has in the neighbourhood commons. On the other hand, not defining

every aspect diminishes the effectiveness of a blockchain system, requiring the neighbourhood to make compromises on efficiency vs value (Attaran, 2022; Dasaklis et al., 2022).

4.4.4 Incentives vs manipulation

Tokens and reputation, as well as the accountability and transparency of a blockchain based governance system might incentivize people to act in a positive manner. On the other hand, acting in accordance to public norms and receiving recognition and reputation might be more important to certain actors than others (Cila et al., 2020; Poux & Ramos, 2022). In a digital domain, badges and other recognizing frameworks can be created, incentivizing actors in the neighbourhood commons to "save a cat" or "help an elderly with groceries". Digital badges for "saving 10x cats" or levels of reputation, can incentivize altruistically driven actors or it can drive selfish behaviour (pressure to be seen as good). As with the reputation system introduced in this thesis, actors are rewarded with recognition of good deeds in the form of reputation. Continuous, conform commons norms, behaviour results in ever growing levels of reputation, and inactivity results in decreasing reputation. In essence, there are a multitude of manners in which reputation, action, goodwill, however it is termed can be recognized and rewarded. How this is done will define if the framework is actually incentivizing or a normative aperture to manipulate certain behaviour (Attaran, 2022; Cila et al., 2020; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Poux & Ramos, 2022).

There is however a potential negative effect in commodifying behaviour in the form of reputation levels or badges, which is social conditioning (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022). A stigma or social pressure might emerge, one which judges users with low reputation levels or not achieving certain digital badges (Cila et al., 2020; Gloerich et al., 2020). In this scenario, otherwise normal and voluntary actions become tasks and chores. Actors will start to internalize rules of the commons, forcing unnatural behaviour (Cila et al., 2020; Poux & Ramos, 2022). Usually, incentives give actors a sense of agency, however incentives can unemotionally also lead to conditioning, nudging behaviour into a specific direction. In relation to the aforementioned challenges faced with quantification, incentives might distort the value of a reward and shift collective action towards rewards with the highest monetary gain, irrelevant of benefit to the commons (Cila et al., 2020; Poux & Ramos, 2022).

4.4.5 Private vs collective interests

Commons contain actors who collectively work together towards a collective objective. However, as is human nature, what the collective wants might not always be in line with what an individual prefers (Cila et al., 2020; Gloerich et al., 2020; Ostrom, 1990). This can hinder collective action, requiring prioritization of views. An example of this challenge occurring, the neighbourhood commons can have decided that all actors donate a fraction of their tokens to the neighbourhood fund. Initially all actors agree, aligned with their preferences of collective benefit and gain. This agreement gets coded into a smart contract and is automatically executed every period. However, as time progresses or due to unforeseen circumstances, a group of actors wishes to no longer contribute to the fund, potentially resulting in shortcomings of funds received. Are the actors who wish to stop contributing to the fund prevented from donating due to the collective agreement, or are they able to choose what they want to do. How does collective action vs private interests get portrayed in the commons, specifically in a blockchain system with encoded rules and contracts. Does enforcing collective action discourage people from joining the system, or does to much freedom defy accountability of the system? This is very important for a blockchain based neighbourhood governance approach, as it decided how resilient and fluid the neighbourhood is. This challenge of private vs collective interests shares close ties with the following limitation and is discussed further.

4.4.6 Human vs machine

If collective interest holds more value than private interest, how does a qualified exception get introduced, if all smart contracts are encoded into the system? Room needs to exist in the blockchain system, which allows for negotiation and human ambiguity. Time and space is needed for successful mediation and conflict resolution, a cornerstone in Ostrom's (1990) design principles for self-governance. It is of vital interest that a blockchain based governance system has room for mediation and resolution mechanisms for exceptions. A challenge with the implementation of a blockchain system, is that rules are already encoded into the system, and thus automatically enforce whatever the code has been told to do (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). Smart contracts, thresholds, and rules have to be encoded before the system can operate, but there is no framework for predicting all possible unique events and exceptions. Any agreements predefined by actors, is automatically enforced by smart contracts, leaving no choice other than accepting the outcome. Effectively this means that laws and rules of the neighbourhood commons are to be made and interpreted algorithmically, irrelevant of what current contexts or external circumstances are (Cila et al., 2020). The code of a neighbourhood commons is written before an event occurs, i.e. "ex-ante", and thus can only regulate what is expected (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022; Rozas et al., 2021). This "ex-ante" approach is what creates the benefits mentioned earlier in this thesis. This creates issues, as once the code is enforced, there is no turning back and this will irrevocably act on everything it has been programmed to do, even if a mistake is recognized by an actor. Thus the implementation of a blockchain system requires adaptability, which is becoming increasingly possible to do. These situational alterations, technically speaking "hard forks", require complete consensus from the system as every node/actor needs to approve the change on their ledger. Needing complete consensus from all actors for trivial exceptions is time consuming and not always feasible (Cila et al., 2020; Gloerich et al., 2020). Thus effectively addressing the challenge of machine-determination vs human ambiguity would remain. Work is being conducted on improved blockchain governance frameworks, which allow on the spot changes of rules (Cila et al., 2020; Gloerich et al., 2020; Poux & Ramos, 2022). However, these are still in development and will require extensive testing. Furthermore, as a regulations are written in algorithmic computer language, a degree of their human ambiguity and flexibility is lost, relating back to the juxtaposition with Ostrom's belief that too much formalization is unfavourable (Gloerich et al., 2020; Ostrom & Walker, 2005).

A solution would be, to have triggers in place for important and determining algorithmic decisions, requiring actors of the neighbourhood to vote before the algorithm continues. As in a traditional commons, not every actor can or wants to vote on every occurrence a decision has to be made, with actors having a limit to the amount of "emergency" calls they would answer (Cila et al., 2020). The benefits of efficiency and "smart contracts" come at a cost of human democratic debate and reasonable interpretation of law. The question then arises, why would a blockchain system be implemented, if essentially it boils back down to neighbourhood actors discussing, debating, and mediating in real life?

Overall the use of a blockchain system is perilous when dealing with complex social dynamics and issues, as can be found in a neighbourhood commons. Informal situations need to be quantified in order to be integrated into the blockchain system, distorting complex social relations. Furthermore, the concept of transparency, as beneficial as it is, might not be the most fitting solution for a social commons. At the same time transparency ensures accountability, whilst also removing any sense of privacy, potentially becoming normative tool to nudge and control actors behaviour (Cila et al., 2020; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020). The introduction of various new

mechanisms, such as *tokens*, reputation, and ability to propose policies, might obfuscate the commons system. Creating an opaque governance system based on complex frameworks of interconnected mechanisms and measurements, being open to misuse and confusion. Unfortunately, a blockchain based governance approach cannot prevent a single, or small group, of actor(s) to become dominate in the commons. As in traditional commons, certain actors might hold more power than others through which ever method. Even in a decentralized governance approach, certain actors might not care, or might be open to collusion with others. There is no real mechanism to check what is said informally in the physical world, and what is done in the digital world, facilitating space for actors to misuse the system (Attaran, 2022; Battah et al., 2021; Cila et al., 2020; Deshpande et al., 2017; Gloerich et al., 2020; Poux & Ramos, 2022).

4.4.7 Technical challenges

Even though blockchain promises to be a revolutionary technology with significant potential for the implementation in a neighbourhood commons setting, it still has significant implementation and development challenges. Besides the aforementioned governance challenges, there are a host of technical challenges which need to be addressed. A multitude of implications and concerns arise when examining storage, processing, costs, and infrastructure. Additionally, blockchain implementations are extremely demanding with regards to energy consumption, raising questions of sustainability and effectiveness (Attaran, 2022; Dasaklis et al., 2022; Deshpande et al., 2017; Kumar et al., 2020; Nartey et al., 2021; Rikken et al., 2019; Tan et al., 2022). This thesis has predominantly on blockchain governance challenges, and to a lesser extent on technical challenges. Further research is necessary to better understand which technical implementation challenges exist. What follows is a non-exhaustive analysis of initial technical implementation challenges:

Hardware Challenges

There is a mismatch between “on-chain” developments and “off-chain” developments, i.e. what happens digitally might not happen physically and vice versa. This would require an actor to play the rule of an enforcer, or would be dependent on the complete honesty of a commons. This might function for a small local community. However, for a neighbourhood commons with actors unknown to each other, this might not work or even be feasible. Blockchain as a technology is still in its very first stages of infancy and is experiencing continuous work and rapid development. Adopting this approach is a gradual process and will come with high costs (Attaran, 2022; Cila et al., 2020; Dasaklis et al., 2022; Gloerich et al., 2020). For this neighbourhood blockchain system to work, it would require extensive network nodes to be present in order to supply computing power to validate, operate, and check thousands of blockchain actions per second (Attaran, 2022; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Nartey et al., 2021). Maintaining such immense levels of computing power, requires significant hardware as well as constant levels of energy, drastically increasing with neighbourhood size (Attaran, 2022). Furthermore, updates, maintenance, or drop-outs, require redundancy measures to be in place, requiring additional hardware. Additionally, this all requires high levels of expertise to implement and operate. A reoccurring theme is the difficulty of translating complex social issues into code, with current hardware finding it difficult to facilitate multi-dimension and multi-faceted data. It is expected that the implementation of such system for a neighbourhood setting can easily cost more than millions of Euro’s to develop, requiring similar levels of funds for maintenance purposes (Davies, 2022). Even with these costs and promises of various gains, it is still not evident that a blockchain system can properly host complex social dynamics.

An additional implementation challenge is the choice in networking frameworks. The implementation of this blockchain system requires extreme levels of technical knowledge, coupled with an extreme

technical understanding of governance mechanics, ensuring that code reflects its governance intention. Furthermore, high costs are associated with the development of such an extensive system, costs which a neighbourhood likely cannot cover. Besides these initial implementation challenges, there are further challenges regarding deployment of hardware, redundancy, bandwidth, maintenance, scalability, and upgradability.

Data Analytics Challenges

With a neighbourhood blockchain system, immense amounts of data are collected, stored, and analysed. This requires efficient data management plans, contingency plans, and ethical considerations. The cost of processing this data must be justifiable for the neighbourhood. Additional challenges arise when trying to connect a blockchain system with other digital systems, and also for what this means for interoperability. For example, how is the neighbourhood commons connected with the municipality? How is information, as taxes or legal rulings recorded, and how is this shared with the municipality (Attaran, 2022; Deshpande et al., 2017)? This technical challenges is closely linked to the aforementioned governance challenges. Protocols and standards developed for the blockchain system might have higher levels of security features, which are not compatible with municipal systems, raising questions of how data is stored and shared (Nartey et al., 2021). Interconnecting with older systems might pose significant cyber security threats, as the connection between a blockchain and legacy system might facilitate backdoor entries. Furthermore, a neighbourhood commons will always remain a target for cyberattacks, whether it be for ransoms, anarchy, or political reasons, requiring continuous and dedicated teams working on cybersecurity.

There is an additional challenge between blockchain principles and legally binding national regulations. Concepts such as GDPR vs complete transparency raise questions of provenance and which legal concept trumps the other. If the neighbourhood commons decide to share all data, is this in breach of national regulations? How are legal jurisdictions defined and implemented, i.e. which law is to be followed and how is this integrated in the blockchain system. Complete isolation of national legislation would essentially create a rogue state of the neighbourhood commons.

Overall, this list of technical implementation challenges is by no means complete. However, it shows that basic concepts already pose immense and challenging implementation considerations, highlighting the novelty of this approach. Additional challenges will be faced in the political realm, with policy and regulation being far behind on the development of blockchain. Questions remain if governments will approve wide and large spread implementation of blockchain systems, essentially undermining their sphere of power. A potential future scenario could see a world where blockchain is not legal recognized as a form of governance and only used for finance and data management. These developments are to futuristic and unstable to predict and incorporate into this thesis and require extensive future research and testing. Furthermore, actors of a neighbourhood commons must want to use and implement a blockchain based system, introducing challenges in adoption (Cila et al., 2020; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Nartey et al., 2021). A multitude of social, political, technological, and organizational barriers still need to be identified and overcome.

4.5 What recommendations for the implementation of a blockchain based neighbourhood commons approach can be formulated?

In order to alleviate the identified implementation challenges and to facilitate effective implementation of a blockchain based governance approach, requires technological and ecosystem maturity of blockchain and DLTs to increase (Allessie et al., 2019). To speed up the implementation and effectiveness of a blockchain based system does not only rely on technological developments, but also on socio-political developments. Technological developments will eventually come far enough that the implementation of a blockchain system should be easy. However, this drive in adoption ultimately stems from changes in governance, societal views, and political regulation. Taking into account the implementation challenges identified in this thesis, four overarching themes of attention have been identified: *Knowledge & Observability, Pilot Use Cases, Institutional Standards*. The development of these themes should lead to the creation of a neighbourhood "ecosystem", which is ready for the adoption and implementation of a blockchain based commons governance approach.

Knowledge & Observability

Firstly, users must be able to understand and use a digital tool, as without any digital literacy this approach will not function. Secondly, all actors in the neighbourhood must be using this blockchain based approach and must be able to access this application at all times. For this to take place, it is a requisite that this blockchain system is observable and that it is deemed to have a relative advantage (Allessie et al., 2019; Lustenberger et al., 2021). Observability requires that local municipalities conduct small scale tests in neighbourhoods, guiding and sharing knowledge with the involved actors. Improved knowledge on how this system can potentially operate, eventually leads to improved adoption rates later on (Allessie et al., 2019). Furthermore, support has to come from (supra)-national levels, in order to develop local expertise, through sharing of best practices and a bottom up approach built on cooperative knowledge production (Allessie et al., 2019). This approach slowly disseminates knowledge amongst actors participating in test runs, and highlight what works best on various scales. Through increased awareness and participation, actors can identify if there is a relative advantage in using such an approach for local contexts.

If technical difficulties are amendable through multiple iterations of a design, and costs of implementation reach a sufficient level, and solutions benefit local contexts, a relative advantage can occur (Lustenberger et al., 2021). However, this is a subjective and context specific matter, as valuating an advantage of an innovation is relatively difficult (Allessie et al., 2019; Lustenberger et al., 2021). A determining factor in disseminating knowledge in the neighbourhood, is how the neighbourhood "ecosystem" is structured (Allessie et al., 2019; Barnes & Xiao, n.d.; Lustenberger et al., 2021; Sternberg et al., 2021). According to Lustenberger et al. (2021), there are three important ecosystem factors which facilitate improved uptake of a blockchain system; i) there must be one actor in the system who puts pressure on the others to adopt, ii) the ecosystem must be large enough for blockchain implementation, iii) the ecosystem must be capable in establishing regulatory certainty for blockchain development and adoption (Lustenberger et al., 2021). The promoting actor is preferably a powerful actor with enough legitimacy to promote a system (i.e. municipality). Essentially, having a ready "neighbourhood ecosystem" boils down to the municipality promoting this concept as well as ensuring regulatory certainty. Without this central municipal role, widespread distribution of knowledge, and a bottom-up approach, the implementation of a blockchain based system will likely not succeed (Clohessy & Acton, 2019; Lustenberger et al., 2021).

Pilot use cases

To complement the previous point, it is deemed essential that local municipalities should support grassroot blockchain projects, incentivizing citizens to experiment with local initiatives (Allessie et al., 2019; Lustenberger et al., 2021). To speed up this process, municipalities should subsidize local neighbourhood projects, focusing on projects which are in line with municipal policy directives. This would enable pilot projects to gain momentum and develop beyond individual capabilities and initial production phases. Eventually, some of these projects can be adopted for test runs on municipal level. This approach further familiarizes neighbourhood actors with the technology, as well as incorporates local needs in the development process. However, this approach relies on expertise and knowledge of actors and are initially focused on local research and technical institutes, rather than neighbourhood actors. Trial and error, through the use of small case blockchain tests, is seen as a major contributor to further exploration of actual benefits and challenges (Clohessy & Acton, 2019).

Institutional Standards

Not only must local municipalities create regulatory and legal clarity, but also larger intergovernmental organizations. For such a blockchain system to function, it needs the legal recognition of (e.g.) the European Union/ Commission. Neighbourhood commons must have a legal space in both local as well as international law, as without this recognition, problems occur. **(Inter)National coordination** must be facilitated, to ensure regulatory certainty is present at different levels and local contexts. Long term national policy agendas must facilitate and focus on the benefits a blockchain system can have, and how this in line with sustainable targets. Grey markets can arise through the use of *tokens,* and questions of legal provenance in court rulings must be defined and understood (Allessie et al., 2019; Attaran, 2022; Cila et al., 2020; Deshpande et al., 2017; Lustenberger et al., 2021). Increased spending allocation must give to the development of frontier technologies, education, research, and connecting industries to encourage robust and modern **digital infrastructure** (Alam, 2020; Allessie et al., 2019; Gloerich et al., 2020). This increased spending must be coupled with increased **education**, introducing grants and incentivizing local research opportunities.

Overall, an effective approach towards the implementation of a blockchain based governance system for a neighborhood commons requires a holistic reimaging of current socio-political norms. A blockchain based system can easily function and be implemented if the main functions are to record and execute simple tasks. However, if the aim of the system is to introduce a new form of governance and act as a fundamental framework in a neighborhood, it requires a reimaging of current socio-political norms and standards. A modern neighborhood is a lose collection of actors with differing preferences, managed through a central municipal authority. The introduction of a decentralized system stands at odds with current socio-political norms. In essence, the implementation of a blockchain based governance system would require creating a “new society” from scratch, with new social norms, rules, and political interactions.

5 Discussion

Foundations laid by Ostrom (1990) have paved a clear pathway in understanding how commons and principles of self-governance function. Since this development, commons have developed from traditional fisheries and forests, to modern equivalents. Commons can now be found in knowledge, science, cities and more, ranging from tangible to abstract. From defining community boundaries to monitoring and to conflict resolution, all of Ostrom's (1990) principles have remained constant and applicable. Occasionally, modern commons require alterations or sub-sets of design principles, with modern commons introducing ideas of decentralization and automatization, with various technologies and frameworks defining these concepts. The creation of blockchain, a DLT, has led to a growing belief that new forms of governance are possible. This thesis aimed to take a deep dive into the analysis of a new commons, namely a neighbourhood commons, by exploring issues faced in a neighbourhood commons and how the implementation of a blockchain system can alleviate these challenges. Throughout this lens, a theoretical neighbourhood was analysed and the implications of a blockchain based governance have been analysed at a neighbourhood commons level.

An in-depth theoretical analysis was conducted using a theoretical framework developed by Rozas (2021). Affordances between Ostrom's (1990) design principles and inherent blockchain characteristics were identified and juxtaposed on a theoretical neighbourhood. This research is based on an extensive literary analysis, substantiated through the use of expert interviews and insights. The findings in this thesis present an exploratory examination of a not-yet developed field of academic research. Commons have been exhaustively studied and understood. However, the field of commons governance and blockchain have just been connected. The theoretical approach in this thesis has contributed as a stepping stone for future research, with these findings adding to the theoretical understanding of how blockchain commons governance might function. Following, various theoretical arguments favouring the implementation of a blockchain governance approach for a neighbourhood commons have been presented. Additionally, practical and realistic challenges have been put forward, challenges which highlight concerns for the implementation of a blockchain based approach. To evaluate these findings, this exhaustive literary analysis was conducted, combined with findings from expert interviews. The implementation of a blockchain based governance approach is two sided. On the one hand it offers efficiency, transparency, and economic benefit. On the other hand, it disregards social value, human ambiguity, and complexity. Multiple design dilemmas are present, ranging from practical implementations to philosophical. Thus, the design of a blockchain based governance approach for a commons must be conducted with a critical and cautious approach.

Blockchain has promised improvements in efficiency and transparency, being beneficial for record keeping and financial transaction. Furthermore, through the development of *tokens* and the *tokenization* of various actions, new economic frameworks are envisioned. The inclusion of smart contracts to automate systems, introduces new programmable governance frameworks, which can interact with other actors and smart contracts. This enables increased control over the commons, through increased efficiency and monitoring. Smart contracts in a neighbourhoods are applied to social benefits, facilitate financial growth, as well as to regulate and forecasts commons resources. The decentralized and distributed nature of blockchain DLT, increases reliability and accountability. However, the implementation of a blockchain system in a neighbourhood commons goes beyond these rudimentary administrative benefits, it is supposed to empower citizens and give agency over their own decisions and direct living space. It promises to shift power away from a central authority and into the commons system. It removes the need for central parties and any associated validating frameworks. This potentially has implications for governance, as it allows for increased levels of self-governance and direct democracy, with certain pioneers envisioning not-yet-present governance

mechanics. Blockchain offers to increase participation in political procedures, such as voting or policy development, not needing to be conducted from a central point anymore, but can be instigated from a bottom-up approach and decentralized approach.

A major issue that is faced with the implementation of a blockchain based governance approach, is the interoperability between the commons and the municipality. Accompanied with significant technical and political considerations, a challenging environment for implementation is created. Furthermore, concerns of privacy, security, costs, and infrastructure are accompanied with challenges faced in developing adequate governance structures. Difficulties arise when transposing physical and social elements into a digital world. Significant challenges are present in the design phase of a blockchain based governance framework, with multiple dilemmas either defying the purpose of a blockchain based implementation, or removing core principles of self-governance (in the case of this neighbourhood commons). Finding a balance, or compromise might prove to be difficult, without significantly diminishing either concept (commons vs blockchain). Neighbourhood actors aiming to implement a blockchain based governance approach for a commons setting, must reflect on what linkages there are between different social and technical levels, to assess what the implications can be for certain decisions on many level. As decentralized as blockchain presents it-self, it is not free of biases, free of central authority, nor is it apolitical. Designers and coders make choices throughout the system, both on micro and macro levels, affecting how certain power dynamics develop. These decisions have effects on various governance decisions, either benefiting or disadvantaging individuals. Preventing this centralized design approach, would require the whole neighbourhood to collectively design and code the system, something which is not possible. Lastly, a whole new dynamic between state and citizen must be envisioned. Provenance over infrastructure, law, and support must be addressed and defined. It can be argued that the introduction of a decentralized, autonomous blockchain system essentially dismisses the need for a government in certain areas. A questioned must be addressed, are governments ready or willing to give up such agency, in exchange for circumstantial benefits?

Examining the challenges identified for a neighbourhood commons and the effects a blockchain based approach might have, show no direct or monumental benefits. Neighbourhood CPR challenges, can be similarly found in other commons settings and are based off social and political factors. Current advantages blockchain present, all revolve around economic and financial gains. These benefits can alleviate some socio-economic challenges a neighbourhood commons faces. However, it does not adequately address social and physical issues, with the disconnect between physical and digital realms still posing a significant challenge. In current blockchain development spheres and in academic literature, little to no concrete evidence or success stories can be presented for effective governance on a blockchain for a physical community. Current benefits of a blockchain implementation favour digital worlds, worlds based on infrastructure which does not have to conform to social norms, digital worlds were anonymity plays a central role. The omission of traditional social pressure and dilemmas in these digital worlds, has resulted in lacklustre analysis of potential effects of blockchain governance in a complex social setting such as a neighbourhood commons. Socio-economic promises a blockchain commons governance approach promises, have no effect if an actor outside of the system decides to meddle in the commons, or if an actor decides to disregard the blockchain system all together. This would require reverting back to traditional forms of governance, based on physical interaction, mediation, and enforcement. The effectiveness of a blockchain based approach is highly reliant on widespread, arguably complete, adoption (Cila et al., 2020; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Lustenberger et al., 2021). Without complete adoption of all actors in the physical area, effectiveness of the blockchain system remains debatable. This is a reason why

blockchain governance has seen so much success in digital worlds and relatively little in physical worlds (Allessie et al., 2019; Attaran, 2022; Cila et al., 2020; Clohessy & Acton, 2019; Dasaklis et al., 2022; Deshpande et al., 2017; Gloerich et al., 2020; Lustenberger et al., 2021; Nartey et al., 2021; Rozas et al., 2021).

The barriers and challenges identified in this thesis do not imply that there is no space for a blockchain based approach in commons setting. Nor do these findings imply that a similar approach would not be suitable for a neighborhood commons. However, the whole concept of decentralization and blockchain has just started, with daily discoveries and developments taking place. It is difficult to factually address the MRQ of this thesis in the current state of standings. Not only is the implementation of such a system incredibly technically advanced (beyond this thesis), it also requires extensive funds, cooperation of neighborhood and support of the municipality. However, with current blockchain developments and implementation challenges, as well as the neighborhood CPR challenges identified, all points towards difficulties in implementation and unsure gains in effectiveness. Currently, the implementation of a blockchain based governance approach for a neighborhood commons does not show any significant benefits or solutions which cannot be addressed in the physical world. Rather, it seems that the implementation of a blockchain system would only complicate and obfuscate social interactions in the commons, create new mechanisms for exploitation, and generally undermine principles of self-governance. Potentially, as the technology matures and knowledge spreads, there might be more congruence between a blockchain system and a physical commons. Currently, the benefits of a blockchain based governance approach are ill suited for physical realms, not offering any substantial benefits without significant design dilemmas. However, the success blockchain governance has in the digital sphere brings hope, and promises potential benefits for physical commons in the future.

Overall, this thesis is not meant to discredit blockchain or to prove nothing beneficial can be expected from the implementation of blockchain. Rather, this thesis presents the beliefs that blockchain has significant beneficial implications for public values, citizenship and agency, as well as transparency and political accountability. Extensive research is required to understand the affordances of blockchain and DLTs, and what the implications are for neighborhood and urban governance. Blockchain is presented as a panacea to modern problems, which is a problematic assumption if no critical reflection is included. However, blockchain technology does offer benefits and should not be seen as a revolutionary and government replacing technology, but rather should be seen as having a supportive and complementary role.

5.1 Limitations

This thesis and the accompanying research has been conducted through a theoretical lens. All findings, results, observations and statements are based on grounded theoretical assumptions. Real world findings might be completely different to what has been presented in this thesis, and are not present in this research. This reliance on theoretical assumptions brings along researcher bias, as content is analysed and presented in a reductive and abstract form, leaving room for interpretation and omissions. The domain of blockchain is incredibly vast, resulting in many views, lenses, considerations, technicalities, and resource's to be left out. This limitation has partially been addressed through expert interviews and a widespread selection of academic sources from various disciplines. Furthermore, this research has focused on a very narrow aspect of blockchain and commons research, leaving out potential interactions with other disciplines. Disciplines such as psychology, economics, and philosophy have been glanced over or completely left out in this research, although having significant implications on the outcome of this research.

The affordances identified by Rozas (2021) with regards to principles of self-governance, are substantiated and are recognized in this research. However, to provide validity to Rozas's (2021) affordance framework, required empirical testing. The findings in this thesis have theoretically confirmed Rozas's (2021) statements on affordance between blockchain and Ostrom's (1990) principles for self—governance. However, these affordance seem to hold more truth to certain commons, rather than others. Future research needs to use different case studies and apply Rozas's (2021) framework of affordances. This thesis believes that these affordances hold more truth in digital commons, rather than physical commons. The design dilemmas presented in this thesis originate from the difficulties in transposing complex social and physical interactions. Which introduces recommendation of enhancing the understanding of how and if it possible to effectively and adequately translate social dynamics into a digital domain. This would require introducing fundamental psychological theories and understanding, in order to adequately assess how social relations are translated. The development of such a blockchain system requires a wide approach and interdisciplinary scientific team to properly understand, hypothesize, and test possible frameworks. The introduction of a system as proposed in this thesis, introduces concepts without proper understanding of interactions between different disciplines.

5.2 Validity

This thesis aimed to answer the MRQ and shed more light on the applicability of a governance based governance framework for a neighbourhood commons. Keeping this in mind, the accompanying research of this thesis has focused on theoretical implications, distilled from combining two disconnected fields of research. The developed theoretical framework of blockchain based governance system, is based on theoretical assumptions. Proving causal relationships through such an approach is difficult and takes away some of the credibility of this thesis. Current literature is ill defined with regards to commons blockchain governance management, making it difficult to evaluate existing frameworks. This is potentially due to the maturity of blockchain and DAOs in general, with no focus given to any congruence between commons governance and blockchain implementation.

The findings in this thesis however, do highlight generalizable statements which are applicable to different contexts exploring the possibility of blockchain governance. Especially modern commons, with increasing social complexities and dynamics face design dilemmas if aiming to implement a blockchain system for governance. Thus the challenges and design dilemmas identified in this thesis does add to a wider field of understanding, further contributing a building block in understanding the scope of collaboration between commons management and blockchain systems. The theoretical statements presented in this thesis do need to act as guiding statements, rather than factual or empirical statements.

5.3 Theoretical & practical implications

Although many believe blockchain is the answer to many modern problems, it should not be seen as revolutionary answer. Rather, it should be seen as a complimenting technology, having the potential to create new frameworks for socio-economic, political, and governance systems. Whether seen as revolutionary or disruptive, a blockchain approach must be responsive and tailored to local needs and contexts. In the last decade, the development of blockchain and DLTs has evolved beyond only cryptocurrencies and finance, having played a role in various economic, social, and political facets. Future researchers need to explore what the legal, institutional, social, and political implications are, understanding what the implications are for commons and governance as a whole.

6 Conclusion

The aim of this thesis is to study and understand how a modern commons, neighbourhood commons, can potentially benefit from the implementation of a blockchain based governance approach. The preceding chapters have illustrated what challenges can be present in a neighbourhood commons, what benefits a blockchain implementation might have, what challenges a blockchain implementation presents, and how to overcome these challenges. To delineate and add insight to this field of research, the following MRQ was posed:

MRQ *What potentials does a blockchain application hold to improve governance of a neighbourhood commons?*

At the time of this research, the implementation of a blockchain based governance approach holds promising benefits for a neighbourhood commons. However, these benefits are diminished or even circumstantial when taking design principles and implementation principles into considerations. The potential benefits gained in efficiency, transparency, accountability, and agency are in conflict with Ostrom's (1990) design principles for self-governance.

The implementation of a blockchain based governance approach has significant potentials for the implementation in a neighbourhood commons. However, these potentials are at best circumstantial and are dependant on limiting implementation challenges. These challenges first need to be better understood, before these potentials can become more than circumstantial. A limiting factor in understanding these challenges, is the technical difficulty in testing this theory.

SRQ1 *What main neighbourhood CPR governance challenges can be identified?*

A neighbourhood commons suffers from a disconnected community, with varying social norms and financial securities. These difference in views, and the accompanying levels of anonymity create issues of trust. Especially in larger neighbourhoods, to anonymity of actors creates situations which require effective discussions and mediation processes. Furthermore, neighbourhoods are facing increasing levels of encroachment, resulting in reduced living spaces and quality of living spaces. This stems from reduced agency of policy developments. Increasing cooperation between neighbourhood actors, as well as cooperation with the municipality can alleviate these issues. Increasing gentrification and commercial development in neighbourhoods has taken away local economic opportunity. This has led to challenges in socio-economic norms, being closely intertwined encroachment challenges.

SRQ2 *What advantages does a blockchain-based governance approach present?*

A blockchain approach promises to increase efficiency of a system, transparency, accountability, and the introduction of new economic frameworks. Through a decentralized approach and the distributed nature of record keeping, accountability is increased as well as allowing individual actors to gain more agency over political developments. Decentralization enables a bottom-up approach for policy development and through the use of smart contracts increases the level of participation and effectiveness of decentralized governance. The use of *tokens* increases and incentivizes the participation of actors in the commons. These *tokens* enable different frameworks for a "shared economy", introducing economic diversity in the commons.

SRQ3 How could blockchain advantages alleviate neighbourhood CPR challenges?

The introduction of a blockchain based governance approach can alleviate the identified challenges through the decentralized approach is facilitates. This approach "removes" the need for trust, increases accountability, and ensures that all knowledge is shared and held by all actors. Through the

use of smart contracts, new voting mechanisms, and *tokens,* this blockchain based governance approach promises to put power and agency into the hands of the actors, resulting in increased influence and control over neighbourhood developments. Furthermore, the use of *tokens* and the *tokenization* of various actions, creates new financial and socio-political opportunities for actors to benefit from.

SRQ4 What are the main blockchain implementation challenges?

The main challenges faced during the implementation process of a such a system in a neighbourhood commons, are the fundamental challenges with unclear solutions. Complex social dynamics and interactions present implementation challenges. Translating social norms, relations, rules, and values into digital standards is seen as problematic. Concerns of privacy, automatization, and legal clarity create problematic design dilemmas. Furthermore, making compromises in favour of either blockchain benefits or commons benefits, diminishes the other concept, raising concerns of effectives and need for implementation. Additional to the design dilemmas, there are multiple technical challenges, ranging from maturity to costs of the technology. Furthermore, compatibility issues and compliance with legal and political bodies remains challenging.

SRQ5 Recommendations for the implementation of a blockchain based neighbourhood commons approach.

Recommendations for further development and successful implementation of a blockchain system require fundamental and institutional changes and support. Increase attention, spending, and legal clarity needs to be given to technological blockchain developments. Increased knowledge needs to be disseminated, through increased education grants, scientific institutional support, and legal clarity. The novelty of blockchain technology means that little understanding of social interactions is present. Current blockchain developments are currently focused on decentralized finance and supply chain traceability, with little research of governance. Testing needs to increase with pilot projects on small scale local settings and municipalities need to support and incentivize local citizen initiatives focused on blockchain developments

Conclusion

To conclude, this thesis has examined what governance issues have to be solved in order to design an affective blockchain based governance system for a neighbourhood commons. Furthermore, this thesis has explored what contextual factors influence how a neighbourhood commons functions and how the implementation of a blockchain based approach might affect these factors. In order to answer the questions posed in this thesis, an extensive academic review was conducted, conducting a theoretical analysis of a neighbourhood commons, based on a synthesis of various academic findings and insights. The theoretical framework used in this thesis, is based of frameworks developed by Ostrom (1990) & Rozas (2021), and stems of off a systematic literature review. Initial findings suggest that the implementation of a blockchain based system, in a neighbourhood commons, introduces challenges in decisions concerning infrastructure, interoperability, decision making mechanisms, incentives mechanisms, consensus mechanisms, accountability, equity, and effectiveness.

The outcome of this research has added further insights in scientific and social contributions. Scientific relevance stems from the exploration and evaluation of governance challenges faced in defining governance mechanics for a neighbourhood blockchain based governance approach. The scientific contribution of this research includes i) a definition of a theoretical and conceptual framework for a neighbourhood commons approach based on a blockchain governance framework, ii) the identification of critical considerations in the implementation of such a system, iii) an attempt at

defining and delineating blockchain governance design standards, iv) contributions to the paradigm of blockchain commons management, v) and lastly recommendations for further research and development of this theoretical framework.

In terms of neighbourhood governance, or urban governance in general, there is still a promising future that such a system as mentioned in this thesis can contribute to a more equitable governance approach, empowering and giving actors more agency. The research direction of this thesis focus on blockchain processes improving governance mechanics in urban settings. This approach has not exhausted all possible considerations, benefits, or limitations, and thus it is argued that further research needs to scrutinize aspects identified in this thesis. The findings and conclusions presented in this thesis are not conclusive, however they indicate that there are a couple of important challenges that should concern policy makers, citizens, and designers of blockchain based systems. Using a blockchain based governance approach in complex social situations is perilous, as intangible social dynamics need to be quantified. Associated benefits of transparency also pose as threats for privacy. Concerns are that this unprecedented level of transparency functions as a normative apparatus, requires significant considerations to be made.

6.1 Future research

This thesis has acted as an exploratory stepping stone for further academic research. Empirical research and validation is necessary to confirm the exploratory findings. Proposed research pathways would be the development of small scale blockchain governance frameworks, to be used extensively in focus groups or even small scale neighbourhoods. Focusing on social interactions and challenges, rather than technical challenges. Increased understanding is needed on how the abstraction of social values in digital frameworks changes how actors think and act. Empirical research is needed that focuses on these changing interactions. This empirical research ultimately needs to shed more light on what is exactly meant with “effective blockchain governance”. This thesis has only established a preliminary framework of what a theoretical blockchain neighbourhood system could entail. Clear standards and definitions need to be created, focusing on defining what “good governance” is. This definition cannot stem from theoretical assumptions, but must be grounded in surveys, interviews, and practical observations. Requiring an approach which takes individual actor preferences into consideration. This can however lead to context specific definitions, as what defines “good” is dependent where and who you are.

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8 Appendix

8.1 Characteristics of CPRs

Characteristic of the resource

Main Neighbourhood Commons Governance Characteristics

Determining Characteristic	Explanation	Literature
Social Diversity (household, age, gender, education, religion, etc)	The composition of the neighbourhood plays an important role in shaping social interactions and dynamics. Factors such as household compositions, age distribution, and political preferences play a role in how (dis)connected the neighbourhood is. Co-management and co-ownership of action development are dependant on the level of trust and connectedness actors have with each other.	(Feinberg et al., 2021)
Neighbourhood population	Size of the neighbourhood plays a role in defining the boundaries and interaction mechanisms in place. Size of the neighbourhood correlates with the complexity in setting boundaries for the commons setting. It is expected that larger neighbourhoods would benefit more from a blockchain based governance approach. This is due to the fact that larger actor sets tend to become increasingly complex, requiring increased transparency and monitoring. This is inherently facilitated with a blockchain based approach.	(Feinberg et al., 2021)
Existing municipal co-governance frameworks	A multitude of different co-governance frameworks can be present in a neighbourhood, which can vary greatly case by case. However, there are overarching frameworks which can be found; - State property regime	(Andersson et al., 2004; Baggio et al., 2016; Cardoso, 2015; Carlisle & Gruby, 2019; Enters & Anderson, n.d.; Feinberg et al., 2021; Kurauchi et al., 2006; Margeson, 2018; Ostrom, 2001; Vallury et al., 2020)

	- Private property regime - Corporate governance Multiple factors influence the effectiveness of this approach, namely; - Governance structure (rigidity/ hierarchy) - Degree of autonomous freedom - Governmental support - Public-municipal actor integration	
Existing social Co-governance	Social frameworks in use can be seen as existing commons governance mechanism or other social forms of collective control; - Open access regime - Common property regime As with the municipal go-governance approach, there are factors that influence the effectiveness of a social neighbourhood governance approach, namely; - Degree of perceived value in co-governance (livelihood, empowerment, health) - Degree of perceived protection (social, financial, legal) - Collective identity (does the actor fit in the "community") - Knowledge infrastructure (can lead to effective management or mismanagement)	(Bartley et al., 2008; Feinberg et al., 2021; S. Foster & Iaione, 2018; Gerber et al., 2008, 2020; Sestáková & Plichtová, 2019; Slough et al., 2021)
Residential vs commercial ratio	The ratio of residential and commercial buildings will dictate to what social dynamics are at play, as well as the	NA

	power dynamics between different actor (groups).	

What this section aims to highlight, is that challenges faced in governing neighbourhood commons, is not generalizable. Neighbourhood commons have developed into complex and multidimensional systems with multiple factors influencing the systems composition.

8.2 Neighbourhood blockchain requirements

Table Theoretical design of basic components for a blockchain based neighbourhood commons system.

Rules	**Description**	**Infrastructure**
Boundaries	Existing rules have to be pre-determined in the community. These rules can then be codified into the blockchain system, for example a DAO. Encoding physical agreed upon boundaries means associating identities with wallets.	For a neighbourhood this would mean; - Where do you live in the neighbourhood - Who you are - Legal guardianship over minors (votes could be increased in weight to reflect extra household member) - Connected and personal wallets - System can only have as many wallets as actual people - Voting rights This will be encoded into a DAO, which functions as the basis for the blockchain based neighbourhood commons. The DAO is the bottom layer, on which additional frameworks will be developed, such as smart contracts and automatizations. Furthermore, a neighbourhood DAO will not ensure boundaries per se, but it will automate the enforcement of boundaries.
Position	Any pre-existing rules or positions in the physical world can be transcoded into the blockchain framework. Furthermore, new positions can be specified and allocated on the blockchain. Positions on	As in a traditional governance setting, roles and positions can be held by any person and can vary in responsibility and reputation. Assigning of roles and positions can be done through voting on the blockchain.

	the DAO can mirror positions held in real life. Roles subject to change or voting process, votes can directly be cast on the blockchain. This allows for easy recording of changes in the position. As in traditional systems, there are levels of decision making power, which can be reflected in the neighbourhood blockchain commons. A feature must exist to mediate or revert back to a previous version of the role.	Roles can be held through the assignment of special *tokens* or reputations. Roles: (not exhaustive) - Citizen - Building representative - Public space representative - Commercial representative - Commons public services rep. - Mediator - Municipal liaison - Neighbourhood representative
Choice	These rules specific what actions and capabilities each role has. As position rules are created, choice rules naturally follow and is dependent on the former. Implementation of these choice rules relies on the use of *tokens*, self-enforcement, and transparent autonomous automatization.	In a DAO pre-determined roles can have unique sets of actions assigned. For the neighbourhood commons it might be beneficial; - Citizens/ representatives can create proposals - Proposals by citizens can only be facilitated if enough votes are gathered within a specified period - Representatives can force voting rounds for proposals - Representatives can assign mediators - Citizens can force role change if predetermined role specific voting thresholds are met. Thus not needing approval of role in question (to overthrow a rogue actor)

(Allessie et al., 2019; Cila et al., 2020; Poux & Ramos, 2022; Rikken et al., 2019; van Pelt, 2019; van Pelt et al., 2021)

8.3 Blockchain vs challenges matrix

This matrix is based wholly on findings from literature, interviews, and independent observations. This means researcher bias can be present. However, these rankings are based on and distilled from a conglomeration of results and information. Thus these findings are not only based on the researchers interpretation but are also based and deduced from other academic statements. No quantitative research was done to present these results, and should be seen as a qualitative and normative statement, open to interpretation. This approach was deemed as the most fitting, given the theoretical and novel nature of this thesis.

	Challenges / Solutions	S1	S2	S3	S4	S5	S6	S7
Enchroachment	Social exclusion	++	++	- -	0	++	- -	0
Challenegs in Values	Lack of Incentives	++	- -	++	++	++	+	++
Financial Viability	Financial Support	++	- -	++	-	++	- -	0
	Knowledge Re-appropriation	-	0	-	-	++	++	- -
Knowledge	Knowledge	+	0	-	0	++	++	- -
	Communication Challenges	0	0	++	++	++	0	++
	Institutionally Effective	0	-	++	++	-	++	++
Governance	Irresponsive	++	++	++	++	0	++	++
	Boundaries	+	++	- -	++	+	++	++
	Legal Recognition	+	-	0	0	-	++	0
Land Accessibility	Accessibility	-	++	- -	- -	- -	- -	- -
	Avaliability	-	++	- -	+	- -	- -	- -
	Encroachment	- -	0	+	++	- -	0	- -
Physical	Privatization	0	++	++	0	- -	0	- -
	Nationalization	0	++	++	0	- -	0	- -

Blockchain Solution		Average Success
Promote Local Capital Development	S1	++
Shared Space Responsibility	S2	+
Local Financial Autonomy	S3	0
Local Strategic Decision making	S4	+
Rezognize Reputation	S5	0
Monitoring & Transperancy	S6	0
Sanctioning	S7	-
Socio-Economic Challenges		+
Institutional Challenges		+
Physical Challenges		-

(Allessie et al., 2019; Andersson et al., 2004; Cila et al., 2020; Colding et al., 2013; Cortés-Cediel et al., 2021; Di Feliciantonio, 2017b; Freni et al., 2022; Hulsemann & Tumasjan, 2019; Ju et al., 2019; Poux & Ramos, 2022; Rozas et al., 2021; Shah & Garg, 2017; Tan et al., 2022; Teck et al., 2014; van Pelt et al., 2021; Voshmgir, 2020)