Implementation of Blockchain Powered Smart Contracts in Governmental Services

Master Thesis

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Implementation of Blockchain Powered Smart Contracts in Governmental Services

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Acknowledgements

This master thesis has been quite the journey, which immersed me in the world of blockchain technology. It has been less than a year when I first heard the term blockchain. Someone tried to explain it to me in one minute, but it was too complicated to understand immediately. I did some research and was overwhelmed by the theoretical possibilities. A technology that could cause the end of banks and notaries, the start of real decentralized government and putting the people in power. This has the potential to be the most disruptive technology of all time. When I learned about blockchain was also the time that I was exploring subjects for my master thesis. The novelty of the technology, the impact on both the public and private sector, the lack of academic research and the important social aspects make blockchain technology a perfect subject for my degree and came into my vision at exactly the right time. I am proud of the result of months of hard work, but many aided me through the process. To those, I would like to dedicate this page of acknowledgements.

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Summary

Blockchain, the rapid developing technology behind Bitcoin, is increasingly becoming popular. Blockchain is a distributed ledger technology that distributes digital transactions peer-to-peer to a decentralized network of nodes that verify the transactions and keep a cryptographic secured copy of the entire history of transactions. The network automatically reaches consensus about the correct history of records, which makes the database transparent and immutable. This consensus role makes it possible to take away the third party in certain processes, such as the bank or the notary. Blockchain also enables digital payments and smart contracts. Smart contracts are digital contracts that can be executed automatically by the blockchain. This enables digital registration of for example identity, birth certificates and votes. But smart contracts have many more automation applications that can be coded in computer code, which has the potential of making many processes in both the public as the private sector more efficient and less costly. Governmental services are especially applicable for blockchain, as they could become more efficient and can even be made obsolete in some cases.

Project teams that develop blockchain powered smart contract applications have to work with nascent tools and technology, and a lack of real life use cases. This leads to a lack of empirical knowledge on how to implement smart contracts in governmental services. An overview of guidelines that assist developing project teams is non-existent, which slows down the implementation process. Blockchain technology is not well-researched and smart contract implementation research is even more scarce. A comprehensive overview that shows design phases, design principles and design dilemmas is non-existent, but could greatly assist project teams that implement smart contract applications. Such an overview would speed up the implementation process and can lead to an acceleration of use cases. Therefore, this research focused on answering the main research question: "*How can blockchain powered smart contracts be implemented in governmental services?"*.

We used the design science approach in order to answer the main research question, which consists of several activities between three arenas: the knowledge base with prior research, the environment with people, organizations and technology, and the design arena, where new knowledge is created. The design science approach allowed us for using several sub methods, such as the literature review, desk research, case studies and expert interviews. We started with a literature review and desk research to understand and analyze blockchain technology and smart contracts, followed by a literature review in order to draft the first version of design principles. These were improved by conducting four case studies on the Gelrepas (municipality of Arnhem), budget assistance (municipality of Schiedam), waste processing (municipality of Utrecht) and the disabled parking permit (municipalities of Drechtsteden). With the second version of the design principles, we built the first version of the design framework. These were assessed by six experts (Pels Rijcken, ICTU, Blockchainpilots.nl, DApp.Design, the municipality of Groningen and Forus), which allowed us to refine the design principles and design framework into a final version.

The design science approach steps led to the second and final version of the design framework and the third and final version of the design principles. The 36 design principles are guidelines to aid project teams that implement smart contracts in governmental services. Figure 1 shows the final design framework which includes the design principles. A division in five categories is made: political [P], economic [E], social [S], technological [T] and legal [L]. The most design principles are in the categories social and technological. This was expected due to the blockchain ecosystem that acts as a complex socio-tech system.

We incorporated these design principles in a framework, that shows which design principles are applicable in the following five phases of smart contract implementation: exploration, conceptualization, testing,

implementation and expansion. Each of these phases has its own results and applicable design principles, which is comprehensively indicated in the framework. However, various pairs of principles affect each other, which we call design dilemmas. The seven dilemmas that challenge project teams into making choices are:

1. *Allocate budget & profitability.* The project team needs budget, which increases in later design phases. Decision makers decide upon the allocation of budget, but they often demand a return on investment. Many smart contract projects are not directly profitable, which limits the allocation of budget;
2. *Communicate significance & examine impact on jobs*. Affected employees need to be convinced by the project team and decision makers about the merit of the new process, but this is hard when smart contracts change their function or even make them superfluous;
3. *Security & open source coding.* Open source coding enables both malicious and benevolent individuals to find vulnerabilities. Choosing for open code leads to improved code for developers, but possibly leads to lower security in the short term as well;
4. *Privacy & decide ledger type.* Project teams decide upon ledger types, which has an implication on the privacy of users. Public ledgers currently offer lower privacy than private ledgers;
5. *Scalability & transaction speed.* Project teams need to decide how many users are expected to use the system. However, the current maximum transaction speed of blockchain platforms limits this choice;
6. *Consider back-ups & decide ledger type.* Deciding upon ledger types also has an implication on the necessity of back-ups. When a public ledger is used, a back-up is not necessary, but it is wise to do so when a private ledger is used;
7. *Define responsibilities & decide ledger type.* The responsibilities of those who add, verify, view and edit data is different for public ledgers, private ledgers and central databases. Project teams that decide upon ledger types experience an impact on the definition of these responsibilities.

We discovered the following strategies that we discovered in interviews and literature: communicate added value, and cooperate with other parties (allocate budget & profitability), involving stakeholders early, and clear communication by decision makers (communicate significance & examine impact on jobs), starting closed source and gradually move towards open source, and start open source from the start (security & open source coding). Many design dilemmas are not commonly present until late design phases, such as the implementation and expansion phase: allocate budget & determine profitability, scalability & transaction speed, responsibilities & decide ledger type, communicate significance & examine impact on jobs, security & code open source. There is still a lack of empirical knowledge on coping strategies to handle these dilemmas, because dilemmas occur in late design phases and there is a lack of projects that are in those phases.

Three of these dilemmas are unique for smart contract implementations: privacy & decide ledger type, consider back-ups & decide ledger type, and define responsibilities & decide ledger type. Two of these dilemmas are expected to be solved by development of blockchain technology: privacy & decide ledger type and scalability & transaction speed, while the other dilemmas will prevail. Table 1 provides an overview of the characteristics per dilemma.

Table 1 - Characteristics of the design dilemmas.

Dilemma	Unique for blockchain	Solution expected
Allocate budget & profitability	No	No
Communicate significance & examine impact on jobs	No	No
Security & open source	No	No
Privacy & decide ledger type	Yes	Yes
Scalability & transaction speed	No	Yes
Consider back-ups & decide ledger type	Yes	No
Define responsibilities & decide ledger type	Yes	No

Finally, we offer the following seven recommendations for further research:

- Validation of the design framework with more cases;
- Adaption of the design framework for the private sector;
- Strategies to cope with the design dilemmas between design principles;
- Construction of an assessment framework for the applicability of blockchain;
- Researching the legal implications of smart contracts;
- Researching the added value of smart contract implementations;
- Researching the decision making process.

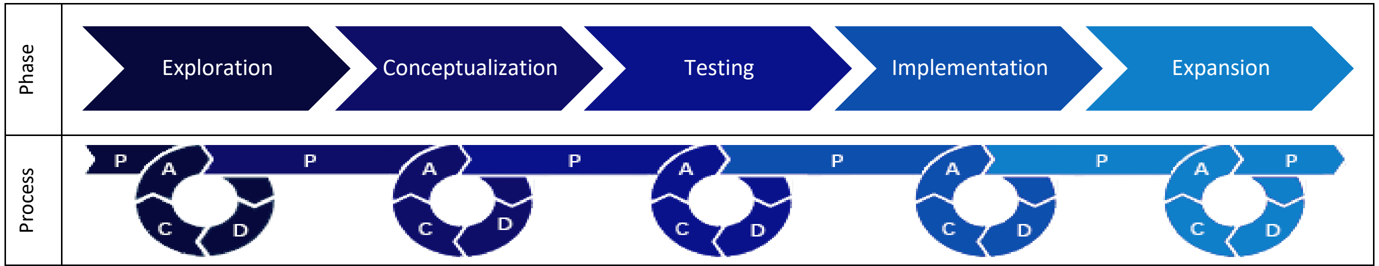
Keywords: blockchain, smart contracts, governmental services, design principles, design framework

Categories

P	Political
E	Economic
S	Social
T	Technological
L	Legal

Principles legend

[DD]	Design dilemma
X	Uncommon
●●●	Possible
√√√	Common



Design principles			Exploration	Conceptualization	Testing	Implementation	Expansion
Result			• Process selection • Initial project team	• Process description • Pilot • Proof of concept	• Prototype	• Working product	• Intermunicipal product • Government as a Service
	P	1. Define a vision	●●●	●●●	●●●	√√√	√√√
	E	2. Invest in blockchain knowledge	√√√	√√√	√√√	√√√	√√√
	E	3. Allocate budget [DD1]	●●●	√√√	√√√	√√√	√√√
	E	4. Determine profitability [DD1]	X	●●●	●●●	√√√	√√√
	S	5. Find experts	√√√	√√√	√√√	√√√	√√√
	S	6. Cooperate with other organizations	●●●	●●●	√√√	√√√	√√√
	S	7. Involve stakeholders	●●●	●●●	●●●	√√√	√√√
	S	8. Share results	X	√√√	√√√	√√√	√√√
	S	9. Compose multidisciplinary team	●●●	√√√	√√√	√√√	√√√
	S	10. Communicate significance [DD2]	X	●●●	√√√	√√√	√√√
	S	11. Examine impact on jobs [DD2]	X	●●●	●●●	●●●	√√√
	S	12. Involve supervisor	√√√	√√√	√√√	√√√	√√√
	S	13. Examine shifting role of the government	X	●●●	●●●	●●●	√√√
	S	14. Define responsibilities [DD7]	X	X	X	√√√	√√√
	S	15. Define project goals	√√√	√√√	√√√	√√√	√√√
	T	16. Account for security [DD3]	X	X	●●●	√√√	√√√
	T	17. Code open source [DD3]	X	X	●●●	●●●	√√√
	T	18. Select process and scope of the project	√√√	X	X	X	X
	T	19. Map the process	X	√√√	√√√	√√√	√√√
	T	20. Build a prototype	X	X	√√√	X	X
	T	21. Start small projects	√√√	√√√	√√√	●●●	X
	T	22. Assess risks	X	●●●	●●●	√√√	√√√
	T	23. Learn from prior development	√√√	√√√	√√√	√√√	√√√
	T	24. Decide ledger type [DD4] [DD6] [D7]	X	X	√√√	√√√	√√√
	T	25. Consider back-ups [DD6]	X	X	X	●●●	●●●
	T	26. Design for scalability [DD5]	X	X	√√√	√√√	√√√
	T	27. Determine desired transaction speed [DD5]	X	X	X	√√√	√√√
	T	28. Design good UI/UX	X	X	●●●	√√√	√√√
	T	29. Determine authorizations	X	●●●	●●●	√√√	√√√
	T	30. Assess applicability of blockchain	√√√	√√√	●●●	X	X
	L	31. Research legal implications	X	√√√	√√√	√√√	√√√
	L	32. Define clear policies and legislation	X	X	●●●	√√√	√√√
	L	33. Define contract types	X	●●●	●●●	√√√	√√√
	L	34. Define participants of the network	X	●●●	●●●	√√√	√√√
	L	35. Translate code to language	X	X	●●●	●●●	●●●
	L	36. Account for privacy [DD4]	X	●●●	√√√	√√√	√√√

Figure 1 – Final version of the smart contract implementation framework for governmental services.

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1. Introduction

Blockchain, Bitcoin and smart contracts are terms that are getting increasingly popular over the last few years (Google Trends, 2017). Some call blockchain technology the biggest invention since the internet, because it can disrupt many sectors, make processes faster and lower transaction costs (Drescher, 2017). Digital currencies that are based on blockchain technology are now valued at more than 292 billion dollars, which shows the degree of interest in this new technology (Coinmarketcap.com, 2017c). The European Commission even hosts a blockchain competition with a five million euro prize (EC, 2017). This chapter offers a short introduction to understand the global idea of blockchain.

Blockchain technology started with the digital currency Bitcoin, which was solely meant for electronic payments (Nakamoto, 2008). This application of blockchain prevents double spending of money and keeps track of the entire transaction history. By using cryptographic fundamentals it is possible to verify transactions in a decentralized network in which, depending on the chosen algorithm, any computer may participate. Each transaction is broadcasted peer-to-peer, verified by the network and the resulting transaction history distributed to the participants in the network. The result is a transparent and secure network for digital payments, with immutable records and a distributed database (Tapscott & Tapscott, 2016). Due to the characteristics of blockchain it is possible to disintermediate the so called middleman. In the digital payment example of Bitcoin, no bank is needed. The verification of payments is done through the blockchain network instead of a third party. This implies a clear advantage: lower transaction costs.

The potential of blockchain technology goes far beyond powering electronic payments. It can be used to record virtually anything, like: “birth and death certificates, marriage licenses, deeds and titles of ownership, educational degrees, financial accounts, medical procedures, insurance claims, votes, provenance of food”(Tapscott & Tapscott, 2016, p.7) and many more. In order to do so, smart contracts are needed. Two parties digitally agree upon rights and obligations, while the computer acts as third party. When two parties want to make a contract, they program this contract in a special code. The code contains the variables on which different outcomes are triggered. When the parties agree on the terms, they both digitally sign the contract. The contract is then “*recorded in the blockchain and executed by distributed nodes of the network, which eliminates the need for a trusted third party*” (Jędrzejczyk & Marzantowicz, 2016, p.7). The contracts are self-enforced and will thus be executed exactly as coded beforehand (Tapscott & Tapscott, 2016, p.88). Besides, the transparent blockchain ledger enables that many variables that are needed for the contract are available. This enables a broad variety of uses: an automatic payment based on a bet (Koulu, 2016, p.42), paying and unlocking doors for an Airbnb house (Tapscott & Tapscott, 2016, p.117), releasing financial aid after a certain period of escrow (Tapscott & Tapscott, 2016, p.190), issuing insurance payments after requirements are automatically checked (Drescher, 2017, p.241), sending payments if someone succeeds in an online learning course (Swan, 2015, p.62) and many more.

Blockchain technology currently is developing rapidly in both public and private uses, but the development for governments is especially interesting, as it has “*the potential to improve all facets of government*” (Tapscott & Tapscott, 2016, p.140). Governmental services for citizens could become “*more personal, immediate and efficient*” when smart contracts are implemented (Government Office for Science, 2016, p.9). By using blockchain, governmental processes could have more efficiency, less friction, less costs and a larger scale (Swan, 2015, p.27). These costs “*determine the efficiency of different governance institutions*”. If blockchain technology can lower transactions costs for certain activities, it is likely that these activities will eventually be processed through the blockchain (Davidson et al., 2016, p.13). But development in governmental services is also challenging, as there are many human, social, organizational and technological factors that could impede this process. The impact of blockchain powered smart contract has much potential to disrupt many sectors, but the future is yet uncertain.

1.1. Current state of research

Scopus has been consulted to derive an overview of blockchain research. Table 2 shows the number of publications for different combinations of keywords and year of publication, where the keywords have been searched in all fields. It is clear that blockchain research is getting increasingly popular and doubles almost every year. Another important finding here is that only 14% of the blockchain research focusses on the government. In the field of blockchain powered smart contracts only 15% of the publications focus on the government. It can be concluded that in current research, blockchain powered smart contracts is by far the most popular in smart contract research (84%). However, it was noted by Yli-Huumo et al. (2016) that only 20% of blockchain research focuses on smart contracts. That percentage has now increased to 27%.

There are sixteen publications that mention smart contract implementation, but do not have a main focus on the topic and do not offer a design framework. Only two publications discussed design principles for blockchain powered smart contracts. The first is a conference paper that evaluates mainly technical issues and decisions for designing such contracts. An example is the discussion about how a contract should be enforced (Idelberger et al., 2016). The other publication proposes technical design principles for a specific authenticated data feed system that bridges smart contracts to existing websites (Zhang et al., 2016). The publications are useful, but only focus on specific technical issues. They do not offer a sufficient set of design principles to help designing smart contracts projects. Concluding, blockchain and smart contracts are topics that are becoming increasingly popular in academic research. There is a substantial amount of research on blockchain for governments, but there is a clear lack of research on smart contracts in governmental services and implementation of smart contracts.

Table 2 - Scopus publications for various keyword combinations (Scopus, n.d.).

	"Blockchain"	"Private blockchain"	"Smart contracts"	"Smart contracts" + "blockchain"	"Blockchain" + "Government"	"Blockchain" + "Government" + "Smart contracts"	"Blockchain" + "Smart contracts" + "Implementation"	"Blockchain" + "Smart contracts" + "Design principles"
2013	6	0	3	0	0	0	0	0
2014	27	0	0	0	4	0	0	0
2015	75	0	23	15	6	1	0	0
2016	246	3	83	73	43	12	11	2
2017	369	10	124	108	49	18	5	0
Total	**723**	**13**	**233**	**196**	**102**	**31**	**16**	**2**

1.2. Problem definition

Project teams that implement blockchain powered smart contract applications are operating in a field where the tools and technology are only a few years old. Consequently, there are not many real life use cases and empirical knowledge. When project teams start with the development they would want to look at best practices to derive guidelines on which they can base their own design. At this moment, these guidelines are non-existent and project teams have to start their design from blank. For the implementation of smart contracts in existing applications, the process becomes even harder. Implementation teams miss knowledge from previous efforts, but will also encounter other impediments. Project teams will need to work with existing processes, architecture, technology, and the interests and goals of a variety of stakeholders.

The literature about blockchain technology mostly mentions issues and opportunities about blockchain in general, but not much literature looks at smart contract applications. This knowledge gap has been acknowledged in another research article before (Yli-Huumo et al., 2016, p.21). There is a substantial amount of research on blockchain practices for governments, but it also revealed a clear lack of research on smart contracts in governmental services and implementation of smart contracts. There is much room for scientific and societal contributions. Consequently, this knowledge gap will be the focus of the research. In conclusion, the implementation of smart contracts in governmental services is interesting, as governments operate in a complex socio-technical system and these improvements are potentially greatly beneficial. This leads to the following problem statement: "*Currently there is no design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services*".

The problem statement shows that there is a need for a design framework in order to support the implementation of blockchain powered smart contracts in governmental services. The research objective of the research therefore is: *"To derive a design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services".*

This leads to the following main research question: *"How can blockchain powered smart contracts be implemented in governmental services?*".

1.3. Definition of implementation

The research objective of the research was determined at: *"To derive a design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services"*. The term implementation needs to be further defined, because there are various definitions at hand.

The Oxford dictionary defines implementation as "*the process of putting a decision or plan into effect*" (Oxford Dictionary, 2017a). This definition thus considers implementation a process to empower a predetermined decision or plan. This implies that the predecessor steps, such as planning, are not a part of implementation.

Smith et al. (2014, p.1) handles a broader definition of implementation: *"a process by which a specified set of activities are designed to put into practice an innovation or program of known dimensions. These activities occur over time in stages that overlap and that are revisited over time"*. This definition is broader than the definition of the Oxford dictionary as it not only describes the putting into practice of an innovation, but also the design of the innovation and successor steps afterwards.

Majone and Wildavsky (1978, p.116) describe implementation in the most broad sense, as a process that *"will always be evolutionary; it will inevitably reformulate as well as carry out policy".* Lane (1983, p.28) notes that this statement implies that implementation is endless: it does not have a start or an end. This definition would consider any predecessor and successor steps as part of the implementation.

Fixsen et al. (2005) performed a literature review and described the implementation process as following six stages:

- *Exploration and Adoption* – Awareness of a potential innovation, exploration of options, assessment of implementation options and setting of a plan;
- *Program Installation* – Preparing actual implementation by preparing resources, such as budget and staff;
- *Initial Implementation* – Stopping the old process and initiating the new process;
- *Full Operation* – The new process is functioning completely;
- *Innovation* – A round of experimentation or innovation to make the process better;
- *Sustainability* – The innovation is fully incorporated and sustains in a changing world.

It is important to note that these steps include not only the actual implementation (Program Installation and Initial Implementation), but also two predecessor steps (Exploration and Adoption) and three successor steps (Full Operation, Innovation and Sustainability).

Concluding, the definition of implementation is not straightforward. Some define it as the actual implementation, the execution of a predetermined plan. Others define implementation as the process starting from the moment they consider implementation and do research and planning. Implementation as meant in this research is from the moment a governmental institution wants to research the possibilities of smart contracts for their services and all the steps afterwards that support the actual implementation and maintenance. Hence, this definition also includes the predecessor and successor steps, such as described by Fixsen et al. (2015). Note that the six steps from Fixsen et al. are used as inspirational starting point and are not the exact steps that will be used for the research deliverables. Therefore, the definition of implementation for this research is: *"a process by which a specified set of activities put into practice the functioning of blockchain power smart contracts in governmental services".*

1.4. Research deliverables

The research is aimed at deriving a design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services. The end results of the research, the so called deliverables, consists of two main parts: the design principles and the design framework. These are explained in this paragraph.

1.4.1. Design principles

In order to construct a design framework, it is necessary to derive design principles first. A definition of design principles by the Open Group is "*general rules and guidelines … that inform and support the way in which an organization sets about fulfilling its mission*" (the Open Group, 2009, p.265). This definition could be applicable if the mission of an organization is the implementation of smart contracts. A more suitable definition would be "*generic prescriptions for the design and implementation of information systems*" (Housel et al., 1986, p.396), because the design and implementation of information systems described the implementation of smart contracts better. However, the term 'generic prescriptions' is somewhat vague, where the Open Group clearly defined 'general rules and guidelines'. The two definitions are combined to suit the objectives of this research in the following definition of design principles: "general rules and guidelines that support the implementation of smart contracts". Hence, a list of general rules and guidelines is generated that supports the implementation of blockchain powered smart contracts in governmental services.

Solely listing the names of the design principles is not sufficient. It should be clear how these principles contribute to the development of the design framework. In their research, Zuiderwijk et al. (2014) add explanation and rationale, and implications. The explanation and rationale is a more elaborately description of how and why the design principle should be implemented. The implication is reasoning what would be the impact from the use of the design principles. Together, this would give a clear overview of the use and usefulness of the design principles. In another research of Zuiderwijk (2015) the sources on which a design principle is based are added as well. This would provide more overview of how many and which sources mention each design principle.

The Open Group (2009, p.266) suggests using the following components: name, statement, rationale and implications. These components mainly overlap the components as used by Zuiderwijk (2014), but use different names. Because the standards from the Open Group are often applied, their proposed structure is used with addition of a column for the sources.

Concluding, the first part of the deliverables consists of a list of design principles, being “general rules and guidelines that will support the development of a design framework for the implementation of blockchain powered smart contract in governmental services”. The list contains a short name of the principle, the statement, the rationale for applying the principle, the expected implication and the sources. Table 3 shows the template that is used to communicate the deliverable with two example design principles.

Table 3 - Template for the design principles deliverable.

Name	Statement	Rationale	Implications	Source
1. Legal obstacles	Research which legal obstacles could be trouble	Legal obstacles can slow down the process	Having clear which legal obstacles exist, it is possible to address these in advance	(Source 1, year); (Source 2, year); (Source 3, year)
2. Local community	Involve the local community to invest and contribute ideas	There is often good knowledge in local communities	Local involvement can improve the acceptation and integration of a new implementation	(Source 1, year); (Source 4, year)

1.4.2. Design framework

The design principles are used to derive a design framework to *“support project teams in the implementation of blockchain powered smart contracts in governmental services”*. This design framework has two main components: the design principles and process components. The design principles are explained in the previous paragraph. The process components describe the actions that are performed during different phases of the implementation process.

A design framework for a similar large implementation is the framework for the implementation of IT in the 1990’s. This development is comparable with the smart contract developments in many ways: a fast developing technology that could heavily disrupt and improve all kinds of public and private services. The AIT, an initiative to implement IT in the manufacturing industry, developed the design framework in figure 2.

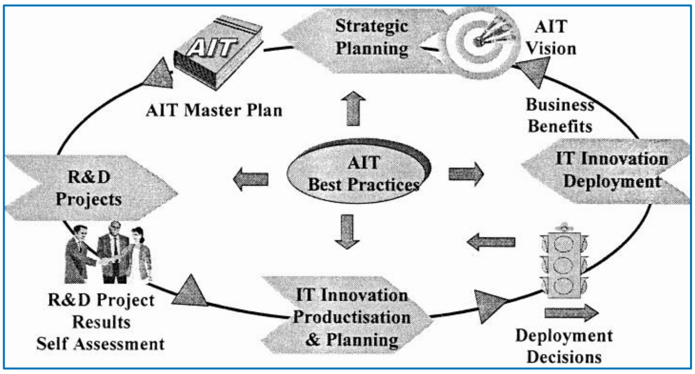


Figure 2 - AIT innovation cycle [retrieved from Segarra, 1999, p.189].

This framework is based on the Plan, Do, Check, Act-model (PDCA) (Segarra, 1999, p.188). The original PDCA model has four phases (Kanji, 1990, p.5): *Plan* is defining the processes and setting objectives, *Do* is executing the process and collecting required information, *Check* is assessing and analyzing the gathered information and *Act* is making future plans and assessing these plans. The framework from AIT clearly applied the PDCA cycle to the IT implementation case: *Plan* becomes *Strategic Planning* and defines the implementation processes and objectives, *Do* becomes *IT Innovation Deployment* and is about executing the implementation, *Check* becomes *IT Innovation Productisation & Planning* and is analyzing data for innovation and *Act* becomes *R&D Projects,* where new products get developed.

A more general example of mapping such an implementation is the organizational change process in socio-technical systems, as visualized in figure 3. The four PDCA steps can be recognized again, but it is less detailed than figure 2. This representation of organizational change could have served as inspiration to make the design framework in figure 2 and could do the same for the design framework of this research.

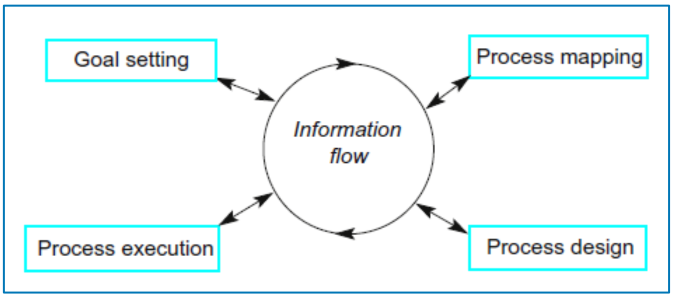


Figure 3 - Organizational change process [retrieved from Baxter & Sommerville, 2011, p.8].

The final deliverable does not use figures 2 and 3 as format, but uses them as inspirational starting point. The most important requirement is that the design framework fulfills the research objective: "*to support project teams in the implementation of blockchain powered smart contracts in governmental services".*

1.5. Research outline

This research proceeds in seven chapters. The second chapter will set out the research approach. This is done by discussing the main research method, the research questions and visualizing the research design. The societal and scientific relevance are discussed as well. The third chapter provides an in-depth description of blockchain, smart contracts, governmental services and the relation with each other. The first set of design principles will be extracted from literature and discussed in chapter four. Several cases are described in chapter five, after which they are used to form a second set of design principles. This will be used as input to design the first version of the framework in chapter six. The framework and the second version of design principles are assessed and refined in chapter seven. Concluding, the eight chapter will offer conclusions, limitations, recommendations for further research and a personal reflection on the research.

2. Research approach

2.1. Design science approach

Finding design principles and forming a design framework for implementing blockchain powered smart contracts is complicated. The field is new, not much academic research has been conducted and the technology is continuously developing. A suitable approach to form these deliverables is the design science approach. This approach is specifically applicable for information systems where only little theory has been developed and people, organizations and technology are important (Hevner et al., 2004). That is true for this subject: the development has only started a few years ago and the technology has an essential relation with engaged people and organizations. This engagement between technological and social aspects and the importance of those aspects are characteristic of a socio-technical system (Johannesson & Perjons, 2014, p12), such as the blockchain ecosystem. This paragraph will elaborate on the design science approach. Three terms are key to understand this approach: the environment, the design process arena and the knowledge base. Figure 4 provides a visualization of these three terms, specified for this research.

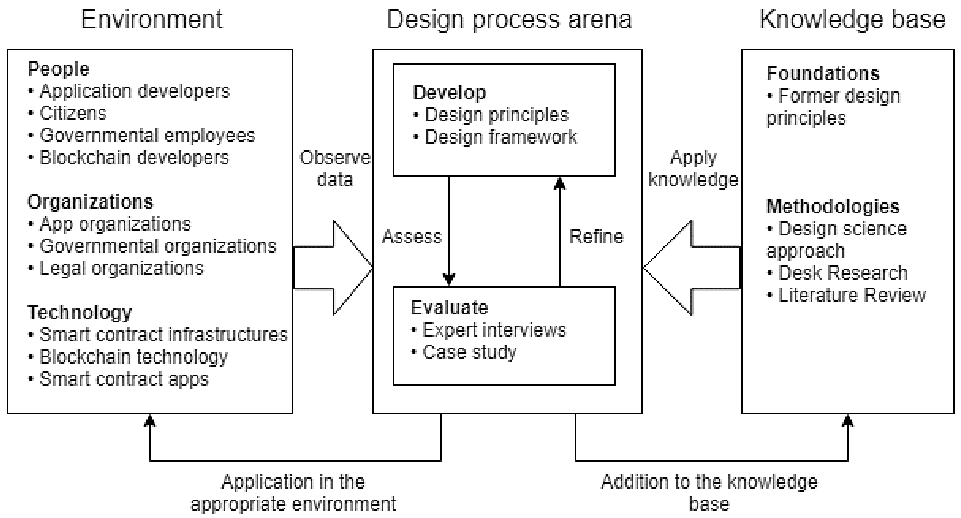


Figure 4 - Design science approach overview [retrieved and adapted from Hevner, 2007, p.88].

The environment can be defined by the goals, capabilities and behavior of the design deliverable itself and individuals, organizations and markets who are interacting with it (Simon, 1996). A more convenient mapping is dividing the environment in three categories: people, organizations and technology (Hill, 2009). In other words, the environment is the ecosystem around smart contracts. The people around the implementation of smart contracts in governmental services are the developers of applications that use smart contracts, the citizens who use the applications, employees for governmental organizations and the developers of blockchain technology in general. The organizations are the organizations behind application development, governmental organizations in domains in which the smart contracts are executed and legal organizations that are or could be involved in translating traditional legislation in smart contracts. Technology around smart contracts can be defined by the infrastructures that support smart contracts, blockchain technology in general and smart contract specific applications.

The knowledge base is filled with information from prior research and serves as starting point for this research (Hevner & Chatterjee, 2010). Relevant theories are gathered and information is combined to form a theoretical framework. The most important knowledge that is used are design principles from previous research and insights about blockchain and smart contracts. Also methodologies to perform research are included in the knowledge base. In this research those are the design science approach, desk research and literature review. At the end of the design process deliverables have been formed, the so called artifacts: the design framework and the design principles on which it is based. Knowledge from these artifacts will be added to the knowledge base as extension of the current theoretical framework.

The design process arena is the most important aspect of the design science approach (Hevner, 2007). The two activities that are performed in this stage are development and evaluation. In an iterative process, design principles and the design framework are developed and evaluated.

2.2. Research questions and methods

Based on the research approach of the design science approach, we formulated the sub questions in table 4. The first phase of the design science approach is *apply knowledge*. The first and second sub questions derive knowledge from the knowledge base in order to form a basic knowledge about the subject. The third sub question enables the second phase *build*. The first version of design principles is built with knowledge from the literature. The third phase is *assess* and *refine*, which is done by observing data from the environment. The fourth sub question enables this phase by conduction case studies, as these are applicable for observing the environment when there is a lack of literature on a subject. The fifth sub question aims at building the first version of the design framework. This is another design phase *build* and uses the first version of design principles as input. Both the design principles and the design framework are *assessed* and *refined* another time by conducting expert interviews in order to answer the sixth research question. This leads to the final version of the design framework and the design principles.

Table 4 - Research questions, methods and outcomes.

Question	Method	Outcome
SQ 1. How can the concept “blockchain powered smart contracts” be described?	• Literature review • Desk research	• Concept definition
SQ 2. Which governmental services are potentially suitable for smart contract implementations?	• Literature review • Desk research	• Overview of possible applications • List of current implementations
SQ 3. Which design principles for smart contract implementation can be derived from literature?	• Literature review • Design science approach (Build)	• First version of design principles
SQ 4. Which design principles can be derived from empirical implementation processes?	• Design science approach (Assess) • Design science approach (Refine) • Case study	• Use case descriptions • Second version of design principles
SQ 5. How can design principles be translated into a design framework?	• Design science approach (Build)	• First version of design framework
SQ 6. Which design principles and design framework can be derived from feedback from the environment?	• Design science approach (Assess) • Design science approach (Refine) • Expert interviews	• Final version of design principles • Final version of design framework

2.3. Research design

Figure 5 visualizes the research steps, the phase of the design science approach and the deliverables.

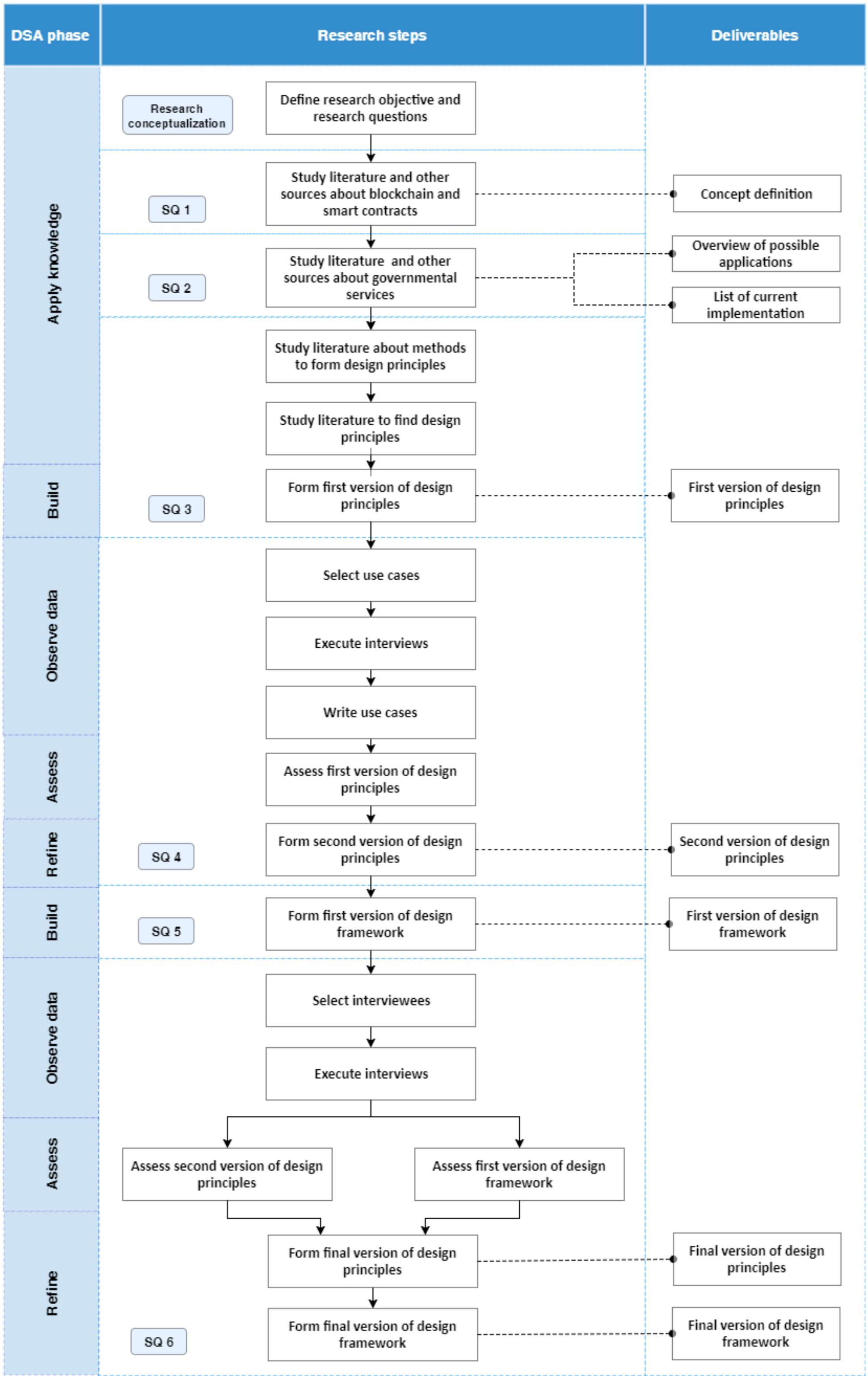


Figure 5 - Research flow diagram.

2.4. Societal relevance

Blockchain technology and smart contracts can possibly disrupt and improve many facets of governments. One of the major issues however, is that there is a major lack of real life implementations of smart contracts in governmental services. Governments are interested (Blockchainpilots.nl, 2016; NASCIO, 2017; Government Office for Science, 2016), but project teams lack tools and guidelines that support them in those implementations. Not many governmental organizations have adopted blockchain solutions (NASCIO, 2017), and blockchain experts are expensive and scarce (Banker, 2017). This research will deliver a design framework and design principles that are tailor made for smart contract implementation in governmental services. It is expected that project teams can be greatly supported by these tools. This could speed up the process of implementation and thus might lead to an acceleration of real life cases of governmental services that use smart contracts.

2.5. Scientific relevance

The topic of smart contracts in governmental services is not popular amongst academics. There have been only 31 academic publications that researched smart contracts in governmental services, but do not have a main focus on the implementation process. As has been concluded in this chapter and acknowledged by many academics, real life cases of smart contract implementations are barely existent. Consequently, there is a major lack of scientific knowledge about the implementation process of smart contracts for governmental services. Only two research publications wrote about design principles and none have developed a design framework for this purpose. The deliverables from this research will therefore fill a major knowledge gap.

3. Apply knowledge: literature

This chapter answers the first two sub questions. The first sub question: *"How can the concept "blockchain powered smart contracts" be described?"*, is answered in paragraph 3.1 and 3.2 by using a literature review and a desk research. This leads to a concept definition for blockchain powered smart contract and offers an understanding of how the technology works and what the potential opportunities and issues are. Paragraph 3.3 answers the second sub question: *"Which governmental services are potentially suitable for smart contract implementations?"*, by performing a literature review and a desk research as well. The results are a list of potentially suitable applications and an overview of the current implementations. This helps to understand in which governmental services smart contract implementation is in process and which services could be viable for implementation later on.

3.1. Blockchain technology

3.1.1. Fundamentals and characteristics

Cryptography

The main problem for electronic payments is the problem of double spending. In traditional banking through internet, the bank acts as central authority to keep record of who owns which money and to verify if a transaction is correct. This makes sure that a party spends the same money only once. In 2008 the pseudonym Nakamoto described a digital currency called Bitcoin. The underlying concept would be known as blockchain technology. Figure 6 shows the basic overview of how Bitcoin works. The idea is that each party has two keys: a public key and a private key. The public key can be seen as someone's bank account number and it is necessary for other parties if they want to transfer money to it. The private key can be seen as their password (Nakamoto, 2008, p.2).

When a party wants to make a transaction, he signs the transaction with his private key and sends it to the timestamp server for approval. A so called block is filled with several transactions. This block is then hashed cryptographically, where also all the previous blocks are considered in the hash (Nakamoto, 2008, p.2). This hash proofs that the history of all blocks and thus the history of all transactions is correct. Due to the cryptographic secure hash functions, this history cannot be forfeited (Haber & Stornetta, 1990). Summarizing, the technology behind Bitcoin prevents double spending, keeps track of the entire transaction history and only allows transactions when someone enters his own private key. Though blockchain technology was used later for many more purposes, Bitcoin was solely meant for electronic payments (Nakamoto, 2008).

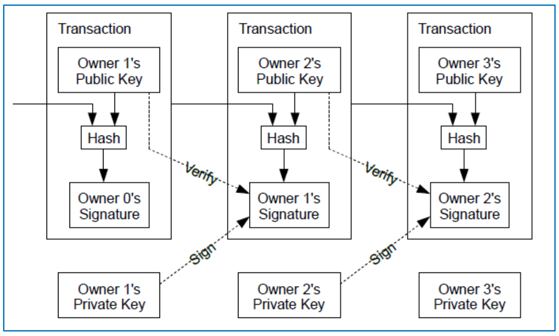


Figure 6 - Hashing scheme of Bitcoin [retrieved from Nakamoto, 2008, p.2].

Verification through the decentralized network

An important feature of blockchain technology is the verification through the decentralized network. Anyone with a computer can contribute in the network as miner. These miners have the purpose of verifying transactions and agreeing on the correct history of blocks (Nakamoto, 2008, p.4). In order to do so they have to solve a mathematical formula. This formula can be seen as a puzzle, which is designed to be solved every ten minutes on average. When the computational power of the network increases, the difficulty of the formula is adapted to retain the average solving time. This formula is extremely hard to solve, but the answer is easy to verify. When someone solves the formula he can create the next block and gets several Bitcoins as reward. This process is called mining. Because thousands of computers try to solve this puzzle, the costs for electricity and computation power is high. It is therefore uneconomical to try to cheat and alter information in the blockchain. This mining method is called *Proof of Work* (Tapscott & Tapscott, 2016, p.31-32). When someone makes a transaction, he does not need to trust the counterparty, because the network does the verification. The blockchain is therefore called *trustless.* The disrupting factor of this process is that there is no need for a third party, like a bank (Swan, 2015). Besides Proof of Work, other mining methods exist, such as Proof of Stake (BitFury Group, 2015) and BFT Replication (Vukolić, 2015).[1] They function differently, but have the same principles of verification through the decentralized network. The differences between these methods are mainly on a detailed technical level and will not be further elaborated in this research.

Peer-to-peer broadcasting and the distributed database

The decentralized network verifies transactions and keeps track of the transaction history. There is not a single node in the network that is more important than others, because information is transmitted to every participating node. This is called peer-to-peer transmission (Iansiti, & Lakhani, 2017). The hash that verifies new transactions also needs the complete history of previous transactions in order to be correct. Hence, when a node mines new blocks, he needs to be in possession of the entire database (Iansiti, & Lakhani, 2017). Therefore, every participating node in the network has a complete copy: the distributed database. There is no single database that can be hacked (Tapscott & Tapscott, 2016, p.6).

To understand this decentralization, it is necessary to compare it with the traditional methods. When for example Alice sends money to Bob with traditional electronic banking, Alice sends the request for the transaction to the bank. The bank verifies this transaction and adapts his central database: the balance of Alice decreases and the balance of Bob increases. Alice and Bob can now check their balance when they connect to the central database of the bank. The bank is the only node that verifies transactions and the only party who controls the database. Alice and Bob need to trust the good intentions and security of this party. When the central database of the bank is hacked or is offline, Alice and Bob have no alternatives to check their correct balances. In the blockchain, the network of many nodes will verify the transaction and keep a history record of the transactions and thus their balances. When one node goes offline or transmits an incorrect database history, the other nodes will act as backup by sharing the correct database.

Transparency

The distributed database also brings transparency as feature. Because every node has a copy of the blockchain, it is known as the public blockchain. Everyone is able to see which transactions are happening, which transaction have happened in the past and the balance of every address (Swan, 2015, p.1). The transaction flows are thus transparent. This transparency is protected with the pseudonymity of addresses. Every node or user has a blockchain address. This address is a unique alphanumeric address with 30 or more characters. This hides the identity of the user, but if they want to they can proof their identity by making a transaction (Iansiti, & Lakhani, 2017). Concluding, the transactions in the blockchain are transparent, but the users can remain pseudonymous.

[1] Suggested further reading on verification methods: Baliga, A. (2017). *Understanding Blockchain Consensus Models.*

Immutability

The cryptographic fundamentals and the distributed database make the data in the blockchain immutable. Each new block is hashed by using all the previous blocks. In order to create a new block, the entire history of blocks that is used in the new hash should therefore be correct. If that does not happen, for example when someone tries to change one minor detail in a previous transaction, the hash references will become invalid and it immediately becomes clear that someone tries to change the history of transactions (Drescher, 2017, p.138). In order to steal bitcoins in the blockchain, one has to rewrite the entire transaction history, which is practically impossible (Tapscott & Tapscott, 2016, p.7). What would happen if someone succeeds in changing the record history is not known. The first blockchain technology Bitcoin for example was never hacked (Vanini, 2017, p.19). The records in the blockchain are therefore considered as truly immutable.

Cryptocurrencies

Bitcoin was the first popular application of blockchain technology and was called a *cryptocurrency coin*. This is often abbreviated to simply a *crypto*. After Bitcoin, many more similar applications developed. They are based on the blockchain technology and sometimes are copies of Bitcoin, but can also differ on many aspects. These other cryptocurrencies are called *alternative coins,* or shortly *altcoins* (Bonneau et al., 2015). Popular altcoins are for example Ethereum, Ripple, Dash, NEO and IOTA (Coinmarketcap.com, 2017a). These altcoins can be programmed to serve as currency in their own network and application. Consequently, each altcoin can be programmed to only be used for certain purposes. For example, Namecoin is an altcoin that can only be used to verify Domain Name System registrations. This altcoin has a value, but can only be used for the intended purpose (Swan, 2015, p.31-32).

Just like regular stocks and options, Bitcoin and altcoins can be traded on exchanges for cryptocurrencies. There are currently more than 1,000 altcoins with a total market value of more than $100,000,000 (Coinmarketcap.com, 2017a). Anyone can buy cryptocurrencies, without having to solve the mathematical process of mining that verifies transactions. But not all cryptocurrencies are created through mining like Bitcoin. They can also be bought in a blockchain version of the initial public offering (IPO). As form of equity capital raising, startups can retrieve millions of dollars by selling their own cryptocurrency (Tapscott & Tapscott, 2016, p.82-83). This is also known as an initial coin offering (ICO) (Dannen, 2017).

Public and private blockchains

So far, the basic ideas behind blockchain technology have been explained: a distributed ledger that keeps record of transactions, which are broadcasted in a transparent peer-to-peer network. This is called the public blockchain, because the blocks and transactions are public for anyone to see and open for everyone to verify. There is no need for permission to interact in the network. Therefore, the public blockchain is also known as *permissionless* (Tapscott & Tapscott, 2016, p.67). Another form is called the private blockchain. This ledger keeps record of transactions, but is only accessible for persons who have been granted permission. Therefore, the private blockchain is known as *permissioned.* Limitations can be set for who can access the blockchain and for who can verify transactions (Tapscott & Tapscott, 2016, p.67).

Both forms of blockchain have their advantages and disadvantages. The main difference is that the private blockchain does not have a decentralized consensus process. This makes it more efficient than the public blockchain, but the immutability could be tampered by the few verifying nodes. Furthermore, the private blockchain is not visible for everyone and thus offers more privacy to users. A comparison between the properties of the two blockchain forms is summarized in table 5.

Table 5 – Comparison between public and private blockchains [retrieved from Zheng et al., 2017, p.6].

Property	Public blockchain	Private blockchain
Consensus determination	All miners	One organization
Read permission	Public	Could be public or restricted
Immutability	Nearly impossible to tamper	Could be tampered
Efficiency	Low	High
Centralized consensus	No	Yes
Consensus process	Permissionless	Permissioned

3.1.2. Issues with blockchain

Smart contracts as defined in this research are powered by blockchain technology. Therefore, the issues that exist in the blockchain are issues of smart contracts as well. This paragraph will look at which issues currently exist in blockchain and why they are important.

Scalability

Applications using blockchain technology work properly in their current scale, but the technology might not yet be ready for mass adoption. Figure 7 visualizes the average number of transactions per second on the Bitcoin network. Between November 2016 and September 2017 there were on average never more than four transactions per second. With the current technical design the maximum number of transactions is approximately seven per second (Croman et al., 2016). In comparison: there are on average approximately 1,700 transactions per second on the Visa network and it is even capable of processing up to 24,000 transactions per second (Visa, n.d.). This means that the Bitcoin network can only process around 0.4% of the number of transactions that Visa handles on average. The Ethereum network has the same scalability issues and developers are actively researching solutions. They propose a solution in a whitepaper, with project name *Plasma*, called *sharding*, *"that is scalable to a significant amount of state updates per second (potentially billions)"* (Poon & Buterin, 2017, p.1). The solution is currently being tested and is expected to be implemented in the future.[2] Other solutions are scarce at the moment. As Yli-Huumo et al. (2016) note, the current literature does not focus on scalability issues of blockchain.

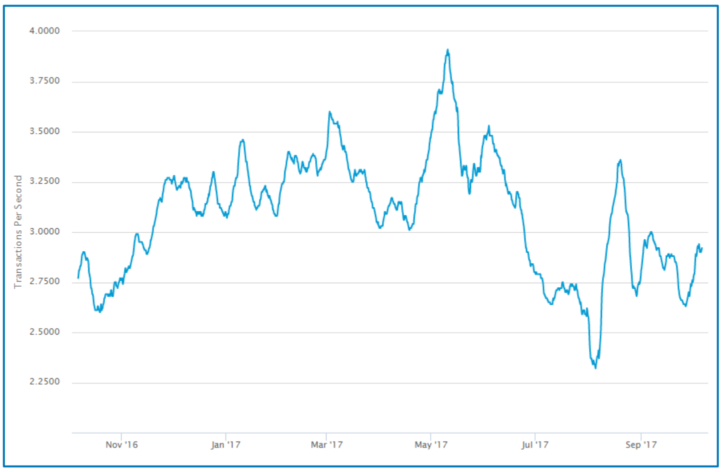


Figure 7 - Transactions per second on the Bitcoin network [retrieved from Blockchain.info, 2017].

[2] Suggested further reading on the implementation of *sharding*: Buntinx, J. P. (2017). *What is Sharding?*

Volatility

Cryptos, short for cryptocurrencies, such as Bitcoin and Ether, are used to pay for transaction costs on the blockchain. Volatility of these cryptos would therefore mean volatility in costs. The price development of Bitcoin in figure 8 shows the volatility problem. The price was around $100 in mid-2013, up to $1,100 in November 2013, back to $500 in December 2013 and up to almost $5,000 in August 2017 (Coinmarketcap.com, 2017b). The volatility of cryptocurrencies make them an unreliable store of value (He et al., 2016, p.17).

Figure 8 - Price development of Bitcoin [retrieved from Coinmarketcap.com, 2017b].

The spectacular value rise of cryptos in 2016 and 2017 has led to statements about the crypto market being in a financial bubble. Jamie Dimon, CEO of financial institution JPMorgan, for example states that the bubble will blow up and the value of cryptos will decrease (Sun et al., 2017). There are however many parties who disagree and think that the market will keep on rising. For example Jon McAfee, computer programmer and founder of security software company McAfee, disagrees and thinks the market will grow even more (Althauser, 2017). Many news articles are written about whether or not there will be a collapse of the crypto bubble, but it is not a popular topic in academic literature (Cheung et al., 2015). Even if the market of cryptocurrencies will not collapse, there is much volatility and thus the transaction costs are unstable. McGinnis and Roche (2017) argue that volatility will decrease while time passes, but this prediction is yet to be seen.

Decentralized decision making

Blockchain technology has been hailed for its decentralization. This also affects the decision making. This is not particularly a problem with transaction verification. The participants in the network vote for which transactions they consider correct. When the majority of the votes flags a transaction as correct, they reach consensus and confirm the transaction history (Drescher, 2017, p.167). This form of decision making is fundamental to blockchain technology. However, this is a point of debate when decisions need to be made on larger scale. When decisions about large technical adaptions need to be made, such as for example changing the consensus rules or block size, there is no central authority to decide upon this.

Large scale decision making is executed in roughly two ways: user votes and miner votes. The first was demonstrated after a major hack (the *DAO hack*) on the Ethereum network. In order to reverse the effects of this hack, the developers let the users decide if they would accept the solution of the developers. Every holder of Ether currencies could vote, after which the decision was made after weighing each vote by the number of Ethers they held (Hacker, 2017, p.14). The individuals with the highest balances could therefore have the most influence on the decision. The other decision method is letting the miners decide. This was demonstrated in the voting for adapting the block size of Bitcoin. The decision would only be supported if at least 75% of the blocks from 1,000 consecutive blocks would be flagged with a yes-vote (Hacker, 2017, p.15). However, most individuals are united in so-called mining pools. By combining the computational power of many computers it becomes easier to find a block. The rewards will then be distributed over all contributors in that pool. The mining pool itself however gets to vote. The three largest mining pools alone already account for approximately 40% of the mining power and thus approximately 40% of the voting right (Sheehan et al., 2017).

Both voting mechanism do not fully comply with the decentralized nature of blockchain: the first allows individuals who possess the most cryptos to vote and the second lets the owners of the mining pool vote.

Security

Blockchain has some security issues. One of the most dangerous issues is the 51-percentage attack. When 51 or more percentage of the nodes in the network vote in a malicious way they could falsely flag transactions as correct and even change the transaction history (Swan, 2015, p.83). It appears to be hard to reach 51-percentage in a network with many nodes, but as discussed in paragraph 2.1.3, individual miners unite in mining pools. The four largest mining pools of Bitcoin, AntPool, BTC.TOP, ViaBTC and BTC.com, together form approximately 56.1% of the computational power (Blockchain.info, 2017). This means that if these four companies agree to manipulate transaction data they might be able to do so by simply flagging their own manipulated block history as correct.

Another important security issue arises in the applications that apply blockchain. Due to the novel character of blockchain, these applications often prove to have bugs. Blockchain companies are vulnerable to scams (He et al., 2016, p.29). Examples are the hack of bitcoin exchange MtGox with a loss of over $500 million (Decker & Wattenhofer, 2014), the $60 million hack of investment platform DAO (Jędrzejczyk & Marzantowicz, 2016, p.14) and the $2 million dollar hack of Vericoin (Swan, 2015, p.85). These hacks are not a result of flaws in the blockchain, but because of security issues in the applications that have been built on top of it.

Besides these bugs, hackers now also target the cryptocurrencies of individuals. A reason for this is that there are no additional security measures when a person loses his private keys (Drescher, 2017, p.207). Individuals keep their own key to verify their transactions are correct. This key is not a physical key, but a password. Because this password is long, it is often written down on paper. If they lose this key they cannot make transactions anymore and thus their balance is useless. When someone else acquires their keys, they can make transactions on their behalf and thus steal from his balance (Jaag & Bach, 2017, p.6). When this happens it is *"nearly impossible to identify the thief"* (Xu, 2016, p.6). While credit card companies can refund balances, in blockchain technology there is no central authority to do so.

Privacy

One of the characteristics of blockchain is that the ledger is transparent. This implies privacy issues, because many transaction details are public for everyone to see. For example, for every transaction it is visible which amount of which cryptocurrency has been transferred, the public address of both the sender and the recipient, and the time of the transaction (Drescher, 2017, p.206). A public key is a random string of letters and digits, and is not directly linkable to an individual. However, it not impossible to link someone's identity to a public address. Various flow-control tools exist that can show someone's past transactions and track them in the future (Raymaekers, 2015, p.38). An example is the research of Barcelo (2007) where the identity of several account owners could be derived. This was done by starting with the public address of the organization Wikileaks. Their address was published on their website in order to receive donations. Several website owners announced the amount of bitcoins they donated. Because the blockchain shows the amount of bitcoins transferring between which accounts, it was possible to couple the addresses of some contributors to their identity.

Choosing between transparency and privacy is an important design dilemma that companies will need to decide upon (He et al., 2017, p.16). The solution of a private blockchain was introduced as result. In a public blockchain, all transactions are public and everyone can join as node. In a private blockchain, the transactions are not publicly visible and the owner of the blockchain can control who has access to it. This increases privacy protection and could be suitable for sectors where this is important, such as health care (Janssen et al., 2017, p.1). However, not much research has been performed on private blockchains. When Scopus is searched for research on this specific topic, only thirteen publications are found (see table 2 in paragraph 1.1). A solution for improving the privacy on the public blockchain is called zero knowledge proof (*zk-SNARK*), which reduces the transparency of transactions (Z.cash, n.d.). The solution is currently being developed on the Ethereum platform (Sharma, 2017).[3]

Regulation and government intervention

Blockchain technology and its cryptocurrencies, which are also necessary for smart contracts, started as initiatives without the control or involvement of governments. Due to the risks as described in this chapter, many governments are currently deploying regulation or considering this to restrict certain parts of it. China will ban the trading of cryptocurrencies and investing in ICO's (Coindesk.com, 2017). Australian officials made official statements to warn consumers about risks involved in this kind of investments (Australian Securities & Investments Commission, n.d.). The Financial Conduct Authority of the United Kingdom warns consumers about the risks of these investments as well, but acknowledges that not all the companies that organize these ICO's will fall under legislation (Financial Conduct Authority, 2017). Also the US-based SEC's Office of Investor Education and Advocacy warns consumers for these risks and states it may suspend trading in certain cryptocurrencies if necessary (Investor.gov, 2017). Though some governments are precautious with blockchain technology, other governments are embracing bitcoin technology. The financial authority of Japan officially allows the trading of cryptocurrencies on eleven platforms (Wada & Sano, 2017). The Dutch government supports the development of blockchain technology and is actively involved in organizing pilots and events (Dutch Digital Delta, 2017). The city of Dubai even plans to become a pioneer by becoming the most blockchain-friendly city in the world (SmartDubai.ae, n.d.). How these different approaches of regulation will work out is yet to be seen.

Another regulatory issue is the possibility of tax evasion and avoidance. Because many governments lack tax rules for blockchain based companies and their currencies, it is possible that the current tax framework does not or does not fully apply to these new companies. In combination with the anonymous character of blockchain, it is also harder to gain overview of the exact income and expenses of individuals and businesses (He et al., 2016, p.30). The lack of transparency in the financial situation of businesses and individuals, and a lack of clarity in tax rules is a challenge governments need to address.

Lack of industry standards

Blockchain technology has only been developed since 2008. Though the blockchain itself has not been hacked yet, there have been hacks on the applications that have been built on it. Industry standards could guide organizations in building their design to make them safer and to stimulate widespread adoption (Goldman Sachs, 2016, p.5). Standards Australia requested the International Organization for Standardization (ISO) to research and develop standards which are applicable for blockchain technology (Guo & Liang, 2016, p.10). ISO complied to this request and is currently developing industry standards for blockchain with 25 members. The members are amongst others Australia, Brazil, China, France, Germany, Japan, the Netherlands, Russia, the United Kingdom and the United States. The standard has been coded as ISO/TC 307 and is currently in the preparatory phase (ISO, n.d.).

3.1.3. Sub conclusion

Blockchain is a distributed ledger technology that distributes digital transactions peer-to-peer to a decentralized network of nodes that verify the transactions and keep a cryptographic secured copy of the entire history of transactions. The network automatically determines consensus about the correct history of records, which makes the database transparent and immutable. This consensus role makes it possible to take away the third party in certain processes, such as the bank or the notary. Blockchain also enables digital

[3] Suggested further reading on zero knowledge proof solutions: De Santis, Micali & Persiano (1987). *Non- interactive zero-knowledge proof systems;* Feige et al. (1988). *Zero-knowledge proofs of identity*; Z.cash (n.d.). *Internet money*.

payments and smart contracts. Blockchain is a new technology that experiences several issues: the technology has a low maximum transaction speed limiting the scalability, the blockchain based cryptocurrencies are volatile and thus the costs of using the blockchain varies, questions arise about how decentralized the decision making is, security issues are present, such as the 51-percentage attack and weak programmed applications, lack of privacy, government intervention and a lack of industry standards.

3.2. Smart contracts

3.2.1. Describing smart contracts

Introduction to smart contracts

Blockchain technology is known for electronic payments, but there are many more uses. With smart contracts, anything can be registered digitally, like for example "*birth and death certificates, marriage licenses, deeds and titles of ownership, educational degrees, financial accounts, medical procedures, insurance claims, votes, provenance of food*" (Tapscott & Tapscott, 2016, p.7). Smart contracts run on the blockchain and thus have the same characteristics, such as transparency and cryptography. A smart contract can be considered as a contract that is programmed in a computer code. Two or more parties digitally agree upon certain rights, obligations and possible outcomes. The contract is "*recorded in the blockchain and executed by distributed nodes of the network, which eliminates the need for a trusted third party*" (Jędrzejczyk & Marzantowicz, 2016, p.7). The contract will execute itself and will behave exactly as coded (Tapscott & Tapscott, 2016, p.88). This enables a broad variety of uses: an automatic payment based on a bet (Koulu, 2016, p.42), paying and unlocking doors for an Airbnb house (Tapscott & Tapscott, 2016, p.117), releasing financial aid after a certain period of escrow (Tapscott & Tapscott, 2016, p.190), issuing insurance payments after requirements are automatically checked (Drescher, 2017, p.241), sending payments if someone succeeds in an online learning course (Swan, 2015, p.62) and many more.

However, the term *smart contract* can be misleading. The term is neither smart nor necessarily a contract. The contract is a computer code, which for the popular smart contract platform Ethereum is written in the JavaScript-like language Solidity. The blockchain executes the contract exactly according to what was programmed (Luu et al., 2016). This implies that all possible outcomes should be determined beforehand. The smart contract simply does what it is programmed to do and does not perform any pro-activity (Smart Contract Werkgroep, 2017, p.12). Smart contracts also do not have to be contracts in the sense that they are legally binding. Paragraph 3.2.2 dives further into the legal character of smart contracts.

Oracles

Many smart contracts can be dependent on external values. For example, the outcome of a football match in a betting contract. Smart contracts make use of a so called *oracle* to collect information. The oracle is a source that provides input for the smart contract (Smart Contract Werkgroep, 2017, p.18). With the football bet example an oracle could be the international football organization that published the match results on their website. A downside to using an oracle is that a third party acts as intermediary, which is contradictory to the principles of blockchain that no third party is needed (Silverberg et al., 2016, p.8).

Example of a smart contract

To illustrate how a smart contract works, the example of a financial swap is visualized in figure 9.

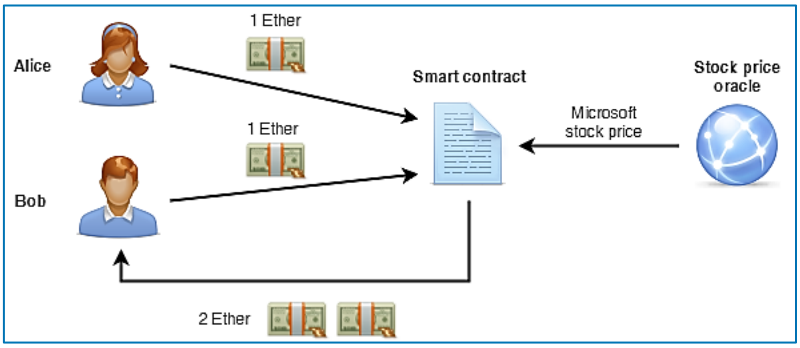


Figure 9 - Smart contract example [retrieved and adapted from Pixel Mixer, n.d.].

Let's say Alice and Bob want to agree to a financial swap. They want to take a bet on the price of a stock. Alice bets that the price of a Microsoft stock will be above $85 and Bob bets that the price of a Microsoft stock will be $85 or lower. In a smart contract they agree to both deposit one Ether currency, signing the contract with their public and private keys. After a certain deadline, the blockchain executes the smart contract. The price of the stock is queried from a stock price authority, which acts as an oracle (Delmolino et al., 2015). If for example the price of a Microsoft stock is $80, Bob wins the bet and the smart contract automatically sends the two Ether to the public address of Bob. Figure 10 shows the part of the code where the result is determined by consulting the oracle and sending the Ether to the winner.

```
data Alice, Bob
data deadline, threshold

# Not shown: collect equal deposits from Alice and Bob
# We assume StockPriceAuthority is a trusted third party contract that can give us the price of the stock

def determine_outcome():
  if block.timestamp > deadline:
    price = StockPriceAuthority.price()
    if price > threshold:
      send(Alice, self.balance)
    else:
      send(Bob, self.balance)
```

Figure 10 - Example of a smart contract code [retrieved from Delmolino et al., 2015, p.5].

3.2.2. Comparison with traditional contracts

Traditional contracts

The term *smart contracts* implies a connection with traditional contracts. According to the Oxford dictionary, the definition of a contract is: "*A written or spoken agreement, especially one concerning employment, sales, or tenancy, that is intended to be enforceable by law*" (Oxford dictionary, 2017c). The definition of when something is an agreement differs per country. For example the Dutch law states that an agreement is valid when two criteria are met: there is an offer of one party and all involved parties accept the offer (art. 3.1, BW 6, 2017). These definitions do not exclude digital agreements and smart contracts, as they are digitally written and have the parties agree upon offered terms. The US law further specifies a contract with four criteria a contract should have (Judicial Education Center, n.d.):

1. *Offer* – One party offers some specified terms;
2. *Consideration* – Something of value is promised in exchange for a service, product or action;
3. *Acceptance* – The other party accept the offer;
4. *Mutuality* – Both parties understand the terms and mutually agree upon it.

In other words, depending on the definition of the applicable law, traditional contracts are written or spoken terms between two or more parties, where one party makes an offer about something of value and all parties understand and agree upon it.

Smart contract forms compared with traditional contracts

The Dutch Smart Contract Werkgroep (2017) compared the seven most used forms of smart contracts in comparison with traditional contracts in their smart contract report.[4] Note that the analysis is done from the point of view from Dutch law and may differ from the law in other nations. The implications and conclusions however are expected to be more or less globally applicable:

1. *Execution of a contract* – A smart contract can trigger a payment automatically, which makes it a contract with legal validity (Smart Contract Werkgroep, 2017, p.23-29). However, the contract is written in computer code which may not be understood well by each party. The contract is only valid if the parties understand all terms (Tai, 2017, p.181) and thus comply with the mutuality criteria;
2. *Suspensive condition or dissolving condition* – The suspension of a contract happens under certain circumstances. Only if certain criteria are met it is possible to suspend the contract. An example would be the expiration date of a contract, where after the contract is suspended. Smart contracts could program the most of these criteria (Smart Contract Werkgroep, 2017, p.29-30). But not all criteria can be programmed into a computer. This issue will be further explained in paragraph 3.2.3;
3. *Unilateral private law legal act* – A unilateral contract is a legal transaction that is triggered by one party, but affects another. This is for example when a landlord terminates a rental agreement. In such an example there are strict criteria which are hard to code. Often a judge has to approve the termination. To incorporate this in a contract, the rental agreement would be a smart contract. The judge would allow the termination of the agreement in real life and submits his decision through an oracle. The smart contract self-destructs afterwards (Smart Contract Werkgroep, 2017, p.30-32). This would limit the workload, but would not eliminate the third party as the judge is still necessary;
4. *Decision under public law* – A decree is a decision by a public authority for individual persons, such as the permission to grant someone subsidy. The possibility to handle this with a smart contract depends on how strict the rules for the outcome of the decree are. If the decision depends on a few criteria that are easily checked, such as place and date of birth, it could be easily set with a smart contract. If the public authority has to make a judgement based on more subjective criteria it is harder to encode this. A solution would be to make the judgement in real life and communicate his decision through an oracle (Smart Contract Werkgroep, 2017, p.32-34);
5. *Means of evidence* – A legal contract is only legally valid if parties can prove that there was an agreement. A traditional contract could be for example a physical paper with autographs. Smart contracts are signed by both parties and auditable by publication in the blockchain. The main problem is that it is hard to proof that the parties that signed the smart contract actually are the parties that claim to have done so (or claim not to have done so) (Smart Contract Werkgroep, 2017, p.34-35);
6. *Automatic execution of a (legal) process* – There are many legal procedures that happen in certain phases. For example, a government can increasingly fine an individual or an organization if the party violates certain laws or agreements. Many of the procedures are physical processes which cannot be coded in a smart contract. This is for example an authority that inspects the physical administration of an organization. Physical processes cannot be replaced by smart contracts, but the outcome could be communicated to a smart contract through an oracle (Smart Contract Werkgroep, 2017, p.35-36);
7. *Taxation* – The rules for taxation are clearly written in the law. Where organizations and citizens can partially have their tax declaration filled in automatically, much information has to be filled in by hand. Because of the clear tax rules it is expected that much taxation can be automated by using smart contracts. Different organizations (such as in the case of a citizen, his bank and his employer) provide

[4] An English version of the report can be consulted via https://www.dutchdigitaldelta.nl/uploads/pdf/Smart-Contracts-ENG-report.pdf.

the input and fill in much of the information. The applicant only has to check the information and confirm it. There are some impediments though, such as complicated tax declarations which a computer cannot simply decide upon (Smart Contract Werkgroep, 2017, p.36-37).

3.2.3. Issues with smart contracts

A smart contract is only a specific application of blockchain technology, with certain characteristics that are different from other blockchain applications. Therefore some issues that are observed are specific for smart contracts. This paragraph looks at issues that are specifically occurring with smart contracts.

Legal inflexibility and uncertainty

The term *smart contract* implies a legal relation between parties. The smart contract is automatically executed and becomes irrevocable once the contract is deployed on the blockchain. If however one of the parties cannot comply to one or more of the conditions, there is a lack of flexibility to deal with this. In contract law, lawyers have the freedom to interpret the contract and handle unforeseen situations (Silverberg et al., 2016). With smart contracts this is not possible. There is no third party that can change conditions and thus all possible outcomes should be accounted for in advance. This restricts smart contracts to handle only simple situations with clear rules, variables and outcomes.

Also the legal status of smart contracts is unclear (He et al., 2016, p.23). When a smart contract specifies that someone needs to perform a physical act, it is not possible for the smart contract to verify this (Tjong Tjin Tai, 2017, p.178). If, for example, someone will be paid €100 to give a performance, the smart contract code cannot verify this physical act. In traditional contract law, the contract will be enforced by a third party. This party will acknowledge the legal status of the contract and demands the parties of the contract to comply. With a smart contract however, there is no third party to enforce it. As a matter of fact, the main purpose of smart contracts is to avoid the necessity of a third party (Levy, 2017, p.2). It is possible to give the smart contracts a legal status after which it is possible to enforce them through traditional authorities. However, until national laws for smart contracts are drafted, their status remains unclear.

Technical issues

Due to the technical nature of smart contracts, several technical issues arise. These are the same technical issues as blockchain in general, but some are specific for smart contracts. One of them is known as the *code is law*-discussion. This is best explained by the example of the *DAO-hack.* In this massive attack a small vulnerability allowed an attacker to receive approximately $60 million worth of cryptocurrencies (Jędrzejczyk & Marzantowicz, 2016, p.14). The DAO was a fundraising platform that used smart contracts. The hacker used the vulnerability in such a way that it seemed that individuals only made one payment, while they actually sent their entire balance. The interesting part was that the smart contract was executed perfectly well. It was the application of DAO that had the vulnerability. The solution was a hard fork. That would split the blockchain in such a way that it was agreed to start over from a block before the hack and the blocks with transactions from the hack were simply not supported anymore (Tjong Tjin Tai, 2017). Figure 11 shows a representation of this hard fork, where the split happens after block 1,919,999. The original blockchain with the transactions from the hack continues from 1,920,000 onward, while the fork starts over at this point and thus does not have transactions from this hack. This led to major discussions over the solution. The opponents of the hard fork keep using the original chain. Their reasoning for this is that the smart contract was well executed. They say that transactions should remain immutable and that "*code is law*" (Ethereum Classic, n.d.).

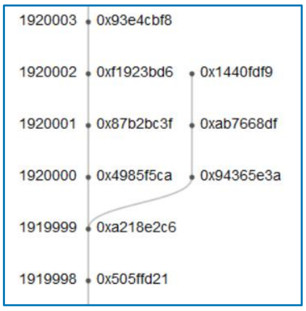


Figure 11 – Hard fork representation [retrieved from Buterin, 2016].

Another issue is that there are still many bugs and problems in the network. Examples are the call-stack bug (Delmolino et al, 2015, p.10), the blockhash bug (Delmolino et al, 2015, p.11), Ethereum-specific incentive bugs (Delmolino et al, 2015, p.10), gasless send, exception disorder, stack size limit (Atzei et al., 2017) and many more. This problem is understandable, as technology needs time to develop, but it is likely that mass adoption is impeded as long as many bugs exist. A non-exhaustive list of these bugs and their description is summarized in table 6.

Table 6 - Smart contract specific bugs.

Bug	Description	Source
Call-stack bug	There is a limit in the call-stack, which can be seen as the temporary memory of the contract. If this is full due to a buggy part, the rest of the contract will not be fulfilled completely.	(Delmolino et al, 2015); (Li et al., 2017); (Luu et al., 2016); (Atzei et al., 2017)
Blockhash bug	The *block.prevhash*-function only supports the previous 256 blocks.	(Delmolino et al, 2015)
Ethereum-specific incentive bug	Miners can withhold blocks if it contains information that they do not want to reveal.	(Delmolino et al, 2015)
Gasless send	For the processing of smart contracts, transaction costs must be paid. This is paid in *gas*. When not enough gas is paid, the contract is terminated at the point there is no more gas.	(Li et al., 2017); (Luu et al., 2016); (Atzei et al., 2017)
Mishandled exception	When a contract calls another contract, its response is an exception and the first contract did not check for exceptions, various threats exist.	(Alharby & van Moorsel, 2017); (Li et al., 2017); (Luu et al., 2016); (Atzei et al., 2017)
Re-entrancy	This is the bug that led to the DAO-hack (paragraph 3.1.2), where multiple withdrawals are performed through a recursive call function, while someone's balance is only deduced once.	(Alharby & van Moorsel, 2017); (Li et al., 2017); (Luu et al., 2016); (Atzei et al., 2017)
Transaction-ordering dependency	The transaction order in the block is determined by the miner. When this order is incorrect, two contracts who invoke the same contract can have unwanted effects.	(Alharby & van Moorsel, 2017); (Li et al., 2017); (Luu et al., 2016)
Timestamp dependency	When the timestamp is used as important input, for example as seed, a dishonest miner could vary the release of the block to influence this.	(Alharby & van Moorsel, 2017); (Li et al., 2017); (Luu et al., 2016)
Ether lost in transfer	There are many (Ethereum) addresses which are still unused. These are called *orphan addresses*. If someone accidently types such an address as recipient, the ether will be lost in transfer.	(Atzei et al., 2017)
Immutable bugs	The blockchain is immutable. Consequently, the smart contracts and their bugs are immutable as well.	(Atzei et al., 2017)

A third technical issue is the limited support for programming languages. The most popular smart contract blockchain is Ethereum. Smart contracts on Ethereum can only be programmed in Solidity, a coding language that is specially made for this purpose. Consequently, developers have no experience with coding in this language and thus need to learn a new language (Dannen, 2017). Another smart contract platform, NEO, does offer the possibility to code in multiple popular languages that already exist, such as Java and C#. According to the NEO developers this reduces the learning curve and thus faster builds a developers community (Canesin et al., 2017). However, Ethereum is far more popular at the moment. The total market value of Ethereum is $29,631,755,688, which is roughly eighteen times the value of NEO (Coinmarketcap, 2017a).

Lack of best practices

Though the principles of smart contracts were already described twenty years ago by Nick Szabo (1994), the first smart contract powered platform was only just proposed and developed in 2013 (Wood, 2017). Applications that use smart contracts, like the smart lock start-up Slock.it (Sun et al., 2016), have been developed the last few years, but the field is still new. Hence, there is still much unclarity in the approach to smart contracts and only few policy recommendations have been made (Koulu, 2016, p.54). Mass adoption of smart contracts is however hindered by amongst others privacy concerns (Kosba et al., 2016) and the difficulty of understanding the fundamentals that are underlying smart contracts (Drescher, 2017). Capgemini argues that mass adoption will only begin to start somewhere after 2020 (Cant et al., 2016). The lack of real life use cases, experience from applications and mass adoption are causes for a lack of best practices. Without best practices, new applications start blank and do not build further on previous experience and knowledge, which would help to design new smart contract applications and to implement smart contracts in existing applications.

3.2.4. Sub conclusion

Smart contracts run on the blockchain and enables registration of digital assets, such as *"birth and death certificates, marriage licenses, deeds and titles of ownership, educational degrees, financial accounts, medical procedures, insurance claims, votes, provenance of food" (*Tapscott & Tapscott, 2016, p.7). Smart contracts are not always contracts in a legal sense, but sometimes they are. Smart contracts experience the same issues as blockchain, but also experience other issues: lack of flexibility in the legal sense, unclear legal status of smart contracts, many bugs and lack of best practices.

3.3. Governmental services

3.3.1. Governmental institutions

Current roles and forms

Governments are necessary to steer organizations and citizens to achieve goals that can only be reached when governed from above, such as for example providing electricity, reducing climate change, subsidizing museums or limiting the sales of tobacco and alcohol for minors. Without these institutions, people with different goals and ideas would constantly fight each other. Governments need to provide citizens and organizations with trust in the future in order to work, invest and consume, which stimulates welfare and wellbeing (Bovens, 't Hart & van Twist, 2007, p.85).

But the term government is used for many institutions. The definition according to the Oxford dictionary is "*the group of people with the authority to govern a country or state*" (Oxford dictionary, 2017b). This definition would imply that the government is only on regional or national level, but governmental institutions appear on many levels. These can differ per country, but the most common levels are: supranational (for example the

European Union), national, regional (for example the state of Ohio) and local (municipalities) (Hooghe & Marks, 2003). Within each of these level there are activities that the government performs by having interactions with other parties. Governmental services can be divided in four different types of interactions (DeBenedictis et al., 2002, p.131):

- *Government-to-government* – Interaction between governmental institutions;
- *Government-to-business* – Interaction between governmental institutions and businesses;
- *Government-to-citizen* – Interaction between governmental institutions and citizens;
- *Citizen-to-citizen* – Interaction between citizens, which are facilitated by governments.

Governmental institutions are thus interacting with businesses and citizens in order to create trust and let businesses and citizens achieve goals together. The role of the third party that connects parties and provides services for citizens also gives much power to the government, which enlarges the need for non-corrupt and efficient governments. Large bureaucratic governments can however have large overhead costs. It can be said that *"manufacturing trust can be expensive"* (Davidson, De Filippi & Potts, 2016, p.5-6).

Effect of blockchain and smart contracts

It is said that blockchain has *"the potential to improve all facets of government"* (Tapscott & Tapscott, 2016, p.140). Because the government is a large scale bureaucratic organization there is much to improve on terms of efficiency, friction and costs (Swan, 2015, p.27). Improving governmental services by making them faster and more efficient surely is desirable, but those characteristics are not why Tapscott & Tapscott (2016) call blockchain a revolution. A disrupting effect could be that blockchain technology can replace parts of the government (Atzori, 2015).

The foundations of blockchain technology were laid in the 1980s and 1990s. Several computer coders and mathematicians united in a group called the Cypherpunks. In a manifesto they made clear their intentions: "*These developments will alter completely the nature of government regulation, the ability to tax and control economic interactions, the ability to keep information secret, and will even alter the nature of trust and reputation. … The State will of course try to slow or halt the spread of this technology*" (May, 1988). A major implication of blockchain is the free use of cryptocurrencies. While national governments can confiscate money from your local (and central) bank account, this is not possible with for example Bitcoin, as the money is registered decentralized and not controlled by one party (Vigna & Casey, 2015, p.113). Digital payments is an example of a blockchain development that the government can only partially control. Governments can prevent the conversion of conventional money to cryptocurrencies through banks (White, 2015, p.391). However, the possession of cryptocurrencies is difficult to track. They can be stored offline and untraceable with a *cold wallet* (Goldfeder et al., 2014).[5] Payments are done through the decentralized and pseudonymous network, which makes banning of payments difficult.

It is possible that some services heavily rely on governmental institutions at the moment, but will become mainly decentralized with blockchain. An example is identification, which already has blockchain technology partially implemented in Estonia (Tapscott & Tapscott, 2016, p.197-199). Estonia issues electronic identities (e-ID) for anyone who wants to. This is not limited to habitants of Estonia, because it does not grant citizenship. It does however enable owners of the e-ID to perform online commercial activities, like *"business and company registration, opening of bank accounts and funds transfers, buying and selling of real estate and other property, and trade of goods and services"* (Sullivan & Burger, 2017, p.1). All those activities are not audited by a governmental institution, but by the blockchain network. Instead of the executor of the process, the government becomes merely the facilitator of the process. Where citizens used to have to trust the government, they can now trust the network. This however does not rule out governmental organizations.

[5] Suggested further reading on cryptocurrency storage methods: Goldfeder et al. (2014). *Securing bitcoin wallets via threshold signatures.*

Though the transactions are performed by the network, it is likely that the government *“will set-up, execute and maintain these architectures”* (Ølnes, Ubacht & Janssen, 2017, p.358).

Concluding, governmental services have many potential benefits from blockchain technology: faster, more secure, less costly and with less friction. But the role of governmental institutions can change as well. In some examples, like land registration and identification, they could become merely the facilitator of the network instead of the controlling third party.

3.3.2. Current implementations of smart contracts

In order to analyze which governmental services are potentially suitable for smart contract implementation it is necessary to look at the current implementations of smart contracts first. Figure 12 visualizes the state of development of blockchain in public sector use cases per March 2017. White, Killmeyer & Chew (2017) listed the ten most active public sector use cases for blockchain in a corporate report for Deloitte. The overview shows that many countries are examining blockchain in governmental services: countries from North-America, South-America, Africa, Europe, Australia and Asia are on the list. It should be noted that in about half of the examples the project has only been planned.

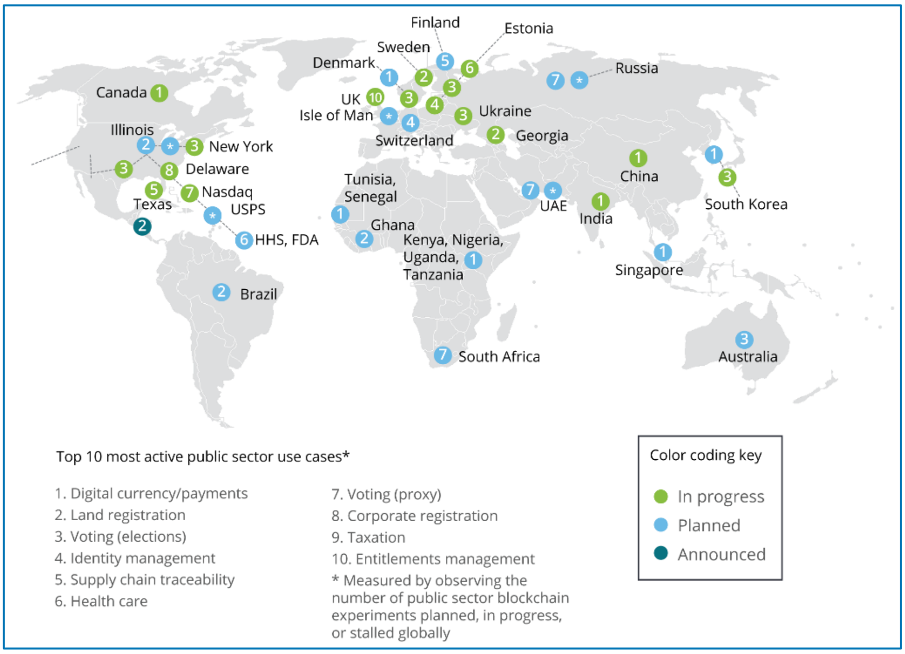


Figure 12 - Blockchain in the public sector per March 2017 [retrieved from White, Killmeyer & Chew, 2017, p.3].

This research has a focus on smart contracts in governmental services. The use cases in figure 12 are thus not all applicable for this research. A more recent, but not exhaustive, overview of use cases is summarized in table 7. The overview shows that the governmental services in which smart contracts have been implemented or are being implemented can be divided in roughly six categories: financial, ownership of property, supply chain, identification, voting and permit application. This list of projects suggests that these six categories are potentially suitable for smart contract implementation, but this is solely a temporarily categorization. We did not find a well-researched categorization of governmental services where smart contracts are being implemented and acknowledge that this is currently a knowledge gap.

Another important observation is that each use case can have multiple types of governmental interaction and can appear on multiple levels of government. Land registration for example, can have all four kinds of governmental interaction. It is a service that can be helpful when governments interact with other governments, businesses or citizens. Though the land registry implementations are at the moment only done on national and local level, it could theoretically also be implemented on regional and supranational level. Another example is voting: it could be used to vote in any governmental level, whether it is about election on supranational, national, regional or local level. It appears that the governmental level or governmental relationship that characterizes the governmental service are not key characteristics to assess the suitability for smart contract implementation.

Table 7 – A non-exhaustive list of current smart contract concepts, pilots and implementations per November 2017.

Category	Use cases	Governmental institutions
Financial	Subsidy and personal budget application	Municipality of Amsterdam (Pomp & Hartog, 2017); Municipality of Den Haag (Pomp & Hartog, 2017); Municipality of Zuidhorn (Zuidhorn.nl, 2017); Municipality of Stichtse Vecht (Pomp & Hartog, 2017)
	Digital payments	Municipality of Schiedam (Pomp & Hartog, 2017)
	Taxation	Municipality of Rotterdam (Pomp & Hartog, 2017)
	Debt assistance	Municipality of Schiedam (Pomp & Hartog, 2017)
	Personal finance	Municipality of Utrecht (Potijk & in't Hout, 2017)
	Discount card	Municipality of Groningen (Hendrison, 2017); Municipality of Arnhem (Bodd & Bolwerk, 2017)
Public records	Land registry	Sweden (Lantmäteriet et al., 2016); Municipality of Eindhoven (Pomp & Hartog, 2017); Municipality of Cook County (Yarbrough, 2017); Brazil (White, Killmeyer & Chew, 2017); State of Illinois (White, Killmeyer & Chew, 2017); Ghana (White, Killmeyer & Chew, 2017); Georgia (White, Killmeyer & Chew, 2017)
	Heritage	Dutch Ministry of Education, Culture and Science (Pomp & Hartog, 2017)
	Marriage	Dutch Ministry of Foreign Affairs (Pomp & Hartog, 2017); State of Florida (Swan, 2015); Municipality of Zaanstad (VNG, 2017)
	Bicycle registration	Dutch Vehicle Authority RDW (de Bruin, 2017)
	Medical records	Estonia (White, Killmeyer & Chew, 2017); Dutch National Health Care Institute (Felix, 2017); U.S. Food and Drug Administration (Mearian, 2017)
	Birth records	State of Illinois (IL Blockchain Initiative, 2017)
Supply chain	Waste processing	Municipality of Utrecht (Pomp & Hartog, 2017)
Identification	E-residency	Estonia (Sullivan & Burger, 2017)
Voting	Voting (elections)	South Korea (White, Killmeyer & Chew, 2017); Australia (White, Killmeyer & Chew, 2017); Colombia (OECD, 2017); Ukraine (White, Killmeyer & Chew, 2017); Municipalities of Almelo, Emmen, Hollands Kroon, Molenwaard and Lingewaard (Van der Steen, 2017)
Permit application	Event permit	Municipalities of Barendrecht, Albrandswaard and Ridderkerk (Pomp & Hartog, 2017)
	Disabled parking permit	Municipalities of Schiedam and Drechtsteden (Pomp & Hartog, 2017)

3.3.3. Potentially suitable governmental services

Paragraph 3.3.1 and 3.3.2 showed that there are many governmental services, divided in various levels and types of interactions. The diverse character makes it hard to list potentially suitable governmental services. White, Killmeyer & Chew (2017) listed four core characteristics to assess whether or not blockchain is useful, which table 8 shows.

Table 8 - Characteristics to assess blockchain usefulness [retrieved from White, Killmeyer & Chew, 2017).

Characteristic	Description
Shared data	Multiple parties share a piece of information
Multiple parties	More than one person uses data from the database
Low trust	The parties do not completely trust each other
Auditability	Transactions need to be immutable

An important note with these characteristics is that they are only mentioned in one corporate report and there are no academic publications available that confirm the usefulness of these criteria. White, Killmeyer & Chew (2017) solely list the four criteria, without explaining how they derived them. Publications with other assessment criteria for the usefulness of blockchain are currently non-existent. Before broadly adopting such an assessment framework, it should be tested in various use cases first. Because the characteristics from table 7 are not yet well researched, we conclude that there is not yet an appropriate assessment framework to determine which governmental services are potentially suitable for smart contract implementations.

Governments are currently performing many experiments to learn how blockchain works and which benefits it could provide (Ølnes, Ubacht, & Janssen, 2017). We notice that because blockchain is still rapidly developing it is too early for a clear categorization and assessment framework for governmental services. We acknowledge this knowledge gap and recommend this to be researched in chapter 8.

3.3.4. Sub conclusion

Governmental institutions offer services that act with several parties: other governments, businesses and citizens. Governmental services have many potential benefits from blockchain technology: faster, more secure, less costly and with less friction. But the role of governmental institutions can change as well. In some examples, like land registration and identification, they could become merely the facilitator of the network instead of the controlling third party. Due to the still rapidly developing technology, there is a lack of a clear categorization of current implementations and an assessment framework for potentially suitable governmental services. An hypothesis from White, Killmeyer & Chew (2017) is that potentially suitable services involve multiple parties who have low trust in each other and that share data which needs to be auditable. However, these criteria need to be researched more before they can be accepted as correct.

3.4. Conclusion

This chapter answers the first two sub questions. The answer to the first sub question, *"How can the concept "blockchain powered smart contracts" be described?"*, shows that blockchain technology enables transparent and immutable transactions that are broadcasted peer-to-peer as a distributed database and that smart contracts are computer codes that are automatically executed by the blockchain ledger. The answer to the second sub question, *"Which governmental services are potentially suitable for smart contract implementations?",* is that potentially suitable services are currently clustered in six categories: financial, public records, supply chain, identification, voting and permit application. This categorization however is not yet well-researched and can change due to rapid developments. There is also a lack of an assessment framework to determine which governmental services are potentially suitable. The next chapter analyzes literature to find the first version of design principles that can be applied when implementing smart contracts in governmental services.

4. Build: principles from literature

This chapter answers the sub question *"Which design principles for smart contract implementation can be derived from literature?"*. The derivation process and categorization of design principles is determined with a literature review. The first version of design principles is drafted after analyzing literature about design principles for smart contract implementations. This version of the design principles is the basis on which the final version of design principles and the final version of the design framework are based upon.

4.1. Design principles

Design principles were defined in chapter 1 to be "*general rules and guidelines that will support the development of a design framework for the implementation of blockchain powered smart contract in governmental services"*. This paragraph explains the derivation methods and categorization.

4.1.1. Derivation

There is not a single best method to derive such principles as literature is silent about derivation methods (Bharosa, Janssen, & Bajnath, 2013, p.2). We found four different methods to derive design principles: literature review, case studies, expert interviews and gamification. These methods will be discussed first, where after the method choice for this research is explained.

Literature review of design principle derivation

Many researchers start by examining prior publications, because it is a crucial step in academic research (Webster & Watson, 2002). Before making a new contribution in science, a researcher must know what already has been written in prior research (Hart, 1998). In perspective of this research, it is necessary to look for prior research on design principles for smart contract implementation in governmental services, because other researchers might already have discovered some design principles which can be used for further extension and development. Other researchers that derived design principles often started with derivation from literature, such as for example Zuiderwijk (2015), Jak (2012) and Nguyen (2016).

But not all research which derives principles performs a literature review. Design principles can also be retrieved by using case studies. For example, in the research for information management from Bharosa & Janssen (2010) design principles were extracted after performing four case studies. The main advantages from this method are the in-depth information and first hand understanding of the dynamics of the case (Bharosa & Janssen, 2010, p.5). Case studies are particularly applicable in explorative studies such as this, because much new information can be gathered (Yin, 2002). As noted in the prior chapters, there are several smart contract implementations in governmental services, but the literature did not yet write about them. With case studies it is possible to generate much new information that can be used for deriving design principles, but also for other researchers to use in their own research.

Expert interviews can be used to retrieve new knowledge (Meuser & Nagel, 2009) or to validate the researcher's assumptions (Buda, 2015, p.60). This also is true for design principle derivation: it can be used to derive new design principles or to assess drafted principles. Jak (2012, p.18) used expert interviews to assess and refine his design principles.

A novel method to derive design principles is gamification in the form of a participative role-playing game. In a recent research, a group of professionals and academics played a role in several rounds. Observing the game led to the derivation of six design principles (Bharosa, Janssen & Bajnath, 2013). Bharosa & Janssen noted that while gamification is not used much for deriving principles, it is a good method to observe how people react. This is because they are given freedom to play the game as they please. But gamification can also be challenging, because *"gamification as an academic topic of study is relatively young, and there are few well-established theoretical frameworks or unified discourses"* (Hamari et al., 2014, p.3030).

Derivation method selection

We have found four methods to derive design principles: literature review, case study method, expert interviews and gamification. When knowledge is derived from solely one source (or even one method) it is possible that it is not generalizable. In order to support the claims of the research, triangulation can be used (Yin, 1994, p.13). Therefore this research will use various methods that fit the design science approach to derive design principles. First, the knowledge base is consulted for knowledge from prior research. This is done by using a literature review, which makes sure no double work is done. Second, information is observed from the environment. This is done by conducting case studies in order to generate information about actual smart contract implementations. This information is used to assess the first version of design principles and refine them into the second version of design principles. Finally, expert interviews are used to assess and refine them into the final version of design principles. Because there is no well-established framework to design a role-playing game and the field of smart contracts is new, this method will not be used in this research.

4.1.2. Categorization

In order to retrieve a comprehensive overview of design principles, the list of design principles needs to be categorized. Previous research did not categorize design principles of blockchain powered smart contract applications. A broad categorization that could be used for different kind of researches is the PEST categorization. The categories are: political factors, economic factors, social factors and technological factors. This categorization is mostly used for examining the environment of businesses (Ho, 2014). Furthermore, it is possible to categorize the opportunities and threats (Healey, 1994). This is not only suitable for private business, but also for public sector organizations (Wilkinson & Monkhouse, 1994). These categories are likely to be usable for categorization of design principles in this research as well. The factors from the PEST-analysis are influential in smart contract implementations and governmental services: political factors like government regulation and intervention, economic factors like profit and savings of transaction costs, social factors like trust, and technological factors like the development of smart contract applications and infrastructure.

With the lack of a categorization for design principles, we use the PEST categorization as sensitizing concept. Blumer (1954, p.7) describes this as a strategy to use when there is a lack of established specifications: *"a sensitizing concept lacks such specification of attributes or bench marks and consequently it does not enable the user to move directly to the instance and its relevant content. Instead, it gives the user a general sense of reference and guidance in approaching empirical instances"*. When the list of design principles is derived, the categories can be assessed for suitability for this research. This can then be adapted in a later stadium of the research. For now, the following categories and definitions will be used to divide the design principles:

- Political – government intervention, regulation and political steering;
- Economic – taxes, profit, subsidy, fees and fines;
- Social – cultural, demographic, strategic and organizational factors;
- Technological – technological infrastructures, technologic inventions and technological devices.

4.2. Findings

4.2.1. Literature selection

The goal of the literature review is to derive a first set of design principles for smart contract implementation in governmental services. Kitchenham et al. (2010) recommend the use of a systematic literature review for engineering questions, where the researcher determines beforehand which sources are to be searched and which keywords are used. This makes the research reproducible for other researchers (Okoli & Schabram, 2010, p.1). Scopus has been consulted and searched to contain all the following keywords in all fields (title, abstract, keywords, etc.): blockchain, design, principles, and government. The exact search term was:

ALL ("blockchain" AND "principles" AND "design" AND "government")

This led to finding 26 documents, which are listed in appendix B. Three additional documents from grey literature are added, because they specifically mention design principles for implementation of smart contracts in governmental services and are published by governmental organizations (Government Office for Science and NASCIO) or by an organization that closely works with the government (Blockchainpilots.nl). A further selection is made based on the following criteria that support the selection of publications that contribute to the aim of the research:

1. The publication is (at least partially) about blockchain powered smart contracts;
2. The publication is (at least partially) about implementation in governmental services;
3. The publication offers design principles;
4. The publication is freely accessible in English.

Eight of the publications was not freely accessible in English. Some were behind a paywall, while others were not written in English. For these publications it was not possible to determine the other criteria and were thus not used. Thirteen articles were (at least partially) about blockchain powered smart contracts, eight were about implementation in governmental services and nine offered design principles. Seven publications complied to all four criteria, which led to the final selection in table 9.

Table 9 – Selection of literature on which the first version of design principles is based.

Title	Author(s) / organization	Year
Blockchain Technology as s Support Infrastructure in E-Government	Ølnes S., & Jansen A.	2017
Block-VN: A Distributed Blockchain Based Vehicular Network	Sharma P.K., Moon S.Y.,, & Park J.H.	2017
Evolving Process Views	Eshuis R., Norta A., & Roulaux R.	2016
Blockchain Technology: Principles and Applications	Pilkington M.	2016
Distributed Ledger Technology: Beyond Block Chain	Government Office for Science	2016
Blockchain Pilots: A Brief Summary	Blockchainpilots.nl	2016
Blockchains: Moving Digitals Government Forward in the States	NASCIO	2017

4.2.2. Analysis

The seven selected publications are scanned with the qualitative data analysis software ATLAS.ti. This enables the selection of phrases that are considered design principles, being general rules and guidelines that will support the development of a design framework for the implementation of blockchain powered smart contract in governmental services. Each of the phrases is coded, which resulted in a list of 29 design principles. The publications that contributed the most design principles are Government Office for Science (eighteen principles mentioned) and Blockchainpilots.nl (seventeen principles mentioned), followed by NASCIO (eight principles), Ølnes & Jansen (three principles), Sharma et al. (three principles), Pilkington (two principles) and Eshuis et al. (one principle). The literature review confirms the lack of a comprehensive overview of design principles, as the found principles are scattered across various publications.

The 29 constructed design principles have been divided in the categories political, economic, social and technological. It is clear that the most design principles (sixteen) are technological, followed by social principles (seven). The least mentioned design principles, both three, are political and economic.

4.3. First version of design principles

Table 10 shows the first version of design principles that results from the analysis.

Table 10 - First version of design principles.

Cat.	Name	Statement	Rationale	Implication	Source(s)
Political	1. Research legal implications	Research legal implications and enforceability	There are possible legal issues	Possible legal issues are addressed in advance	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016)
	2. Define a vision	Define a vision for blockchain based government	There has to be a shared vision for what blockchain can bring stakeholders	Stakeholders share the same vision for what blockchain will do	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016)
	3. Define clear policies and legislation	Define clear policies and legislation about blockchain and smart contracts	The legislative framework was made when blockchain did not yet exist	The policies and legislation address opportunities and threats of blockchain	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016)
Economic	4. Invest in blockchain knowledge	Invest in blockchain knowledge	The field is new and much specific knowledge is necessary	Specific knowledge increases	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016)
	5. Allocate budget	Allocate budget for research and development	Research and development are costly and need to be financially stimulated	Research and development increases	(Blockchainpilots.nl, 2016)
	6. Fund penetration testing	Fund penetration testing of security	Pilots are often not attacked, but need to be tested before large implementation	Testing will find security flaws	(Government Office for Science, 2016)
Social	7. Find technical experts	Find blockchain and smart contract experts	The field is new and much specific knowledge is necessary	The development team has more specific knowledge and experience	(Blockchainpilots.nl, 2016)
	8. Cooperate with other organizations	Cooperate with other public and private organizations and universities	There are many parties who can share knowledge and cooperate	Knowledge and best practices are shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (NASCIO, 2016); (Government Office for Science, 2016)
	9. Involve stakeholders	Involve all stakeholders	Different stakeholders can have different requirements and goals	Requirements are discussed and broadly accepted	(Blockchainpilots.nl, 2016); (NASCIO, 2016)
	10. Share results	Share the results of each project	Parties can learn from each other	Project results share knowledge amongst each other	(Blockchainpilots.nl, 2016); (NASCIO, 2016)
	11. Multidisciplinary team	Compose a multidisciplinary team	Smart contract implementation needs experts in different fields	The project has experts on different fields to address different issues	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016)
	12. Communicate significance	Communicate significance of smart contract projects to others	Due to the new character of the field, others need to be convinced of the significance	Broad audience is aware of the possibilities of smart contracts	(Government Office for Science, 2016)

	13. Understand implications	Understand ethical and social implications	Smart contract implementations can have important ethical and social implications	Stakeholders are aware of possible implications before implementation	(Government Office for Science, 2016)
Technological	14. Security	Prioritize security	Blockchain and smart contracts demand strict security attention	Security becomes a priority and the system becomes safer	(Sharma et al., 2017); (Ølnes & Jansen, 2017); (Government Office for Science, 2016)
	15. Privacy	Prioritize privacy	Blockchain and smart contracts demand strict privacy attention	Possible privacy risks are known and addressed	(Sharma et al., 2017); (Government Office for Science, 2016)
	16. Fault tolerance	Prepare for faults	Program to withstand failures of the system	Unpredictable failures have less impact	(Sharma et al., 2017)
	17. Process selection	Select the process for implementation	It is necessary to select the correct process	The focus of implementation is clear	(Blockchainpilots.nl, 2016); (NASCIO, 2016)
	18. Map the process	Map the current process	Implementation builds on the prior process	It is clear how the current process works	(Blockchainpilots.nl, 2016); (Eshuis et al., 2016)
	19. Prototype development	Develop a prototype	Testing is necessary before the old process can be completely replaced	Viability of implementation can be tested	(Blockchainpilots.nl, 2016)
	20. Determine viability	Determine viability of prototype	Not every prototype is successful	Viability of implementation is known	(Blockchainpilots.nl, 2016)
	21. Start small projects	Start development with small projects	There is a lack of experience and knowledge, so small projects are the safest option	Knowledge develops with low effort and low threats	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016)
	22. Open source coding	Code in open source	Shared code spreads knowledge	Knowledge is efficiently shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016)
	23. Establish standards	Establish blockchain standards	Systems are better compatible if there are broadly used standards	Every developer uses the same standards	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016)
	24. Learn about prior development	Learn about prior projects and development	Prior projects show what the possible opportunities and threats are	Better understanding of possible opportunities and threats	(Ølnes & Jansen, 2017); (NASCIO, 2016); (Government Office for Science, 2016)
	25. Build on prior development	Use prior development and develop further based on it	By using prior development, proven technology can quickly be used for other cases	Fast use of proven technology	(Ølnes & Jansen, 2017)
	26. Risk assessment	Assess the risks per use case	New technology can bring new risks that need to be assessed	Clear view of risks per case	(Government Office for Science, 2016)
	27. Usability	Assess the usefulness per use case	It needs to be clear which case is useful	Clear view of usefulness per case	(Government Office for Science, 2016)
	28. Decide ledger type	Decide on the type of ledger	There are different ledger types with different opportunities and threats	Ledger type fits the case	(Government Office for Science, 2016)
	29. Enable back-ups	Enable offline back-ups	Enable offline back-ups for system failure	Better protection against system failure	(Government Office for Science, 2016)

4.4. Conclusion

The sub question of chapter 4 is: *"Which design principles for smart contract implementation can be derived from literature?".* A literature review made use of seven publications about design principles for smart contract implementations. This led to the extraction of the first version of design principles: 29 principles in the categories political (three principles), economic (three principles), social (seven principles) and technological (sixteen principles). The principles were scattered across the publications. It confirms the statement from chapter 1 that a comprehensive overview is non-existent. Chapter 5 will use a case study approach to assess and refine these principles into the second version of design principles.

5. Assess and refine: case study

This chapter will answer the sub question: "*Which design principles can be derived from empirical implementation processes?*", by using the design science approach steps *assess* and *refine*. Four use cases of smart contract implementations are analyzed with the case study method. This enables the assessment and refinement of the first version of the design principles. This will lead to the second version of design principles on which the design framework is based.

5.1. Case study setup

5.1.1. Goal

The case study is aimed at deriving in-depth knowledge about different governmental services that implemented or ran a pilot about implementation of smart contracts. The goal of the case study is threefold:

1. *Assess and refine the first version of the design principles.* We use empirical knowledge from the case studies to assess and refine the design principles from the literature. This is done by making in-depth case descriptions and comparing the first version of principles with these descriptions. Furthermore, stakeholders involved in the cases will read and assess the principles;
2. *Learn about how smart contracts are implemented into the existing process.* We examine how the old process in the cases works and how the new process with smart contracts is different from the old process. We use BPMN-models[6] to clearly communicate which activities stakeholders do in the old and new process. Points of interests are especially the potential benefits that smart contracts add and the differences between smart contract implementations and other IT solutions;
3. *Learn about how the entire implementation process works.* We noted in the previous chapters that the literature lacks empirical knowledge about the implementation process. We examine the cases to gain knowledge about how the projects are implemented, which phases are conducted, in which design phase the project currently is, and which stakeholders were involved.

5.1.2. Protocol

In order to increase the reliability of the results derived from the four case studies, it is advised to use a case study protocol (Yin, 2002). A structured design for the case studies can strengthen uniformity when multiple sources are used (Pervan & Maimbo, 2005). Note that in this research the case study method is a sub method of the design science approach to facilitate the steps *assess* and *refine*. The case study protocol is adapted to serve that goal. Eisenhardt (1989) advised the following steps in a case study protocol: getting started, selecting cases, crafting instruments and protocols, entering the field, analyzing data, shaping hypotheses, enfolding literature and reaching closure. Pervan & Maimbo (2005) noted that the Eisenhardt protocol actually consists of three phases: model development, model testing and model refinement. Such a process is especially applicable in the design science approach. The research of Jak (2012) shows that a case study protocol is not solely a process description, but also describes the motives of the researcher and the aim of the case studies. His model consisted of four components: general (aim of the research and motives of the researcher), procedures, research instruments and data analysis guideline (process flow). A more comprehensive protocol from Rowley (2002) describes the protocol as containing three sections: an overview of the case study project,

[6] Business Process Modeling Notation.

field procedures and the case study questions. The prior discussed case study protocols have been adapted to fit this research and led to the case study protocol in appendix D.

5.1.3. Case selection

There are many methods to select cases with their own benefits and barriers, such as random selection, extreme cases and maximum variation cases (Flyvbjerg, 2006, p.230). The field of smart contract implementations is still developing, so the case studies will be mainly exploratory. The *most different* method selects cases that are different on specified variables, which makes the results broadly generalizable for those variables (Seawright & Gerring, 2008, p.306). That would be for example selecting a case for every category of potentially suitable governmental services. However, paragraph 3.3 concluded that there is not yet a well-researched categorization of smart contract applications for governmental services. Paragraph 3.3 also offered an overview of current smart contract implementations. Many of these projects are conducted in Dutch municipalities. Because we want to conduct face-to-face interviews and noticed that most of the available interviewees work on projects at Dutch municipalities as well, we delineate the case studies to municipalities.

There is no potentially suitable governmental service categorization to apply the *most different* method upon, but it is possible to *"fill theoretical categories"* (Eisenhardt, 1989, p.537). We use two categories in order to have an indication about the difference between cases: municipality department, such as for example education, housing, sports, and work and income (Municipality of Amsterdam, n.d.), and process type, which indicates which actors are involved in the process. The latter was discussed in paragraph 3.3.1. Concluding, the four cases in table 11 are selected based on the following criteria:

1. The case has implementation of blockchain powered smart contracts as an important component;
2. A Dutch local municipality is involved;
3. The involved parties have at least one person who is willing to be interviewed;
4. The case study is about a process from another department or process type than the other cases.

Table 11 – Case study selection.

Case	Organization	Short description	Department	Process type
Gelrepas	Municipality of Arnhem	The Gelrepas is a discount card for citizens of the municipality of Arnhem. Through smart contracts it is possible to connect small and medium sized enterprises and let them offer discounts directly to citizens.	Work and income	Citizen-to-organization
Debt assistance	Municipality of Schiedam	The municipality of Schiedam offers smart debt assistance through the blockchain. With smart contracts it is possible to manage the budget of citizens in debt by offering more insights in their spending and automate certain payments.	Social domain	Citizen-to-government
Waste processing	Municipality of Utrecht	Many parties in the municipality of Utrecht are involved in the waste processing. The administration requires many resources, which can be greatly reduced with smart contracts.	Housing and living	Government-to-organization
Disabled parking permit	Municipalities of Schiedam and Drechtsteden	To obtain a permit to park on spots for disabled persons, many steps need to be followed between different parties. By using smart contracts this process becomes faster.	Parking, traffic and transportation	Citizen-to-organization

5.2. Case study descriptions

The following sub paragraphs are descriptions of the case studies. For each description there are three main parts: the old process, the new process with smart contracts and the implementation process. The old process describes the background information about the process without smart contracts that we derived from secondary sources. The process with smart contracts describes how the new process with smart contracts functions and which benefits the new process brings. Because the cases are not fully implemented yet and the effects not yet proven, we talk about expected benefits. We discuss the current status of the project and the implementation process that led to that status in the third part. The information in that part is based on interviews, with some additional information from secondary sources. We share the observations that we based on the case studies in paragraph 5.2.5.

5.2.1. Case 1: Gelrepas

Old process

The Gelrepas from the municipality of Arnhem is a physical card which citizens of the municipalities of Arnhem, Duiven, Overbetuwe, Renkum, Rheden, Rozendaal, Westervoort and Zevenaar can use to receive discounts on sportive and cultural activities (VNG/KING, 2017, p.8). There are several restrictions for the application of the Gelrepas, such as that the person needs to be a citizen of the municipalities named above and has a monthly income below €1,124.63 (VNG/KING, 2017, p.9). The old situation consists of many manual steps. Each stakeholder has many manual activities and has to work with physical forms, cards and coupons. A citizen applies for the card with a physical form that is send to the municipality of Arnhem. An employee of the municipality manually checks if the person is a citizen of one of the participating municipalities and checks if the income of the citizen is below the threshold. The employee then prints and sends the physical Gelrepas to the citizen along with paper discount coupons. This function is a full-time job. The citizen can now pay at the participating organizations and stores by showing the Gelrepas and giving them the coupons. The organization offers the citizen the discount and sends the coupons to the municipality. The municipality checks the coupons and sends a payment to the organization to compensate for the discount given (VNG/KING, 2017, p.10). The old process is modeled in figure 13.

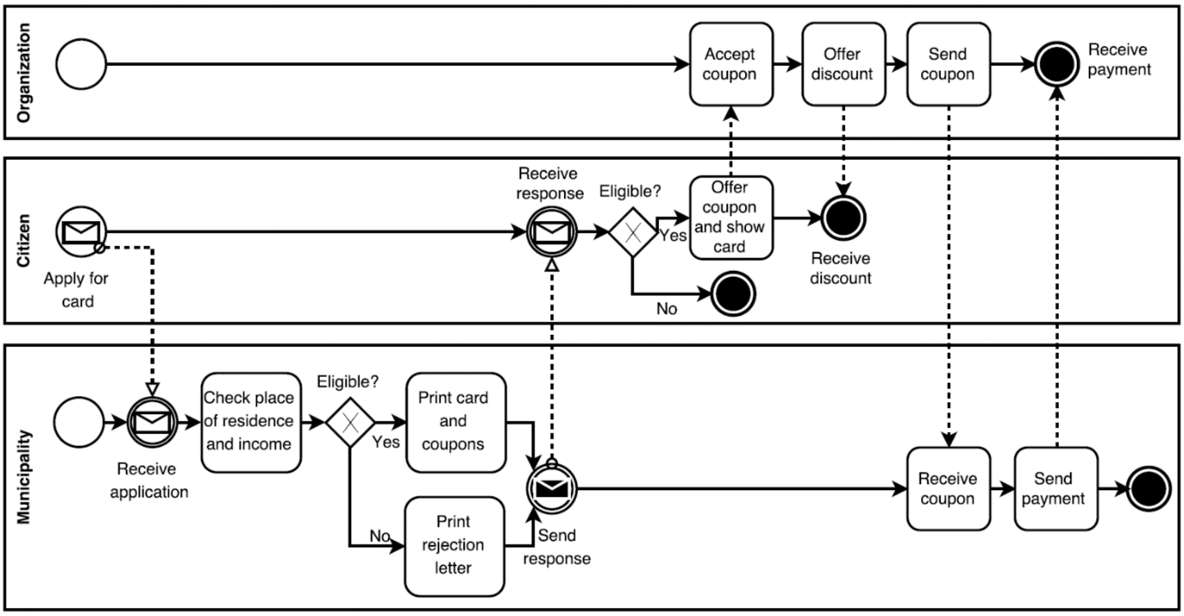


Figure 13 – BPMN model of the old situation of the Gelrepas.

New process with smart contracts

The new process automates many manual steps. The citizen does not have to apply with a physical form anymore. The municipality has a database with every citizen that fulfills the requirements and uploads this database to the blockchain. The citizen no longer keeps coupons, but installs an application which serves as Gelrepas, for example with a QR-code (VNG/KING, 2017, p.11). The organization now scans the QR-code instead of viewing the citizen's card, but the verification is done automatically. The organization does not keep and send coupons anymore. The applications connects with the blockchain and verifies the code. If the code is valid, the organization approves the transaction and provides the citizen the discount. The application adds the transaction to the blockchain and notifies the municipality. The municipality verifies the transaction in the blockchain and sends a payment to the organization. A potential benefit of the new situation is reduced costs. The interviewees expect that the employee will have less workload than a full-time job, but could not yet indicate how large this reduction is. The employee of the municipality only has to upload the approved citizens in the blockchain once a year. However, the employee still has to manually send the payments, because they did not automate this yet. Furthermore, each transaction is registered in the blockchain, which makes the transaction history immutable, transparent and auditable. Another potential benefit is avoiding fraud and manipulation. Because the coupons cannot be printed and are verified through the blockchain, no more fraudulent coupons can be used. However, the municipality did not indicate that fraudulent coupons were ever used. The new process also provides direct access to the participating organization, where in the old process they would have to trust the validness of the physical card. These benefits are based on the process descriptions and the expectations of the interviewees. They are not yet truly experienced, because the project is not yet implemented. The new process is modeled in figure 14.

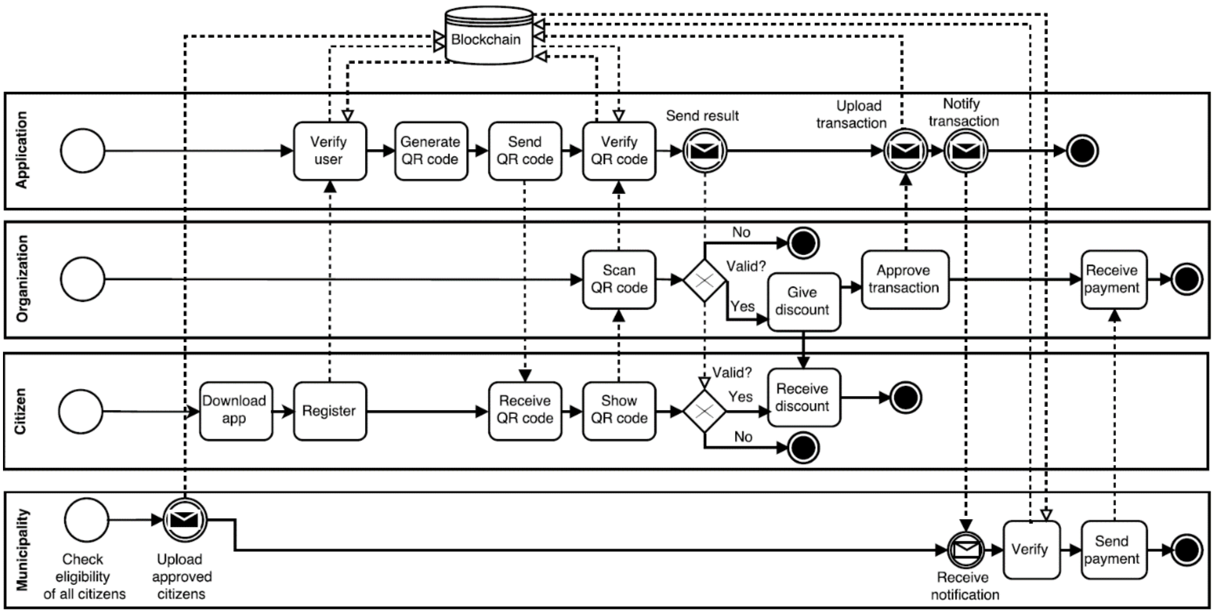


Figure 14 – BPMN model of the new situation of the Gelrepas.

Some benefits are reached through the automation of the process, where the physical coupons are replaced by an application with a QR-code, but such a feature could also be enabled with existing IT. The added value of blockchain is that both the organization and the municipality have direct access to add data to and verify transactions from the database. However, blockchain has more potential than this application. The municipality performs three tasks: check and upload approved citizens, verify transactions and send payments. All these tasks could be done through smart contracts, but the interviewees indicated that they want to gradually learn about blockchain and add such functions later. Automated payments will not be implemented in the short term due to the negative image of cryptocurrencies, specifically the image of Bitcoin.

Implementation process

The municipality of Arnhem learned about blockchain through the website of the VNG (Association of Dutch Municipalities) and KING. VNG/KING offered municipalities the chance to learn about blockchain together. The Advisor Business Intelligence of Arnhem thought the concept of blockchain could potentially benefit many processes of the municipality and applied for the program. This individual action is often the starting point for innovation in organizations: *"some member of the organization becomes aware of (or actually invents) a new idea. … He conceives a plan of action that the organization, in his judgment, should pursue"* (Becker & Whisler, 1967, p.466). He then started a project team with the Advisor Process Management, Advisor Information Management, Council Advisor Smart City and the Chief Information Officer. VNG/KING gave the municipalities a presentation about what blockchain is and how it could be used. This was followed by a blockchain game, demonstrating the functioning of blockchain that gave the municipalities a better understanding of blockchain. At the end of the game, Arnhem decided that the Gelrepas would be a good process to examine on blockchain potential. Together with the municipalities of Barneveld and Breda they would start a round of pilots.

In the round of pilots, which was coordinated by VNG/KING, the project team of Arnhem made a conceptualization of the process of the Gelrepas. It was examined which steps are taken in the Gelrepas and which stakeholders are participating. Surprisingly, organizations often do not involve the targeted users of the new innovation: *"organisations make the initial decision to adopt and the targeted users have few alternatives but to adopt the innovation and make the necessary adjustments for using it to perform their jobs"* (Kamal, 2006, p.195). The municipality of Arnhem thinks it is crucial to have personal communication with those employees, as their tasks may change due to smart contract implementation. That was done by having conversations with the persons in the process, for example with the employee who is currently processing the physical coupons of the Gelrepas. The interviewees reported that the affected employee showed reduced resistance to the implementation, because she was involved from the very start. The end result of this phase was a process description in the modelling tool Engage. It came with a table with every process step: who is in the lead, which examples are used and which information needs to go to which entity. The process was also distilled by a visual representation of the process in the form of a drawing. The goal was to have a more comprehensive overview of the process, that is easier to communicate. During the process, the municipality of Arnhem started a network to share blockchain knowledge with ICTU, associate professor Pouwelse from the Delft Blockchain Lab and the municipalities of Utrecht, Groningen, Nijmegen, Zuidhorn and Breda.

The municipality of Arnhem made a planning, where they committed to build the first prototype in the first quarter of 2018. Important learning points before implementation are amongst others the social aspects, such as acceptation. For the future, the municipality of Arnhem believes that blockchain can have a major impact on the role of the government. It might lead to changing entire functions where the municipality becomes superfluous. For example, applying for a permit will not have to go through the municipality anymore. The steps that the municipality followed are characteristic for organizations with a lack of knowledge on a certain innovation: gaining knowledge about how an innovation functions, forming an attitude towards the innovation and making a decision to adopt or reject the innovations (Rogers, 2010, p.5). The municipality of Arnhem is currently gaining knowledge and forming an attitude, but is not ready to decide on the actual implementation.

5.2.2. Case 2: debt assistance

Old process

Citizens in the municipality of Schiedam who have financial problems can currently be assisted in two ways: municipality assisted settlement of payments with the creditors and budget management. The latter involves a budget manager who takes control of (a part of) the finances of the citizen, for example by paying their bills. The budget manager performs many manual tasks, that he effectively takes over from the citizen. The monthly payment that the citizen receives from the municipality is controlled by the budget manager. This enables the creditor to faster receive his payment. Budget management is currently not a service of the municipality itself, but the costs of the budget manager are eventually paid by the municipality (Pomp & Hartog, 2017). The old process is modeled in figure 15.

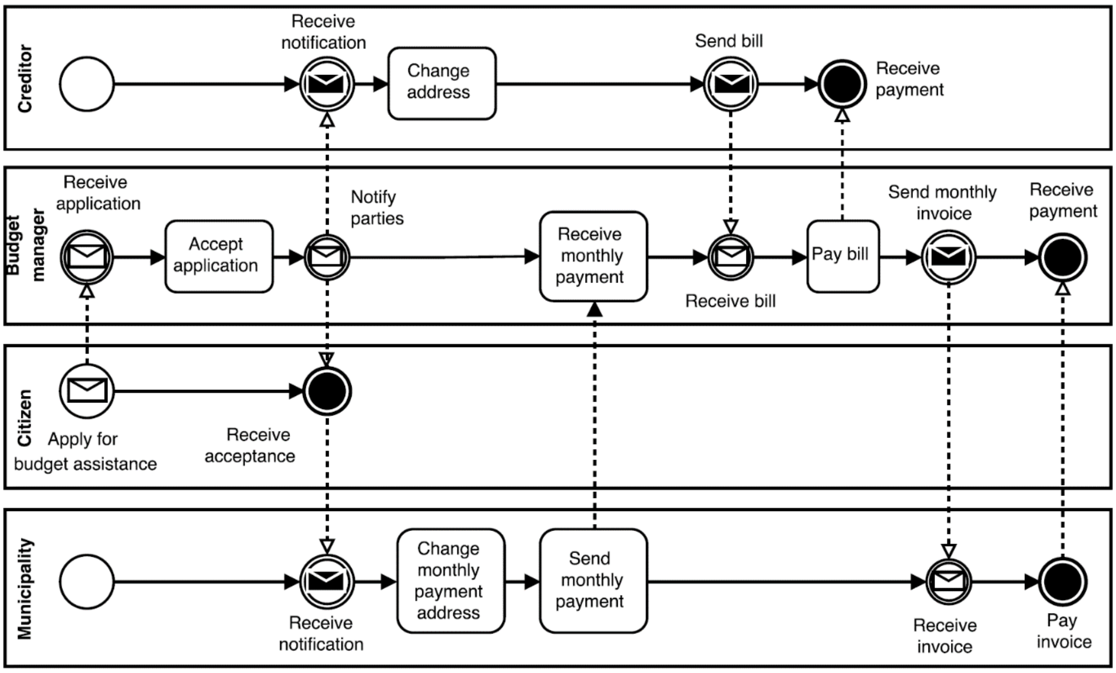


Figure 15 – BPMN model of the old situation of the debt assistance.

New process with smart contracts

Smart contracts can be used in this process, with the so called BAS (Budget Assistant Schiedam). Citizens of the municipality who have financial problems can voluntarily use the service of BAS. The budget manager in the current situation aids with paying bills, but cannot restrict other expanses. The budget manager is no longer active in the new situation. His activities are now fully automated by the smart contract. The expenses of the citizen can be restricted with smart contracts, allowing for example only expanses on rent and energy bills. It can also be programmed how much free expenses the citizens will have. Whenever the creditor claims a payment through the blockchain, the smart contract automatically determines if the claim is valid and directly sends a payment. The citizen also has free space for payments, depending on the specific restrictions. If they want to spend money on something else, the smart contract determines if they still can spend money. They can only send payments if the smart contract allows for it (Pomp & Hartog, 2017). As the municipality paid the costs of the budget manager, the new situation leads to reduced costs. The stakeholders also are expected to experience increased trust: the creditor trusts that the bill will be automatically paid if he fulfills the smart contracts' requirements, the municipality trusts that the monthly payments will be spend on creditors and the citizen trusts that his bills are paid and that he still has free money to spend. Of course, it is important to point out that this potential benefit of trust is based on argumentation, rather that empirical evidence. Another benefit is that the restrictions of the smart contract on which the stakeholders base their trust is transparent. Each stakeholder knows which rules apply and thus what will occur with the monthly payments. This transparency can also enable the increase of predictive capability. When a citizen is on the verge of financial problems it is possible to automatically detect this and signal the municipality to intervene. This could imply a conversation with the citizen to prevent financial problems beforehand. In the current situation, a budget assistant often only starts helping a citizen when he is already having financial problems, while the new process can prevent this. This additional feature was mentioned by stakeholders, but not yet incorporated in the new process design. The new process is modeled in figure 16.

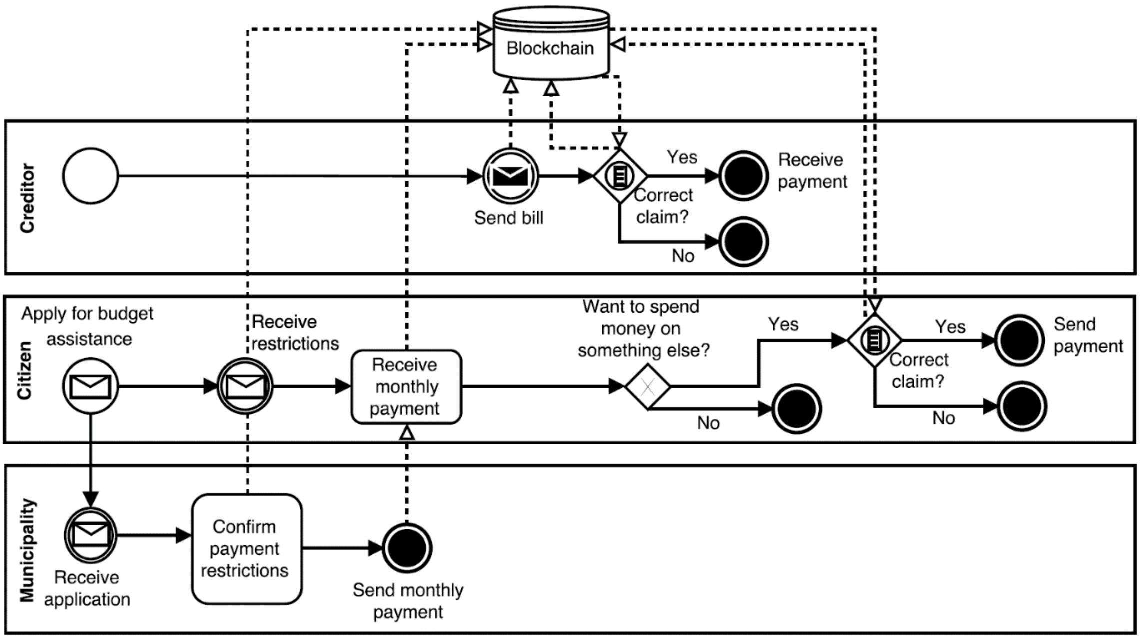


Figure 16 – BPMN model of the new situation of the debt assistance.

The possibilities of restricting where money can be spend on is a unique feature of smart contracts, that could not be implemented with other IT solutions. The entire function of the middleman, the budget manager, is replaced by a smart contract.

Implementation process

The municipality of Schiedam is open to innovation and the board of the municipal department Open Government raised enthusiasm within the organization to do something with blockchain. The vision on innovation is described as crucial for successful implementations: "*strategic planning for IT is the primary key to the effectiveness of the whole implementation process. Local governments who do not make use of a Strategic Plan for IT run the risk of investing in technologies which may not prove to be viable in the long term*" (Beaumaster, 2002, p.6). The board involved some employees in the organization that were interested. They wanted to do something with the debt assistance and eventually they came across the possibility to try something with blockchain. Different from the Gelrepas-case, the starting point and enthusiasm from this case came from the decision makers. Schiedam joined the second round of the national blockchain pilots from www.blockchainpilots.nl, where they were mentored by blockchain experts and developers from DApp.Design. In the pilot they made a conceptualization of how the process currently looks like and how it would function by using smart contracts. This led to a process description of the old and new process, and a PowerPoint presentation of the use case of the new process. Schiedam had internal discussions about continuation of the project at the end of the pilot. The board decided to build a working and testable prototype. Unsurprisingly, financial support is key for the success of IT implementation: "*for organisational innovation, especially for adopting advanced IT, financial support is indispensable for procuring and developing adequate levels of hardware and software*" (Kamal, 2006, p.209). This was also the reason to not develop a working project right away. The financial costs are high and the municipality wanted to further understand the impact of the implementation.

Schiedam made a project plan for building the prototype and is currently deciding what the prototype should be able to do. It is going to be built by the developers that helped with the construction of the use case. This phase is expected to take two to three months. The prototype is ideally tested with approximately ten citizens. These citizens would then dedicate a part of their monthly income. This income would be managed with the smart contract powered prototype. Schiedam is not yet ensured that testing the prototype with citizens will be possible, because people will have to stake a part of their salary and Schiedam wants to guarantee that their salary can be reimbursed if the projects fails. After the prototype phase it is necessary to assess the risks. Schiedam thinks it is likely that the AFM[7] will have an opinion on the financial part of the implementation. Earlier, the AFM warned Dutch citizens for investing in cryptocurrencies (AFM, 2017). If that conversation shows enough perspective on success, the municipality will examine how they can implement a final product. Ideally other municipalities will join in order to share the risks and the financial costs. However, Schiedam finds the details of the implementation phase still unpredictable. They focus on the development of the prototype at the moment and will look further after completion of that phase.

5.2.3. Case 3: waste processing

Old process

The municipality of Utrecht collects waste from citizens and companies, and offers the waste to waste processing organizations. The legal responsibility of the municipality does not apply to the process after that. Nevertheless, the municipality has the ambition to have a good overview of what happens to the waste from the city. The ILT[8] is the inspectorate that provides permits to waste process organizations, which allows them to collect and process waste. The municipality does not have direct access to the status of the permits. Once in a while, the municipality verifies the permits of the processing organizations with the ILT, that has to manually verify the permit and communicate this with the municipality (Pomp & Hartog, 2017). When the permit is not valid, the municipality finds another waste processor and verifies their permit with the ILT. This process demands effort and causes the municipality to not check the permits on a regular basis. The interviewee states that sometimes they offer waste to organizations that lost their permit, but they were unaware of that fact. When the permit of the processor is valid, they collect the waste from the municipality and process it. The municipality does not know what happens to the waste after they offered it to the processor. The old process is modeled in figure 17.

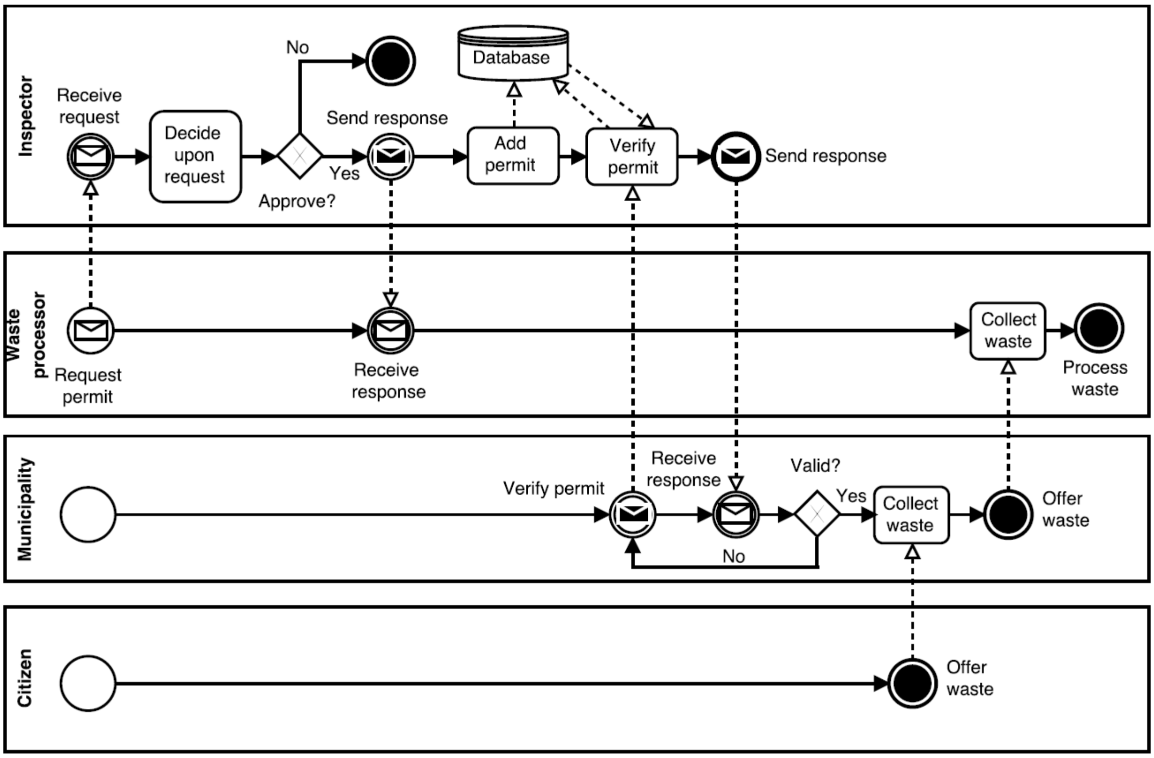


Figure 17 – BPMN model of the old situation of the waste process.

[7] The Dutch Authority for the Financial Markets.
[8] The Dutch Human Environment and Transport Inspectorate.

New process with smart contracts

The ILT provides his permits for the waste process organizations in a smart contract and deploys this on a blockchain. The information about the details, terms and status of the permit is incorporated in the smart contract. The municipality of Utrecht now has direct access to the permit to ensure that only allowed waste process organizations collect and process waste. They can now check the validness of the permits on a regular basis (Pomp & Hartog, 2017). This increases the trust, as it ensures that the municipality offers waste to processor with a valid permit. Also, the ILT does not have to manually verify permits and send responses to the municipality, decreasing costs. The municipality does not have to wait for the response of the municipality anymore, which decreases the process time. Furthermore, there is also more transparency on where waste goes to after collection by the process organization. This is enabled by the waste process organization that records on the blockchain when waste is collected and what happens with that waste. The interviewee also noted that in the current system some waste processors manipulated data. The new process makes the transaction history immutable, which avoids fraud and manipulation. The new process is modeled in figure 18.

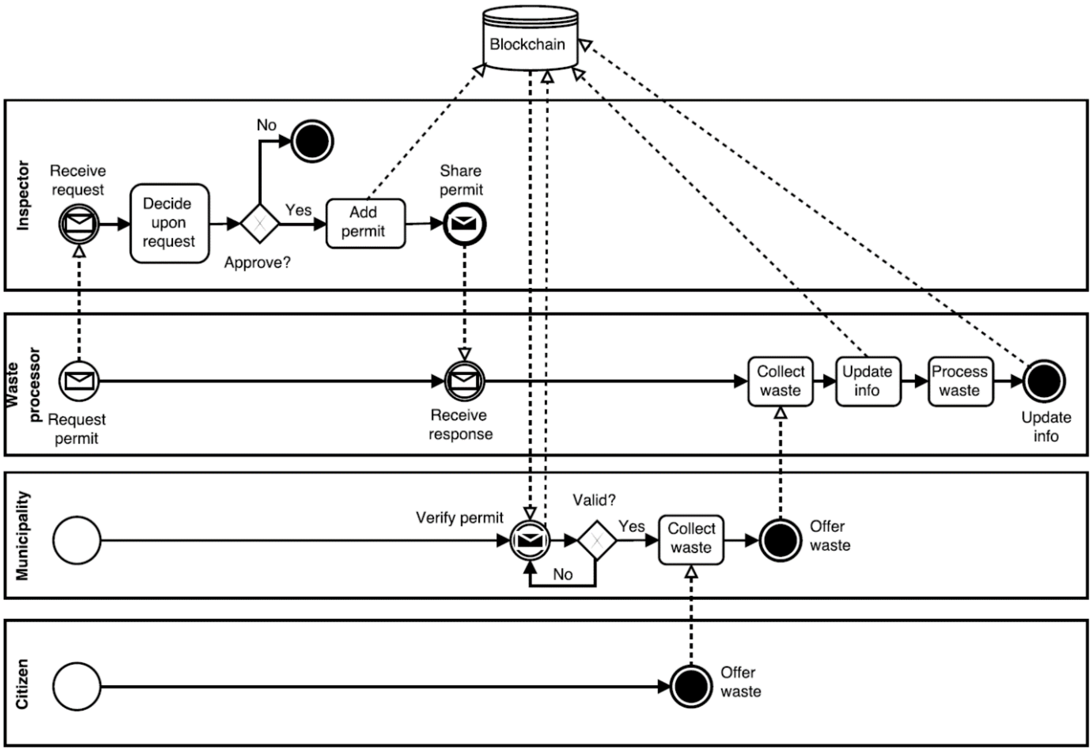


Figure 18 – BPMN model of the new situation of the waste process.

The addition of the permit to a database was already present in the old process. However, the direct access of the municipality and the possibility of the waste processor to add information themselves is unique for blockchain technology and could not have been possible with other IT.

Implementation process

The municipality of Utrecht participated in a blockchain workshop organized by the Dutch Ministry of Economic Affairs and Climate Policy. The goal of this workshop was to generate ideas about how blockchain can be applied in governmental services. The employees of the municipality generated ideas on flip charts in a creative session. At the end, each employee could vote for a process. This led to selecting the waste processing as process that would be examined for smart contract implementation. Utrecht made a business case together with IT service provider Ordina, describing how blockchain could be applied in the waste process. The end result of this phase was a presentation with the conceptualization of the process and an offer to develop a working and testable prototype. The offer from Ordina was not accepted by the municipality, as the decision makers did not want to invest in a project with a lack of certainty about the success. Similar to the Schiedam-case, financial support is an important factor for project success. Different from the other cases is the project team of the municipality of Utrecht consists of a data scientist and not with a program manager or department board. This missing link with the decision makers can explain why the process did not yet pass the conceptualization phase as the interviewee notes that it is difficult to attract funds for the project. The municipality decided to make another conceptualization in cooperation with students. They will map the process and determine the added value of blockchain. A second group of students will make a working prototype based on the conceptualization of the other students, which will be presented during 2018. The result of that prototype will be presented internally to gain support of decision makers and other employees.

5.2.4. Case 4: disabled parking permit

Old process

The disabled parking permit in the Netherlands is a physical card that is valid in all countries of the European Union and allows the holders of the card to park at disabled parking spots. Disabled citizens of municipalities that cannot walk more than 100 meters without support can apply for a permit at the municipality, which is allowed to charge a fee (Rijksoverheid, n.d.). The permit application process has multiple stakeholders: the municipality, the GGD (Public Health Service), the RDW (Netherlands Vehicle Authority), the CIB (prints the physical card), the European Union and the citizens. In 2015 266,996 disabled parking permits were registered in the Netherlands. These permits enabled parking in 3,998 parking spots of which 61 percent were free of costs, while the remaining 39 percent of the parking spots demanded a fee (Pomp & Hartog, 2017). Disabled citizens have to keep the parking permit card in their car and is often stolen from their owners' car and sold on the black market. The card has much value as holders can park for free or a reduced tariff on many places in the Netherlands (Servicehuis Parkeer- en Verblijfsrechten, n.d.). The old process is modeled in figure 19.

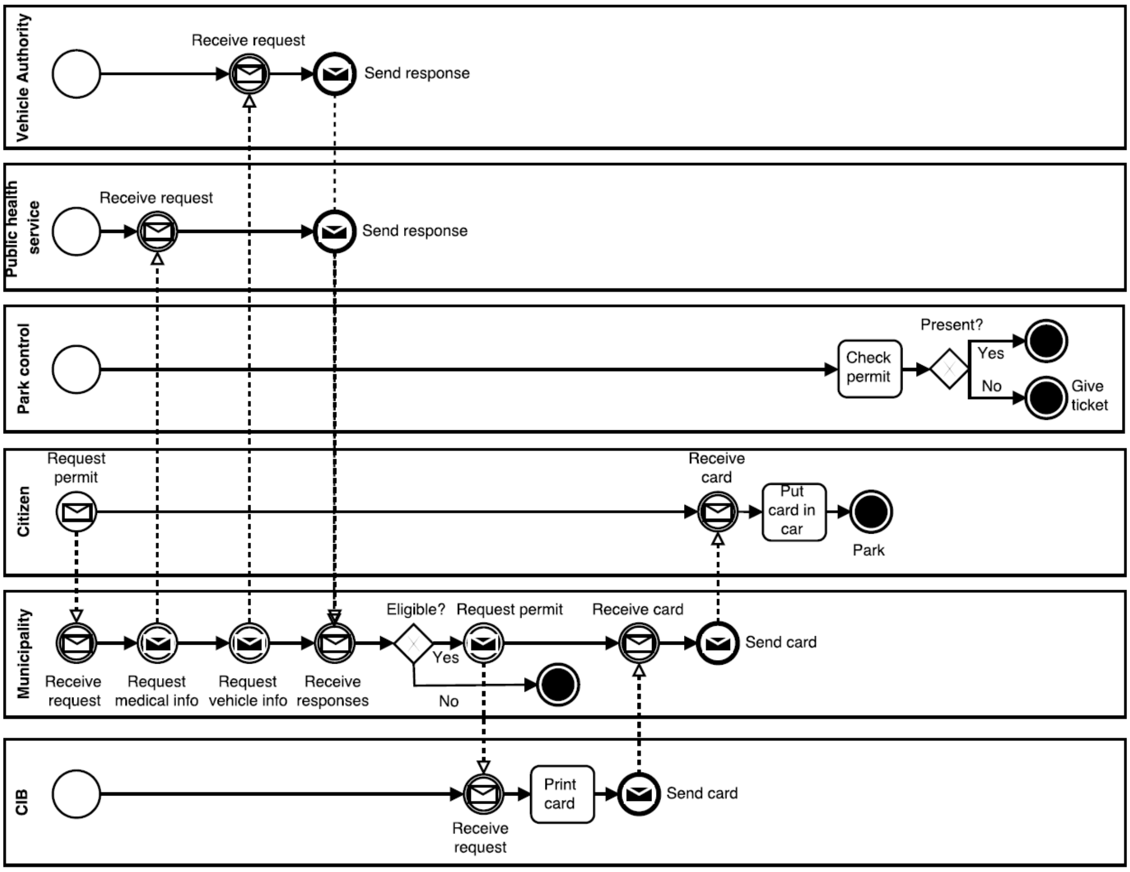


Figure 19 – BPMN model of the old situation of the disabled parking permit.

New process with smart contracts

In a cooperation between Drechtsteden (a cooperation between the municipalities of Alblasserdam, Dordrecht, Hendrik-Ido-Ambacht, Papendrecht, Sliedrecht and Zwijndrecht) and the municipality of Schiedam, smart contracts are used to prevent fraud, misuse and theft. The physical card is not used anymore and the mobile application is available for holders of the disabled parking permit. The CIB records the details and validity of the card in a smart contract and deploys them on the blockchain, visible for multiple stakeholders. The CIB does not have to print and send the physical card anymore, which decreases costs and process time. A permit holder with a valid permit confirms that he parks on a disabled parking spot, which is registered in the blockchain. Parking inspectors use scan cars that scan the license plate of parked cars. The system automatically checks in the blockchain if the license plate is authorized to park on the disabled parking spot. Misuse of the permit is not possible, because the physical card cannot be stolen or passed on to others and the application can be protected with fingerprint access. Another functionality is to provide disabled citizens an overview of where parking spots are still available and what the tariff of these parking spots are (Pomp & Hartog, 2017). Furthermore, the new process increases the privacy of the citizen. Whereas in the old process they had to present the physical card indicating their disability while parking, they can now hide such personal information. The new process is modeled in figure 20.

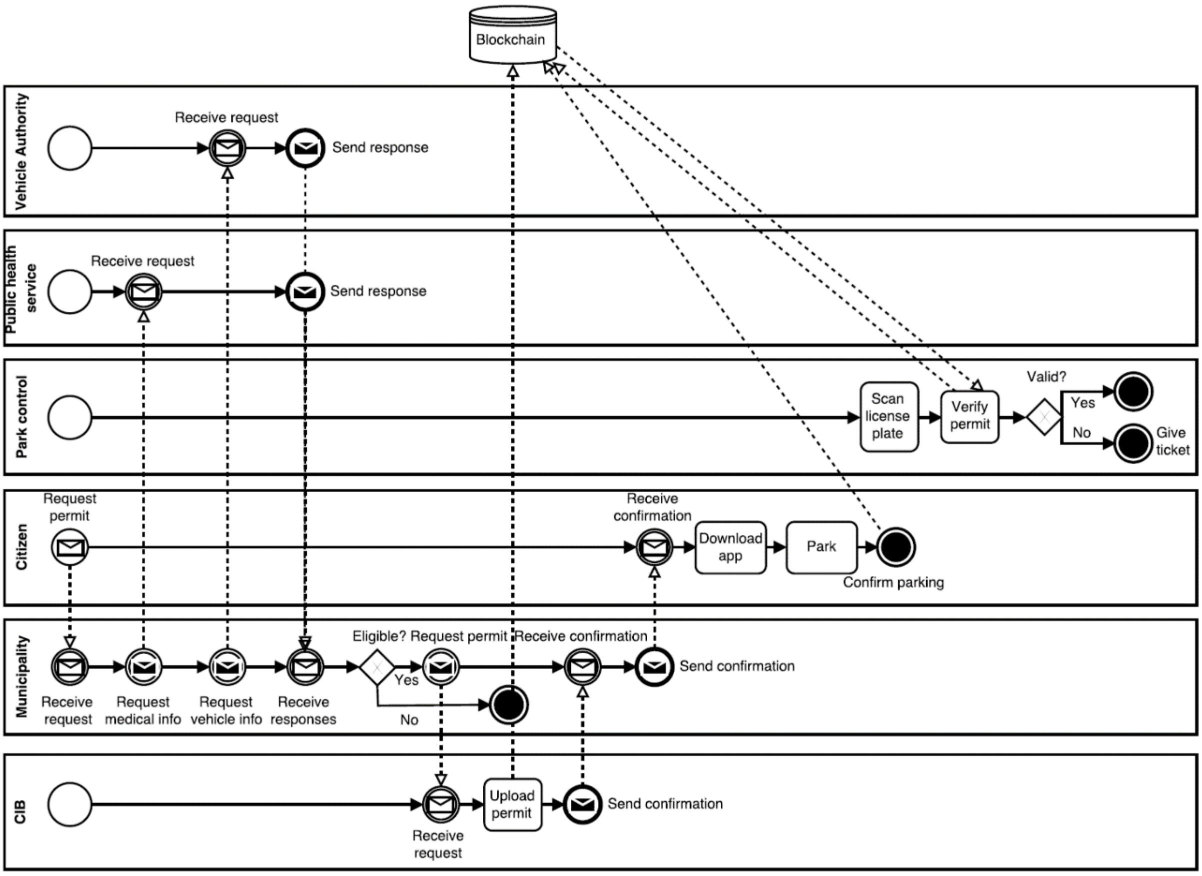


Figure 20 – BPMN model of the new situation of the disabled parking permit.

Avoiding the theft of the physical card and providing an overview of free parking spaces could also have been enabled by digitizing the permit with other IT solutions. Unique for the smart contract implementation is that the citizen and park control have direct access to the information. However, the case has more potential benefits of blockchain that they did not incorporate in the design. For example, the request of medical and vehicle information is done manually between the municipality, the public health service and the vehicle authority. This slows down the process and increases the costs, while this could be automated through smart contracts.

Implementation process

The Business Consultant of Drechtsteden was already aware of blockchain technology and was immediately interested when the VNG/KING website looked for municipalities that wanted to join a round of pilots. Together with his colleague he started to look for suitable problems and internal support to investigate the implementation of blockchain powered smart contracts. The first step was guided by an explorative conversation by a project leader of VNG/KING, supported with a blockchain game. Drechtsteden adapted the game for internal use and teaching. This was followed by an internal discussion to determine if Drechtsteden wanted to start a pilot and which subjects they could potentially use. Drechtsteden chose two subjects for further examination: internal settlement[9] and the disabled parking permit. They split these two projects: the disabled parking permit was done in cooperation with VNG/KING and the internal settlement was done internally. Having two separate working methods would offer more learning points. Drechtsteden cooperates with the developers startup LAB15 for internal settlement, who built a proof of concept, showing how the process would work with blockchain. For the parking permit a use case was described with VNG/KING. The end results of this phase was a PowerPoint presentation describing the global idea and the potential benefits and threats of smart contract implementation. The proof of concept of the internal settlement generated much internal enthusiasm. This led to the decision to make a working and testable pilot version, which was done in multiple design sprints. The difference with the other cases is that the project team quickly gained internal support of decision makers who enabled financial funds to become available to accelerate the implementation.

For the parking permit project, Drechtsteden cooperated with the CIB, who prints the physical permits. The CIB proposed to examine implementation, but wanted to use a central database instead of blockchain. Drechtsteden chose to stop the cooperation with CIB and examined if they could implement the process in blockchain themselves. At the moment they have a design that is ready for implementation and support from sixteen other municipalities. The step from prototype to implementation is a long process, because it needs trust and support from decision makers inside the municipality. Drechtsteden expects that the trust in the new process must develop over time and will encounter discussions about privacy, durability, image and others. The implementation of smart contracts in the disabled parking permit project also does not have an immediate business case. That is a consideration that the decision makers of the municipality will have to make.

An implementation of smart contracts in the disabled parking permit project offers many possibilities to other municipalities as well. Drechtsteden believes that the application that they want to build can be expanded to other municipalities relatively easy, because the code is open source and other municipalities are free to join. This would mean that the parking permit service of Drechtsteden is available for citizens of other municipalities as well. The availability of the service then would not depend on the geographical location of the citizen, but is available from everywhere. This is called government-as-a-service. Drechtsteden even believes that in the future it is possible that the government will become superfluous for many services. The government can implement a service, which becomes self-maintaining, without intervention of the government. Drechtsteden admits that this forecast is premature and ambitious, but points out that technical possibilities to enable it exist.

5.2.5. Observations

The following observations are made from the case studies:

- The four cases did not yet implement a working product. Because they have a lack of knowledge about blockchain, they first want to learn about the potential benefits and possibilities. This cautious approach is often caused by the financial steering of governmental organization. Project teams first

[9] Drechtsteden is a cooperation between six municipalities, which complicates the procurement and settlement of internal payments. Internal settlement refers to the automatic settlement of the invoicing between the entities in Drechtsteden (LAB15.io, n.d.).

need to convince decision makers that the proposed implementations are valuable, before they receive sufficient funds for a prototype or an actual implementation.

- The various roles in project teams were: Advisor Process Management, Advisor Business Intelligence, Program Manager Social Infrastructure, Data Scientist, Business Consultant, decision makers, external blockchain developers and students. The involvement of decision makers seems to accelerate the development, because they decide upon funds, which are essential for the success of IT projects.
- Ølnes, Janssen & Ubacht (2017, p.359) presented a list of potential benefits and promises of blockchain technology based on literature, but note that "*there was no review of benefits yet and many of the benefits are not supported by argumentation or empirical evidence*". The following potential benefits and promises were present in the four cases: transparency (Atzori, 2015; Underwood, 2016), avoiding fraud and manipulation (Cai & Zhu, 2016; Swan, 2015), increased trust (Palfreyman, 2015; Zyskind & Nathan, 2015; Mainelli & Smith, 2015; Swan, 2015), transparency and auditability (Palfreyman, 2015; Tapscott & Tapscott, 2016; Atzori, 2015), increased predictive capability (Tapscott & Tapscott, 2016), reduced costs (Palfreyman, 2015; Tapscott & Tapscott, 2016; Ølnes, 2016), access to information (Palfreyman, 2015; Swan, 2015), privacy (Tapscott & Tapscott, 2016; Zyskind & Nathan, 2015), and persistency and irreversibility (Atzori, 2015; Underwood, 2016; Swan, 2015). Although our findings strengthen the list of potential benefits, the benefits in the cases are theoretical as well, as the projects are not yet implemented and thus the benefits yet to be confirmed. Then again, the argumentation behind the cases show that the mentioned benefits are likely to be present if the system works as described.
- From the same list from Ølnes, Janssen & Ubacht (2017, p.359) the following potential benefits and promises were not present in the four cases: reducing corruption (Kshetri, 2017), increased control (Zyskind & Nathan, 2015; Kraft, 2016; Mainelli & Smith, 2015), clear ownership (Yermack, 2017), increased resilience to spam and DDOS attacks (Gervais et al., 2016), data integrity and higher data quality (Tapscott & Tapscott, 2016), reducing human errors (Cai & Zhu, 2016 & Tapscott & Tapscott, 2016), reliability (Tapscott & Tapscott, 2016; Swan, 2015), security (Gervais et al., 2016; Tapscott & Tapscott, 2016; Underwood, 2016; Ølnes, 2016; Mainelli & Smith, 2015) and reduced energy consumption (Tapscott & Tapscott, 2016). This does not mean these potential benefits and promises are not existent in other cases. After all, solely four cases were analyzed. Nevertheless, the potential benefits that were not present in the case studies remain theoretical if they cannot be strengthened by empirical evidence.
- Two new benefits were identified: reduced process time and prevention of theft of a physical item. The former was experienced in all four cases: many manual processes were automated and led to faster process times. The latter was only applicable with the physical parking permit that was transformed into an application. Both of these benefits are not unique for blockchain and could be enabled by other IT implementations as well.
- Another key point is that the process descriptions also leave many possibilities of blockchain untouched, for instance automatic payments with the Gelrepas and the automatic processing of the request of medical and vehicle information with the disabled parking permit. Secondary sources and the interviewees from the cases mention many possible features that could be implemented in the future. The reason that they do not have these features in the process description is they want to start with small projects: first learn about how blockchain works, create a small working product and add additional features later.

5.3. Assessment first version of design principles

The case studies and the interviews with stakeholders reveal how the first version of design principles is applicable in the four cases. The design principles are each discussed below, based on the case study interviews. From the interviews 133 statements were coded in ATLAS.ti. The statements are referred to as a combination of a letter and a number. The letter refers to the municipality of the case study: A is for Arnhem, U is for Utrecht, S is for Schiedam and D for Drechtsteden. The number refers to the number of the statement for that municipality. The reference *[A.19]* for example is the 19th statement from the municipality of Arnhem. The full list of statements is placed in appendix F. Note that the interviews were conducted in Dutch and we translated the quotations to English, which might lead to slightly different interpretations.

1. Research legal implications

Three of the four municipalities acknowledged that researching legal implications is important [A.22; U.17; D.20] and no one disagreed. Drechtsteden explained that the legal implications are still not fully known: *"We scheduled a meeting where she will assess the legal viability of the implementation of the disabled parking permit. It is due to the new technology we do not know yet what the legal implications are"* [D.20]. The design principle is therefore maintained as in the prior version.

2. Define a vision

Arnhem and Schiedam have or are working on a vision at the moment [A.2; A.6; A.30; A.35; S.17]. Arnhem stressed the importance of this design principle: *"Actually, I find this one crucial, because there is much technology. Normally you would not think about it much and simply implement, no need for making a vision. But with blockchain there is much more possible than a simple function, blockchain can change the world. You really have to write down a vision for which direction we are heading … Because this is so powerful you have to think about it. This is so different from normal technology. That is why it is good to have a good vision on it"* [A.35]. Utrecht does not disagree, but states that they currently do not have a vision yet [U.18]. Drechtsteden also does not have a vision yet: *"That is something that will come later, but we did not make one yet. Maybe you would not want to do that as individual municipality, but with a group, such as with VNG. What is our vision to implement blockchain in the society?"* [D.21]. A vision can thus be defined locally, but also nationwide. And though the stage in which it happens differs, no one disagrees that it is important at some point. The design principle is therefore maintained as in the prior version.

3. Define clear policies and legislation

Drechtsteden agrees that the legislation should be altered [D.22]. Schiedam and Utrecht both agree that it is necessary, but state that in their current state this is not yet applicable: *"Following the experience you can examine how it fits our policies and what we want to do with it. I would do it in another phase. I think it is something you should learn and cannot say it in advance"* [S.18] and *"That is certainly not yet the case, but you should have to change the legislation. In the legislation it says that everything has to be registered on paper. That should be changed when it is done through the blockchain. And every party would have to join"* [U.19]. This principle is thus applicable, but it is not applicable in every design phase. The design principle is therefore maintained as in the prior version.

4. Invest in blockchain knowledge

All four municipalities agree that this design principle is applicable [A.36; U.16; U.20; S.19; D.23]. Schiedam is not planning to retrieve the blockchain knowledge internally: "*I do not intent to build that expertise. I think by doing these pilots you can sense more how you can use it. But the expertise to build, we will not retrieve that into the municipality*" [S.16]. Some knowledge is needed however: *"You do not have to execute it yourself, but you should have the knowledge as client to assess, do I get what I asked? You need some knowledge to understand what they do and what you can expect. If you do not have that, you get IT projects that keep continuing, cost money and do not bring what you want"* [U.16]. The design principle is therefore maintained as in the prior version.

5. Allocate budget

Three of the four municipalities agreed that allocating budget is important: *"Budget is important, because we are financially steered"* [A.16], *"It is true that developing is costly"* [S.10], *"It actually always needs budget"* [S.20] and *"Budget is always necessary of course"* [U.21]. Utrecht however notes that budget should only be allocated when the project is useful: *"We are not investing loads of money on something where it is uncertain it will ever be a success"* [U.6]. This could be hedged by for example determining profitability, which we will discuss as possible new principle in paragraph 5.4. The design principle is therefore maintained as in the prior version.

6. Fund penetration testing

Schiedam and Utrecht agree that penetration testing is important [S.21; U.22]. Schiedam however notes that "*Safety is very important. If you do something as government you cannot make it unsecure. I think design principles 5 and 6 belong together. I see it as whole. You have to allocate budget for blockchain and security is a part of it*"[S.21]. That statement is valid: the penetration testing is part of the security and funding it is part of the budget allocation. That is why this design principle is deleted and the penetration testing is added to the security principle.

7. Find technical experts

Drechtsteden and Arnhem did specifically mention cooperation with experts [A.10; D.10]. Drechtsteden however commented that the focus on experts is not particularly on technical experts: *"I would place technical within quotation marks. I have more use of someone who can explain the possibilities and implications of blockchain than someone who can explain the technology"* [D.24]. The multidisciplinary nature of blockchain indeed needs experts from different fields. This design principle is altered to describe multiple experts.

8. Cooperate with other organizations

All four municipalities mention multiple times that they cooperate with other organizations [A.7; A.10; U.7; U.9; U.10; U.13; U.14; S.6; S.7; S.8; S.13; D.1; D.6; D.8; D.13]. Reasons are that working together adds value: *"If you can do it together it has added value for sure"* [D.1] and shares risks and costs: *"The moment you start developing the risk should decrease. In my opinion that is done with other municipalities. You share the costs and risks"* [S.7]. Cooperation was seen with other municipalities, students, the Dutch national blockchain pilot coordinator, VNG/KING and theme specific experts. The design principle is therefore maintained as in the prior version.

9. Involve stakeholders

Arnhem states that "*All parties must be involved*" [A.31], which is exactly how the design principle was formulated. Other statements from Arnhem and Utrecht agree with the principle as well [A.19; A.20; U.15], but Utrecht and Schiedam also note that the involvement of stakeholders is dependent on the phase in which the development is at: *"I also noted that it is very difficult, and I believe other municipalities are stakeholders as well, to convince, because it is so complex. Involve all stakeholders is something you should want eventually, but it can be impeding at first, because the result is so uncertain"* [S.22] and "*Eventually yes. Now with a low number. Is it possible to get support for it? With some parties you can think they might have some critique"* [U.23]. The description of the design principle is altered slightly: it does not state that all stakeholders should be involved, but it should be carefully examined which and when certain stakeholders are involved.

10. Share results

Arnhem and Utrecht both are actively sharing their results in their network [A.27; A.28; U.12]. A good argument is: *"You want to learn from each other. We are a learning organization and want to learn together. What someone else already did, we do not have to learn again. That would be a waste"* [A.28]. The design principle is therefore maintained as in the prior version.

11. Multidisciplinary team

Arnhem and Schiedam state that they have a multidisciplinary team at the moment [A.15; A.37; S.11]. Utrecht does not have a multidisciplinary team yet, because it is too early at the moment and they consider using a scrum approach later [U.24]. It implies that the design principle will be valid later and is therefore maintained as in the prior version.

12. Communicate significance

Three of the four cases confirm that communication of significance is important [A.11; A.38; D.19; D.7; U.8]. An important reason is that it can be used to show societal value to decision makers in order to have more resources become available [U.8]. The design principle is therefore maintained as in the prior version.

13. Understand implications

Drechtsteden and Utrecht show that understanding implications is important [A.2; A.5; D.25]. Utrecht does not disagree, but states: *"We did not think about that yet. It strongly depends on the process"* [U.25]. Some processes will have more implications than other processes, but can nonetheless be examined. The design principle is therefore maintained as in the prior version.

14. Security

Security is important for blockchain projects as Arnhem [A.13] and Utrecht [U.26] show. As Utrecht states, security is important in many IT projects: *"That is always applicable in such cases*" [U.26]. Schiedam also mentioned that penetration testing is a part of security. The design principles is therefore slightly altered to include penetration testing.

15. Privacy

Arnhem and Drechtsteden both agree that privacy is important: *"Do you want to have a successful blockchain project, you will have to show you are privacy compliant, that the citizen can trust on it"* [D.26] and *"There is so much happening with personal data. Security and privacy is becoming more important, because the data is accessible for everyone. At least, that is the sentiment" … "It is the feeling that we give away data, our personal data. Our data is on the blockchain. It takes time to gain trust"* [A.39]. The design principle is therefore maintained as in the prior version.

16. Fault tolerance

Schiedam and Utrecht talk about this principle, but do not fully agree: *"You should prepare for it, but should not have the intention that all faults can be prevented. We should make sure that you can make faults without having fatal consequences"* [S.23] and *"We are not that far yet, by long. At implementation you should of course know what happens when the system crashes"* [U.27]. They talk about risk assessments and contingency planning, but not tolerance of faults. This design principle is therefore deleted.

17. Process selection

All four municipalities have selected a process [A.17; A.8; D.27; D.4; S.3; U.1]. The design principle is therefore maintained as in the prior version.

18. Map the process

Three of the four municipalities mapped the process first [A.1; A.23; S.4; U.32]. The design principle is therefore maintained as in the prior version.

19. Prototype development

All four municipalities are currently working or are going to work on a prototype [A.29; D.9; S.9; U.11]. The design principle is therefore maintained as in the prior version.

20. Determine viability

None of the cases confirm the determination of the project's viability. It seems that the viability determination is incorporated in other design principles, such as process selection and prototype development. This design principle is deleted.

21. Start small projects

Arnhem, Schiedam and Utrecht specifically mention the perks of taking small steps [A.18; S.15 and U.28]. Utrecht for example explains that blockchain and the examined process is too complex to completely implement at once: *"That is one of the reasons we want to do this, because it is specific and comprehensive and not the too complex entire waste process. We chose a small part of the waste process, of which we say: this is fairly comprehensive. If you want to involve all it becomes too complex very fast"* [U.28]. The design principle is therefore maintained as in the prior version.

22. Open source coding

All four municipalities are working in open source [A.41; D.15; S.24; U.29]. Drechtsteden states that government project should be open source as it is paid with tax money: *"Everything we do is open source, it is already on GitHub. It is everyone's, right, it is tax money"* [D.15]. The design principle is therefore maintained as in the prior version.

23. Establish standards

Only one of the four municipalities shortly responds to establishing standards with: *"That is something that is ought to"* [D.28]. It is likely that the municipalities are not yet troubled with the establishment of such standards. Because no one disagrees with this design principle it is maintained for now.

24. Learn about prior development

Arnhem and Schiedam think that learning about prior development is important. Schiedam for example mentions that *"The learning effect is very important, I think"* [S.25]. Utrecht however notes that it is important, but there is a major lack of successful cases to learn from at the moment: "*Such projects, we do not have at the moment. You should have experience first. This is a too early phase to do it*" … " *It would be pleasant if there would be a successful case, where you can say: it works here and you can see how it functions. I did not see them yet*" [U.30]. More successful cases would however be useful, thus the design principle is maintained as in the prior version.

25. Build on prior development

Not a single municipality mentioned that they were building on prior development. On the other hand, not a single municipality disagreed with the design principle either. A reasonable explanation is that in the current development space there is not much prior development to build upon yet. Utrecht explains: "*Such projects, we do not have at the moment. You should have experience first. This is a too early phase to do it*" … " *It would be pleasant if there would be a successful case, where you can say: it works here and you can see how it functions. I did not see them yet*" [U.30]. It is likely that this design principle is not yet applicable in the current state of the overall blockchain development, but is useful later when more projects are developed. This design principle is merged with design principle 24 in order to learn from prior development.

26. Risk assessment

Drechtsteden and Schiedam announce that they will have risk assessments in later phases [D.29; S.14]. Drechtsteden stresses that this design principle will become specifically important: *"Risk assessment needs extra focus, because you can have blind spots due to the new character … Do I dare to take risks by signing a smart contract? I think the focus will be on smart contracts … I would like to let someone audit the smart contracts to check if I thought of all risks" [D.29].* Interviewees mention risks such as security, privacy and finance. The design principle is therefore maintained as in the prior version.

27. Usability assessment

None of the cases confirms the determination of the usability assessment. It seems that this is incorporated in other design principles, such as process selection and prototype development. This design principle is deleted.

28. Decide ledger type

Every municipality is already thinking about which ledger type they will use [A.42; D.30; S.26; U.4]. Arnhem for example already is quite specific: *"We want to have the Gelrepas in a private ledger, we are not doing it directly in the public ledger. I think that is important"* [A.42]. The design principle is therefore maintained as in the prior version.

29. Enable back-ups

This design principle is a point of discussion amongst municipalities. Arnhem does not worry about back-ups [A.43], while Utrecht does not find it of importance yet [U.31]. Drechtsteden explains that due to the characteristics of the blockchain it is only important for private ledgers: *"That has to do with the principles of the blockchain. I assume it is not necessary. At least if we use a public ledger. With a private ledger we will have to*" [D.31]. Because it might be necessary for certain ledger types, the design principle is slightly altered from *enable back-ups* to *consider back-ups*.

5.4. Construction second version of design principles

The case studies and the interviews with stakeholders revealed new design principles. These are discussed per principle in the parts below. Appendix F contains a list with all statements from the interviews that were coded in ATLAS.ti and used for this paragraph.

Involve supervisor

The interviewees from Arnhem and Schiedam both explained that involving the supervisor is important to gain internal support: *"That the board is in favor shows that it is found important"* [S.1] and *"That is why it is important to involve the supervisor in the process"* [A.3]. As supervisors in governmental services often can decide upon resources for development, this is an important design principle.

Cooperate internally

All four municipalities cooperate internally and stress that enthusiasm from within is necessary to gain support [A.26; A.4; D.2; D.3; S.2; U.13]. For example Utrecht praises the network effects from internal cooperation: "*You see that persons who have interest say: "We are interested as well", where after you form a network within the municipality. That's how I came in contact with Hogeschool Utrecht as well. You connect such contacts at such meetings. Share information and gain support for certain things"* [U.13]. It also means that other departments can be involved like in Arnhem: *"We are talking now with the legal department. We will give them a blockchain presentation and will involve them from now on"* [A.26].

Examine shifting role of the government

Arnhem and Drechtsteden notice that smart contracts can shift the role of the government [D.17, A.17; A.34]. As Arnhem says that technology can make tasks disappear: *"You can see that some tasks disappeared, such as tasks that go to the market. You have to make smarter use of information, also with blockchain. You can see that the government will have a very different role later. Buying a house or applying for a permit later does not have to go through the municipality anymore"* [A.12]. This could eventually lead to a future where many tasks are not necessarily performed by the government and the role of the government is very different: *"My ultimate goal is to make the government unnecessary. Everything you do not have to have a role in anymore you should not do anymore as government … Government-as-a-service: you are not dependent on a geographic* *bound entity … In relation to blockchain I see many possibilities. The man in the middle, you can see it disappearing. You realize that the government mostly is that man in the middle"* [D.17]. That would be a major impact and has to be examined.

Profitability

Arnhem, Drechtsteden and Schiedam stress that profitability is important for most of the projects in municipalities [A.14; A.32; D.16; S.5]. For example Schiedam states: *"So we can use a business case that justifies the investment"* [S.5] and Arnhem states: *"Everything has to be earned back. Innovation is very contradictory in that. We could state that the administrative costs are lower"* [A.14]. That is all in terms of money and not every implementation is cost effective, like the disabled parking permit: *"The parking permit for disabled is not something that has a valid business case directly, but is the town council prepared to invest money to ease the life of a disabled citizen?"* [D.16]. Profitability should therefore not only refer to cost effectiveness, but also social costs.

Examine impact on jobs and functions

Arnhem and Utrecht think that smart contract implementations can have an impact on jobs. Utrecht for example states that: *"If you do other activities on the blockchain … I can imagine it will effect jobs. But no one ever got fired due to automation. There can always be some shifting within the municipality"* [U.2] and Arnhem: *"You have to cooperate, but you will lose your job. You cannot convince with that, but that is how it works*" [A.21]. Utrecht however thinks that this is not a major problem as municipalities continuously shift employees within the organization: "*In practice it is not such a problem. The moment you implement something, you shift with tasks. They will get other tasks. Their function is not suddenly gone*" [U.2]. This does however mean that their tasks change, which needs to be examined.

Define responsibilities

With the changing role of the government and the disintermediation of the third party, some responsibilities can change [S.27; A.40]. This raises questions about responsibilities and risks: *"With blockchain I see that the new thing is that the central role will disappear, like banks with Bitcoin and the budget manager with our project. There is a sort promise of trust that is not hackable. I think that is really different. With everything that we do now a central role verifies transaction. The internet did not change that. Before, the central role also was the carrier of risks. Who should carry the risk now in case of faults?"* [S.27]. These responsibilities should be defined before implementation.

Define project goals

Before starting with a project it is important to define the goals [D.5; S.12]. Drechtsteden stated that *"I defined firstly what we wanted to achieve with the pilots"* [D.5]. An example of a goal is "*The most important thing to me is that the prototype works"* [S.12]. Such goals can help to assess the outcome and evaluate the results after each design phase.

Scalability

Drechtsteden noted that scalability is an important feature due to two main reasons. The first is added value to others: *"When you have a good idea of how you can add value to the society it is worth to introduce it nationwide"* [D.11]. The second is that it is necessary in case of the disabled parking permit: *"Moreover there is a necessity to scale it nationwide: if municipality X uses it and municipality Y does not, it is not of use at all"* [D.14]. The governmental services thus can be expanded beyond the initial user group. Where many municipal services are designed for their own municipality, blockchain technology enables the expansion of the services to other municipalities. In the case of national services, these could be expanded to and used by other countries as well.

Transaction speed

Drechtsteden noted that transaction speed is important [D.12]. For example in the disabled parking-case, when the citizen wants to park, they cannot be expected to wait for two hours for their transaction to be confirmed. As noted in paragraph 3.1.2, there is a limit of four transactions per second on the Bitcoin network and slightly faster limits on the Ethereum network. These limits may be impeding for certain projects and thus project teams need to determine which transaction speed they desire for their project. The reason only Drechtsteden noted this problem is the state in which many projects are at the moment. Projects will not experience the actual transaction speed until they operate on the actual network and thus at implementation.

Good UI/UX design

Drechtsteden noted that the main user will not be in direct touch with blockchain technology: *"In my opinion the technology behind blockchain does not have to be visible. When you have a good user interface and make the result good, trust is gained faster. UI/UX design is very important"* [D.18]. The user interface and user experience (UI/UX) thus must be well designed.

Determine authorizations

An important principle that is mentioned by Utrecht is the determination of authorizations: *"Which parties should be able to read data? With authorization for example, that you can enter data that not everyone can read. Who hides it?"* [U.5]. Due to the characteristics of blockchain there will be different roles and authorizations, which need to be defined, because they can be very different from other IT solutions.

Paragraph 5.3 confirmed the design principles 1, 2, 3, 4, 5, 8, 10, 11, 12, 13, 15, 17, 18, 21, 22, 23, 26 and 28. These design principles are maintained. Paragraph 5.3 also marked flaws in design principles 6, 7, 9, 16 20, 24, 25, 27 and 29. These principles are changed or deleted. This paragraph noticed new design principles as well: involve supervisor, cooperate internally, examine shifting role of the government, determine profitability, examine impact on jobs, define responsibilities, define project goals, scalability, transaction speed, good UI/UX design and determine authorizations. This has led to the second version of design principles which is displayed in table 12. The adaptions in comparison with the first version are indicated with a bold font.

Table 12 – Second version of design principles.

Cat.	Name	Statement	Rationale	Implication	Source(s)
Political	1. Research legal implications	Research legal implications and enforceability	There are possible legal issues	Possible legal issues are addressed in advance	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); **(Utrecht interview, 2017); (Arnhem interview, 2017); (Drechtsteden interview, 2018)**
	2. Define a vision	Define a vision for blockchain based government	There has to be a shared vision for what blockchain can bring stakeholders	Stakeholders share the same vision for what blockchain will do	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Schiedam interview, 2017)**
	3. Define clear policies and legislation	Define clear policies and legislation about **blockchain and smart contracts**	The legislative framework was made when blockchain did not yet exist	The policies and legislation address opportunities and threats of blockchain	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); **(Drechtsteden interview, 2018)**
Economic	4. Invest in blockchain knowledge	Invest in blockchain knowledge	The field is new and much specific knowledge is necessary	Specific knowledge increases	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	5. Allocate budget	Allocate budget for research and development	Research and development are costly and need to be financially stimulated	Research and development increases	(Blockchainpilots.nl, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**
	6. Profitability	**Determine economic and social profitability**	**Successful projects are profitable in terms of educational, economic or social effects**	**Prevention of waste of resources**	**(Arnhem interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
Social	7. Find experts	Find **relevant experts from different fields**	The field is new and much specific knowledge is necessary **from different domains**	**Experts have more specific knowledge and experience**	(Blockchainpilots.nl, 2016); **(Arnhem interview, 2017); (Drechtsteden interview, 2018)**
	8. Cooperate with other organizations	Cooperate with other public and private organizations and universities	There are many parties who can share knowledge and cooperate	Knowledge and best practices are shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (NASCIO, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	9. Involve stakeholders	Involve **the right stakeholders at the right moment**	Different stakeholders can have different requirements and goals	Requirements are discussed and broadly accepted	(Blockchainpilots.nl, 2016); (NASCIO, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**
	10. Share results	Share the results of each project	Parties can learn from each other	Project results share knowledge amongst each other	(Blockchainpilots.nl, 2016); (NASCIO, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017)**

	11. Multidisciplinary team	Compose a multidisciplinary team	Smart contract implementation needs experts in different fields	The project has experts on different fields to address different issues	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Schiedam interview, 2017)**
	12. Communicate significance	Communicate significance of smart contract projects to others	Due to the new character of the field, others need to be convinced of the significance	Broad audience is aware of the possibilities of smart contracts	(Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Drechtsteden interview, 2018)**
	13. Understand implications	Understand ethical and social implications	Smart contract implementations can have important ethical and social implications	Stakeholders are aware of possible implications before implementation	(Government Office for Science, 2016); **(Arnhem interview, 2017); (Drechtsteden interview, 2018)**
	14. Involve supervisor	**Involve supervisor in the process**	**Supervisors can decide on resources that are available for the project**	**More support from the supervisor and more resources**	**(Arnhem interview, 2017); (Schiedam interview, 2017)**
	15. Cooperate internally	**Cooperate with others from within the organization**	**There are many others from within the organization that have expertise**	**More internal support and a network of interested colleagues**	**(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	16. Examine shifting role of the government	**Examine the possible change of government roles**	**Implementation of smart contract can drastically change the role of the government, which needs to be examined beforehand**	**A better understanding of how smart contracts can change the role and tasks of governmental institutions**	**(Arnhem interview, 2017); (Drechtsteden interview, 2018)**
	17. Examine impact on jobs	**Examine the impact on current jobs and tasks**	**Implementation of smart contracts can cause certain jobs and tasks to be superfluous**	**Employees can be better prepared for a change of their job or task**	**(Arnhem interview, 2017); (Utrecht interview, 2017)**
	18. Define responsibilities	**Define responsibilities in the new process**	**Smart contracts can change the responsibilities for certain tasks**	**Clarity about responsibilities**	**(Schiedam interview, 2017)**
Technological	19. Security	Prioritize security **and execute penetration testing**	Blockchain and smart contracts demand strict security attention	Security becomes a priority and the system becomes safer	(Sharma et al., 2017); (Ølnes & Jansen, 2017); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**
	20. Privacy	Prioritize privacy	Blockchain and smart contracts demand strict privacy attention	Possible privacy risks are known and addressed	(Sharma et al., 2017); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Drechtsteden interview, 2018)**
	21. Process selection	Select the process for implementation	It is necessary to select the correct process	The focus of implementation is clear	(Blockchainpilots.nl, 2016); (NASCIO, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	22. Map the process	Map the current process	Implementation builds on the prior process	It is clear how the current process works	(Blockchainpilots.nl, 2016); (Eshuis et al., 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**

	23. Prototype development	Develop a prototype	Testing is necessary before the old process can be completely replaced	Viability of implementation can be tested	(Blockchainpilots.nl, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	24. Start small projects	Start development with small projects	There is a lack of experience and knowledge, so small projects are the safest option	Knowledge develops with low effort and low threats	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**
	25. Open source coding	Code in open source	Shared code spreads knowledge	Knowledge is efficiently shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	26. Establish standards	Establish blockchain standards	Systems are better compatible if there are broadly used standards	Every developer uses the same standards	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); **(Drechtsteden interview, 2018)**
	27. **Learn from** prior development	**Learn about prior projects and development, and build upon it**	**Prior projects show opportunities and threats, and prevents building from scratch**	**Proven technology can be learned from and used**	(Ølnes & Jansen, 2017); (NASCIO, 2016); (Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)**
	28. Risk assessment	Assess the risks per use case	New technology can bring new risks that need to be assessed	Clear view of risks per case	(Government Office for Science, 2016); **(Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	29. Decide ledger type	Decide on the type of ledger	There are different ledger types with different opportunities and threats	Ledger type fits the case	(Government Office for Science, 2016); **(Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	30. **Consider** back-ups	**Consider offline back-ups**	**Some (private) ledgers need back-ups**	Better protection against system failure	(Government Office for Science, 2016); **(Utrecht interview, 2017); (Drechtsteden interview, 2018)**
	31. Define project goals	**Define project goals**	**Projects are hard to evaluate when project goals are not defined beforehand**	**Clear preset goals**	**(Schiedam interview, 2017); (Drechtsteden interview, 2018)**
	32. Scalability	**Make project scalable**	**Projects can be scaled up later if needed**	**Option to scale up easily**	**(Drechtsteden interview, 2018)**
	33. Transaction speed	**Define the desired minimum transaction speed**	**Many blockchain platforms have a low maximum transaction throughput**	**Understanding of the speed of the application**	**(Drechtsteden interview, 2018)**
	34. Good UI/UX design	**Design a good user interface and user experience**	**Blockchain technology is not visible for users, so UI/UX is important for their experience**	**Good user experience**	**(Drechtsteden interview, 2018)**
	35. Determine authorizations	**Determine data view and edit authorizations**	**Blockchain demands new definitions for who can view, edit and delete data**	**Clear authorization management**	**(Utrecht interview, 2017)**

5.5. Design dilemmas

The interviews from the case studies revealed that stakeholders experience or foresee various dilemmas when implementing the design principles. Some pair of design principles invoke discussions between members of the project team, software developers or decision makers. This is caused by the correlation that some principles have, where implementing the one principle affects another. Note that this does not necessarily mean they are contradictory to each other. No single straightforward solution exist for implementing those pairs of principles, because various solutions have different pros and cons. We call such pairs of principles design dilemmas. We define a design dilemma as follows: "*a decision that needs to be made on how to apply two design principles that raises discussion about various implementation alternatives*". We discuss the design dilemmas that we found in the case studies in this paragraph in full.

Allocate budget & profitability

Allocation of budget is necessary to invest in blockchain knowledge and development, because financial support is essential for the success of IT projects (Kamal, 2006). An important aspect of governmental services is that they are financially steered. Projects often need to be profitable in order to gain support from decision makers. However, governmental services also serve other goals, such as quality of services for their citizens (Mulgan & Albury, 2003, p.6). Innovation is contradictory in that sense: investing money does not necessarily lead to financial savings, but can also have social improvement. Where private sector organizations have multiple funding sources, governmental services often lack funds for innovation (Borins, 2001, p.311). For example Drechtsteden expects that the disabled parking permit will need significant budget to develop a working product. From the BPMN-models we learned that the Drechtsteden-case potentially leads to benefits such as direct access to data, improved privacy and prevention of theft, but no direct cost savings or additional profitability. Drechtsteden confirmed that the allocation of budget is difficult, because their project does not lead to financial profitability. He currently sees two strategies that can be conducted in order to overcome this dilemma. Firstly, they want to show the municipal decision makers the added value of the project through the development of a prototype. Secondly, they are cooperating with sixteen other municipalities. By developing such a project together, it is possible to use the system in those sixteen municipalities and share the benefits, while also sharing the costs of development. The dilemma was also discussed in the cases where the projects are expected to lead to cost savings, such as the debt assistance-case. The reason for this was that decision makers are often not yet convinced by the project team that the costs savings will actually occur.

Communicate significance & examine impact on jobs

The case studies showed that the implementation of smart contracts in governmental services can lead to jobs and functions to change. In the Gelrepas-case, the municipal employee has less tasks to perform, the budget manager in the debt assistance-case does not perform any task anymore, and the inspector and the municipal employee in the waste processing-case have less tasks. Communicating the significance of implementation can be potentially difficult when blockchain has many benefits, but also implies that someone could lose his job or his functions changes in another way: "*You have to cooperate, but you will lose your job. You cannot convince with that, but that is how it works*" (Arnhem interview, 2017). It is a dilemma that is known from other innovations as well. Many technologies heavily impacted jobs, which impeded the communication of the technology's benefits: the automation of the textile product process with the textile artisans (David, 2015, p.1), the automation of agriculture and farming employees (David, 2015, p.5), the automation of the automobile belt and belt employees (David, 2015, p.5), and the worldwide workplace automation (Chui, Manyika & Miremadi, 2015, p.3). The interviewees from the Gelrepas-case noted that this dilemma is important and needs to be well communicated. They point out that it is important that one of the decision makers, the municipal Chief Information Officer, will communicate the decision with those affected. Hence, decision makers also need to communicate the motivation for their decision to those affected in order to reduce resistance. The other interviewees did not yet investigate strategies to cope with this dilemma yet.

Security & open source coding

Many governmental services release their source code for the public. For example the municipality of Arnhem released their source code of the municipality's Linux servers and all web services. But having the code open source also means that malicious individuals can see the code to find vulnerabilities. It is often argued that open source coding improves the security, as (good willing) others can find vulnerabilities and bugs (Payne, 2002), but the technology is new and the applications that use blockchain are often full of vulnerabilities (for example the ten vulnerabilities in table 6 in paragraph 3.2.3). In the long term, open source coding leads to better security (Hoepman & Jacobs, 2007), but vulnerabilities can always be found. An example is the open-source cryptographic library Open-SSL. They experienced six vulnerabilities in the last thirteen years, which allowed "*attackers to read sensitive memory from vulnerable servers, potentially including cryptographic keys, login credentials, and other private data*", of which a famous vulnerability is the Heartbleed-bug (Durumeric et al., 2014, p.476). However, the interviewees from all four cases revealed they plan on releasing the smart contract projects as open source in the future, because they want to share the knowledge about smart contract implementations. The design dilemma is thus not experienced by case study interviewees, but is a controversial discussion from the literature. We will specifically discuss this dilemma during the expert interviews.

Privacy & decide ledger type

Paragraph 3.1.1 discussed that the transparent characteristic of the blockchain ledger also implies privacy issues, because certain transaction details are public to see. Choosing between the benefits of a centralized database, a private blockchain and a public blockchain has an impact on the privacy of the users of governmental services. Choosing for a public blockchain means choosing for distributing personal data to every node in the network. Although the data is encrypted, certain information is transparent. In the debt assistance-case for example, the balance of the wallets of citizens and transactions they make are visible. It is theoretically possible to find out which wallet belongs to which citizen, especially in cases with a low number of participants. This is one of the reasons that some project teams choose to start on a private blockchain. However, the private blockchain has disadvantages as well, such as centralized consensus and possibility of tampering by the nodes (Zheng et al., 2017, p.6). Zero knowledge proof (*zk-SNARKs*), as discussed in paragraph 3.1.2 is a possible solution for the privacy issues in blockchain technology and is currently in development. Until a solution is available, the project team needs to choose between the various ledger types and their impact on the privacy.

Scalability & transaction speed

Paragraph 3.1.2 also revealed that one of the issues with blockchain technology is that scalability is limited by the maximum transaction speed. Smart contract platform Ethereum for example currently supports up to fifteen transaction per second worldwide (Etherscan.io, n.d.). Scaling a municipal service and having sufficient transaction speed are both design principles, but these are limited in the current development of blockchain technology. The project team needs to define the minimal desired transaction speed of their project, compare that to the maximum transaction speed provided by the network and adapt the wish for scalability accordingly. However, blockchain technology is still developing. Ethereum is currently implementing the *sharding*-solution (see paragraph 3.1.2), which significantly improves the maximum transaction speed. The interviewees from the four cases are not yet troubled with this design dilemma, because they do not have a working product yet.

5.6. Conclusion

The sub question of chapter 5 is: *"Which design principles can be derived from empirical implementation processes?".* We examined four case studies and found various potential benefits of smart contract implementations, but also noticed that some potential benefits from the literature were not present. The case studies confirmed the design principles 1, 2, 3, 4, 5, 8, 10, 11, 12, 13, 15, 17, 18, 21, 22, 23, 26 and 28, which are maintained. It also provided insights based on which design principles 6, 7, 9, 16 20, 24, 25, 27 and 29 are altered or deleted. The case studies generated new design principles as well: involve supervisor, cooperate internally, examine shifting role of the government, determine profitability, examine impact on jobs, define responsibilities, define project goals, scalability, transaction speed, good UI/UX design and determine authorizations. Furthermore, we discovered five design dilemmas between pairs of principles that can possibly occur when implementing smart contracts: allocate budget & profitability, communicate significance & examine impact on jobs, security & open source coding, privacy & decide ledger type, and scalability & transaction speed. Interviewees revealed several coping strategies for some dilemmas: communicate added value, and cooperate with other parties (allocate budget & profitability), involving stakeholders early, and clear communication by decision makers (communicate significance & examine impact on jobs), starting closed source and gradually move towards open source, and start open source from the start (security & open source coding). The second version of 35 design principles and five design dilemmas are used to develop the first version of the design framework in chapter 6.

6. Build: framework design

This chapter will answer the sub question “*How can design principles be translated into a design framework?*”. The first version of the design framework will be drafted by examining the components that such a design framework should have and how they can be connected to the second version of the design principles that were drafted in chapter 5. The first version of the framework will be used as input on which the final version of the framework is designed in chapter 7.

6.1. Purpose

The purpose of the framework was determined in paragraph 1.4.2 to *“support project teams in the implementation of blockchain powered smart contracts in governmental services”*. This goal is reached by composing a comprehensive overview with multiple components of the design process of smart contract implementation for services of governmental organizations. The components are build, refined and assessed with literature about the public sector and case studies of municipalities. Project teams can use this framework as inspiration for their own design process. Note that each process is different and demands a different approach. The case studies have shown that there is not a single path towards implementation of smart contracts. The design framework therefore is not aimed at teaching project teams the perfect strategy for implementation, but rather being a guideline to show how smart contract implementation generally is performed. Project teams can learn from this framework and are ought to decide upon which parts of the framework is applicable for their specific case.

6.2. Components

The design framework consists of four components: the design phases, the outcome per phase, the design process, and the design principles. The design phases and outcomes are discussed in paragraph 6.2.1, the design process in paragraph 6.2.2 and the design principles in paragraph 6.2.3.

6.2.1. Design phases and outcomes

The four case studies revealed that their path towards smart contract implementation and ideas about what comes after that, follow more or less the same design phases. All municipalities from the case studies at least followed three steps: exploring opportunities, conceptualizing a process that is suitable for possible implementation and the development and testing of a prototype. Furthermore, many municipalities consider actual implementation of blockchain powered product and some municipalities think about expansion afterwards. Figure 21 visualizes these phases, which are discussed in the sections below.

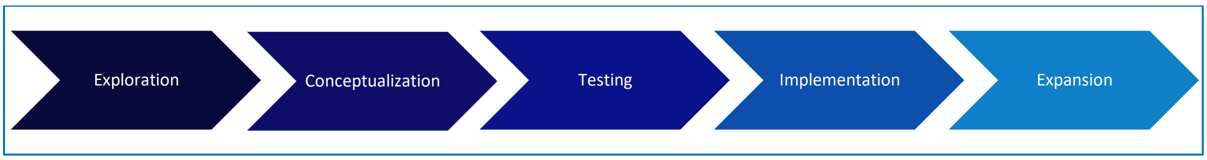


Figure 21 – Smart contract design phases for governmental services.

Exploration

All four municipalities begin their smart contract implementation process with an exploration phase. Some employees already know about blockchain technology and smart contracts, while others do not. Due to the technical difficulties, all need to learn more about the subject. This could be done through workshops (Utrecht), through an interactive blockchain game (Drechtsteden) or presentations (Arnhem). In this phase enthusiastic employees gather interested colleagues who want to join an initial project team (Schiedam). At the end of the phase a potentially suitable process is selected for further examination. This could also be the selection of multiple processes, which then follow their own path. An example is Drechtsteden, that selected both the disabled parking permit process and the internal settlement process.

Conceptualization

The next phase is about mapping how the selected process is currently working. All four municipalities from the case studies had as end result a process description in the form of a PowerPoint presentation that serves as proof of concept (PoC). This process is by some municipalities also called a pilot. This phase is characterized by having clarity about the current process in detail, the potential process with smart contracts and the information flow between stakeholders. Arnhem for example had personal conversations with the involved employees to ensure that the potentially impacted employees are heard in an early phase. Each municipality was guided by external experts, amongst others VNG/KING, DApp.Design, Ordina and LAB15. Utrecht chose to do this phase again with students, because the decision makers were not yet prepared to invest in further steps and they needed to describe the process with more clarity. Drechtsteden did two separate conceptualization phases synchronically: one for the disabled parking permit process and one for the internal settlement process. The outcome of this phase is a process description which serves as proof of concept, where after decision makers assess whether or not they will provide resources for further development.

Testing

All four municipalities are currently developing or planning to develop a working and testable prototype. Schiedam for example is currently making a project plan that describe what the prototype should be able to do and is going to let it be built by the same developers that helped them construct the process description of the conceptualization phase. They are considering to involve citizens that dedicate a part of their income to test the prototype. Utrecht chose to develop the prototype with a group of students of the same institution that made the process description. Drechtsteden performed multiple design sprints of the testing phase and is currently approaching a working prototype. The prototype is used to show others how the application works, what it looks like and what it could do. It is considerate to be a tool to convince decision makers to provide resources for actual implementation and to gain support from other employees. The decision to continue from testing to implementation is the largest step, mostly due to financial reasons.

Implementation

The four municipalities from the case studies did not yet finish their prototypes, but they agree that the next step would be actual implementation. Note that not all municipalities are certain that they will implement the product of which they are developing a prototype at the moment. Drechtsteden explains that blockchain technology has a bad image due to bitcoin and trust needs to be built over time. They have a plan for implementation ready and got other municipalities supporting them, but they are waiting for support from VNG before they will start implementation. Utrecht stated that the result of the prototype will be demonstrated internally and depending on the reactions on that might lead to implementation. Schiedam will assess the risks of implementation after the testing phase and will decide upon implementing a final product based on the results of that.

Expansion

With the four municipalities of the case studies still being in testing phase or on the verge of the implementation phase, they are not focused on potential steps after that. Arnhem does think that blockchain will have a major impact on the role of the government, where various processes that are currently performed by the government will be done through the blockchain. This phase would be called expansion: the service expands beyond the municipality towards a national or even an international product. Drechtsteden elaborates on this potential future, by starting with the explanation that they envision their product to be freely accessible and easily connected to other municipalities. Their application of the disabled parking permit would be available for citizens of other municipalities as well. Because their service is not bound to the geographical location of their municipality nor the location of their users, it is called government-as-a-service. The service could become self-maintaining, where the government will not intervene any further. Note that this phase is currently speculation and not yet officially planned, but it shows what the potential next step would be.

6.2.2. Design process

Every process of the phases from paragraph 6.2.1 will be different, but they all have something in common: they have a starting point and ending point. Another observation is that at the beginning of each phase there are plans and goals for that phase, for example Schiedam set what the prototype should be able to do in the testing phase. At the end of each phase it is assessed how well the results are, compared to the goals that were set beforehand. Based on that result, decisions and actions are made. This is for example the municipality of Utrecht that decided after the first conceptualization round to do another conceptualization cycle. The processes that were described in the case studies can be well described with the Plan-Do-Check-Act-model (PDCA-model).

The PDCA-model – also known as the Deming Cycle or the Shewhart cycle – has four phases: *Plan*, *Do*, *Check* and *Act* (Kanji, 1990, p.5), which is visualized in figure 22. *Plan* is making a plan for implementation and setting goals, *Do* is executing the plan, *Check* is analyzing the results by comparing them to the preset goals and *Act* is making a decision about future plans. Such a decision is often the start of a new *Plan* phase (Dahlgaard, Kristensen & Kanji, 1995). The PDCA-cycle is "*a well-known model for continual process improvement*" (Johnson, 2002, p.120). The four case studies showed that the municipalities are organizations that are eager to learn about innovative technologies like smart contracts and continuously improve their process by moving to the next design phase. This makes the PDCA-cycle a suitable model.

Figure 22 – The PDCA cycle [retrieved from Kanji, 1990].

Figure 23 shows how the PDCA-model can be combined with the design phases from paragraph 6.2.1. Each design phase is connected with a PDCA-cycle. At the start of each phase, a plan is made and goals are set (*Plan*). This could be for example planning to make a prototype and determining that it should at least have certain basic functions. This plan is then executed (*Do*), which means that the plan is developed. This could be for example that the prototype is developed. The execution is then assessed (*Check*), for example, it is evaluated if the prototype indeed has the preset basic functions. The last step of the cycle is making a decision (*Act*). The decision could have several outcomes: do another PDCA-cycle in the same phase (which happened in the conceptualization phase for the municipality of Utrecht), proceed to the *Plan*-step of the next phase or stop the process. The implementation process can thus be described with five design phases with multiple connected PDCA-cycles.

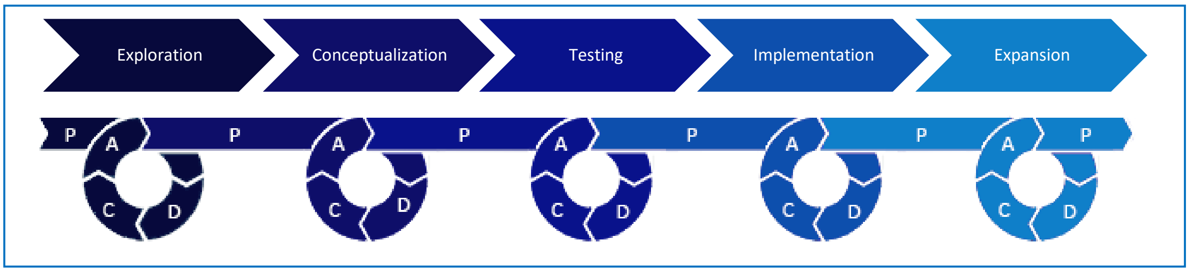


Figure 23 – Smart contract design process for governmental services.

6.2.3. Design principles

Ideally it would be clear which design principles are applicable in each design phase. However, the case studies revealed that different stakeholders have different opinions on when the principles should be applied and when not. The design principles are each discussed on their applicability per design phase with three different categorizations: uncommon, possible and common. When it is clear that a design principle is normally applied in a certain design phase it is labeled *common*. When a design principle is applied in a certain phase in some, but not all projects, it is labeled *possible*. If a design principle is not applied in a certain phase it is labeled *uncommon*. This categorization then serves as a guideline to give the developer of a smart contract implementation a sense of which design principles are commonly used in the design phase he is in and leaves room to decide which design principles he will use.

1. Research legal implications

The explorative phase will be used in order to grasp the idea of blockchain and not yet to research the legal implications. The conceptualization phase and the testing phase are used to describe the process and test a working prototype. The legal implication will not be valid until implementation, but they can be researched beforehand. Drechtsteden and Arnhem for example are researching the legal implications from the conceptualization phase. The moment it is really necessary is implementation, because then it is a live product and thus subjective to legalization. The expansion phase will even have more legal implications as it affects more regions and thus more legislative frameworks. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

2. Define a vision

Municipalities think defining a vision is important, but none have defined one in the exploration or the conceptualization phase. Arnhem for example thinks that a vision is crucial, because blockchain technology can disrupt many services and are planning to make a vision after the conceptualization phase. Drechtsteden believes it will be made somewhere during the process towards implementation. All municipalities agree that eventually a vision is important, which would be in the implementation and expansion phase. This design principle is labeled uncommon for *exploration* and *conceptualization*, possible for *testing*, and common for *implementation* and *expansion*.

3. Define clear policies and legislation

Utrecht and Schiedam argue that this design principle is important in later phases. It should be clear first how the product works in the conceptualization and testing phase. After that, the policies and legislation should be prepared for implementation first and again for expansion. This design principle is labeled uncommon for *exploration* and *conceptualization*, possible for *testing*, and common for *implementation* and *expansion*.

4. Invest in blockchain knowledge

All municipalities agree that investing in blockchain knowledge is important from the start. Utrecht notes that this is not necessarily a large financial investment, but when employees dedicate some time to learning about blockchain, it can be seen as investment as well. Because every phase demands at least time, this design principle is labeled common for all phases.

5. Allocate budget

Schiedam, Arnhem and Utrecht state that budget is necessary for every governmental project. However, the exploration phase can be so short that the budget is minimal. This could for example be one workshop where employees draft ideas for smart contract implementation. Therefore, this design principle is labeled possible for *exploration* and common for *conceptualization*, *testing*, *implementation* and *expansion*.

6. Determine profitability

The exploration phase is to explore blockchain and not directly to determine profitability. Each phase afterwards can have some aspects that determine profitability: the conceptualization phase for example can already map what the profit of implementation would be. This becomes necessary at the implementation phase. Schiedam for example states the implementation is costly, which makes it necessary to determine profitability at the start of the process. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

7. Find experts

All municipalities were in touch with experts in every phase. The first phase for example is guided by experts that explain how blockchain work. The conceptualization and testing phases need experts on process management and smart contract coding. In later phases, also legal experts are involved. This design principle is labeled common for all phases.

8. Cooperate with other organizations

All municipalities work together with other organizations after the exploration phase, but the exploration phase can already see cooperation with other organizations. This can be for example workshops and conversations with other municipalities. The conceptualization phase is often done with other organizations, but Drechtsteden did the parking permit project internally. Testing, implementation and expansion needs computer specialists that municipalities do not have, which requires cooperation. This design principle is labeled possible for *exploration* and *conceptualization,* and common for *testing, implementation* and *expansion*.

9. Involve stakeholders

It is possible to involve all stakeholders in an early process, but Utrecht thinks that critical stakeholders can slow down the process in a too early phase. More stakeholders need to be involved in every phase, but the exploration, conceptualization and testing can be done with relatively small project teams. For implementation many stakeholders are affected and require to be involved. The exploration phase also involves mapping the stakeholders, which excludes involving stakeholders from that phase. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

10. Share results

Arnhem and Utrecht state that the conceptualization and testing phase have sharing results as important activity, as this might convince decision makers and other employees, which can result in more resources for development. Drechtsteden and Schiedam have shared their results in the conceptualization phase as well. It is likely that sharing results is an important principle in every phase, as more exposure can lead to more enthusiasm and possible partners. This design principle is labeled uncommon for *exploration* and common for *conceptualization*, *testing*, *implementation* and *expansion*.

11. Multidisciplinary team

Municipalities have different ideas about when to start a multidisciplinary team. Utrecht for example thinks the exploration and conceptualization phase are too early, while for example Schiedam is already working in a team with employees with other functions and employees from a debt assistance organization from the start. Arnhem is involving the legal department now they are approaching the testing phase. Utrecht lets students develop a prototype, while the team from the municipality stays monodisciplinary. However, the implementation phase will need experts from other disciplines. This design principle is labeled possible for *exploration*, *conceptualization* and *testing*, and common for *implementation* and *expansion*.

12. Communicate significance

Utrecht states that significance cannot be communicated until a working prototype can be shown. However, Arnhem believes that it is not only demonstrating a working prototype, but also explaining how blockchain works and what can be realized with it. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and common for *testing, implementation* and *expansion*.

13. Understand implications

Understanding social and ethical implications is something that Arnhem is doing from the conceptualization phase onwards. They believe personal communication is crucial with smart contract implementations, as some functions and jobs may change. Drechtsteden indicates that they are working on this as well. Utrecht however states that they did not think of it yet. The actual implications will not happen until implementation and thus that is the phase that those implications should be known. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

14. Involve supervisor

Arnhem is talking with the supervisor about important decisions and Schiedam has a supervisor in the project team. Because the supervisor is responsible for allocation of resources, which includes the dispatch of the working hours of the project team members as well, involving the supervisor is crucial in every phase. This design principle is labeled common for all phases.

15. Cooperate internally

The four municipalities each state that internal cooperation is important in order to gain support and resources. An exploration can be done by an individual, but after that phase internal cooperation will become increasingly important. This design principle is labeled possible for *exploration* and common for *conceptualization*, *testing*, *implementation* and *expansion*.

16. Examine shifting role of the government

Arnhem and Drechtsteden state that the role of the government could change due to smart contract implementation. That is not a process that will be of importance before the implementation phase, but surely in the expansion phase. Depending on the process, it could already be that local implementation changes the role of the government This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, possible for *implementation* and common for *expansion*.

17. Examine impact on jobs

Smart contract implementations can change jobs and functions in the implementation and expansion phase, where this design principle will be important. Utrecht does not examine this in the conceptualization and testing phase yet, while Arnhem already is thinking about possible consequences in the conceptualization phase. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

18. Define responsibilities

Arnhem and Schiedam indicate that blockchain will change the responsibilities of stakeholders, which thus need to be redefined. However, they are not yet defining these responsibilities before the implementation phase. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, and common for *implementation* and *expansion*.

19. Security

Arnhem, Schiedam and Utrecht stress that security is an important aspect for smart contract implementation. This is due to the characteristics of blockchain that promise security, but users can feel unsafe due to the new technology. The testing phase can already be tested for penetrations for example and implementation will need high security for certain. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and common for *testing, implementation* and *expansion*.

20. Privacy

The privacy may be even more important than security as blockchain enables everyone to see personal information from users. The information is encrypted and thus not actually readable, but Arnhem states that citizens can feel unsafe nonetheless. This design principle was often discussed in the same way as security and is thus labeled uncommon for *exploration*, possible for *conceptualization* and common for *testing, implementation* and *expansion*.

21. Process selection

The process selection always happens in the first phase. Before any conceptualization or programming can be done, the municipality selects the process which it is going to examine. This design principle is labeled common for *exploration* and uncommon for *conceptualization*, *testing*, *implementation* and *expansion*.

22. Map the process

Every design phase implements another step of the process, with exception of the exploration. This design principle is therefore labeled uncommon for *exploration* and common for *conceptualization, testing, implementation* and *expansion*.

23. Prototype development

The prototype development only happens during the testing phase. This design principle is therefore labeled uncommon for *exploration*, *conceptualization*, *implementation* and *expansion*, and common for *testing*.

24. Start small projects

The municipalities start with small projects during the exploration, conceptualization and testing phases. They take a small process which is comprehensible. Implementation can still be a small project, but it can be a large process as well. Expansion involves cooperation with many other parties and is likely not small anymore. This design principle is labeled common for *exploration*, *conceptualization* and *testing*, possible for *implementation* and uncommon for *expansion*.

25. Open source coding

Each of the four municipalities indicated that they are using or will use open source for the code of all their coded products. Because the exploration and conceptualization phases are not coded yet, this design principle is labeled uncommon for *exploration* and *conceptualization*, and common for *testing, implementation* and *expansion*.

26. Establish standards

Drechtsteden is the only municipality from the case studies that thought establishing standards was important. The other municipalities are not troubled with that yet, because standards are important when systems are connected to each other. When the service expands and is available in other municipalities, standards are needed to ensure the systems are compatible. Setting a standard however could be done in the implementation. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, possible for *implementation*, and common for *expansion*.

27. Learn from prior development

There is a lack of successful implementations that others can learn from. Therefore in most of the design phases, this principle is uncommon. Arnhem for example does state that they looked at the Stadjerspas from the municipality of Groningen, which is similar to the Gelrepas. It is likely that the subsequent phases will potentially be improved by learning from prior development, but these cases are not yet widely existent. The exploration phase is the only phase where it is common to learn about prior development: to grasp the idea of the potential of smart contracts, municipalities are presented an overview of applications. This design principle is labeled common for *exploration* and possible for *conceptualization, testing*, *implementation* and *expansion*.

28. Risk assessment

The assessment of risks is about the risks of the final product. It is therefore only necessary in the implementation and expansion phases. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, and common for *implementation* and *expansion*.

29. Decide ledger type

Deciding the ledger type can be done in an early stage. Arnhem for example already determined that the Gelrepas will start in a private blockchain in the conceptualization phase. The prototype needs to run on a (test version of the actual) blockchain and thus it is necessary that the ledger type is decided there. The decision for the ledger type can be changed in the implementation and expansion phase if wanted. This design principle is labeled uncommon for *exploration*, possible for *conceptualization, implementation* and *expansion*, and common for *testing.*

30. Consider back-ups

The case studies provided as insight that considering back-ups is not common, as some interviewees claim that back-ups are unnecessary due to the distributed history of the transactions characteristic of the blockchain. Other municipalities think that for implementation and expansion a back-up is potentially needed. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, and possible for *implementation* and *expansion*.

31. Define project goals

Each of the design phases starts with the *Plan*-step of the PDCA-cycle, which means there are goals set to be reached for that phase. Defining those goals are common for every phase, for example the *exploration* phase will have as goal to learn about blockchain and the *testing* phase can have multiple goals, amongst others that the prototype works. This design principle is therefore labeled common for all design phases.

32. Scalability

Scalability will become of importance when many transaction are taking place due to the scalability issues with blockchain in general. This is possibly of importance at implementation, depending on the process. When the service would expand this design principle becomes likely to be important. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, possible for *implementation*, and common for *expansion*.

33. Transaction speed

The characteristics of blockchain can limit the transaction speed of the service. The transaction speed is important to assess when the user has access to the service: the implementation and expansion phases. This design principle is labeled uncommon for *exploration*, *conceptualization* and *testing*, and common for *implementation* and *expansion*.

34. Good UI/UX design

The UI/UX is the interface of the service and the experience of the user. This is important for the end product, but can also be important for the prototype. Many municipalities see the prototype as tool to gain more support and resources for further development, which implies that UI/UX design is potentially helpful. This design principle is labeled uncommon for *exploration* and *conceptualization*, possible for *testing*, and common for *implementation* and *expansion*.

35. Determine authorizations

The characteristics of smart contracts demand determination of authorizations, as they are different from current services. The determination of authorizations is necessary for the *implementation* and *expansion* phases, but can already be determined in the *conceptualization* and *testing* phases. This design principle is labeled uncommon for *exploration*, possible for *conceptualization* and *testing*, and common for *implementation* and *expansion*.

6.3. Construction first version of design framework

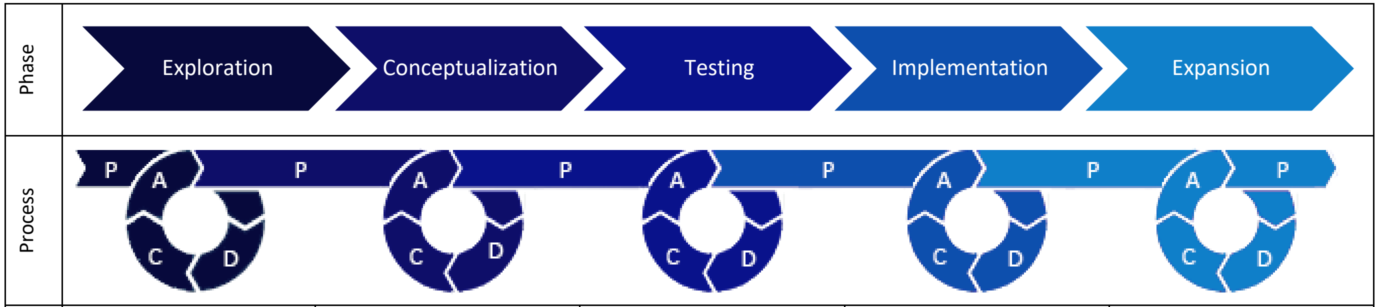
In order to provide a comprehensive overview for designers of smart contract implementations for governmental services, the framework should be connected and shown on a single page. Figure 24 shows the result, which is called the smart contract implementation framework for governmental services. The design framework consists of four rows that correspond to the four components: the design phases, the process, the outcome and the design principles. The design phases are displayed in the first row and divide the table in five columns: one for each of the design phases. This creates a comprehensive overview of each phase and its process, outcome and applicable design principles. The design principles have been divided in three categories in paragraph 6.2.3. These categories are visualized in the framework as follows: a red cross (uncommon), blue dots (possible) and green checks (common). In order to comprehensively show the design dilemmas (see paragraph 5.5), the numbering of the design principles is slightly altered to have these pairs underneath each other. The red letter combination DD is added between brackets with the indication of which dilemma it refers to.

Categories

P	Political
E	Economic
S	Social
T	Technological

Principles legend

[DD]	Design dilemma
X	Uncommon
●●●	Possible
√√√	Common



Outcome		Exploration	Conceptualization	Testing	Implementation	Expansion
		• Process selection • Initial project team	• Process description • Pilot • Proof of concept	• Prototype	• Working product	• Intermunicipal product • Government as a Service
Design principles – Political	1. Research legal implications	X	●●●	●●●	√√√	√√√
	2. Define a vision	X	X	●●●	√√√	√√√
	3. Define clear policies and legislation	X	X	●●●	√√√	√√√
Econ.	4. Invest in blockchain knowledge	√√√	√√√	√√√	√√√	√√√
	5. Allocate budget [DD1]	●●●	√√√	√√√	√√√	√√√
	6. Profitability [DD1]	X	●●●	●●●	√√√	√√√
Social	7. Find experts	√√√	√√√	√√√	√√√	√√√
	8. Cooperate with other organizations	●●●	●●●	√√√	√√√	√√√
	9. Involve stakeholders	X	●●●	●●●	√√√	√√√
	10. Share results	X	√√√	√√√	√√√	√√√
	11. Multidisciplinary team	●●●	●●●	●●●	√√√	√√√
	12. Communicate significance [DD2]	X	●●●	√√√	√√√	√√√
	13. Examine impact on jobs [DD2]	X	●●●	●●●	√√√	√√√
	14. Involve supervisor	√√√	√√√	√√√	√√√	√√√
	15. Cooperate internally	●●●	√√√	√√√	√√√	√√√
	16. Examine shifting role of the government	X	X	X	●●●	√√√
	17. Understand implications	X	●●●	●●●	√√√	√√√
	18. Define responsibilities	X	X	X	√√√	√√√
Tech	19. Security [DD3]	X	●●●	√√√	√√√	√√√
	20. Open source coding [DD3]	X	X	√√√	√√√	√√√
	21. Process selection	√√√	X	X	X	X
	22. Map the process	X	√√√	√√√	√√√	√√√
	23. Prototype development	X	X	√√√	X	X
	24. Start small projects	√√√	√√√	√√√	●●●	X
	25. Risk assessment	●●●	●●●	●●●	√√√	√√√
	26. Establish standards	X	X	X	●●●	√√√
	27. Learn from prior development	√√√	●●●	●●●	●●●	●●●
	28. Privacy [DD4]	X	●●●	√√√	√√√	√√√
	29. Decide ledger type [DD4]	X	●●●	√√√	●●●	●●●
	30. Consider back-ups	X	X	X	●●●	●●●
	31. Define project goals	√√√	√√√	√√√	√√√	√√√
	32. Scalability [DD5]	X	X	X	●●●	√√√
	33. Transaction speed [DD5]	X	X	X	√√√	√√√
	34. Good UI/UX design	X	X	●●●	√√√	√√√
	35. Determine authorizations	X	●●●	●●●	√√√	√√√

Figure 24 – First version of the smart contract implementation framework for governmental services.

6.4. Observations

The following observations are made from the design framework:

- The design principles in the political category (research legal implications, define a vision and define clear policies and legislation) are not common until the *implementation* phase. It seems that these design principles are not yet considered important in the early phases.
- The design principles in the economic category (invest in blockchain knowledge, allocate budget and profitability) are not uncommon from the *conceptualization* phase onwards. It implies that the economic principles are considered important. This confirms the statements from municipalities that they are financially driven.
- The number of common design principles from the *conceptualization* phase to the *expansion* phase is respectively 7, 9, 16, 26 and 29. Especially the step from the *testing* phase to the *implementation* phase is large, with ten additional design principles.
- Design dilemmas do not yet occur in the *exploration* phase, because there are no dilemma pairs that are both in the category possible of common.
- The design dilemma *allocate budget & profitability* is possible from the *conceptualization* phase and common from the *implementation* phase. It can be explained by the costs of actual implementation, which is higher in the *implementation* phase than in the prior phases.
- The design dilemma *communicate significance & examine impact on jobs* is possible from the *conceptualization* phase and common from the *implementation* phase. This corresponds with the results from the case studies. For example Arnhem experienced this dilemma already in the *conceptualization* phase, but Utrecht does not yet recognize the dilemma, while they are approaching the *testing* phase.
- The design dilemma *security & open source* is only common from the *testing* phase onwards, because that is the phase where the first coding occurs. The dilemma was discussed in the interview with Arnhem, but Arnhem did not see open source coding as threat for the security. Municipalities seem to believe that open source coding will automatically increase security and scientific research supports this vision. However, some still disagree with that claim and we mentioned some examples in paragraph 5.5 that show that this dilemma is controversial.
- The design dilemma *privacy & decide ledger type* is possible from the *conceptualization* phase and common from the *testing* phase. Arnhem for example stated that they are going to use a private blockchain to protect personal data from citizens. Drechtsteden however believes that choosing a public blockchain is better for protecting data, because the public blockchain is more secure than the private blockchain. The dilemma is already a point of discussion in early stages and will increase in each stage.
- The design dilemma *scalability & transaction speed* is possible from the *implementation* phase and common from the *expansion* phase. The municipalities from the case studies did not mention this dilemma yet, because they are not in the implementation phase yet. Only Drechtsteden acknowledged that this will indeed be important when implementation will occur.

6.5. Conclusion

The sub question of chapter 6 is: "*How can design principles be translated into a design framework*?", where the goal of the framework is to *"support project teams in the implementation of blockchain powered smart contracts in governmental services"*. Project teams need a comprehensive overview of when to use which design principles. This led to the first version of the smart contract implementation framework for governmental services. Five design phases are discovered: exploration, conceptualization, testing, implementation and expansion. Each phase has its own process, outcomes and applicable design principles. The design dilemmas occur in different design phases as well: allocate budget & profitability and communicate significance & examine impact on jobs are possible in the conceptualization phase and common in the implementation phase. Security & open source coding is common in the testing phase. Privacy & decide ledger type is possible in the conceptualization phase and common in the testing phase. Scalability & transaction speed is possible in the implementation phase and common in the expansion phase. The latter is not yet applicable before the implementation phase, which explains why this dilemma was not yet experienced in the cases in chapter 5. The first version of the framework will be assessed and refined in chapter 7 in order to form the final framework.

7. Assess and refine: framework validation

This chapter will answer the sub question *"Which design principles and design framework can be derived from feedback from the environment?"*. Expert interviews are performed to conduct the design science approach steps *assess* and *refine* in order to improve the second version of the design principles and the first version of the design framework. This leads to the final version of the design principles and the design framework.

7.1. Interview approach

7.1.1. Goal

The expert interviews are aimed at assessing and refining the design principles and the design framework by having experts provide feedback on them. Furthermore, the experts will assess the applicability of the framework for the entire public sector. Appendix G contains the interview protocol to support this goal.

7.1.2. Interviewee selection

Experts can be defined as *"people who possess special knowledge of a social phenomenon which the interviewer is interested in"* (Gläser & Laudel, 2009, p.117), being people who possess the knowledge of implementing smart contracts in governmental services. Therefore the experts in this research are defined as "*people who possess special knowledge of implementing smart contracts in governmental services*". These people should be involved in the implementation of such projects. This could also be a conceptual description, a detailed brainstorm or a pilot. The selection of experts in table 13 was based on the following criteria:

1. Has been involved in the implementation of smart contracts in a governmental service;
2. The involved party has at least one person who is willing to be interviewed.

Table 13 – List of interviewees for the framework validation.

#	Interviewee	Organization	Function
1.	Koen Hartog	Blockchainpilots.nl	Project manager national blockchain pilots
2.	Karel Frank Artist	DApp.Design	Blockchain developer
	Jan ter Laak	DApp.Design	Blockchain developer
3.	Steven Gort	ICTU	Data scientist for the Dutch government
4.	Sandra van Heukelom	Pels Rijcken	Law expert with smart contract expertise
5.	Paul Spoelstra	Municipality of Groningen	Project leader Stadjerspas
6.	Jamal Vleij	Forus	Blockchain developer
	Maarten Velthuys	Forus	Blockchain developer

7.2. Assessment second version of design principles

The interviewed experts assessed the second version of the design principles and the design framework. The design principles are each discussed below. From the interviews 148 statements were coded in ATLAS.ti. The statements are referred to as a combination of letters and a number: B is for Blockchainpilots.nl, DD for DApp.Design, I for ICTU, P for Pels Rijcken, G for the municipality of Groningen and F for Forus. The number refers to the number of the statement for that party. The reference [DD.19] for example is the 19th statement from the DApp.Design interview. The full list of statements is placed in appendix I. Note that the interviews were conducted in Dutch and we translated the quotations to English, which might lead to slightly different interpretations. This paragraph will also discuss the applicability of the design principles for each design phase.

1. Research legal implications

Researching legal implications was a controversial point in the interview. Some interviewees think that it is a crucial activity to do from the start [PR.1; PR.2; PR.3; F.1]. A reason for that is explained by Pels Rijcken: *"Many make the technical parts first and involve the law experts after. The downside is that they then say they should have made another technical choice, because that fits better. If you help building from the start and translate legal requirements in technology, you comply better to the law, without wasting money. It would save much money."* [P.1]. In other words: legal barriers can be overcome with technological choices and thus need to be made in an early stage. On the other hand, accounting for legal implications can limit innovation [I.6; DD.4; F.1]. DApp.Design provides an example: *"The problem I have as entrepreneur, when Airbnb had given a presentation in the Netherlands before they started, where housing corporations and lawyers were present, they would have said: this is not possible, if you rent a house you cannot sublet a room."* [DD.4]. This is true, especially for disrupting technologies that encounter the boundaries of current legislation. A solution that Pels Rijcken offered was to do a legal impact analysis in the conceptualization phase, which is a textual display of the legal implications [P.3]. DApp.Design and Forus state as well that this is something that should be thought of in an early stage, as long as it does not limit you in your thinking process [DD.4; F.1]. ICTU believes that regulation parties should be ignored and one starts building from scratch [I.6], but Forus and DApp.Design believe that it is wise to at least know which laws apply. When you have made a prototype you can then lobby for changing those laws. Forus states this as: *"If you show something nice with the prototype and show that it works, you can make a proposal to change legislation."* [F.1]. Researching legal implications is therefore considered common from the conceptualization phase onwards, but in the description it is mentioned that it should not be limiting the thinking process.

2. Define a vision

The experts think that defining a vision is important [DD.5; G.4; F.2]. Forus even thinks that it *"is the most important of all. You must know why you want to use blockchain. Based on that vision you can account for the scope of your project: do you analyze one project?" … "Do you map the process in blockchain? How does the process change if there is not a central party anymore? That is not the same as translating each step in a smart contract." … "You need a broader vision for the entire organization. From there you define your future role, where things are automated."* [F.2]. Groningen also has a vision on the implementation of blockchain with a clear idea behind it [G.4]. DApp.Design state that as developers it is pleasant for them to be able to follow the vision of a public party [DD.5]. Having a vision is not mandatory in the early phases, but can be beneficial. Zuidhorn and Groningen have a clear vision on blockchain and are currently the only municipalities in the Netherlands with a live product that runs on blockchain. Defining a vision therefore becomes possible for the exploration and conceptualization phase as well.

3. Define clear policies and legislation

Groningen stated that they are still looking into their policies and legislation [G.1]. Blockchainpilots.nl noted that it *"also correlates very much with 1 (legal implications). If they do that, they probably also define clear* *policies and legislation."* [B.2]. However, the case studies and the other expert interviews showed that researching legal implications and having clear which laws apply is different from defining new policies and altering legislation, which is often done in a later stage. The design principle is therefore maintained as in the prior version.

4. Invest in blockchain knowledge

This design principle is considered important from the very start [B.3; F.4]. A valid point, that was also noted by the municipality of Utrecht in the case study, is that *"for someone to be able to judge if a prototype is useful, he has to know the basics of blockchain technology and that needs investment."* [F.4]. Groningen for example states that investing in blockchain knowledge *"has been mediocre, because we are just working with it. I know some of it, how the network and transparency work, but it just passes me a bit."* [G.2]. He claims that he did not invest much in blockchain knowledge and surely he is not an expert, but he invested in obtaining a fundament of blockchain knowledge that was needed in order to assess whether or not the tender from the developers of the project was feasible. The design principle is therefore maintained as in the prior version.

5. Allocate budget

Experts agree that budget is necessary for activities that lead to implementation of smart contracts [B.4; G.3; F.26]. It is noted that *"You always need budget to do something, but not too much. There are always free activities you can do."*[B.4]. Following a workshop in the exploration phase for example could be done in the free time of an employee and thus allocation of budget is considered possible in that phase. The design principle is therefore maintained as in the prior version.

6. Determine profitability

Profitability indeed is important when implementing smart contracts [B.5; DD.6; F.26]. Experts did not provide suggestions to adapt this design principle and therefore is maintained as in the prior version.

7. Find experts

Many agree that finding experts is important [B.6; G.5], but in practice also difficult [DD.7; F.5]. Necessary experts that have been mentioned are from the fields of security, coding, blockchain and law. Especially the blockchain coders are still hard to find: *"We notice that there are hardly any developers. We concluded that we have to train them ourselves."* [DD.7]. Yet, these experts are crucial to actually code. The design principle is therefore maintained as in the prior version.

8. Cooperate with other organizations

Experts agree that cooperation with other organizations is crucial [B.7; DD.8; G.6; F.6], but they do not agree on which phase would be the most ideal. DApp.Design and Forus think it should be done from the start [DD.8; F.6]. Blockchainpilots.nl argues that it is *"optional in the first part. Sometimes we tell them, not yet. The moment you work with a large group in the first phase, it is not the most efficient. You need tight steering. I often try to keep the pilot groups somewhat smaller"* [B.7]. This viewpoint is confirmed by the case studies as they showed that large groups can slow down the process. Therefore cooperation remains optional in the exploration and conceptualization phase.

9. Involve stakeholders

Involving stakeholders has been a point of discussion in the case studies, which the experts experience as well. The experts who have an opinion about this design principle agree that it is important, but disagree about when it is important. On the one hand, it is noted that *"it could slow down the process."* … *"You involve stakeholders when you have something to show"* [DD.9]. On the other hand involving stakeholders in an early stage is important as they add valuable knowledge about their point of view on the process [F.7]. A valid point from blockchainpilot.nl is that "*it would be a waste if you test it by yourself. It can be done, working with made up data, but you see that many ask other organizations if they want to be involved. Because if they do not want* *to cooperate, what is the point then?"* [B.34]. Involving stakeholders thus is important, but the implementation team should consider if it is valuable to involve them from early on or it is better to have a prototype to show the functioning first. This design principle is made possible in the exploration, conceptualization and testing phases and common in the implementation and expansion phase. The rationale is adapted to include the consideration with the added value and slowing down the process.

10. Share results

Experts agree that sharing results is crucial [B.8; DD.10; G.7; F.8]. Forus explained that they *"started with a hackathon. We shared the result with the organization. The results helped us a lot. With the demo we could move away from the abstract and show something tangible where people become enthusiastic about."* [F.8]. The results thus helped them in gaining internal support and accelerating the implementation process. The design principle is therefore maintained as in the prior version.

11. Multidisciplinary team

Experts agree that a multidisciplinary team is important [B.9; DD.11; G.8; F.9] and as early as the conceptualization phase [B.9; DD.11; F.9]. The reason for this is that the developer does "*have blockchain knowledge, but we need to hear from someone else what we need to build*" [DD.11]. You need people who know something about the substance of the process. An example was the case study of the budget assistance, where someone was involved from an organization that was specialized in budget management. DApp.Design advised to *"start small in the conceptualization phase and scale up"* [DD.11]. This design principle is adapted to be common in the conceptualization and testing phase as well, while the description is adapted to emphasize that the team can scale up after each phase.

12. Communicate significance

Communicating the significance of the new process is found important by the experts [B.10; DD.3; DD.12; F.27]. It could lead to some resistance (design dilemma communicate significance & examine impact on jobs), but especially then it is important to explain the merit of the project. Forus explains that communicating the significance, while involving the ones who are affected can lead to reduced resistance [F.27]. Still, it is important to first get clear what the merit of the new system will be and that might not yet be clear in the conceptualization phase. The design principle is therefore maintained as in the prior version.

13. Examine impact on jobs

Blockchainpilots.nl noted that this principle *"is not one that is specifically examined now, because it is still small"* [B.11], while Groningen does not think jobs will be affected that much [G.9]. Forus examined the impact on jobs in an early phase, which led to a positive result [F.27], but DApp.Design states: *"I would not start with that too early, you do not want to cause commotion. The working product is a good moment to show the pros and cons"* [DD.13]. It shows that it depends on the process if the impact on jobs is large. For example, the process of Kindpakket (Forus) changed the function of an employee and therefore needed early examination. The process of Stadjerspas (Groningen) did not change the function of an employee much and did not receive much attention. When expanding the service however, it is likely that functions will change a lot. This design principle therefore becomes possible in the conceptualization, testing and implementation phases and common for the expansion phase. In the explanation of the design principle it is noted that it depends on the process how important this design principle is.

14. Involve supervisor

Experts agree that the supervisors should be involved in an early stage [B.12; DD.14]. Forus notes that *"you can also invest time on your own, so the moment you involve your supervisor, you can explain him the idea"* [F.10]. It is true that an employee can explore blockchain in his free time, but the moment an initial project team has to be formed, a supervisor needs to be involved. The design principle is therefore maintained as in the prior version.

15. Cooperate internally

Groningen confirms that they cooperate a lot internally [G.10], but other experts believe that this design principle is already covered by other design principles [B.13; F.11]. DApp.Design questions the need for this design principle: *"Why do you have this one? I think this is culture. I would almost say, scrap it. I think this is an effect. The cause is that we start a project, the effect is that you have to cooperate"* [DD.15]. It is true that this design principle is covered by other principles, such as *involve stakeholders*, *multidisciplinary team* and *involve supervisor*. This design principle is thus considered to be superfluous and is deleted.

16. Examine shifting role of the government

Five of the six experts agree that the shifting role of the government need to be examined [I1; I.2; I.3; I.10; B.14; DD.16; G.11; F12]. ICTU believes that the role of the government needs to be different in the future, where blockchain enables citizens to possess their own data and identity [I.1; I.2; I.3] and where people eventually go from a forty hour workweek to a sixteen hour workweek [I.10]. Of course, those visions on the shifting role of the government are important, but at the moment it is still intangible for many people. People need to first understand the implications by seeing how smart contract projects work. It is also noted that *"when it is done, you are already experiencing it"* [DD.16]. For smaller projects, the shifting role of the government can thus be experienced by learning and does not need to be actively examined. Groningen and Zuidhorn do actively examine their shifting role as municipalities, because it fits their vision [G.11; F.12]. Concluding, examining the shifting role of the government is often found important. Blockchain technology and smart contracts promise to disrupt many sectors and governments and thus it is logical that a shifting role of the government is possible. However, it is not necessary for each party to actively examine this shift. This design principle therefore becomes possible for the phases conceptualization, testing and implementation.

17. Understand implications

Blockchainpilots.nl and DApp.Design note that understanding the implications is useful [B.14; DD.17], but Groningen notes that it is something that is hard to determine [G.12]. Forus states that *"you cannot understand it in the first phase." … "I think that understanding implications is more a side effect. You want to grasp the effect of blockchain by doing. The effect of building is that you begin to understand the implications. You do not have to do it actively, it just happens"* [F13]. Just like with cooperate internally, this design principle is something that happens during the implementation process and is not an activity that you can plan. Therefore this design principle is deleted.

18. Define responsibilities

Groningen states that they defined the responsibilities before implementation and explain why it is important: *"When there is a hack in the system and it is hosted by DutchChain[10], it is their problem. It is their system. However, there is nothing to steal. We have all personal data within the municipality. We thought it through"* [G.13]. Blockchainpilots.nl and Forus do note that defining responsibilities in an early stage is hard, because the shift in responsibilities in relation to blockchain can be still intangible for some participants [B.16; F.14]. Forus also notes that responsibilities are constantly developing as blockchain technology develops as well [F.14]. Therefore, the statement of the principle is adapted to emphasize that the definition of responsibilities is constantly evolving.

19. Security

Security is not yet found important before the implementation phase. DApp.Design explains: *"For Schiedam we will build a prototype, where we do not account for security. In IT you have different roles: in one role you can do this and in the other you cannot. This is RBAC[11]. Everything around it you will think about with the working product. The prototype is quick-and-dirty. The prototype is always made in a secured environment"* [DD.18]. The

[10] DutchChain is the organization that implemented the blockchain solution for the municipality of Groningen.
[11] Role-based access control.

risk of a lack of security is high: *"You could hack very good with smart contracts first. Many people without coding knowledge did it unsafe. There was money in those contracts. With smart use of software you could extract the contract. But we did not do that. Others did. And they stole millions by doing that"* [DD.37]. So the stakes are high. Blockchainpilots.nl note that some begin to think about security in the prototype already [B.17]. Therefore, this principle is adapted to be uncommon in the conceptualization phase and possible in the testing phase.

20. Open source coding

ICTU, Blockchainpilots.nl, DApp.Design and Forus agree that open source coding is in principle important for coding in the public sector [I.4; B.18; DD.19; I.11; F.23]. The main reason is that public parties should not all spend public money multiple times for the same software: *"Spend public money two times: do I think that is a good idea? No, I do not think that is a good idea, so development costs for blockchain need open source"* [I.4]. However, open source coding might also lead to security problems (design dilemma security & open source coding), which will be discussed further in paragraph 7.4. Therefore, this design principle becomes possible for the testing and implementation phase, but with an emphasis in the statement that open source coding should be applied in the long term.

21. Process selection

Blockchainpilots.nl agree that the selection of a process should be done in the conceptualization phase [B.19]. Forus notes that: *"It also depends on the scope of your project. The question then is how far you will go. Are we going to decentralize everything? I do not think so. Determining your scope is important, so everyone knows what is going to happen"* [F.15]. It should be clearly defined which process is selected and how far the scope of the project reaches. Is it just about a part of a process of an entire process? The design principle is adapted into *select process and scope of the project*.

22. Map the process

The experts agree to this design principle and the phases that were indicated in the framework [B.20; DD.21; F.16]. The design principle is therefore maintained as in the prior version.

23. Prototype development

The only critique to this principle is the name. DApp.Design advises: *"I would call it build. Developing is broader. You already developed it, and now we are going to build it"* [DD.22]. With this principle we indeed meant the actual building of the prototype and therefore the name is adapted into *build a prototype*.

24. Start small projects

The experts agree that starting small projects is a good idea [B.21; DD.23; F.17]. The design principle is therefore maintained as in the prior version.

25. Risk assessment

Most of the interviewees think that a risk assessment is important to do when implementing the actual product [B.22; DD.24; G.15]. Forus explains that they are constantly *"discussing that. You should never be guided by fear, but you have to account for it"* [F.18]. Just like with the possible legal barriers, other risks should be accounted for as well, but should not be a reason to limit innovation. This design principle becomes uncommon for exploration, possible for conceptualization and testing, and common for the subsequent phases.

26. Establish standards

Groningen stated that they are not working on establishing standards [G.16] and DApp.Design thinks that standards could slow down development [DD.25]. Blockchainpilots.nl explains that *"it is very early for that"* [B.23] and Forus believes that *"establishing standards is an ambitious goal." … "I think it is more an effect"* [F.19]. Blockchain technology is still rapidly developing, which hampers the establishment of standards. This design principle is currently already covered by the design principles *share results* and *learn from prior development*. This may lead to the establishment of standards as effect, but is not an activity that should be planned for. This design principle is therefore deleted.

27. Learn from prior development

Many experts agree that learning from prior development is important [B.24; DD.26; G.17; F.20], because *"you do not have to make the same mistakes"* [B.24]. Especially in a rapidly developing field as blockchain it is important to share new insights. Forus advises to *"make something continuous of it"* [F.20]. This design principle was first only common in the exploration phase, as that is the phase where you look at other cases to get inspiration for your own process selection. However, each phase comes with unique challenges and questions that can be partially tackled by learning from prior development. This design principle is therefore made common for each phase.

28. Privacy

Privacy is an issue that lays within the character of blockchain and is experienced as important [DD.27; F.28]. Privacy is common in the testing phase already, while security is not. DApp.Design confirms that placement: *"I am strongly considering to already introduce that in the prototype, because it is technical. You should have it built in there already"* [DD.27]. The design principle is therefore maintained as in the prior version.

29. Decide ledger type

Experts confirm that deciding the ledger type is important [B.26; DD.28; G.18], foremost because there are several design dilemmas that depend on this principle [F.29; F.28; F.25]. Those dilemmas are further discussed in paragraph 7.4. An important note is that *"I think that will only be done at the actual product. With many prototypes I see that they just pick a blockchain, based on assumptions or the preferences of the developer. If you implement you will need to make a well-considered choice for the ledger"* [B.26]. As with many aspects of the prototype, it is done quick-and-dirty, but even if it is a temporary choice, a choice for a ledger type is made. Also, the development of blockchain technology can trigger choosing for another ledger type in a later stage of the project [F.28]. This principle therefore becomes uncommon for the conceptualization phase and common for the testing, implementation and expansion phases.

30. Consider back-ups

Experts confirm that back-ups are not necessary in a public blockchain, because there are many nodes who keep a copy of the data and thus each act as a back-up [F.25; B.27; DD.29]. The reality however is that in the current development of blockchain, the private ledger type has some benefits over a public ledger. This drives project teams to the use of a private ledger, which still needs a back-up. The description of the design principle is altered to specify that it should only be considered in the case of a private ledger.

31. Define project goals

Blockchainpilots.nl and DApp.Design explicitly agreed with this design principle, while none disagreed [B.28; DD.30]. The only note is *"maybe in the exploration phase. It is optional there I think"* [B.28]. That is a valid point, as some go into the exploration phase to learn about the opportunities, without a clear goal. The design principle is therefore adapted to be possible in the exploration phase.

32. Scalability

Scalability is an issue for blockchain technology in the current development and experts confirm that determining what the desired scalability is, is important [B.29; DD.31]. A minor note is that *"it is something you should consider in your prototype, because the design determines if it is scalable"* [DD.31]. The technical design thus influences how scalable a project can be. Therefore, the design principle is altered to be common in the testing and implementation phase.

33. Transaction speed

Transaction speed is also a major issue due to the current development of blockchain. Experts think accounting for the maximum transaction speed is important, because there currently are limits [B.30; DD.32]. However, the experts also expect that this issue will be solved in the near future [DD.32; I.12]. The example of Kindpakket shows that the transaction speed is not a major problem in small scale projects, but will be *"when you apply Kindpakket in for example Amsterdam or five municipalities"* [F.24]. The design principle is therefore maintained as in the prior version.

34. Good UI/UX design

UI/UX design is found important by the experts: the user needs to be able to comfortably use the application and the application should look nice [I.5; B.31; DD.33; G.19; F.22]. There is some discussion about when the UI/UX should be professional. DApp.Design for example believes that *"you should do that from the prototype. You should show the functioning of the prototype as fast as possible. It does not have to look nice." … "I show the prototype first and we will make it nicely looking afterwards"* [DD.31]. On the other hand, Forus explained that *"with the Kindpakket, that we could show something, helped us very much in other phases and conversations. That you have a product to communicate with"* [F.22]. The choice for a good UI/UX design can thus cost time, but makes it easier to communicate. Choosing for a good UI/UX design is thus optional in the prototype phase and the design principle is therefore maintained as in the prior version.

35. Determine authorizations

Blockchainpilots.nl explain their view on this design principle clearly: *"It depends how you do the conceptualization phase, if you want to determine that early on or not. I manage a pilot now where you want to know very precise if it is possible to share certain income information in a very large network, without enabling every organization to see all information. The UWV[12] for example cannot see all information, it is simply not legally allowed. Certain things yes, but other things not. It makes sharing everything in a ledger very complex. It also depends on the process. That is of course fundamental to have clear when going towards a working product"* [B.32]. Groningen confirms that they have the authorizations determined [G.20] and DApp.Design believes that it should not be determined before the implementation phase [DD.34]. The example of Blockchainpilots.nl shows that in some cases it can be wise to determine the authorizations beforehand. This design principle is therefore kept possible for the conceptualization and testing phases, and common for the implementation and expansion phases.

7.3. Construction final version of design principles

The interviews with experts also revealed new design principles. These are discussed per principle in the parts below. Appendix I contains a list with all statements from the interviews that were coded in ATLAS.ti and used for this paragraph.

Assess applicability of blockchain

Blockchain can be beneficial for many processes, but it does not always improve the process. It needs to be assessed if blockchain is applicable for the process [DD.20; F3]. Forus states that *"You should definitely determine somewhere if blockchain is applicable to the process. Even if it is just a pilot, sometimes we are talking about hundreds of thousands of euros." … "Blockchain can definitely be revolutionary for a process, but not per definition"* [F.3]. The applicability of blockchain should be determined in an early phase in order to prevent costs. White, Killmeyer & Chew (2017) list four criteria (shared data, multiple parties, low trust and auditability), but the authors do not offer solid argumentation or testing of the criteria. Therefore we concluded in paragraph 3.3.3 that no appropriate applicability framework exists yet. Project teams therefore

[12] Dutch Employee Insurance Agency.

need to carefully examine and argue whether or not the implementation of smart contracts are expected to deliver sufficient benefits compared to the costs. This design principle is marked common for the exploration and conceptualization phases, possible for the testing phase and uncommon for the implementation and expansion phases.

Define contract types

Pels Rijcken noted that it should be defined what kind of contract types the code of the application has: *"You should also define the smart contract itself. Then you know which legislation is applicable. What kind of legal product is this? Does it push a process? Does it grant a subsidy?"* [PR.5]. That is important, because smart contracts often have a legal meaning and thus legislation applies. The Dutch Smart Contract Werkgroep (2017, p.23-37) discovered seven smart contract forms that can be compared with traditional contracts: execution of a contract, suspensive condition or dissolving condition, unilateral private law legal act, decision under public law, means of evidence, automatic execution of a (legal) process and taxation. Each of those contract forms has different legal responsibilities and thus tasks that are expected to be executed by the project team that deploys the contract on the blockchain. At the same time, a smart contract is just computer code that is executed by the blockchain (Luu et al., 2016). This means that a smart contract is not always a contract in a legal sense. Concluding, various smart contract types with legal meaning and responsibilities exist. The project team needs to know which contract types they deploy to know their responsibilities. This principle is marked uncommon for the exploration phase, possible for the conceptualization and testing phases, and common for the implementation and expansion phases.

Define participants

Pels Rijcken also advised to define the participants: *"I would also look very strongly into who are going to be the participants in the blockchains. Who will participate and who will host the nodes? You have to check that early. Elsewise you cannot check who has which legal obligations. I would do that together with the process selection. You got to have room there to look to the parties. Which parties exchange which information?"* [PR.4]. Surprisingly, no other interviewees mentioned this point before. As we discussed in paragraph 3.1.1, the use of a public blockchain enables each node to verify transactions and receive an encrypted copy of the database, while the private blockchain limits the number of nodes (Tapscott & Tapscott, 2016, p.67). In the private blockchain, one organization grants permission to several other organizations to act as node. The low number of nodes increases the possibility of the database to be tampered (Zheng et al., 2017, p.6), which makes it crucial to carefully choose participants that are fully trusted by the project team. Using "*private blockchains requires a permission management component to authorize the participants within the network*" (Xu et al., 2016, p.4). Public blockchains do not have this implication and thus the principle is only applicable when using private blockchains. This principle is marked uncommon for the exploration phase, possible for the conceptualization and testing phases, and common for the implementation and expansion phases.

Translate code to language

Pels Rijcken also noted that *"the public sector and the Dutch Supreme Court have the opinion you should be able to translate code into language and that is something different. That is really difficult. We are working together with multiple parties to figure that out. The judge demands you, based on the PAS-ruling, to translate code into language that is understandable for a citizen, so he can check if each step is done correctly. That is a very important technical requirement." … "When you automate decision making, you have to make your decision available."* [PR.10]. In the case of a decision under public law about a citizen, the government is obliged to be able to explain their decision [PR.8], and thus the code needs to be translated in natural language in those cases. Smart contracts could be manually translated, but the use of many contracts would mean much processing time. A possible solution is a Ricardian Contract, where the parties sign a digitally drafted paper in which the computer code is automatically translated to human readable language (Grigg, 2004). However, Al-Khalil et al. (2017) note that Ricardian Contracts also have limitations and suggest the use of the Web Ontology

Language (OWL). Another possible solution is the AgrelloLanguage (Norta et al., 2017). These solutions are currently being developed and are not yet well-researched.[13] We challenge project teams to test solutions that translate code into human understandable language. This principle is marked uncommon for the exploration and conceptualization phases. Because this principle is only applicable in certain cases it is marked possible for the testing, implementation and expansion phases.

PEST categorization

The interviewees from the case studies did not criticize the choice for the categories political, economic, social and technological. Pels Rijcken however noted: *"you do not have a place for legal. I do not find research legal implications political. Political is more about political support. The first and third design principle would also be a part of that"* [PR.6]. Those points are indeed different from political and specific for the legal field. The category legal is therefore added and design principle 1 (research legal implications) and 3 (define clear policies and legislation) are moved to that category. Blockchainpilots.nl noted that the design principle *privacy*: *"can go under legal implications. This is just one of the most important legal questions"* [B.25]. Privacy is indeed an important legal question and is therefore moved to the legal category. A final remark about the categorization is Forus that noted that *define project goals* is something more general and not really technological [F.21]. This principle is therefore moved to the social category.

Active statements

Some interviewees noticed that design principles that do not describe an activity, such as for example *profitability* or *scalability*, were too vague. Often, we had to explain first what was exactly meant with these principles. Each design principle is therefore made into an active statement in order to improve clarity. The following adaptions in the name of design principles are made:

- Profitability → Determine profitability;
- Multidisciplinary team → Compose multidisciplinary team;
- Security → Account for security;
- Open source coding → Code in open source;
- Risk assessment → Assess risks;
- Privacy → Account for privacy;
- Scalability → Design for scalability;
- Transaction speed → Determine desired transaction speed;
- Good UI/UX design → Design good UI/UX.

The adaptions that were discussed in this chapter led to the final version of the design principles, which can be found in table 14. The adaptions in comparison with the second version are indicated with a bold font.

[13] Suggested further reading on translating smart contracts to human understandable language: Grigg (2004). *The Ricardian* Contract; Al-Khalil et al. (2017). *Trust in Smart Contracts is a Process, As Well*; Norta et al., (2017). *Self-Aware Agent-Supported Contract Management on Blockchains for Legal Accountability.*

Table 14 – Final version of design principles.

Cat.	Name	Statement	Rationale	Implication	Source(s)
Pol.	1. Define a vision	Define a vision for blockchain based government	There has to be a shared vision for what blockchain can bring stakeholders	Stakeholders share the same vision for what blockchain will do	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Schiedam interview, 2017)
Economic	2. Invest in blockchain knowledge	Invest in blockchain knowledge	The field is new and much specific knowledge is necessary	Specific knowledge increases	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	3. Allocate budget	Allocate budget for research and development	Research and development are costly and need to be financially stimulated	Research and development increases	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	4. **Determine** profitability	Determine economic and social profitability	Successful projects are profitable in terms of educational, economic or social effects	Prevention of waste of resources	(Arnhem interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
Social	5. Find experts	Find relevant experts from different fields	The field is new and much specific knowledge is necessary from different domains	Experts have more specific knowledge and experience	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Drechtsteden interview, 2018)
	6. Cooperate with other organizations	Cooperate with other public and private organizations and universities	There are many parties who can share knowledge and cooperate	Knowledge and best practices are shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	7. Involve stakeholders	Involve the right stakeholders at the right moment	Stakeholders can have different requirements and goals, **but need to be involved at the right time to prevent slowing down the process**	Requirements are discussed and broadly accepted	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	8. Share results	Share the results of each project	Parties can learn from each other	Project results share knowledge amongst each other	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017)
	9. **Compose** multidisciplinary team	Compose a multidisciplinary team	**Blockchain demands a team with different backgrounds, which can scale up during time**	The project has experts on different fields to address different issues	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Schiedam interview, 2017)
	10. Communicate significance	Communicate significance of smart contract projects to others	Due to the new character of the field, others need to be convinced of the significance	Broad audience is aware of the possibilities of smart contracts	(Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Drechtsteden interview, 2018)
	11. Examine impact on jobs	Examine the impact on current jobs and tasks	Blockchain can cause certain jobs and tasks to be superfluous, **but it depends on the process**	Employees can be better prepared for a change of their job or task	(Arnhem interview, 2017); (Utrecht interview, 2017)
	12. Involve supervisor	Involve supervisor in the process	Supervisors can decide on resources that are available for the project	More support from the supervisor and more resources	(Arnhem interview, 2017); (Schiedam interview, 2017)

	13. Examine shifting role of the government	Examine the possible change of government roles	Implementation of smart contract can drastically change the role of the government, which needs to be examined beforehand	A better understanding of how smart contracts can change the role and tasks of governmental institutions	(Arnhem interview, 2017); (Drechtsteden interview, 2018)
	14. Define responsibilities	Define responsibilities in the new process	**As blockchain develops, the responsibilities for certain tasks can change as well**	Clarity about responsibilities	(Schiedam interview, 2017)
	15. Define project goals	Define project goals	Projects are hard to evaluate when project goals are not defined beforehand	Clear preset goals	(Schiedam interview, 2017); (Drechtsteden interview, 2018)
Technological	16. **Account for** security	Prioritize security and execute penetration testing	Blockchain and smart contracts demand strict security attention	Security becomes a priority and the system becomes safer	(Sharma et al., 2017); (Ølnes & Jansen, 2017); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	17. **Code open source**	Code in open source	Shared code spreads knowledge**, but can limit security in the short term. Strive for full open source coding in the long term**	Knowledge is efficiently shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	18. **Select process and scope of the project**	Select the process **and scope of the project**	It is necessary to select the correct process **and to clearly communicate how far the scope reaches**	The focus of implementation is clear	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	19. Map the process	Map the current process	Implementation builds on the prior process	It is clear how the current process works	(Blockchainpilots.nl, 2016); (Eshuis et al., 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	20. **Build a prototype**	**Build a working and testable prototype**	Testing is necessary before the old process can be completely replaced	Viability of implementation can be tested	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	21. Start small projects	Start development with small projects	There is a lack of experience and knowledge, so small projects are the safest option	Knowledge develops with low effort and low threats	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	22. **Assess risks**	Assess the risks per use case	New technology can bring new risks that need to be assessed	Clear view of risks per case	(Government Office for Science, 2016); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	23. Learn from prior development	Learn about prior projects and development, and build upon it	Prior projects show opportunities and threats, and prevents building from scratch	Proven technology can be learned from and used	(Ølnes & Jansen, 2017); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)

	24. Decide ledger type	Decide on the type of ledger	There are different ledger types with different opportunities and threats	Ledger type fits the case	(Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	25. Consider back-ups	Consider offline back-ups **when using a private ledger**	**Private ledgers need back-ups, but public ledgers do not**	Better protection against system failure	(Government Office for Science, 2016); (Utrecht interview, 2017); (Drechtsteden interview, 2018)
	26. **Design for** scalability	Make project scalable	Projects can be scaled up later if needed	Option to scale up easily	(Drechtsteden interview, 2018)
	27. **Determine desired** transaction speed	Define the desired minimum transaction speed	Many blockchain platforms have a low maximum transaction throughput	Understanding of the speed of the application	(Drechtsteden interview, 2018)
	28. **Design** good UI/UX	Design a good user interface and user experience	Blockchain technology is not visible for users, so UI/UX is important for their experience	Good user experience	(Drechtsteden interview, 2018)
	29. Determine authorizations	Determine data view and edit authorizations	Blockchain demands new definitions for who can view, edit and delete data	Clear authorization management	(Utrecht interview, 2017)
	30. Assess applicability of blockchain	**Assess if blockchain is applicable for the process**	**Blockchain can benefit many processes, but is not applicable to each process**	**Good assessment of the applicability of blockchain**	**(Forus interview, 2018); (DApp.Design interview, 2018)**
Legal	31. Research legal implications	Research legal implications and enforceability	There are possible legal issues	Possible legal issues are addressed in advance. Note that these should not limit the thinking process	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Utrecht interview, 2017); (Arnhem interview, 2017); (Drechtsteden interview, 2018)
	32. Define clear policies and legislation	Define clear policies and legislation about blockchain and smart contracts	The legislative framework was made when blockchain did not yet exist	The policies and legislation address opportunities and threats of blockchain	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Drechtsteden interview, 2018)
	33. Define contract types	**Define different contract types**	**Certain smart contracts have legal meaning that imply application of legislation**	**Clear overview of contract types and applicable laws**	**(Pels Rijcken interview, 2018)**
	34. Define participants	**Define participants when using private blockchains**	**Participants in private blockchains can have legal meaning and need to be trusted**	**Clear definition of participants and applicable legislation**	**(Pels Rijcken interview, 2018)**
	35. Translate code to language	**Translate application code to understandable language**	**Legislation demands certain decisions under public law to be translate to natural language**	**Text that explains how the application code comes to a decision**	**(Pels Rijcken interview, 2018)**
	36. **Account for** privacy	Prioritize privacy	Blockchain and smart contracts demand strict privacy attention	Possible privacy risks are known and addressed	(Sharma et al., 2017); (Government Office for Science, 2016) (Arnhem interview, 2017); (Drechtsteden interview, 2018)

7.4. Assessment first version of design framework

The first version of the design framework contained five design dilemmas, which we discussed in full in paragraph 5.5. The interviewees assessed the validity of and their experience with these dilemmas. We discuss the results of that assessment in this paragraph.

Design dilemma: allocate budget & profitability

Forus agrees with this dilemma and recognizes it from their own case: *"Of course. There is much investing in Zuidhorn I would say. It is a relatively large investment. And if you would only look what it would mean for the Kindpakket and what do we save with it, I think it is currently not balanced." … "But it does comply to the vision." … "You should account for a sort of business case. I think that misses in many municipalities. Where is my return on investment? It does not always have to be in euros." … "It goes to expansion. Kindpakket is not meant to work only in Zuidhorn. It will be implemented in other municipalities as well. We are talking about things like kickback, so Zuidhorn can retrieve a part of the investment back. Then Zuidhorn has done a relatively normal investment, while others still benefit"* [F.26]. The statement shows the dilemma: smart contract implementations demand investments that are not likely to be retrieved in the short term, but also other aspects such as social improvement need to be accounted for. The experts confirmed the dilemma as discussed with the case study interviewees and is therefore maintained.

Design dilemma: communicate significance & examine impact on jobs

The case of Zuidhorn showed that this dilemma can lead to positive effects: *"In our case it was pleasant she does not lose her job, but her function changes." … "On large scale we should accept that people will lose their job. I expect that we will have more free time." … "For the lady who keeps the coupons it was scary at first, she did everything manually. Now there is a CSV-parser that automatically scans the file. She has a program on her computer now, with which she is very happy. You take something from her, but also give something back. Because we involved everyone, there was less resistance."* [F.27]. Communicating clearly and involving the stakeholders early on in the process can reduce resistance. DApp.Design however warned for this dilemma: *"My experience is that people want to know: what is in it for me? If they sense that it will impact their job in the future, you have a problem. I did a project where people really needed to be educated about the added value of the project. I think that it is important to communicate" … "I would not start with that too early, you do not want to cause commotion."* [DD.13]. These examples show that the dilemma needs a careful approach as discussed in chapter 5.5 and is therefore maintained.

Design dilemma: security & open source coding

Chapter 5.5 discussed that open source coding leads to better security in the long term, but possibly decreases security in the short term. ICTU does not see this dilemma as present: *"I completely disagree. There is only one secure option and that is radically transparent and open source without compromises"* [I.11]. That may be true in the long term, but when dealing with personal data and wallets that contain money, solid security is essential. Forus recognizes that: *"We want complete open source, but Kindpakket is not open source because of security. We want to do that." … "It depends on scale. You need enough eyes to look at the code, before giving it to the community. And the community has to be strong enough to do that." … "It also involves users having a wallet with money on it and that needs a high level of security." … "We are working each day to make it open source. In the long term I believe that open source coding is safe." … "The private sector probably does not want that, because they want to sell a product. We are a market party, but not a commercial party"* [F.23]. Forus agrees with the viewpoint from ICTU in the long term, but also sees the short term threats as discussed earlier. Hissam et al. (2002, p.51) argue the same way as Forus about how the dilemma between security and open source coding develops through time: "*the openness of OSS*[14] *development can lead to better designs, better implementations, and eventually better software over time. However, until a steady state in any software release can be achieved, the influx of changes, rapid release of software (perhaps before its time), and introduction of new features and invariably flaws will continue to feed the vicious cyclic nature of attack and countermeasure*". The dilemma is controversial in literature, but there is a lack of quantitative data to strengthen arguments for either open or closed source software (Schryen & Kadura, 2009). Forus chose to start with closed source development and publish the code as open source in a later stadium. Not much is known about the application of open source in smart contract implementations, because there is a lack of empirical data. We challenge researchers to examine strategies to cope with this dilemma in chapter 8.

Design dilemma: privacy & decide ledger type

We discussed the dilemma between privacy and the various ledger types in paragraph 3.1.1 and paragraph 5.5. The private ledger currently offers better privacy in comparison to the public ledger, but solutions are being developed. Forus acknowledges this dilemma and even sees this as one of the reasons why they still use a private ledger: *"Yes, there certainly is. We see that also with Kindpakket. We want to use a public blockchain, but cannot do so due to privacy problems. That is why we are actively researching zero knowledge solutions, which enables privacy on the blockchain. That is something of which we hope it will change in time." … "I think it also depends on your long term vision"* [F.28]. The dilemma is caused by privacy issues in the current development of the public blockchain. The dilemma is expected to be solved in the future, but the expert interviews confirmed that it is currently still applicable and thus maintained for now.

Design dilemma: scalability & transaction speed

Another dilemma that we discussed in paragraphs 3.1.1 and 5.5 is scalability and transaction speed. The current state of development limits the scalability and thus the transaction speed: *"This is one of the problems. If I see the developments at the moment, this is one of the major problems in blockchain. They are developing this full speed. This will be solved, this year. But not now. You can do fifteen transactions per second, which is too slow. I have an example in which two or three transactions per day are necessary, it is not a problem for that process"* [DD.32]. It depends on how many transactions the system is required to have, because Zuidhorn at the moment does not have this problem yet: *"We have approximately 200 children in the system and until now there have been around 500 financial transactions in a few months' time." … "That is not a problem now, but you should account for it when you apply Kindpakket in for example Amsterdam or five municipalities." … "We are constantly looking at the boundaries of what is possible with the current technology."* [F.24]. Though ICTU has much faith in the development of blockchain [I.12], the dilemma is still present in the current development. The expert interviews confirmed the existence of this dilemma and is therefore maintained.

7.5. Construction final version of design framework

The interviewees also noted two new dilemmas, which we discuss in full in this paragraph.

Design dilemma: consider back-ups & decide ledger type

Multiple interviewees noted that back-ups are not necessary when choosing for a public ledger, while it remains necessary when choosing for a private ledger. Forus explains: *"The nice thing about a public chain is that it is a back-up." ... "We have that with Kindpakket at the moment. Because of the trade-offs*[15] *we are still on a private blockchain. It also depends on the ledger type. Storage can be done decentralized with IPFS. If you really do it decentralized with something like IPFS you are done, but it depends on your ledger type"* [F.25]. Using a private chain thus limits project teams to the necessity of back-ups. The need for a back-up is caused by

[14] Open Source Software.
[15] Forus refers to the design dilemmas.

the characteristics between private and public ledgers: public ledgers have many nodes with an encrypted copy of the data, while private ledger have a limited amount of nodes with such a copy (Zheng et al., 2017, p.6). The strength of a large number of nodes in a public blockchain is that many copies exist and thus a back-up can be considered as unnecessary (Matanović, 2017, p.4). The developers of DApp.Design confirm this viewpoint: *"Our design principle is no back-ups, because all nodes in the blockchain are each other's back-up"* [DD.29]. Concluding, choosing for a private chain restricts the project team to use back-ups, while choosing for a public chain means that a back-up is not necessary. This dilemma will not be solved as it is an inherent characteristic of a private chain. Therefore, this dilemma is added to the framework.

Design dilemma: define responsibilities & decide ledger type

Forus noticed another new dilemma: *"If you use a private ledger, the one who uses the private ledger carries responsibility for the technology and you can adapt things if you would like to. You can fork internally and no one would notice. With a public ledger, the miners carry responsibility and the consensus algorithm guarantees that responsibility"* [F.29]. This dilemma is also caused by the inherent characteristics of the public and private ledger, which is caused by the determination of who is allowed to verify data (Zheng et al., 2017, p.6). The responsibility for the verification of data thus lies at many nodes in a public blockchain and at some nodes in a private blockchain. Especially when multiple organizations are involved in the process "*it is necessary to clarify the responsibilities of each participating organization*" (Hou, 2017, p.4). Another responsibility that needs to be clarified is the responsibility for adding data to the database. For example, Honduras experimented with the registration of land on the blockchain by using the Factom solution. The Property Institute, responsible for land registration, acts as trusted third party that registers land in the blockchain and carries responsibility for the addition of data (Lemieux, 2016, p.128). If however two parties want to make a transaction and exchange land, it would be theoretically possible to do this without a trust third party. Just like with Bitcoin, the transaction would be verified by the network if the two parties sign the transaction with their public and private keys. In that case, the responsibility for the verification would be for the network. Such responsibilities can vary when applying different ledger types and are important to be defined. This dilemma shows another inherent characteristic of different types of ledgers, which will not be changed by development. Therefore, this dilemma is added to the framework.

The adaptions that were discussed in this chapter are applied to the first version of the framework. The final version of the framework is placed in figure 25.

Categories

P	Political
E	Economic
S	Social
T	Technological
L	Legal

Principles legend

[DD]	Design dilemma
X	Uncommon
●●●	Possible
√√√	Common

Phase		Exploration	Conceptualization	Testing	Implementation	Expansion
Result		• Process selection • Initial project team	• Process description • Pilot • Proof of concept	• Prototype	• Working product	• Intermunicipal product • Government as a Service
Design principles – P	1. Define a vision	●●●	●●●	●●●	√√√	√√√
E	2. Invest in blockchain knowledge	√√√	√√√	√√√	√√√	√√√
E	3. Allocate budget [DD1]	●●●	√√√	√√√	√√√	√√√
E	4. Determine profitability [DD1]	X	●●●	●●●	√√√	√√√
S	5. Find experts	√√√	√√√	√√√	√√√	√√√
S	6. Cooperate with other organizations	●●●	●●●	√√√	√√√	√√√
S	7. Involve stakeholders	●●●	●●●	●●●	√√√	√√√
S	8. Share results	X	√√√	√√√	√√√	√√√
S	9. Compose multidisciplinary team	●●●	√√√	√√√	√√√	√√√
S	10. Communicate significance [DD2]	X	●●●	√√√	√√√	√√√
S	11. Examine impact on jobs [DD2]	X	●●●	●●●	●●●	√√√
S	12. Involve supervisor	√√√	√√√	√√√	√√√	√√√
S	13. Examine shifting role of the government	X	●●●	●●●	●●●	√√√
S	14. Define responsibilities [DD7]	X	X	X	√√√	√√√
S	15. Define project goals	√√√	√√√	√√√	√√√	√√√
T	16. Account for security [DD3]	X	X	●●●	√√√	√√√
T	17. Code open source [DD3]	X	X	●●●	●●●	√√√
T	18. Select process and scope of the project	√√√	X	X	X	X
T	19. Map the process	X	√√√	√√√	√√√	√√√
T	20. Build a prototype	X	X	√√√	X	X
T	21. Start small projects	√√√	√√√	√√√	●●●	X
T	22. Assess risks	X	●●●	●●●	√√√	√√√
T	23. Learn from prior development	√√√	√√√	√√√	√√√	√√√
T	24. Decide ledger type [DD4] [DD6] [DD7]	X	X	√√√	√√√	√√√
T	25. Consider back-ups [DD6]	X	X	X	●●●	●●●
T	26. Design for scalability [DD5]	X	X	√√√	√√√	√√√
T	27. Determine desired transaction speed [DD5]	X	X	X	√√√	√√√
T	28. Design good UI/UX	X	X	●●●	√√√	√√√
T	29. Determine authorizations	X	●●●	●●●	√√√	√√√
T	30. Assess applicability of blockchain	√√√	√√√	●●●	X	X
L	31. Research legal implications	X	√√√	√√√	√√√	√√√
L	32. Define clear policies and legislation	X	X	●●●	√√√	√√√
L	33. Define contract types	X	●●●	●●●	√√√	√√√
L	34. Define participants of the network	X	●●●	●●●	√√√	√√√
L	35. Translate code to language	X	X	●●●	●●●	●●●
L	36. Account for privacy [DD4]	X	●●●	√√√	√√√	√√√

Figure 25 – Final version of the smart contract implementation framework for governmental services.

7.6. Observations

The following observations are made on the design framework and expert interviews:

- The design framework consists of 36 design principles. The majority of the design principles is in the categories technological (fifteen principles) and social (eleven principles), followed by legal (six principles) and economic (three principles). The category with the least principles is political, which consists of one design principle.
- There are seven design dilemmas between design principles. Five of these are in the categories technological and social. It confirms the complexity of the socio-technical system. The remaining dilemmas are in the economical category and between the technological and legal categories.
- Three of the seven design dilemmas are unique for blockchain technology when compared to other IT implementations: privacy & decide ledger type, define responsibilities & decide ledger type and consider back-ups & decide ledger type. Two of these dilemmas are expected to be solved when blockchain technology develops further: privacy & decide ledger type and scalability & transaction speed. Two other dilemmas are inherent characteristics of blockchain and will remain: define responsibilities & decide ledger type and consider back-ups & decide ledger type. Table 15 shows an overview of the characteristics per dilemma.

Table 15 - Characteristics of the design dilemmas.

Dilemma	Unique for blockchain	Solution expected
Allocate budget & profitability	No	No
Communicate significance & examine impact on jobs	No	No
Security & open source	No	No
Privacy & decide ledger type	Yes	Yes
Scalability & transaction speed	No	Yes
Consider back-ups & decide ledger type	Yes	No
Define responsibilities & decide ledger type	Yes	No

- Some design dilemmas possibly occur in early stages, such as conceptualization and testing (allocate budget & determine profitability, communicate significance & examine impact on jobs, and security & code open source). However, most design dilemmas are not common until later phases, such as implementation (allocate budget & determine profitability, scalability & transaction speed, and responsibilities & decide ledger type) and expansion (communicate significance & examine impact on jobs, security & code open source). This late occurrence of design dilemmas and the scarcity of cases which are in later design phases are possible explanations for the lack of knowledge on coping strategies.
- The framework was constructed from the viewpoint of the public sector. Experts were asked about the difference with the commercial sector and did not notice many differences [G.24]. A difference that was mentioned is the open source coding [F.23]. Commercial parties want to sell a product and for example in the case of municipalities, they want to sell it to each of the 380 municipalities in the Netherlands. By making their product open source, every party can freely use it without paying. That is desirable in the public sector, as that prevents the other 379 municipalities to pay the same development costs with public money [I.10]. Another difference of the framework is the profitability. DApp.Design noted that *"governments and municipalities are not about business cases, but about helping people"* [DD.35], while commercial parties aim to make profits. The third difference is about the properties of the government: *"So the constitutional properties are very crucial and that is what makes public services special. There is no freedom of legal position when it comes to you and the*

government. At the bank or car fabricant, you can change from provider if you do not like the services. That is different for the government. If you do not like the public service, you cannot change government" [I.8]. Governments do not experience competition in their services, while the private sector needs to maximize the quality of their services in order to increase their profit. A final difference is the legal requirement of public institutions: *"Is the framework different for the commercial sector: yes. The government also has to comply to the general properties of proper governance"* [PR.9]. This causes the design principles in the legal category to be of more importance for the public sector. An example is the requirement to translate code into human language, which does not apply to the private sector.

- Finding experts is important, because blockchain technology is complicated. The knowledge about blockchain is limited at the moment [DD.1] and experts are hard to find [DD.2; F.5].

7.7. Conclusion

The sub question of chapter 7 is: *"Which design principles and design framework can be derived from feedback from the environment?".* The second version of the design principles and the first version of the design framework have been assessed and refined by conducting six expert interviews. This led to the final versions of the design principles, design framework and design dilemmas. The majority of principles and dilemmas are in the categories technological and social, which confirms the complexity of the socio-technical system. Three design dilemmas are unique for blockchain technology and two dilemmas are expected to be solved due to the development of blockchain. Furthermore, most design dilemmas commonly occur in later stages, which explains the lack of knowledge on coping strategies. The results from this chapter are the main deliverables of this research, which are further discussed in chapter 8. It is now possible to use these deliverables to answer the main research question.

8. Conclusions and discussions

Chapter 7 produced the final versions of the design principles and the design framework, which were needed in order to answer the main research question. This chapter will draw conclusions in paragraph 8.1, offer recommendations for further research in paragraph 8.2, discuss the limitations of the research in paragraph 8.3 and reflect on the research in paragraph 8.4.

8.1. Conclusions

This research aims at answering the main research question: *"How can blockchain powered smart contracts be implemented in governmental services?"* by using the design science approach. The sub questions have been composed to follow the steps of this method. This paragraph offers the conclusions per sub question, which are needed to answer the main research question.

Sub question 1. How can the concept "blockchain powered smart contracts" be described?

For the first sub question a literature review and desk research are used as part of the design science approach step *Apply Knowledge*. Smart contracts are scripts that are automatically executed by the blockchain ledger, where blockchain technology enables transparent and immutable transactions that are broadcasted peer-to-peer as a distributed database. Issues that arise around smart contracts are lack of scalability, volatility of costs, decentralized decision making, lack of security, lack of privacy, unclear regulation and government intervention, lack of industry standards, legal issues, technical issues and lack of best practices.

Sub question 2. Which governmental services are potentially suitable for smart contract implementations?

In order to answer the second sub question, a literature review and desk research are used again as part of the design science approach step *Apply Knowledge*. There is a lack of research that shows potentially suitable governmental services for smart contract implementations. An overview of current implementation shows that there are currently roughly six categories where pilots or implementation are developing: financial, ownership of property, supply chain traceability, identification, voting and permit application. We found only one assessment framework that indicates the usefulness of blockchain, which uses the following four characteristics: shared data, multiple parties, low trust and auditability (White, Killmeyer & Chew, 2017). The four characteristics do not limit to certain sectors, governmental levels or interaction types. An important note with these characteristics is that they are only mentioned in one report and there are no assessment reports available that confirm the usefulness of these criteria. Therefore we recommend to better research applicability assessment frameworks in chapter 8.2.

Sub question 3. Which design principles for smart contract implementation can be derived from literature?

In order to use the design science approach step *Apply Knowledge* to search for design principles in prior research, a literature review has been conducted in Scopus. Combining the keywords *blockchain*, *design*, *principles*, and *government* led to finding 26 documents. Three additional documents from grey literature were added, because they specifically mentioned design principles for smart contracts. From these documents, seven publications were selected after applying the following criteria: the publication is about blockchain powered smart contracts, the publication is about implementation in governmental services, the publication offers design principles and is freely accessible in English. In the software program ATLAS.ti 73 quotations from the literature review were coded. The design science approach step *Build* led to the first version of 29 design principles of which the names are listed in table 16. The letter indicates the category to which the principle belongs: political [P], economic [E], social [S] and technological [T]. This categorization is used, because there is not yet a categorization for such design principles and PEST categories are broadly applicable. We used them as sensitizing concept, which means that they offer a starting point and are assessed and adapted later.

Table 16 - Overview of the first version of design principles.

1. Research legal implications [P]	**11. Multidisciplinary team [S]**	**21. Start small projects [T]**
2. Define a vision [P]	12. Communicate significance [S]	22. Open source coding [T]
3. Define clear policies and legislation [P]	13. Understand implications [S]	23. Establish standards [T]
4. Invest in blockchain knowledge [E]	14. Security [T]	24. Learn about prior development [T]
5. Allocate budget [E]	15. Privacy [T]	25. Build on prior development [T]
6. Fund penetration testing [E]	16. Fault tolerance [T]	26. Risk assessment [T]
7. Find technical experts [S]	17. Process selection [T]	27. Usability assessment [T]
8. Cooperate with other organizations [S]	18. Map the process [T]	28. Decide ledger type [T]
9. Involve stakeholders [S]	19. Prototype development [T]	29. Enable back-ups [T]
10. Share results [S]	20. Determine viability [T]	

Sub question 4. Which design principles can be derived from empirical implementation processes?

The design science approach step *Observe Data* was conducted by performing case studies to the following four smart contract implementation projects: the Gelrepas in Arnhem, waste processing in Utrecht, budget assistance in Schiedam and the disabled parking permit in Drechtsteden. Stakeholders of these cases have been interviewed and the interview reports were coded in ATLAS.ti, leading to coding 133 quotations. These quotations were used to conduct the design science approach steps *Assess* and *Refine*. Four design principles were deleted: fund penetration testing, fault tolerance, determine viability and usability assessment. We added eleven new design principles and changed the name of two principles. This led to the second version of 35 design principles in table 17. The changes in comparison with the first version are indicated with bold text.

Table 17 - Overview of the second version of design principles.

1. Research legal implications [P]	**13. Understand implications [S]**	**25. Open source coding [T]**
2. Define a vision [P]	**14. Involve supervisor [S]**	26. Establish standards [T]
3. Define clear policies and legislation [P]	**15. Cooperate internally [S]**	27. Learn **from** prior development [T]
4. Invest in blockchain knowledge [E]	**16. Examine shifting role of the government**	28. Risk assessment [T]
5. Allocate budget [E]	**17. Examine impact on jobs [S]**	29. Decide ledger type [T]
6. Profitability [E]	**18. Define responsibilities [S]**	30. **Consider** back-ups [T]
7. Find experts [S]	19. Security [T]	**31. Define project goals [T]**
8. Cooperate with other organizations [S]	20. Privacy [T]	**32. Scalability [T]**
9. Involve stakeholders [S]	21. Process selection [T]	**33. Transaction speed [T]**
10. Share results [S]	22. Map the process [T]	**34. Good UI/UX design [T]**
11. Multidisciplinary team [S]	23. Prototype development [T]	**35. Determine authorizations [T]**
12. Communicate significance [S]	24. Start small projects [T]	

Sub question 5. How can design principles be translated into a design framework?

The design science approach step *Build* is used again to construct a first version of the design framework with as input the first version of design principles and the interviews with the stakeholders from the case studies. It was noticed from the case studies that implementation of smart contracts in governmental services follows five phases: exploration, conceptualization, testing, implementation and expansion. Each phase has its own results, which is shown in table 18. In each of the phases the project team goes through one or more PDCA-cycles (plan-do-check-act). The second version of the design principles are combined with table 18 by indicating in which phase each design principle is commonly used, possible or uncommon.

Table 18 - Design phases, process and results.

Phase	Exploration	Conceptualization	Testing	Implementation	Expansion
Process					
Result	• Process selection • Initial project team	• Process description • Pilot • Proof of concept	• Prototype	• Working product	• Intermunicipal product • Government as a Service

Sub question 6: Which design principles and design framework can be derived from feedback from the environment?

This sub question starts with the design science approach step *Evaluate*, which is enabled by conducting expert interviews. The experts were defined as "*people who possess special knowledge of implementing smart contracts in governmental services*", which led to interviews with Blockchainpilots.nl, DApp.Design, ICTU, Pels Rijcken, the municipality of Groningen and Forus. The interview reports were coded in ATLAS.ti, leading to coding 148 quotations. These quotations are used to enable the design science approach steps *Assess* and *Refine* on the design principles and the design framework. Three design principle were deleted: understand implications, cooperate internally and establish standards. We added five new design principles, changed the name of eleven principles, added the category legal [L] and changed the category of four principles. This led to the final version of 36 design principles of which the names are listed in table 19. The additions and changes in comparison with the first version are indicated with bold text. Most design principles are in the categories technological (fifteen principles) and social (eleven principles), followed by legal (six principles) and economic (three principles). The category with the least principles is political, which consists of one design principle. Figure 26 shows the final version of the design framework.

Table 19 - Overview of the final version of design principles.

1. Define a vision [P]	**13. Examine shifting role of the government**	**25. Consider back-ups [T]**
2. Invest in blockchain knowledge [E]	14. Define responsibilities [S]	26. **Design for** scalability [T]
3. Allocate budget [E]	15. Define project goals **[S]**	27. **Determine desired** transaction speed
4. **Determine** profitability [E]	16. **Account for** security [T]	28. **Design** good UI/UX [T]
5. Find experts [S]	17. **Code** open source [T]	29. Determine authorizations [T]
6. Cooperate with other organizations [S]	18. Select process **and scope of the project** [T]	**30. Assess applicability of blockchain [T]**
7. Involve stakeholders [S]	19. Map the process [T]	31. Research legal implications **[L]**
8. Share results [S]	20. **Build a** prototype [T]	32. Define clear policies and legislation **[L]**
9. **Compose** multidisciplinary team [S]	21. Start small projects [T]	**33. Define contract types [L]**
10. Communicate significance [S]	22. **Assess** risks [T]	**34. Define participants [L]**
11. Examine impact on jobs [S]	23. Learn from prior development [T]	**35. Translate code to language [L]**
12. Involve supervisor [S]	24. Decide ledger type [T]	36. **Account for** privacy **[L]**

Categories

P	Political
E	Economic
S	Social
T	Technological
L	Legal

Principles legend

[DD]	Design dilemma
X	Uncommon
•••	Possible
√ √ √	Common

Phase		Exploration	Conceptualization	Testing	Implementation	Expansion
Process						
Result		• Process selection • Initial project team	• Process description • Pilot • Proof of concept	• Prototype	• Working product	• Intermunicipal product • Government as a Service
Design principles						
P	1. Define a vision	•••	•••	•••	√ √ √	√ √ √
E	2. Invest in blockchain knowledge	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √
E	3. Allocate budget [DD1]	•••	√ √ √	√ √ √	√ √ √	√ √ √
E	4. Determine profitability [DD1]	X	•••	•••	√ √ √	√ √ √
S	5. Find experts	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √
S	6. Cooperate with other organizations	•••	•••	√ √ √	√ √ √	√ √ √
S	7. Involve stakeholders	•••	•••	•••	√ √ √	√ √ √
S	8. Share results	X	√ √ √	√ √ √	√ √ √	√ √ √
S	9. Compose multidisciplinary team	•••	√ √ √	√ √ √	√ √ √	√ √ √
S	10. Communicate significance [DD2]	X	•••	√ √ √	√ √ √	√ √ √
S	11. Examine impact on jobs [DD2]	X	•••	•••	•••	√ √ √
S	12. Involve supervisor	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √
S	13. Examine shifting role of the government	X	•••	•••	•••	√ √ √
S	14. Define responsibilities [DD7]	X	X	X	√ √ √	√ √ √
S	15. Define project goals	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √
T	16. Account for security [DD3]	X	X	•••	√ √ √	√ √ √
T	17. Code open source [DD3]	X	X	•••	•••	√ √ √
T	18. Select process and scope of the project	√ √ √	X	X	X	X
T	19. Map the process	X	√ √ √	√ √ √	√ √ √	√ √ √
T	20. Build a prototype	X	X	√ √ √	X	X
T	21. Start small projects	√ √ √	√ √ √	√ √ √	•••	X
T	22. Assess risks	X	•••	•••	√ √ √	√ √ √
T	23. Learn from prior development	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √
T	24. Decide ledger type [DD4] [DD6] [DD7]	X	X	√ √ √	√ √ √	√ √ √
T	25. Consider back-ups [DD6]	X	X	X	•••	•••
T	26. Design for scalability [DD5]	X	X	√ √ √	√ √ √	√ √ √
T	27. Determine desired transaction speed [DD5]	X	X	X	√ √ √	√ √ √
T	28. Design good UI/UX	X	X	•••	√ √ √	√ √ √
T	29. Determine authorizations	X	•••	•••	√ √ √	√ √ √
T	30. Assess applicability of blockchain	√ √ √	√ √ √	•••	X	X
L	31. Research legal implications	X	√ √ √	√ √ √	√ √ √	√ √ √
L	32. Define clear policies and legislation	X	X	•••	√ √ √	√ √ √
L	33. Define contract types	X	•••	•••	√ √ √	√ √ √
L	34. Define participants of the network	X	•••	•••	√ √ √	√ √ √
L	35. Translate code to language	X	X	•••	•••	•••
L	36. Account for privacy [DD4]	X	•••	√ √ √	√ √ √	√ √ √

Figure 26 – Final version of the smart contract implementation framework for governmental services.

Various pairs of principles affect each other, which forces project teams into making choices. We call those principles design dilemmas. We discovered the following seven dilemmas from literature and interviews:

1. *Allocate budget & profitability.* The project team needs budget, which increases in later design phases. Decision makers decide upon the allocation of budget, but they often demand a return on investment. Many smart contract projects are not directly profitable, which limits the allocation of budget;
2. *Communicate significance & examine impact on jobs*. Affected employees need to be convinced by the project team and decision makers about the merit of the new process, but this is hard when smart contracts change their function or even make them superfluous;
3. *Security & open source coding.* Open source coding enables both malicious and benevolent individuals to find vulnerabilities. Choosing for open code leads to improved code for developers, but possibly leads to lower security in the short term as well;
4. *Privacy & decide ledger type.* Project teams decide upon ledger types, which has an implication on the privacy of users. Public ledgers currently offer lower privacy than private ledgers;
5. *Scalability & transaction speed.* Project teams need to decide how many users are expected to use the system. However, the current maximum transaction speed of blockchain platforms limits this choice;
6. *Consider back-ups & decide ledger type.* Deciding upon ledger types also has an implication on the necessity of back-ups. When a public ledger is used, a back-up is not necessary, but it is wise to do so when a private ledger is used;
7. *Define responsibilities & decide ledger type.* The responsibilities of those who add, verify, view and edit data is different for public ledgers, private ledgers and central databases. Project teams that decide upon ledger types experience an impact on the definition of these responsibilities.

Some coping strategies on how to handle these design dilemmas were discovered in the interviews and literature, but there still is a lack of empirical knowledge on strategies. We discovered and briefly analyzed the following possible strategies: communicate added value, and cooperate with other parties (allocate budget & profitability), involving stakeholders early, and clear communication by decision makers (communicate significance & examine impact on jobs), starting closed source and gradually move towards open source, and start open source from the start (security & open source coding). Many dilemmas are not commonly present until the implementation and expansion phase (allocate budget & determine profitability, scalability & transaction speed, responsibilities & decide ledger type, communicate significance & examine impact on jobs, security & code open source). This late occurrence and a lack of projects in late design phases are possible explanations for the scarce knowledge on strategies. We offer suggestions to further research in paragraph 8.2.

Three of these dilemmas are unique for smart contract implementations: privacy & decide ledger type, consider back-ups & decide ledger type, and define responsibilities & decide ledger type. Two of these dilemmas are expected to be solved by future development of blockchain technology: privacy & decide ledger type and scalability & transaction speed, while the other design dilemmas will remain. Table 20 provides an overview of the characteristics per dilemma.

Table 20 - Characteristics of the design dilemmas.

Dilemma	Unique for blockchain	Solution expected
Allocate budget & profitability	No	No
Communicate significance & examine impact on jobs	No	No
Security & open source	No	No
Privacy & decide ledger type	Yes	Yes
Scalability & transaction speed	No	Yes
Consider back-ups & decide ledger type	Yes	No
Define responsibilities & decide ledger type	Yes	No

Main research question: How can blockchain powered smart contracts be implemented in governmental services?

The results of the six sub questions together answer the main research question. In order to verify that the main research question is indeed answered, the main research objective from paragraph 1.2 is examined: "*To derive a design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services"*. The design framework provides teams that develop blockchain powered smart contracts in governmental services an overview of 36 design principles that can be used when implementing such projects, it shows the design dilemmas that need to be considered and indicates which design principles are applicable in which of the five design phases. Such a comprehensive overview satisfies the main research goal and thus it can be concluded that the conclusions in this paragraph answer the main research question.

Scientific relevance

As has been concluded in chapter 2, the topic of blockchain powered smart contracts is not popular amongst academics as of yet. There is a major lack of empirical and scientific knowledge about the implementation process of smart contracts for governmental services. The literature review on design principles found 29 design principles, but these were scattered in seven different publications: Government Office for Science (eighteen principles mentioned) and Blockchainpilots.nl (seventeen principles mentioned), followed by NASCIO (eight principles), Ølnes & Jansen (three principles), Sharma et al. (three principles), Pilkington (two principles) and Eshuis et al. (one principle). The literature review confirmed the lack of an overview of design principles, which is essential to support implementation processes. This research delivered a comprehensive overview of 36 design principles, which is the result of iterating steps of the design science approach. By using this method, the results are strengthened by prior research, case studies of real implementations and interviews with experts. This research also delivered the first design framework for implementing smart contracts for governmental services, which describes which design phases such an implementation has and when each design principle is commonly applicable. Furthermore, there is a lack of research on what hampers implementation processes: "*However, given the promising benefits that blockchain technology holds, it is also important that researchers in the field of e-Government begin discussing important questions: Are governmental agencies ready to investigate the potential of blockchain technology, and what are the main barriers?"* Ølnes & Jansen (2017, p.225). Key insights from our design framework are the seven design dilemmas, which are barriers to implementation and thus contribute to that knowledge gap as well.

Social relevance

Blockchain technology and smart contracts can possibly disrupt and improve many facets of governments. NASCIO (2017, p.7) recommended governmental organizations to: *"consider developing a preliminary strategy on how you could adopt blockchain technology for future use"*, but project teams lack tools that support them in the implementation. This research delivered a design framework and design principles that are tailor made for smart contract implementation in governmental services and we expect that project teams can be greatly supported by these tools. By offering a comprehensive overview, it becomes clear which design principles are commonly applicable in which design phases and which design dilemmas the project team needs to make. Expert Pels Rijcken acknowledges this and calls the framework *"very nice and very recognizable. A good summary"* [PR.7]. The development experts from DApp.Design confirm the usefulness of the framework: *"I would like to use the model to show clients our approach: this is the process and this is the model how we do it. It is a comprehensive overview." … "You see that blockchain is a large field where much is yet to be build. I think that this, when talking about the organizing part, is a very good document to steer with"* [DD.36]. The deliverables could speed up the process of implementation and thus might lead to an acceleration of cases of governmental services that use smart contracts. Another key point is that the implementation of more projects will lead to more empirical evidence that is available for researchers, and more research can benefit the implementation of new projects.

8.2. Recommendations for further research

We offer the following seven recommendations for further research:

Validation of the design framework with more cases

The design framework was built from a literature review of seven publications, four case studies and six expert interviews. The case studies focused on Dutch municipalities and the experts work in Dutch organizations as well. The design framework needs more validation from other governmental organizations (regional, national and international) and other countries in order to be more generalizable for the entire public sector. This can be done by assessing the framework with various governmental organizations from different levels and countries, and with processes with different forms of smart contracts as mentioned in paragraph 3.2.2.

Adaption of the design framework for the private sector

The experts acknowledge that the design framework is applicable to the public sector and contains some characteristics that are different from the private sector. Further research could assess the design framework with private sector case studies and expert interviews in order to adapt the framework to make it applicable to the private sector.

Strategies to cope with the design dilemmas between design principles

We found seven dilemmas between design principles: allocate budget & profitability, communicate significance & examine impact on jobs, security & open source coding, privacy & decide ledger type, scalability & transaction speed and consider back-ups & decide ledger type. We discussed why these dilemmas exist, their uniqueness in comparison with other IT and possible solutions due to development of blockchain technology. We also discovered some coping strategies for those dilemmas in the case studies and in the interviews with experts. However, we acknowledged that we solely discussed a handful of coping strategies and the discussion was not in-depth due to a lack of empirical knowledge. We recommend to perform further research on this topic in order to answer the following research question: "*How can project teams cope with design dilemmas that occur when implementing blockchain powered smart contracts in governmental services?*". We propose the following research steps, which can be used as sub methods of the design science approach in a similar method as in this research:

1. *Literature review and desk research.* The research should start with analyzing prior literature in order to find design dilemmas and coping strategies. We determined that no comprehensive overview of design dilemmas existed prior to our research and thus our research can be used as starting point. We referred to several authors that discussed parts of the dilemmas and encourage researchers to search for other publications. The result of this phase should be an updated and well-analyzed overview of which design dilemmas exist when implementing smart contracts in governmental services and possible coping strategies.
2. *Case studies*. As noted, there is a lack of empirical knowledge on coping strategies. In order to create new knowledge, it is recommended to perform case studies. Our design framework shows that most of the design dilemmas only occur in later design phases. Therefore, we recommend to perform case studies on implementation projects that are in a late phase of development. The result of this phase should be an in-depth description of dilemmas that were experienced by project teams that actually implemented smart contracts and a discussion on which coping strategies they used. That information can be used to assess and refine the dilemmas and strategies from the first phase.
3. *Expert interviews*. Finally, the third phase will have the researchers interview experts in the field of smart contract implementations and ask them to assess the dilemmas and strategies in order to refine them. Possible experts are people that have been involved in the implementation of smart contracts. It is important to interview various roles, as design dilemmas could be different for different stakeholders. The result of this phase is a final version of dilemmas and coping strategies.

Construction of an assessment framework for the applicability of blockchain

Design principle 31 advises project teams to assess if blockchain is applicable to the process they are examining, because not all processes are appropriate for implementation. Paragraph 3.3.3 concluded that one publication mentioned an assessment framework with four criteria to assess the applicability of blockchain: shared data, that needs to be auditable, which is shared between multiple parties, that have low trust amongst each other (White, Killmeyer & Chew, 2017). There is not a single publication that verified or discussed that assessment framework. Further research could assess the framework from White, Killmeyer & Chew or derive their own assessment framework.

Researching the legal implications of smart contracts

Six design principles are in the legal category: research legal implications, define clear policies and legislation, define contract types, define participants of the network, translate code to language and account for privacy. Paragraph 3.2.3 also determined that legal issues arise when implementing smart contracts and the legal status of smart contracts is unclear (He et al., 2016, p.23). Further research could dive deeper into which legal implications exist and how project teams can cope with these legal issues.

Researching the added value of smart contract implementations

Blockchain has been hailed as technology that can disrupt many public and private sectors, but the real added value is not researched much. The implementations that were mentioned in this thesis are mostly still in the conceptualization and testing phase, and mainly focus on learning how blockchain works. We described the potential benefits of the four examined cases, but these benefits need to be strengthened with more empirical evidence. It is important to see through the blockchain hype and research what the real added value of blockchain is in comparison to the current processes and other solutions. This would also better inform decision makers that often do not yet agree to allocate sufficient budget for actual implementation, due to uncertainty about the added value of blockchain.

Researching the decision making process

The case studies and interviewees revealed that decision makers of public organizations decide upon allocation of budget, allocation of staff and approval of starting a new design phase. Though we did not focus on the decision making process, decision makers often interact with the project team and decide upon important factors that limit or accelerate the implementation process. We recommend to analyze the decision making process in the implementation of smart contracts in governmental services and further research the considerations that decision makers make.

8.3. Limitations

We acknowledge the following four limitations of this research:

Limited availability of articles

In the literature review that was performed in chapter 4 in order to retrieve the first version of the design principles, 29 publications were selected with a specific combination of keywords. A selection of seven publications was filtered on basis of four criteria. One of these criteria was that the publication was freely accessible in English. Eight publications did not comply to this, as seven publications were not freely accessible and one publication was only available in Chinese and thus not readable. It is possible that these publications contain valuable information that was not included in the first version of the design principles, but it was not possible to use them. Appendix B describes in detail which keywords are used and how the publications are selected in order to ensure transparency about the selection.

Selection of case study interviewees

The four cases studies in chapter 5 were conducted in order to assess and refine the design principles into a second version. The selection of them depended on which persons were involved in smart contract implementation projects in Dutch municipalities and were willing to perform a face-to-face interview. These selection criteria resulted in the four cases. The interviewees had different roles in the organization (Advisor Process Management, Advisor Business Intelligence, Program Manager Social Infrastructure, Data Scientist and Business Consultant), but were all part of the main blockchain project team in their municipality. As team members of the main blockchain team it is possible to see these interviewees as *believers*: people that believe in blockchain and might miss a critical view. The second version of design principles therefore possible misses some points of critique. Six expert interviewees were conducted in order to assess the effects of this limitation.

Selection of case study municipalities

The four case studies were all four Dutch municipalities. The reason for this selection is twofold. First, Dutch municipalities are relatively far in the development of blockchain compared to other organizations. For example the municipalities of Zuidhorn and Groningen are the only two organizations in the Netherlands that have blockchain implemented and use it every day. Second, we wanted to perform interviews with stakeholders from the cases in a face-to-face setting. Because the research was conducted in the Netherlands, the willingness to perform an interview was logically high in the Netherlands. This selection could therefore impact the framework to be specific for Dutch municipalities, but we believe that the framework is generalizable for the entire public sector. This is due to the many steps of the design science approach, where for example the literature study and expert interviews built, assessed and refined the framework and principles to be applicable to the entire public sector.

Translation and interpretation of interviews

The four case study interviews and the six expert interviews were conducted in Dutch, because the interviewees have Dutch as native language. We transcribed the interviews word for word and had the interviewees correct the transcripts for any errors. The transcripts were coded in ATLAS.ti and translated from Dutch to English in order to be used for this research. It is possible that some meanings are lost or altered due to this translation. It is not expected that this can cause major errors, but the translation can slightly alter the tone of a quotation. To enable others to verify the correctness of the translations, the original transcripts are available in Dutch on request to the author.

8.4. Reflection on research

Finally, we reflect on how we prevented pitfalls that are common for the used methods, the influence of knowledge gaps in the literature on this research, the robustness of the results due to the rapid development of blockchain, the link between our study program and the research, and a personal reflection on the process.

Prevention of common pitfalls

The main research method, the design science approach, was shaped by using a literature review, a desk research, four case studies and expert interviews. For each of these methods, common pitfalls were described beforehand in order to account for them and prevent them where possible.

We determined three possible pitfalls to the literature review: a lack of completeness of publications (Hauge et al., 2010, p.1148), a low quality of sources (Hauge et al., 2010, p.1148-1149) and a limited use of keyword combinations (Yli-Huumo et al, 2016). The lack of completeness of publications was unavoidable and was determined early on by performing a literature overview. It showed that there was a lack of literature and contributed to the choice to use the design science approach, which is especially applicable when there is a lack of knowledge. The low quality of sources was not a problem. Though not many publications exist, those that were used were of sufficient quality. The limited use of keyword combinations could be a limiting factor to the literature review: we used a combination of the words *blockchain*, *design*, *principles* and *government*. This could have ruled out publications that for example used the combination *distributed ledger* instead of *blockchain*, and *guidelines* instead of *principles*.

The case studies had three possible pitfalls: writing solely descriptions (Rowley, 2002), shifting the research orientation (Yin, 1994, p.42) and lack of generalization (Gomm et al., 2000, p.72). The first pitfall implies that the cases are too descriptive, without deriving useful knowledge. This is avoided by making a clear research design (the case study protocol in appendix D) and by conducting face-to-face interviews where necessary information was retrieved. The shifting research orientation could happen when the researcher change the objective of their research during the case studies. This was not a problem, because the case studies only contributed to the design science approach and did not affect the main research question. The lack of generalization could arise when too few cases are used. We avoided this by using four cases in different categories of services. A side note is that the case studies all focus on Dutch municipalities, which is a limitation we acknowledge in paragraph 8.3. However, we believe that the results are still generalizable due to the various steps of the design science approach.

The interviews had three common pitfalls: lack of quality of the interviewees, not being able to find sufficient experts and the effect of the interviewing method. The lack of quality of the interviewees arises when the researcher chooses interviewees that are not appropriate or have a lack of knowledge. We prevented this by doing sufficient background research and asking other experts who they think we should interview. The second pitfall was possible due to the new field of development, but this was not a problem. Because the network of blockchain experts in the Netherlands is relatively small, it was possible to retrieve contact information from other interviewees. The final pitfall, the effect of the interviewing method, happens when the interview is conducted through telephone or conference call. One of the most effective interviewing methods is in a face-to-face setting in order to decrease the distraction of the interviewee and interpretation of non-verbal language (Bogner, Littig & Menz, 2009, p.10). All ten interviews have been conducted in face-to-face settings. Two interviewees requested to conduct the interview per telephone, but with this pitfall in mind we succeeded in changing their minds.

Knowledge gaps in the literature

Many knowledge gaps exist in the literature about blockchain and smart contracts that hampered this research. The literature review would be better with more publications, the case studies would be better if more cases would exist and the lack of an assessment framework to determine the applicability of blockchain could help to make a better categorization of potential governmental services. However, these knowledge gaps are expected in a developing field as blockchain. We believe this research truly contributed to the academic field, filling up a knowledge gap that eases future research.

Robustness of research due to new developments

Blockchain technology is rapidly developing, which could quickly make some parts of this research obsolete. The parts of the research that could be outdated are some of the issues in chapter 3 and some of the design dilemmas in chapter 7 (privacy & decide ledger type due to solutions as *zk-SNARK*, and scalability & transaction speed due to solutions as *sharding*). We discussed the current developments for those parts and predicted if it could change. When these dilemmas are not existent anymore, the design framework should be adapted, where those design dilemmas can be removed from the overview.

Link between the MSc. Program Complex System Engineering and Management and this research

This research was conducted as part of the Master Complex System Engineering and Management at the TU Delft, which focusses on large-scale problems in socio-technical systems. The field of blockchain powered smart contracts has a strong link with this degree: blockchain is a complex technology that is implemented worldwide with technical, social, legal, political and economic impact. The courses from this degree learned us to look at such a system not just from the view of a developer or from the view of the management, but to take into account various viewpoints. The result is the design framework, which contains design principles in the categories political, economic, social, technological and legal, while keeping in mind that not only project teams need to understand the framework, but also governmental employees, supervisors, decision makers and users. Our degree gave us the tools to produce a design framework that can truly aid project teams that implement smart contracts.

Personal reflection on the execution of the research

Finally, I offer a personal reflection on the execution of the research. The following points were the main obstacles I struggled with or would have done differently in hindsight:

- As early as four months before the start I knew I wanted to conduct my research on blockchain powered smart contracts. However, I did not want to delineate, because so many amazing potential applications exist and I wanted to describe them all. My supervisor pushed me to delineate, which led to researching governmental services. It would have been better to make this delineation earlier, because I lost quite some time struggling with what I exactly wanted to focus on.
- In the case studies, I researched four cases from projects that were not yet in the implementation phase. Later, I performed two interviews with stakeholders from cases that executed an actual implementation (the municipality of Zuidhorn and the municipality of Groningen). I was not aware of the exact status of each project and could have done more background research. Using these two additional cases in the case studies would have generated more empirical knowledge in an earlier stage of the research, because the other cases experienced less design phases.
- After processing the case studies I did not spend much time on the description of the cases. This made the descriptions dull and did not fulfill the goals of the case studies. After feedback of my supervisors I adapted the chapter and described in-depth how the cases are benefited by smart contracts, made comprehensive BPMN-models to explain the process and better described the implementation process and the involved stakeholders.
- In my case studies and expert interviews I did not interview decision makers. The reason for this is that those stakeholders were not available for such an interview. It was difficult to research those considerations without empirical knowledge. The addition of those interviews would offer a broader perspective on the results of my interview. As a result, one of my suggestions for further research is to research considerations of decision makers.

Furthermore, I want to reflect on the main points that I learned due to this research:

- To start off, I learned much about the field of blockchain and smart contracts. The moment I heard about blockchain I was enthusiastic, which greatly benefited me in the motivation for the research. In my free time I often read about new applications of blockchain, started some small investments in cryptocurrencies and won an international prize for the conceptual description of a blockchain design concept to fight counterfeit football tickets.[16]
- I first described the results of the case studies and the expert interviews, without critically assessing them with prior research. Instead, I just accepted the statements of the interviewees. After feedback of my supervisors, I reread the chapters and assessed them with literature. This helped me to strengthen the discussion on the results, especially on the various viewpoints on design dilemmas.
- Where reading literature has been a challenge for me in earlier years of my study program, I can now analyze publications and understand where it is about. The main reason for this is that I find the

[16] My design concept can be viewed on https://github.com/AventusSystems/aventus-dapp-proposals/issues/12.

subject so interesting that I am truly interested in various viewpoints of other researchers. Furthermore, it became easier to quickly scan an article and determine whether or not the publication has valuable information.

- One of the common pitfalls, as described in this chapter, is not performing interviews in a face-to-face setting, which taught me to have all interviews in such a setting rather than interviews through telephone. As a result, I quickly improved my interviewing techniques. In the first interview, I was slightly shy and struggled with extracting the information I needed from the interviewees. In the last interview I was more confident and truly could lead the interview. I noted that the interviewees in later interviews often enjoyed the discussion, which caused the interviews to be longer than planned.
- A major personal improvement is communication. Before, I often did not ask for clarification when there was something I did not understand. During the interviews and the feedback conversations with my supervisors I learned that it is better to acknowledge your doubt and receive clarification than having doubt afterwards.
- I also learned to critically assess statements from interviewees in the light of their role and corresponding motives. It is logical that a law expert pleads for more legal assessments and app developers plead for faster development rather than assessing legal issues. It was a challenge to see what is a fact and what is an opinion, but the most important thing was to critically think about it.

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Appendices

Appendix A. Scientific article

Blockchain Technology for Governmental Services:

Dilemmas in the Application of Design Principles

Paulus A. Corten

Abstract — Blockchain is rapidly developing and experiences increasing popularity. The technology is a peer-to-peer broadcasted transaction network with transparent and cryptographic secured information that enables smart contracts. These automatic executed contracts can significantly improve many services from both the public as the private sector by replacing the middleman in many processes. However, the rapid development of blockchain is hampered by a lack of knowledge, empirical research and skilled developers. Hardly any research has a focus on blockchain for governmental services. Neither are the dilemmas that need to be addressed during the design of smart contract implementations analyzed. This causes project teams to lack guidelines to support them in the implementation of smart contracts in governmental services. We used the design science approach to answer the research question: Which design dilemmas occur when applying design principles for smart contract implementation in governmental services? Based on a literature review, four case studies and six expert interviews we formulated 36 design principles for the implementation of smart contracts in governmental services. We discovered and analyzed seven dilemmas that can occur when applying these principles. The findings offer project teams that implement smart contracts valuable insights into which design actions are recommended and which dilemmas possibly occur. We recommend further research that strengthens the generalizability of these dilemmas. We also recommend further research into strategies to cope with the seven dilemmas we formulated.

Keywords — Governmental Services, Blockchain Technology, Design Science Approach, Design Principles, Design Dilemmas

I. Introduction

The interest in blockchain technology, the fundament of Bitcoin and other cryptocurrencies, has grown since the last months of 2017 (Gaggioli, 2018). The valuation of cryptocurrencies is over 385 billion dollars (Coinmarketcap.com, n.d.), main stream media are publishing articles about blockchain (Financial Times, 2018; CNN, 2018; BBC, 2018) and blockchain startups are raising billions of dollars with the blockchain equivalent of the initial public offering (IPO): the initial coin offering (ICO) (Zetsche et al., 2017, p.3). Some even call blockchain technology the biggest invention since the internet (Drescher, 2017).

Blockchain started in 2008 when the pseudonym Nakamoto published a paper describing the theory behind the digital currency Bitcoin (Nakamoto, 2008). Transactions between individuals are secured by cryptography, broadcasted peer-to-peer, verified by nodes in a network and the history of transactions are distributed to all nodes in the network (Tapscott & Tapscott, 2016). There is no longer a need for an intermediary that verifies the correctness of the transaction, such as a bank, because the blockchain is designed to automate this verification (Swan, 2015).

Blockchain also enables smart contracts. The smart contract was first described in 1994 by Nick Szabo as being a *"computerized transaction protocol that executes the terms of a contract"* (Szabo, 1994, p.1). Ethereum is the first platform that enables the use of blockchain powered smart contracts, enabling applications such as financial derivatives, hedging contracts, wills, employment contracts, identity systems, decentralized file storage, voting, peer-to-peer gambling, prediction markets and many more (Buterin, 2013). Many firms deal with contracts every day. Intermediaries such as lawyers, accountants and managers currently function as trusted third parties. Smart contracts can radically change their roles (Iansati & Lhakani, 2017, p.10), because smart contracts can be used to authorize, verify and approve transactions (Ølnes, Ubacht, & Janssen, 2017, p.363). Blockchain enables a decentralized peer-to-peer network that disables the need for a trusted intermediary (Bahga & Madisetti, 2016, p.534), such as the above mentioned.

Potential benefits and promises of blockchain are amongst others: transparency, avoiding fraud and manipulation, reducing corruption, increased trust, auditability, reduced costs, reducing human errors, access to information, privacy, reliability and security (Ølnes, Ubacht, & Janssen, 2017, p.359). Though many of these benefits lack empirical evidence (Ølnes, Ubacht, & Janssen, 2017, p.359), it shows the potential disruptive effects in the private sector (Drescher, 2017, p.24). Moreover, blockchain has the potential to disrupt and improve many facets of governments as well (Tapscott & Tapscott, 2016, p.140). Smart contracts can decrease costs, improve efficiency (Swan, 2015, p.27), and improve governmental services to be "more personal, immediate and efficient" (Government Office for Science, 2016, p.9).

However, blockchain is a nascent technology: Bitcoin was first described in 2008 and the first smart contract platform Ethereum was developed in 2013. Only a few developers and people with in-depth knowledge exist in the blockchain ecosystem (DApp.Design interview, 2018) and blockchain powered smart contracts lack academic research (Yli-Huumo et al., 2016). There is especially a lack of empirical knowledge on the implementation of smart contracts in governmental services. An overview of guidelines to assist project teams is non-existent (Corten, forthcoming), hampering the project development. Such guidelines, so called *design principles*, could greatly benefit project teams with the implementation process and would accelerate the creation of more use cases and empirical knowledge. In this article we are the first to address this knowledge gap by defining design principles for smart contract implementation in governmental services and analysing the dilemmas that occur when applying those principles. Our leading research question is: Which design dilemmas occur when applying design principles for smart contract implementation in governmental services?

This paper is structured as follows. In section II we present our research approach: the design science approach. Within this approach we used a literature review, four case studies and six expert interviews to explore and categorize design principles for smart contracts in the domain of governmental services. In section III we present a comprehensive overview of the 36 design principles we retrieved. Additionally, we discuss seven dilemmas that exist between those design principles and present the characteristics of those dilemmas. Finally, we offer conclusions and suggestions for further research in section IV.

II. Research approach

We used a design science approach as described by Hevner et al. (2004) in order to derive design principles. Considering that this approach is especially applicable in developing information systems such as blockchain, we deemed this research method as appropriate for our research. The design science approach enables the creation of new empirical knowledge and consists of multiple steps where information is observed, applied, assessed and refined by using several research methods. This research consists of six steps of the design science approach: applying knowledge with a literature review, building the first version of design principles, observing data with six case studies in Dutch municipalities, assessing and refining the design principles, evaluating with six expert interviews, and assessing and refining the design principles to form the final version. We discuss these steps in more detail in the paragraphs below.

A. A*pply knowledge: literature review*

In the first phase of our design science approach we conducted a literature review in order to apply knowledge by finding design principles in the literature. We consulted Scopus for the keywords '*blockchain*', '*principles*', '*design*' and '*government*', with the exact search term: ALL ("blockchain" AND "principles" AND "design" AND "government"). A selection of the result of 26 publications was made on basis of the following criteria: freely accessible in English, offers design principles, focusses on blockchain powered smart contracts and focusses on implementation in governmental services. This narrowed down the list to four publications (Ølnes & Jansen, 2017; Sharma, Moon & Park, 2017; Eshuis, Norta &

Roulaux, 2016; Pilkington, 2016). In grey literature we found three additional publications with design principles from a more practical point of view, which we added to the selection (Government Office for Science, 2016; NASCIO, 2017; Blockchainpilots.nl, 2016).

B. Build: first version of design principles

The total of seven publications were coded in the software program ATLAS.ti. We used the coded quotations to build the first version of design principles, which were initially divided into four categories: political, economic, social and technological. We used these categories, because there is not yet a categorization for such design principles. These categories were used as sensitizing concepts that provided us "*a general sense of reference and guidance in approaching empirical instances"* (Blumer, 1954, p.7). The categorization was assessed and refined in later stages of the research.

C. Observe data: case studies

We conducted four case studies in order to observe data from the environment and assess the first version of the design principles. The cases concern four Dutch municipalities that can be considered as early adopters in the implementation of smart contracts and were conducted as national coordinated pilots, where the results are used to retrieve and share empirical knowledge, research the potential impact of specific use cases and start building blockchain applications (Blockchainpilots.nl, 2016). The cases were the Gelrepas (municipality of Arnhem), debt assistance (municipality of Schiedam), waste processing (municipality of Utrecht) and the disabled parking permit (municipalities of Schiedam and Drechtsteden). The information for the case studies was retrieved by means of secondary background information and primary information from face-to-face interviews with various roles in the project teams: advisor process management, advisor business intelligence, program manager, data scientist and business consultant. The following four sub paragraphs offer an introduction to the four smart contract implementation projects that were used for the case studies.

C.1 Case study 1: Gelrepas

The municipality of Arnhem offers a physical card, the Gelrepas, to citizens with a low income of several neighboring municipalities in order to receive discounts on several sportive and cultural activities (VNG/KING, 2017, p.8). Currently, a citizen has to apply through a physical form. An employee of the municipality checks if the applicant applies to the requirements, such as the maximum monthly income and the citizenship of participating municipalities. The employee sends the physical Gelrepas by mail to the applicant along with physical discount coupons. The citizen pays at the participating organizations by demonstrating his Gelrepas and giving the coupons. The organization needs to send the coupons to the municipality, which will transfer money to the organization as compensation (VNG/KING, 2017, p.10). The process can be eased by applying blockchain. The municipality holds a database with citizens that fulfill the requirements. Citizens do not have to apply through a physical form anymore, but can install an application with a QR-code. The participating organization scans the citizens' code, which automatically verifies in the blockchain whether or not the citizen has the right to claim the discount and registers the transaction. (VNG/KING, 2017, p.11). Expected benefits of the new process are: reduced costs, improved transparency and auditability, avoiding fraud and manipulation, and improved access to information (Corten, forthcoming).

C.2 Case study 2: budget assistance

The organization Stroomopwaarts in the municipality of Schiedam currently assists citizens with financial problems with the help of a budget manager that takes control of the citizens' financial administration. This could for example be that the budget manager pays the bills, taking over the financial control from the citizen. The budget assistance is currently not a municipal service, but the municipality pays for the costs. The expenses of the citizen can also be restricted with smart contracts, for example by programming how much money can be spent on rent, energy and free expenses. The budget manager is no longer necessary, as his actions are replaced by the smart contract's restrictions. By using the blockchain it is also possible to early detect citizens that are heading to financial problems and signal the municipality to intervene (Pomp & Hartog, 2017).

Expected benefits of the new process are: reduced costs, increased trust, transparency and increase of predictive capability (Corten, forthcoming).

C.3 Case study 3: waste processing

Waste of citizens in the municipality of Utrecht is collected and processed by multiple organizations. They need a permit from the ILT (Dutch Human Environment and Transport Inspectorate) to be allowed to collect waste. The municipality and his citizens currently cannot directly access the details and validity of the permits. Those permits can be deployed by the ILT as a smart contract on the blockchain, which contains the details and validity of each permit. The municipality can then automatically validate the permit of an organization each time a transaction is registered in the blockchain (Pomp & Hartog, 2017). Expected benefits of the new process are: improved access to information, increased trust, reduced costs, reduced process time, improved transparency, avoiding fraud and manipulation, and persistency and irreversibility of data (Corten, forthcoming).

C.4 Case study 4: disabled parking permit

The disabled parking permit is a physical card that allows citizens of European Union countries to park at disabled parking spots. Disabled citizens apply for the card through the municipality, which verifies at the GGD (Dutch Public Health Service), the RDW (Netherlands Vehicle Authority) and the European Union if the citizen is eligible to receive the card. Drechtsteden (a cooperation between the municipalities of Alblasserdam, Dordrecht, Hendrik-Ido-Ambacht, Papendrecht, Sliedrecht and Zwijndrecht) deploy the disabled parking permit on a blockchain by using smart contracts to prevent fraud and theft. The license plate of the vehicle of the disabled citizen is registered in a smart contract and the physical card is replaced by a mobile application. The citizen confirms that he parked through the application, that registers the action on the blockchain. Parking inspectors scan the license plate of the vehicle. The system automatically verifies the parking permit through the blockchain. The card is not physical anymore and thus cannot be stolen or misused (Pomp & Hartog, 2017). Expected benefits of the new process are: reduced costs, reduced process time, avoiding fraud and manipulation, and increased privacy (Corten, forthcoming).

D. Assess and refine: second version of design principles

The interviewees from the four case studies read and discussed the first version of principles. We refined the principles based on that information. In addition, we discussed possible design dilemmas with the interviewees. This led to an adapted overview of the design principles from literature, based on empirical experiences from the cases.

E. Evaluate: expert interviews

We interviewed six experts in the field of smart contract implementation from a diversity of backgrounds and roles in this domain in order to evaluate the second version of design principles. Experts can be defined as *"people who possess special knowledge of a social phenomenon which the interviewer is interested in"* (Gläser & Laudel, 2009, p.117). The experts were the project manager of Dutch blockchain pilots (Blockchainpilots.nl), blockchain developers from DApp.Design that cooperated with the municipality of Schiedam, a data scientist for the Dutch government (ICTU), a law firm with smart contract expertise (Pels Rijcken), the project leader of the Stadjerspas (municipality of Groningen) and blockchain developers from Forus that cooperated with the municipality of Zuidhorn. The experts validated the design principles and offered their opinions on possible dilemmas.

F. Assess and refine: final version of principles

We coded the transcripts from the expert interviews in ATLAS.ti. The second version of the design principles were assessed and refined using the coded quotations from the interviews. This led to the final version of design principles and dilemmas.

III. Results

A. Overview of design principles

The application of the six described steps from the design science approach resulted in the final version of design principles for the implementation of smart contracts in governmental services, that are listed in table 21. The 36 design principles are divided into five categories: political (one principle), economic (three principles), social (eleven principles), technological (fifteen principles) and legal (six principles). The initial categorization (see section II) was expanded with the category legal on the basis of the expert validation.

Based on the case study and the experts interviews we discovered seven design dilemmas between pairs of design principles:

1. Allocate budget & profitability;
2. Communicate significance & examine impact on jobs;
3. Security & open source coding;
4. Privacy & decide ledger type;
5. Scalability & transaction speed;
6. Consider back-ups & decide ledger type;
7. Define responsibilities & decide ledger type.

In the next paragraphs we elaborate on each of these dilemmas in full.

B. Allocate budget & profitability

Smart contract implementations demand the allocation of budget (Blockchainpilots.nl, 2016; Arnhem interview, 2017; Utrecht interview, 2017; Schiedam interview, 2017), while managers will also determine the profitability of each project, because governmental organizations are financially steered (Arnhem interview, 2017; Schiedam interview, 2017; Drechtsteden interview, 2018). This can be a dilemma, because smart contract implementations will not necessarily lead to costs savings. The disabled parking permit for example will not lead to cost savings, but can improve the life of disabled citizens, because they are protected from theft of the permit and can view free parking spaces in an application: *"The parking permit for disabled is not something that has a valid business case directly, but is the town council prepared to invest money to ease the life of a disabled citizen?"* (Drechtsteden interview, 2018). Another example is the implementation of smart contracts in Zuidhorn. This Dutch municipality has a system, the Kindpakket, that offers discounts to children in families with a low budget (Municipality of Zuidhorn, 2017). Experts recognize the dilemma: *"There is much investing in Zuidhorn I would say. It is a relatively large investment. And if you would only look what it would mean for the Kindpakket and what do we save with it, I think it is currently not balanced"* (Forus interview, 2018). The interviewees confirm that blockchain innovation demands budget, whereas the profitability cannot be retrieved in the short term.

This dilemma is not unique for blockchain technology, but characteristic for the public sector. The main difference with the private sector is that the private sector has profitability as main motivation for innovation, whereas the public sector aims at other goals, such as the quality of services or fighting poverty (Mulgan & Albury, 2003, p.6). Public sector organizations lack funds for innovation, while private sector organizations have venture capitalists (Borins, 2001, p.311).

Allocation of budget and profitability is a dilemma that is not unique for smart contract implementations, but it is characteristic for innovation in governmental services. It will therefore remain a dilemma in the future as well.

C. Communicate significance & examine impact on jobs

Implementing smart contracts can improve many processes, but has a potential impact on jobs and functions as well (Arnhem interview, 2017; Utrecht interview, 2017). From the interviews it became clear that it is important that the benefits of the implementation are communicated with stakeholders (Government Office for Science, 2016; Arnhem interview, 2017; Utrecht interview, 2017; Drechtsteden interview, 2018). However, explaining that the implementation is beneficial is hampered by the possibility of someone losing their job or changing their function: *"You have to cooperate, but you will lose your job. You cannot convince with that, but that is how it works"* (Arnhem interview, 2017). The blockchain developers from DApp.Design acknowledge this dilemma: *"My experience is that people want to know: What is in it for me? If they sense that it will impact their job in the future, you have a problem. I did a project where people really needed to be educated about the added value of the project. I think that is important to communicate." ... "I would not start with that too early, you do not want to cause commotion"* (DApp.Design interview, 2018). It is clear that the interviewees see the dilemma as a sensitive issue that needs to be handled with care.

Table 21 – Design principles for the implementation of smart contracts in governmental services [Corten, forthcoming].

Cat	Name	Statement	Rationale	Implication	Source(s)
Political	1. Define a vision	Define a vision for blockchain based government	There has to be a shared vision for what blockchain can bring stakeholders	Stakeholders share the same vision for what blockchain will do	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Schiedam interview, 2017)
Economic	2. Invest in blockchain knowledge	Invest in blockchain knowledge	The field is new and much specific knowledge is necessary	Specific knowledge increases	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	3. Allocate budget	Allocate budget for research and development	Research and development are costly and need to be financially stimulated	Research and development increases	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	4. Determine profitability	Determine economic and social profitability	Successful projects are profitable in terms of educational, economic or social effects	Prevention of waste of resources	(Arnhem interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
Social	5. Find experts	Find relevant experts from different fields	The field is new and much specific knowledge is necessary from different domains	Experts have more specific knowledge and experience	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Drechtsteden interview, 2018)
	6. Cooperate with other organizations	Cooperate with other public and private organizations and universities	There are many parties who can share knowledge and cooperate	Knowledge and best practices are shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	7. Involve stakeholders	Involve the right stakeholders at the right moment	Stakeholders can have different requirements and goals, but they need to be involved at the right time to prevent slowing down the process	Requirements are discussed and broadly accepted	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	8. Share results	Share the results of each project	Parties can learn from each other	Project results share knowledge amongst each other	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017)
	9. Compose multidisciplinary team	Compose a multidisciplinary team	Blockchain demands a team with different backgrounds, which can scale up during time	The project has experts on different fields to address different issues	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Schiedam interview, 2017)
	10. Communicate significance	Communicate significance of smart contract projects to others	Due to the new character of the field, others need to be convinced of the significance	Broad audience is aware of the possibilities of smart contracts	(Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Drechtsteden interview, 2018)
	11. Examine impact on jobs	Examine the impact on current jobs and tasks	Blockchain can cause certain jobs and tasks to be superfluous, but it depends on the process	Employees can be better prepared for a change of their job or task	(Arnhem interview, 2017); (Utrecht interview, 2017)

	12. Involve supervisor	Involve supervisor in the process	Supervisors can decide on resources that are available for the project	More support from the supervisor and more resources	(Arnhem interview, 2017); (Schiedam interview, 2017)
	13. Examine shifting role of the government	Examine the possible change of government roles	Smart contract projects can drastically change the role of the government, which needs to be examined prior to implementation	A better understanding of how smart contracts can change the role and tasks of governmental institutions	(Arnhem interview, 2017); (Drechtsteden interview, 2018)
	14. Define responsibilities	Define responsibilities in the new process	As blockchain develops, the responsibilities for certain tasks can change as well	Clarity about responsibilities	(Schiedam interview, 2017)
	15. Define project goals	Define project goals	Projects are hard to evaluate when project goals are not defined beforehand	Clear preset goals	(Schiedam interview, 2017); (Drechtsteden interview, 2018)
Technological	16. Account for security	Prioritize security and execute penetration testing	Blockchain and smart contracts demand strict security attention	Security becomes a priority and the system becomes safer	(Sharma et al., 2017); (Ølnes & Jansen, 2017); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	17. Code open source	Code in open source	Shared code spreads knowledge, but can limit security in the short term. Strive for full open source coding in the long term	Knowledge is efficiently shared	(Blockchainpilots.nl, 2016); (Pilkington, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	18. Select process and scope of the project	Select the process and scope of the project	It is necessary to select the correct process and to clearly communicate how far the scope reaches	The focus of implementation is clear	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	19. Map the process	Map the current process	Implementation builds on the prior process	It is clear how the current process works	(Blockchainpilots.nl, 2016); (Eshuis et al., 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	20. Build a prototype	Build a working and testable prototype	Testing is necessary before the old process can be completely replaced	Viability of implementation can be tested	(Blockchainpilots.nl, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	21. Start small projects	Start development with small projects	There is a lack of experience and knowledge, so small projects are the safest option	Knowledge develops with low effort and low threats	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)
	22. Assess risks	Assess the risks per use case	New technology can bring new risks that need to be assessed	Clear view of risks per case	(Government Office for Science, 2016); (Schiedam interview, 2017); (Drechtsteden interview, 2018)
	23. Learn from prior development	Learn about prior projects and development, and build upon it	Prior projects show opportunities and threats, and prevents building from scratch	Proven technology can be learned from and used	(Ølnes & Jansen, 2017); (NASCIO, 2016); (Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017)

	24. Decide ledger type	Decide on the type of ledger	There are different ledger types with different opportunities and threats	Ledger type fits the case	(Government Office for Science, 2016); (Arnhem interview, 2017); (Utrecht interview, 2017); (Schiedam interview, 2017);
	25. Consider back-ups	Consider offline back-ups when using a private ledger	Private ledgers need back-ups, but public ledgers do not	Better protection against system failure	(Government Office for Science, 2016); (Utrecht interview, 2017); (Drechtsteden interview, 2018)
	26. Design for scalability	Make project scalable	Projects can be scaled up later if needed	Option to scale up easily	(Drechtsteden interview, 2018)
	27. Determine desired transaction speed	Define the desired minimum transaction speed	Many blockchain platforms have a low maximum transaction throughput	Understanding of the speed of the application	(Drechtsteden interview, 2018)
	28. Design good UI/UX	Design a good user interface and user experience	Blockchain technology is not visible for users, so UI/UX is important for their experience	Good user experience	(Drechtsteden interview, 2018)
	29. Determine authorizations	Determine data view and edit authorizations	Blockchain demands new definitions for who can view, edit and delete data	Clear authorization management	(Utrecht interview, 2017)
	30. Assess applicability of	Assess if blockchain is applicable for the process	Blockchain can benefit many processes, but is not applicable to each process	Good assessment of the applicability of blockchain	(Forus interview, 2018); (DApp.Design interview, 2018)
	31. Research legal implications	Research legal implications and enforceability	There are possible legal issues	Possible legal issues are addressed in advance. Note that these should not limit the thinking process	(Blockchainpilots.nl, 2016); (Government Office for Science, 2016); (Utrecht interview, 2017); (Arnhem interview, 2017); (Drechtsteden interview, 2018)
Legal	32. Define clear policies and legislation	Define clear policies and legislation regarding blockchain and smart	The legislative framework was made when blockchain did not yet exist	The policies and legislation address opportunities and threats of blockchain	(Blockchainpilots.nl, 2016); (NASCIO, 2016); (Government Office for Science, 2016); (Drechtsteden interview, 2018)
	33. Define contract types	Define different contract types	Certain smart contracts have legal meaning that imply application of legislation	Clear overview of contract types and applicable laws	(Pels Rijcken interview, 2018)
	34. Define participants	Define participants when using private blockchains	Participants in private blockchains can have legal meaning and need to be trusted	Clear definition of participants and applicable legislation	(Pels Rijcken interview, 2018)
	35. Translate code to language	Translate application code to understandable language	Legislation demands certain decisions under public law to be translate to natural language	Text that explains how the application code comes to a decision	(Pels Rijcken interview, 2018)
	36. Account for privacy	Prioritize privacy	Blockchain and smart contracts demand strict privacy attention	Possible privacy risks are known and addressed	(Sharma et al., 2017); (Government Office for Science, 2016) (Arnhem interview, 2017); (Drechtsteden interview, 2018)

This dilemma was also noticed by the developers of the Kindpakket in Zuidhorn. Before smart contracts were implemented, the employee managed coupons by hand. Smart contracts automate the management of the coupons, but allow the position of the employee to change into someone who manages the program: *"In our case it was pleasant she does not lose her job, but her function changes." … "On a large scale we should accept that people will lose their job." … "For the lady who keeps the coupons it was scary at first, she did everything manually. Now there is a CSV-parser that automatically scans the file. She has a program on her computer now, with which she is very happy. You take something from her, but also give something back. Because we involved everyone, there was less resistance"* (Forus interview, 2018). This example shows that involving the employees can decrease resistance.

This dilemma is not new and certainly not unique for smart contract implementation. Throughout history there are many examples of technologies where some hailed the significance of implementation, while others feared the impact on jobs: the textile artisans and the automation of textile production in the 19th century (David, 2015, p.1), the automation of agriculture in the 20th century (David, 2015, p.5), the automation of the automobile belt (David, 2015, p.5) and the automation of many activities in the workplace (Chui, Manyika & Miremadi, 2015, p.3).

The communication of the significance and the impact on jobs is a dilemma that will be different for each process: some implementations will have a major impact on jobs and some will not. Involving the employees who will see their job affected can decrease resistance.

D. Security & open source coding

Academic researchers as well as practitioners agree that smart contract implementations should focus on a high level of security (Sharma et al., 2017; Ølnes & Jansen, 2017; Government Office for Science, 2016; Arnhem interview, 2017; Utrecht interview, 2017; Schiedam interview, 2017). On the other hand, sharing results and derived knowledge is also essential in order to learn from each other (Blockchainpilots.nl, 2016; NASCIO, 2016; Arnhem interview, 2017; Utrecht interview, 2017). By making the source code open for every party to see and use, knowledge is easily shared (Blockchainpilots.nl, 2016; Pilkington, 2016; Arnhem interview, 2017; Utrecht interview, 2017; Schiedam interview, 2017; Drechtsteden interview, 2018). Making the code open source has two potential effects on the security of the application. On the one hand, malicious individuals can find vulnerabilities in the code and misuse them. On the other hand, benevolent individuals can find vulnerabilities as well and report or improve them (Payne, 2002). Open source coding improves the security in the long term (Hoepman & Jacobs, 2007), but experts foresee threats in the short term: *"We want complete open source, but Kindpakket is not open source because of security." … "You need enough eyes to look at the code, before giving it to the community. And the community has to be strong enough to do that." … "It also involves users having a wallet with money on it and that needs a high level of security." … "We are working each day to make it open source. In the long term I believe that open source coding is safe"* (Forus interview, 2018). ICTU however disagrees with that point of view: *"I completely disagree. There is only one secure option and that is radically transparent and open source without compromises"* (ICTU interview, 2018). These two viewpoints show the controversy of the dilemma that can be found in the literature as well. However, arguments for either viewpoint are often not strengthened with quantative data (Schryen & Kadura, 2009).

This dilemma is not unique for smart contract implementations. Many computer programs that are closed source have an open source equivalent: Internet Explorer (closed) and Firefox (open), Adobe Photoshop (closed) and Gimp (open), and Microsoft Office (closed) and OpenOffice.org (open) (Pfaffman, 2007, p.42). Admittedly, the closed source examples are also closed source to protect their revenue model, but the open source programs embrace the possibility of everyone to find and improve bugs (Pfaffman, 2007, p.38).

Open source coding is thus not unique for smart contract implementations, but can hamper the security in the short term. Experts expect that the dilemma will be less important in the long term, when a strong community has been built. The open source coding will then be less of a threat to the security. However, the dilemma is still controversial in the literature and amongst practitioners.

E. Privacy & decide ledger type

Blockchain offers two main different ledger types. The public ledger is a transparent copy of all transactions and the balances of each address, which is distributed between many nodes (Swan, 2015, p.1). The private ledger runs between one or a few organizations, where the transactions are only transparent for a few selected nodes (Zheng et al., 2017). The transparency of the public ledger decreases the privacy of users (He et al., 2017, p.16), which can be undesirable when handling personal data. The private blockchain does not have these issues: only certain trusted parties are allowed to have a copy of the transaction history and thus increases the privacy (Janssen et al., 2017, p.1). However, the private blockchain has disadvantages over the public blockchain, such as the possibility of tampering and centralized consensus (Zheng et al., 2017, p.6). The choice for a ledger type strongly impacts the privacy. Experts acknowledge this design dilemma: "*We see that also with Kindpakket. We want to use a public blockchain, but cannot do so due to privacy problems. That is why we are actively researching zero knowledge solutions, which enables privacy on the blockchain"* (Forus interview, 2018).

Thus, the dilemma is important at the moment, but solutions are expected. The dilemma is unique for blockchain technology as it relies on specific characteristics of public and private blockchains. The potential solution that the experts mention is zero-knowledge proof of knowledge. The theory of zero-knowledge proofs is that one party possesses knowledge (the *prover*) and wants to prove that he possesses this knowledge to another party (the *verifier*). In order for this verification to be zero-knowledge proof, the verifier needs to verify that the prover possesses knowledge, without the verifier to see any of the information (Feige, 1988). This method does not reveal the information of the prover and increases his privacy (De Santis, Micali & Persiano, 1987, p.58). A specific application of this theory, called zk-SNARK, disables the transparency of transactions in the blockchain, which is already functioning in the blockchain application Zcash (Z.cash, n.d.). The most popular smart contract platform Ethereum is currently developing this application on their blockchain too (Sharma, 2017).

The importance of privacy limits the choice for a ledger type and is an unique dilemma that does not appear in other applications. However, the development of the zero-knowledge proof of knowledge is expected to address this dilemma.

F. Scalability & transaction speed

Each of the smart contract applications needs a certain transaction speed, but most blockchain based platforms are limited by their lack of scalability (Drechtsteden interview, 2018). Ethereum for example currently only allows approximately fifteen transactions per second worldwide (Etherscan.io, n.d.). This implies that if there is one single application that requires fifteen transactions per second, all other applications in the world could not use the Ethereum platform. The developers of Forus, that implemented the Kindpakket in Zuidhorn, explain that they currently have no problems with their transaction speed, but would see this dilemma as their application scales: *"We have approximately 200 children in the system and until now there have been around 500 financial transactions in a few months' time." … "That is not a problem now, but you should account for it when you apply Kindpakket in for example Amsterdam or five municipalities"* (Forus interview, 2018). The developers of DApp.Design acknowledge the problem as well, but are optimistic: "*If I see the developments at the moment, this is one of the major problems in blockchain. They are developing this full speed. This will be solved, this year. But not now. You can do fifteen transactions per second, which is too slow. I have an example in which two or three transactions per day are necessary, it is not a problem for that process"* (DApp.Design interview, 2018).

The main solution that improves the transaction speed and scalability is called *sharding*. Ethereum is developing this solution under the project name Plasma, where it applies the MapReduce framework to the blockchain (Poon & Buterin, 2017). Currently, every transaction is validated by the entire network of nodes. Sharding will create subsets of nodes that each act as their own network of nodes. This increases the number of transactions that can be validated and thus increases the transaction speed and scalability (Buntinx, 2017).

The MapReduce framework was designed for high-performance, massively-scalable distributed systems (Rohloff & Schantz, 2010) and not for blockchain, which shows that this dilemma is not unique for blockchain. The dilemma is important until a solution is implemented, but it is expected that development of solutions such as sharding will stop this dilemma.

G. Consider back-ups & decide ledger type

Choosing between a public and private ledger also determines the need for a back-up. The fundament of blockchain technology is that a copy of the blockchain is distributed amongst all nodes in the network (Iansati & Lhakani, 2017). In a public blockchain many copies exist as there is an unlimited amount of nodes that may participate. A private blockchain however limits the number of nodes and thus the number of participants that hold a copy of the blockchain (Tapscott & Tapscott, 2016). Parties agree that a backup of data is important (Government Office for Science, 2016; Utrecht interview, 2017; Drechtsteden interview, 2018). When the number of nodes with a copy of the data is large, a back-up can be considered unnecessary, but a private blockchain only has a handful of nodes, which decreases the security of the backup function (Matanović, 2017, p.4). The interviewees acknowledge this dilemma: *"I assume it is not necessary. At least if we use a public ledger. With a private ledger we will have to"* (Drechtsteden interview, 2018). Also Zuidhorn is currently obliged to use back-ups due to the choice for a private ledger: *"The nice thing about a public chain is that it is a back-up." … "We have that with Kindpakket at the moment. Because of the trade-offs we are still on a private blockchain"* (Forus interview, 2018).

The backup characteristic of the blockchain makes this dilemma unique for smart contract implementations. The reliability of the backups depends on the number of nodes. Hence, the necessity for back-ups is inherent to private blockchains, whereas public blockchains make backups superfluous. This dilemma will therefore continue to exist.

H. Define responsibilities & decide ledger type

The prior dilemma showed that a small amount of nodes keep a record of the data in the case of a private blockchain. The responsibility for that data is for those who keep it and thus for those nodes. However, it is not clear who is responsible for the data in a public blockchain, where thousands of nodes have a back-up. Developers from the expert interviews address this dilemma: *"If you use a private ledger, the one who uses the private ledger carries responsibility for the technology and you can adapt things if you would like to. You can fork internally and no one would notice. With a public ledger, the miners carry responsibility and the consensus algorithm guarantees that responsibility"* (Forus interview, 2018). So the responsibility of data verification lies at the handful of nodes in a private ledger and with many nodes in a public ledger. Note that in a private blockchain it is easier to tamper and alter information, while this is nearly impossible in a public blockchain (Zheng et al., 2017, p.6). The division of responsibilities is different from standard IT solutions, which makes it especially important to define responsibilities in a private blockchain: "*it is necessary to clarify the responsibilities of each participating organization*" (Hou, 2017, p.4). Concluding, choosing between a public and a private ledger has a great impact on how responsibilities are divided between participants of the network.

This dilemma is inherent to the characteristics of the blockchain and thus both unique for blockchain as a permanent feature.

IV. Conclusion

The field of blockchain lacks academic research and empirical knowledge. An overview of design principles to aid project teams that implement smart contracts in governmental services and design dilemmas they encounter was non-existent, hampering the implementation of smart contracts. We used the design science approach in order to create the first overview of 36 principles with empirical knowledge from four case studies. This overview can support project teams in accelerating the implementation process, which can lead to more actual implementations. Furthermore, we found the following seven dilemmas that force project teams to make design choices:

1. Allocate budget & profitability;
2. Communicate significance & examine impact on jobs;
3. Security & open source coding;
4. Privacy & decide ledger type;
5. Scalability & transaction speed;

6. Consider back-ups & decide ledger type;
7. Define responsibilities & decide ledger type.

Three dilemmas are unique for smart contract implementations and are not yet seen in other IT projects: privacy & decide ledger type, consider backups & decide ledger type, and define responsibilities & decide ledger type. Their uniqueness comes from the new characteristics that blockchain offers when choosing between a public and private ledger, which therefore were not yet known from other IT projects. These dilemmas demand extra attention as research on their effects and coping strategies is non-existent. The other four dilemmas are known from other IT projects, which makes it interesting to assess if existing coping strategies for these dilemmas are applicable in smart contract implementation projects as well.

Two dilemmas are expected to be solved in the short term due to the developments of blockchain technologies themselves: privacy & decide ledger type can be solved with *zero-knowledge proof* solutions and scalability & transaction speed can be solved with *sharding*. Project teams will have to cope with these dilemmas for now, but it is expected that these will be solved by future technological improvements. Five of the dilemmas are considered to be permanent, which means that project teams will need to account for them in the future as well. Table 22 provides an overview of the characteristics per dilemma.

Table 22 - Characteristics of the design dilemmas.

Dilemma	**Unique**	**Solution expected**
Allocate budget & profitability	No	No
Communicate significance & examine impact on jobs	No	No
Security & open source	No	No
Privacy & decide ledger type	Yes	Yes
Scalability & transaction speed	No	Yes
Consider back-ups & decide ledger type	Yes	No
Define responsibilities & decide ledger type	Yes	No

Further research is essential to describe the characteristics of these dilemmas more in-depth, as we used a limited amount of cases and experts in order to derive a first overview. More case studies and expert interviews can be conducted to derive more information about these dilemmas and to assess if these dilemmas exist in all governmental services that implement smart contracts. Another recommendation is to study the coping strategies of these dilemmas. We derived a first overview of the dilemmas and described some potential coping strategies, but these strategies can be researched more in-depth. Further research can assess the applicability of existing strategies on our overview of design dilemmas on the one hand and can find new strategies for the dilemmas on the other hand.

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Appendix A: List of interviewees

Table 23. Details of the interviews

Date	**Organization**	**Interviewee role(s)**
December 20, 2017	Municipality of Arnhem	Advisor Process & Advisor Business Intelligence
December 21, 2017	Municipality of Schiedam	Program Manager Social Infrastructure
December 22, 2017	Municipality of Utrecht	Data Scientist
January 4, 2018	Municipalities of Drechtsteden	Business Consultant
January 23, 2018	Blockchainpilots.nl	Project Manager National Blockchain Pilots
January 25, 2018	DApp.Design	Blockchain Developers
January 22, 2018	ICTU	Data Scientist for the Dutch Government
January 22, 2018	Pels Rijcken	Law Expert
January 26, 2018	Municipality of Groningen	Project Leader Stadjerspas
January 29, 2018	Forus	Blockchain Developers

Appendix B. Search results of literature review

The publications in table 24 were the Scopus search results for on the 15th of December 2017 for the term: ALL ("blockchain" AND "principles" AND "design" AND "government"). The additional documents that were added are shown in table 25. The green (true) and red (false) cells mark if the criteria are met. The publications that were not freely accessible show question marks for the other criteria, because they cannot be verified:

1. The publication is (at least partially) about blockchain powered smart contracts;
2. The publication is (at least partially) about implementation in governmental services;
3. The publication offers design principles;
4. The publication is freely accessible in English.

Table 24 - Scopus search results for literature review.

#	Title	Author(s)	Year	Criteria			
				1	2	3	4
1	Why Security and Privacy Research Lies at the Centre of the Information Systems (IS) Artefact: Proposing a Bold Research Agenda	Lowry P.B., Dinev T., & Willison R.	2017				
2	Agile Procurement	Nicoletti B.	2017	?	?	?	
3	Agile Procurement: Volume I: Adding Value with Lean Processes	Nicoletti B.	2017				
4	Preliminary Applications of Blockchain Technique in Large Consumers Direct Power Trading	Ouyang X., Zhu X., Ye L., & Yao J.	2017	?	?	?	
5	Smart Leadership - Wise Leadership: Environments of Value in an Emerging Future	Steed C.	2017	?	?	?	
6	Blockchain Application Development Techniques	Tsai W.-T., Yu L., Wang R., Liu N., & Deng E.-Y.	2017	?	?	?	
7	Democratic Centralism: A Hybrid Blockchain Architecture and Its Applications in Energy Internet	Wu L., Meng K., Xu S., Li S.Q., Ding M., & Suo Y.	2017				
8	The Internet-of-Things: Review and Research Directions	Ng I.C.L., & Wakenshaw S.Y.L.	2017				
9	Decentralized Computing Using Blockchain Technologies and Smart Contracts: Emerging Research and Opportunities	Asharaf S., & Adarsh S.	2017	?	?	?	
10	Blockchain Technology as s Support infrastructure in e-Government	Ølnes S., & Jansen A.	2017				
11	Story Blocks: Reimagining Narrative Through the Blockchain	Maxwell D., Speed C., & Pschetz L.	2017				
12	Block-VN: A Distributed Blockchain Based Vehicular Network Architecture in Smart City	Sharma P.K., Moon S.Y., & Park J.H.	2017				

13	Beyond Bitcoin: An Early Overview on Smart Contracts	Cuccuru P.	2017	?	?	?	
14	Private Data System Enabling Self-Sovereign Storage Managed by Executable Choreographies	Alboaie S., & Cosovan D.	2016				
15	The Politics of the Commons: Reform or Revolt?	Papadimitropoulos V.	2016				
16	SIRI-OUSLY 2.0: What Artificial Intelligence Reveals about the First Amendment	Massaro T.M., Norton H., & Kaminski M.E.	2016				
17	Evolving Process Views	Eshuis R., Norta A., & Roulaux R.	2016				
18	Blockchain Technology: Principles and Applications	Pilkington M.	2016				
19	Making Sense of Big Data in Health Research: Towards an EU Action Plan	Auffray C., Balling R., Barroso I., Bencze L., Benson M., Bergeron J., Bernal-Delgado E., Blomberg N., …	2016				
20	A System View of Financial Blockchains	Tsai W.-T., Blower R., Zhu Y., & Yu L.	2016				
21	Beyond Bitcoin Enabling Smart Government Using Blockchain Technology	Ølnes S.	2016	?	?	?	
22	Blockchains and Smart Contracts for the Internet of Things	Christidis K., & Devetsikiotis M.	2016				
23	Indo-French Educational Partnerships: Institutions Technologies and Higher Education	Pilkington M.	2015	?	?	?	
24	Transacting in Data: Tax Privacy and the New Economy	Thimmesch A.B.	2016				
25	The Future of Digital Business Innovation: Trends and Practices	Morabito V.	2016				
26	Revisiting Democratic Mining in Bitcoins: Its Weakness and Possible Remedies	Paul G.	2015				

Table 25 – Additional documents for the literature review.

#	Title	Organisation	Year	Criteria			
				1	2	3	4
1	Distributed Ledger Technology: Beyond Block Chain	Government Office for Science	2016				
2	Blockchain Pilots: A Brief Summary	Blockchainpilots.nl	2016				
3	Blockchains: Moving Digitals Government Forward in the States	NASCIO	2017				

Appendix C. List of interviewees

Table 26 - List of interviewees for the case studies.

#	Date and time	Case	Interviewee	Organization	Function
1.	December 20th 2017 from 10.30 till 12.30	Gelrepas	Janny Bodd	Municipality of Arnhem	Advisor Process Management
			Walter Bolwerk	Municipality of Arnhem	Advisor Business Intelligence
2.	December 21st 2017 from 13.00 till 14.00	Debt assistance	Laurens Steerneman	Municipality of Schiedam	Program Manager Social Infrastructure
3.	December 22nd 2017 from 10.30 till 11.30	Waste processing	Dick Joosten	Municipality of Utrecht	Data Scientist
4.	January 4th 2018 from 10.00 till 11.00	Disabled parking permit	Dennis van der Valk	Municipalities of Drechtsteden	Business Consultant

Table 27 - List of interviewees for the framework validation.

#	Date and time	Interviewee	Organization	Function
1.	January 23rd 2018 from 11.30 till 12.00	Koen Hartog	Blockchainpilots.nl	Project manager national blockchain pilots
2.	January 25th 2018 from 13.00 till 15.00	Karel Frank Artist	DApp.Design	Blockchain developer
		Jan ter Laak	DApp.Design	Blockchain developer
3.	January 22nd 2018 from 16.00 till 17.00	Steven Gort	ICTU	Data scientist for the Dutch government
4.	January 22nd 2018 from 15.00 till 15.30	Sandra van Heukelom	Pels Rijcken	Law expert
5.	January 26th 2018 from 13.00 till 14.00	Paul Spoelstra	Municipality of Groningen	Project leader Stadjerspas
6.	January 29th 2018 from 11.30 till 13.00	Jamal Vleij	Forus	Blockchain developer
		Maarten Velthuys	Forus	Blockchain developer

Appendix D. Case study protocol

Table 28 shows the case study protocol that is used for the case studies. Note that the case studies are a part of the *assess and refine* phase of the design science approach and not the main research method of this research.

Table 28 – Case study protocol description.

Section	Content	Description
General description	Aim of case studies	The aim of the case studies is to contribute to answering the main research question: *"How can blockchain powered smart contracts be implemented in governmental services?"*. The case studies are a part of the *assess and refine* phase of the design science approach. By describing empirical implementations it is possible to assess design principles found in literature and refine them into an improved version. These design principles will then serve as input for a design framework.
	Aim of overarching research	The research is aimed at deriving a design framework to *"support project teams in the implementation of blockchain powered smart contracts in governmental services"*.
Procedure	Getting started	• Form case study goals (paragraph 5.1.1)
	Case selection	• Form selection criteria (paragraph 5.1.3) • Select cases (Gelrepas, debt assistance, waste processing and disabled parking permit)
	Derive secondary information	• Find and describe background information about the cases (paragraphs 5.2.1 through 5.2.4)
	Derive primary information	• Prepare a topic list (appendix E) • Conduct interviews • Transcribe interviews (in Dutch)
	Verify information	• Send case study descriptions to interviewees • Adapt incorrect or missing information • Write interview summary (paragraph 5.2)
	Analyze data	• Code text that is suitable as design principle in ATLAS.ti • Translate coded text (appendix F)
	Shape new knowledge	• Assess first version of design principles with coded text • Refine design principles into a second version

Appendix E. Case study interview topic list

This interview is executed as a part of a TU Delft research. The research has as goal to derive a design framework to support project teams in the implementation of blockchain powered smart contracts in governmental services. Certain implementation projects and pilots in Dutch municipalities are examined. Information from these cases will provide valuable information. Your municipality is involved in such a project. This interview aims at answering questions about your project and design principles.

After the interview, the transcript will be combined with information about your case from other sources. This will lead to a case description. This information will be send to you, in order for you to verify that the statements are correct. That makes sure the information in the research is valid.

1. **Introduction**
    a. Agreements about recording the interview
    b. Introduction interviewer
    c. Introduction interviewee
    d. Introduction research background and goal of the interview
2. **Use case**
    a. What was the goal of the project?
    b. Why did you choose this process?
    c. What is the added value of blockchain in this process?
    d. Which steps have been taken so far? Who was involved?
    e. What is the current state of the project?
    f. What were and/or are impediments during the process?
    g. What are (possible) future steps?
3. **Assessment design principles**
    a. Are the design principles in the appendix[17] relevant for your case?
    b. Which design principles are missing?
    c. Which design principles are different from other IT implementation projects?
4. **Last round for questions**
5. **Wrap up**

[17] The appendix of the interview topic list contained the first version of the design principles as in table 10 from paragraph 4.3.

Appendix F. Statements from case study interviews

Table 29 contains the statements from the case interviews. Note that the interviews were conducted in Dutch and we translated the quotations to English. Raw data can be requested at the author.

Table 29 – Statements from the case interviews.

Case	Code	Statement	Subject
Arnhem	A.1	"At first we looked at the process"	Design principle 18 (Map the process)
	A.2	"The next steps are the social aspects, such as acceptation, which are crucial for successful implementation"	Design principle 13 (Understand implications
	A.3	"That is why it is important to involve the supervisor in the process"	Involve supervisor
	A.4	"So we have to cooperate with staff, organization and information"	Cooperate internally
	A.5	"We have to examine the influence of blockchain on social aspects"	Design principle 13 (Understand implications)
	A.6	"We are making a strategic plan for 2018"	Design principle 2 (Define a vision)
	A.7	"We are working together now with VNG/KING and other municipalities."	Design principle 8 (Cooperate with other organizations)
	A.8	"Thereafter we learned with a game what it is and from that we thought the Gelrepas was a good process to apply blockchain on"	Design principle 17 (Process selection)
	A.9	"First we wanted to hear what it is and what you can do with it. Thereafter we learned with a game what it is"	Design principle 4 (Invest in blockchain knowledge)
	A.10	"There were explorative conversations, where various municipalities examined if they wanted to try something with blockchain. Eventually we continued with the municipalities of Barneveld, Breda and Arnhem."	Design principle 8 (Cooperate with other organizations)
	A.11	"We presented this PowerPoint internally, amongst others to the CIO. With that we can learn the organization about the changing reality"	Design principle 12 (Communicate significance)
	A.12	"You can see that some tasks disappeared, such as tasks that go to the market. You have to make smarter use of information, also with blockchain. You can see that the government will have a very different role later. Buying a house or applying for a permit later does not have to go through the municipality anymore."	Examine shifting role of the government
	A.13	"Safety is also an issue. There is much fraud, which you want to stop"	Design principle 14 (Security)
	A.14	"Everything has to be earned back. Innovation is very contradictory in that. We could state that the administrative costs are lower"	Determine profitability
	A.15	"We developed a main team. Rob, Janny, me, Bas Bloemberg (council advisor Smart City) and the CIO and politics"	Design principle 11 (Multidisciplinary team)
	A.16	"Budget is important, because we are financially steered"	Design principle 5 (Allocate budget)
	A.17	"We had an internal knowledge session to select a blockchain process"	Design principle 17 (Process selection)

	A.18	"You have to do it in parts, else it is not possible to oversee it all and it will be to big" … "Simplicity is good to show what you are doing exactly"	Design principle 21 (Start with small projects)
	A.19	"Someone who works in the process feels that something will change regarding his position. He will retreat then. You have to try to prevent this and talk with them about the new technology and working method. However, we are not there yet"	Design principle 9 (Involve stakeholders)
	A.20	"We have personal conversations. What does it mean for you and how do you see it? Hearing each other out" … "That is really necessary, else it is doomed to fail"	Design principle 9 (Involve stakeholders)
	A.21	"You have to cooperate, but you will lose your job. You cannot convince with that, but that is how it works" … "Eventually the CIO and the cluster manager of Work and Income will have to see how the game works"	Examine impact on jobs
	A.22	"What was an eye opener for us was the legal aspect. That you have to involve a law expert in the blockchain project, so you will not come across barriers" … "What also was interesting was that they questioned how far the current legislation is connected to the blockchain. Legislation is standing still. That is why the blockchain is not incorporated. That can also induce barriers"	Design principle 1 (Research legal implications)
	A.23	"We also made a table with all the process steps"	Design principle 18 (Map the process)
	A.24	"Privacy has to be right as well"	Design principle 15 (Privacy)
	A.25	"In cooperation with law experts we have here and other organisations"	Design principle 7 (Find technical experts)
	A.26	"We are talking now with the legal department. We will give them a blockchain presentation and will involve them from now on"	Cooperate internally
	A.27	"We made our own network: municipalities of Utrecht, Groningen, Steven Gort from ICTU, Johan Pouwelse from TU Delft, municipality of Nijmegen is watching, municipality of Zuidhorn, VNG/KING and the municipality of Breda. That is where we can share and retrieve our knowledge"	Design principle 10 (Share results)
	A.28	"You want to learn from each other. We are a learning organization and want to learn together. What someone else already did, we do not have to learn again. That would be a waste."	Design principle 10 (Share results)
	A.29	"The first quarter of 2018 we will develop the first prototype with Scrum"	Design principle 19 (Prototype development)
	A.30	"We are developing strategy and vision"	Design principle 2 (Define a vision)
	A.31	"All parties must be involved"	Design principle 9 (Involve stakeholders)
	A.32	"A business model should be made"	Determine profitability
	A.33	"To see if it is wise to join other initiatives"	Design principle 24 (Learn from prior development)
	A.34	"Moreover, the entire role as municipality can change. That is way bigger. You will limit yourself as municipality, but you have to join"	Examine shifting role of the government

	A.35	"Actually, I find this one crucial, because there is much technology. Normally you would not think about it much and simply implement, no need for making a vision. But with blockchain there is much more possible than a simple function, blockchain can change the world. You really have to write down a vision for which direction we are heading … Because this is so powerful you have to think about it. This is so different from normal technology. That is why it is good to have a good vision on it"	Design principle 2 (Define a vision)
	A.36	"Invest in knowledge of course"	Design principle 4 (Invest in blockchain knowledge)
	A.37	"I think that with making smart contract you should do it together with various experts: involve persons with different expertise"	Design principle 11 (Multidisciplinary team)
	A.38	"So, communication has grown more important and more difficult to bring to the attention"	Design principle 12 (Communicate significance)
	A.39	"There is so much happening with personal data. Security and privacy is becoming more important, because the data is accessible for everyone. At least, that is the sentiment" … "It is the feeling that we give away data, our personal data. Our data is on the blockchain. It takes time to gain trust"	Design principle 14 (Security) and design principle 15 (Privacy)
	A.40	"In a public ledger, how responsible is the municipality? Do we even want to think about that?" … "Who is then responsible for it all? What are the responsibilities of the owner?" … "I think it is important to know who is in the lead in case of faults" … "That is crucial"	Define responsibilities
	A.41	"We already have much open source" … "But it must fit the strategy of the municipality of Arnhem"	Design principle 22 (Open source coding)
	A.42	"We want to have the Gelrepas in a private ledger, we are not doing it directly in the public ledger. I think that is important"	Design principle 28 (Decide ledger type)
	A.43	"Back-ups, we do not worry about back-ups"	Design principle 29 (Enable back-ups)
Schiedam	S.1	"That the board is in favor shows that it is found important"	Involve supervisors
	S.2	"They initiated the pilots and raised enthusiasm within the organization in order to have a pilot on a certain subject"	Cooperate internally
	S.3	"That is when we started and examined what would be interesting to apply blockchain in debt assistance on"	Design principle 17 (Process selection)
	S.4	"We focused on the person who takes over your financial administration. That costs much time. So we examined how we could eliminate the third party and if blockchain can be used"	Design principle 18 (Map the process)
	S.5	"So we can use a business case that justifies the investment"	Determine profitability
	S.6	"The development will cost around three or four hundred thousands of euros. I do not think we will do that alone"	Design principle 8 (Cooperate with other organizations)
	S.7	"The moment you start developing the risk should decrease. In my opinion that is done with other municipalities. You share the costs and risks"	Design principle 8 (Cooperate with other organizations)
	S.8	"Koen Hartog was in the team as a kind of project manager. There were two blockchain developers. Three persons from Stroomopwaarts with knowledge about debt assistance. Two persons from the municipality, me and the manager Open Overheid (Open Government)"	Design principle 8 (Cooperate with other organizations)

	S.9	"We are now in the first phase where a project plan is developed for making a prototype. In January we will assign someone to develop the prototype"	Design principle 19 (Prototype development)
	S.10	"It is true that developing is costly"	Design principle 5 (Allocate budget)
	S.11	"We are making some kind of project group"	Design principle 11 (Multidisciplinary team)
	S.12	"The most important thing to me is that the prototype works"	Define project goals
	S.13	"It is also useful to use the network of national pilots. Which municipalities would want to join then?"	Design principle 8 (Cooperate with other organizations)
	S.14	"We are going to assess the risks, probably the AFM (authority financial markets) will have an opinion"	Design principle 26 (Risk assessment)
	S.15	"It is very unpredictable. We are just not exactly sure. It is examining step by step. You are thinking short term"	Design principle 21 (Start with small projects)
	S.16	"I do not intent to build that expertise. I think by doing these pilots you can sense more how you can use it. But the expertise to build, we will not retrieve that into the municipality"	Design principle 4 (Invest in blockchain knowledge)
	S.17	"Blockchain is something that slowly is gaining traction in the news and in the society at citizens of the city, so you cannot really say as government: we do not want to use that. We want to look at citizens about what to do"	Design principle 2 (Define a vision)
	S.18	"Following the experience you can examine how it fits our policies and what we want to do with it. I would do it in another phase. I think it is something you should learn and cannot say it in advance"	Design principle 3 (Define clear policies and legislation)
	S.19	"Of course that is important, the knowledge development in blockchain"	Design principle 4 (Invest in blockchain knowledge)
	S.20	"It actually always needs budget"	Design principle 5 (Allocate budget)
	S.21	"Safety is very important. If you do something as government you cannot make it unsecure. I think design principles 5 and 6 belong together. I see it as whole. You have to allocate budget for blockchain and security is a part of it"	Design principle 6 (Fund penetration testing)
	S.22	"I also noted that it is very difficult, and I believe other municipalities are stakeholders as well, to convince, because it is so complex. Involve all stakeholders is something you should want eventually, but it can be impeding at first, because the result is so uncertain"	Design principle 9 (Involve stakeholders)
	S.23	"You should prepare for it, but should not have the intention that all faults can be prevented. We should make sure that you can make faults without having fatal consequences"	Design principle 16 (Fault tolerance)
	S.24	"We are going for open source, as I understood"	Design principle 22 (Open source coding)
	S.25	"The learning effect is very important, I think"	Design principle 24 (Learn about prior development)
	S.26	"I think we will do that. The idea is that we have a sort hub, where you can access a part of the blockchain. We will think that through with the prototype"	Design principle 28 (Decide ledger type)

	S.27	“With blockchain I see that the new thing is that the central role will disappear, like banks with Bitcoin and the budget manager with our project. There is a sort promise of trust that is not hackable. I think that is really different. With everything that we do now a central role verifies transaction. The internet did not change that. Before, the central role also was the carrier of risks. Who should carry the risk now in case of faults?”	Determine responsibilities
Utrecht	U.1	“Then we chose a process, it was about waste processing”	Design principle 17 (Process selection)
	U.2	“In practice it is not such a problem. The moment you implement something, you shift with tasks. They will get other tasks. Their function is not suddenly gone”	Examine impact on jobs
	U.3	“If you do other activities on the blockchain … I can imagine it will effect jobs. But no one ever got fired due to automation. There can always be some shifting within the municipality”	Examine impact on jobs
	U.4	“Which versions of blockchain are there? Which version would be useful here and which parties will have which rights?”	Design principle 28 (Decide ledger type)
	U.5	“Which parties should be able to read data? With authorization for example, that you can enter data that not everyone can read. Who hides it?”	Determine authorizations
	U.6	“We are not investing loads of money on something where it is uncertain it will ever be a success”	Design principle 5 (Allocate budget)
	U.7	“They are not yet investing in it, that is why we are making it more specific with students first”	Design principle 8 (Cooperate with other organizations)
	U.8	“If there is a working prototype and you can show the societal value, it could be that resources become available to implement. It is too uncertain now. You are in a phase where everyone finds it interesting, but it is too vague and not specific. There are only few cases where we see it works. They do not dare to invest in that yet, so they hold back”	Design principle 12 (Communicate significance)
	U.9	“We also were in contact with ILT, the controlling organization for logistics and transport, who were working on it as well, also around waste processing”	Design principle 8 (Cooperate with other organizations)
	U.10	“There are now a few students from the Hogeschool Utrecht working on the pilot. They mostly mapped the process and mapped the added value of blockchain in this process”	Design principle 8 (Cooperate with other organizations)
	U.11	“We agreed a second team will make a demo, a working prototype”	Design principle 19 (Prototype development)
	U.12	“Thereafter we will give a presentation here. Periodically we have presentations about innovations. Everyone who is interested then comes. Mostly when it is about blockchain some 50 to 100 persons are here”	Design principle 10 (Share results)
	U.13	“You see that persons who have interest say: “We are interested as well”, where after you form a network within the municipality. That’s how I came in contact with Hogeschool Utrecht as well. You connect such contacts at such meetings. Share information and gain support for certain things”	Cooperate internally; Design principle 8 (Cooperate with other organizations)
	U.14	“Later we had conversions with other municipalities who were working on blockchain as well. Once in a month or once every six weeks we met, where everyone presented their status on a stage”	Design principle 8 (Cooperate with other organizations)

	U.15	"When many parties cooperate, mostly there is only one leading party. The others are just following. You also see it delays" … "If you cooperate with many parties it can lead to delays. You should have one main group with a few enthusiastic parties who contribute and periodically a few parties that join"	Design principle 9 (Involve stakeholders)
	U.16	"It means that you should have the knowledge internally to do that" … "But it should add value to what you already have. You do that the moment you say you want to continue with it. You do not have to execute it yourself, but you should have the knowledge as client to assess, do I get what I asked? You need some knowledge to understand what they do and what you can expect. If you do not have that, you get IT projects that keep continuing, cost money and do not bring what you want"	Design principle 4 (Invest in blockchain knowledge)
	U.17	"That is also already applicable in standard IT. We work a lot with that"	Design principle 1 (Research legal implications)
	U.18	"We do not really have a vision yet. First we need to know what we can do with it before we can make a vision on it"	Design principle 2 (Define a vision)
	U.19	"That is certainly not yet the case, but you should have to change the legislation. In the legislation it says that everything has to be registered on paper. That should be changed when it is done through the blockchain. And every party would have to join"	Design principle 3 (Define clear policies and legislation)
	U.20	"Well, the investments are not large yet, but we invest much time"	Design principle 4 (Invest in blockchain knowledge)
	U.21	"Budget is always necessary of course"	Design principle 5 (Allocate budget)
	U.22	"We did thought about that. We are not actually implementing yet, but you should think of it"	Design principle 6 (Fund penetration testing)
	U.23	"Eventually yes. Now with a low number. Is it possible to get support for it? With some parties you can think they might have some critique"	Design principle 9 (Involve stakeholders)
	U.24	"No, not yet. We consider that if we continue to use a Scrum approach. But it is too early now"	Design principle 11 (Multidisciplinary team)
	U.25	"We did not think about that yet. It strongly depends on the process"	Design principle 13 (Understand implications)
	U.26	"That is always applicable in such cases"	Design principle 14 (Security)
	U.27	"We are not that far yet, by long. At implementation you should of course know what happens when the system crashes"	Design principle 16 (Fault tolerance)
	U.28	"That is one of the reasons we want to do this, because it is specific and comprehensive and not the too complex entire waste process. We chose a small part of the waste process, of which we say: this is fairly comprehensive. If you want to involve all it becomes too complex very fast"	Design principle 21 (Start with small projects)
	U.29	"Yes, it is indeed an open source thing"	Design principle 22 (Open source coding)
	U.30	"Such projects, we do not have at the moment. You should have experience first. This is a too early phase to do it" … "It would be pleasant if there would be a successful case, where you can say: it works here and you can see how it functions. I did not see them yet"	Design principle 25 (Build on prior development)

	U.31	“When we are ready, yes. It is not of importance now”	Design principle 29 (Enable back-ups)
	U.32	“They mostly mapped the process and mapped the added value of blockchain in this process”	Design principle 18 (Map the process)
Drecht-steden	D.1	“If you can do it together it has added value for sure”	Design principle 8 (Cooperate with other organizations)
	D.2	“Then I started to search problems internally and support to research the whole thing”	Cooperate internally
	D.3	“First I examined who was interested in this innovation”	Cooperate internally
	D.4	“Thereafter, we had an internal discussion if we wanted to join and which subjects we could examine”	Design principle 17 (Process selection)
	D.5	“That is why I defined firstly what we wanted to achieve with the pilots”	Define project goals
	D.6	“For this project I examined the startup world and search for a startup that could help us making a proof of concept”	Design principle 8 (Cooperate with other organizations)
	D.7	“To show internally how this works”	Design principle 12 (Communicate significance)
	D.8	“We also cooperated more with each other”	Design principle 8 (Cooperate with other organizations)
	D.9	“Scale op to a testable pilot version”	Design principle 19 (Prototype development)
	D.10	“We also started conversations with experts and market parties who had more knowledge about it”	Design principle 7 (Find technical experts)
	D.11	“Moreover there is a necessity to scale it nationwide: if municipality X uses it and municipality Y does not, it is not of use at all”	Scalability
	D.12	“A decent amount of transaction speed”	Transaction speed
	D.13	“We involved many municipalities: sixteen municipalities that actively support it”	Design principle 8 (Cooperate with other organizations)
	D.14	“When you have a good idea of how you can add value to the society it is worth to introduce it nationwide”	Scalability
	D.15	“Everything we do is open source, it is already on GitHub. It is everyone’s, right, it is tax money”	Design principle 22 (Open source coding)
	D.16	“The parking permit for disabled is not something that has a valid business case directly, but is the town council prepared to invest money to ease the life of a disabled citizen?”	Determine profitability
	D.17	“My ultimate goal is to make the government unnecessary. Everything you do not have to have a role in anymore you should not do anymore as government … Government-as-a-service: you are not dependent on a geographic bound entity … In relation to blockchain I see many possibilities. The man in the middle, you can see it disappearing. You realize that the government mostly is that man in the middle”	Examine shifting role of the government
	D.18	“In my opinion the technology behind blockchain does not have to be visible. When you have a good user interface and make the result good, trust is gained faster. UI/UX design is very important”	Good UI/UX design
	D.19	“The goal is to grow the publicity of blockchain and government within the organization. And to show some example to show how far we are within the Drechtsteden: how far are we and which barriers we encounter?”	Design principle 12 (Communicate significance)

	D.20	"We do that. I work together with Sandra van Heukelom from Pels Rijcken (the nation's attorney). We scheduled a meeting where she will assess the legal viability of the implementation of the disabled parking permit. It is due to the new technology we do not know yet what the legal implications are"	Design principle 1 (Research legal implications)
	D.21	"That is something that will come later, but we did not make one yet. Maybe you would not want to do that as individual municipality, but with a group, such as with VNG. What is our vision to implement blockchain in the society?"	Design principle 2 (Define a vision)
	D.22	"The legal implications are fairly large. Which rights do you have with smart contracts for example? Seen from a legal perspective it means that you shift from a process validity to a contract validity"	Design principle 3 (Define clear policies and legislation)
	D.23	"By Drechtsteden I am not hindered to partake on blockchain conferences. In that sense they invest in me to gain that knowledge"	Design principle 4 (Invest in blockchain knowledge)
	D.24	"I would place technical within quotation marks. I have more use of someone who can explain the possibilities and implications of blockchain than someone who can explain the technology"	Design principle 7 (Find technical experts)
	D.25	"Something which we think through … The hard part is to identify them. That is a learning process"	Design principle 13 (Understand implications)
	D.26	"Do you want to have a successful blockchain project, you will have to show you are privacy compliant, that the citizen can trust on it"	Design principle 15 (Privacy)
	D.27	"I always do that at the very start. You should prevent that it is not a solution looking for a problem, but the other way around. Is the problem really the problem? Which added value has the problem for the society?"	Design principle 17 (Process selection)
	D.28	"That is something that is ought to"	Design principle 23 (Establish standards)
	D.29	"Risk assessment needs extra focus, because you can have blind spots due to the new character … Do I dare to take risks by signing a smart contract? I think the focus will be on smart contracts … I would like to let someone audit the smart contracts to check if I thought of all risks"	Design principle 26 (Risk assessment)
	D.30	"Not really which organization, but if it is private, permissioned or public"	Design principle 28 (Decide ledger type)
	D.31	"That has to do with the principles of the blockchain. I assume it is not necessary. At least if we use a public ledger. With a private ledger we will have to"	Design principle 29 (Enable back-ups)

Appendix G. Expert interview protocol

Table 30 – Expert interview protocol description.

Section	Content	Description
General description	Aim of expert interviews	The aim of the expert interviews is to contribute to answering the main research question: "*How can blockchain powered smart contracts be implemented in governmental services?*". Experts will assess the second version of the design principles and the first version of the framework. The expert interviews are part of the *assess and refine* phase of the design science approach. Afterwards it is possible to form the final version of the design principles and design framework.
	Aim of overarching research	The research is aimed at deriving a design framework to "*support project teams in the implementation of blockchain powered smart contracts in governmental services*".
Procedure	Getting started	• Form expert interview goal (paragraph 7.1.1)
	Expert selection	• Form selection criteria (paragraph 7.1.2) • Select experts
	Derive primary information	• Prepare a topic list (appendix H) • Conduct interviews • Transcribe interviews (in Dutch)
	Verify information	• Send interview report to interviewees • Adapt incorrect or missing information
	Analyze data	• Code text in ATLAS.ti • Translate coded text (appendix I)
	Shape new knowledge	• Assess second version of design principles with coded text • Refine design principles into a final version • Assess first version of design principles with coded text • Refine design framework into a final version

Appendix H. Expert interview topic list

This interview is executed as a part of a TU Delft research. The research has as goal to derive a design framework to support developers in the implementation of blockchain powered smart contracts in governmental services. By using literature and case studies, a first version of the design framework is made. By using expert interviews the framework is assessed and refined. A transcript of the interview will be made and send to you afterwards in order for you to verify that the statements are correct. That makes sure the information in the research is valid.

1. **Introduction**
   a. Agreements about recording the interview
   b. Introduction interviewer
   c. Introduction interviewee
   d. Introduction research background and goal of the interview
2. **Assessment design principles**
   a. Do you agree with the design principles in the appendix?[18]
3. **Assessment design framework**
   a. Do you recognize the five implementation phases
   b. Do you agree with the division of when each design principle is valid?
   c. Do you recognize the trade-off pairs?[19]
   d. What makes the framework unique for smart contract implementation?
   e. Is the framework different for the private sector?
   f. Is the fact that an organization already knows in the beginning that he wants to implement smart contracts of influence on the design process?
   g. Do you see the added value of the design framework?
4. **Last round for questions**
   a. How do you see the double role of the government (user and monitor)?
   b. Where in the process are vulnerabilities for hacking?
5. **Wrap up**

[18] The appendix of the interview topic list contained the second version of the design principles as in table 12 from paragraph 5.4 and the first version of the design framework as in figure 24 in paragraph 6.3.
[19] We initially referred to the design dilemmas as trade-off pairs.

Appendix I. Statements from expert interviews

Table 31 contains the statements from the expert interviews. Note that the interviews were conducted in Dutch and we translated the quotations to English. Raw data can be requested at the author.

Table 31 – Statements from the expert interviews.

Interviewee	Code	Statement	Subject
Pels Rijcken	PR.1	"Many make the technical parts first and involve the law experts after. The downside is that they then say they should have made another technical choice, because that fits better. If you help building from the start and translate legal requirements in technology, you comply better to the law, without wasting money. It would save much money."	Design principle 1 (Research legal implications)
	PR.2	"With the new GDPR you have to conduct a small privacy impact analysis. Is the privacy guaranteed? Blockchain works with nodes who all share a copy of the information. Often, one forgets that nodes have a legal role as well. If you knew that beforehand, you can cover that with technology, such as an extra key or authorization. If you forget that you have to start building from the start again."	Design principle 1 (Research legal implications)
	PR.3	"The problem is, that what is written down become a sort bible for the developer, who will do what is in there. If the right choices are not made, you fail when developing. It would be pleasant if you would at least made a textual display of what you want to do in order to conduct a light legal test, this would be in the conceptualization phase. We call it the legal impact analysis. Will the blockchain have a heavy legal impact, for example with much medical personal data. Or does it have a low legal impact, for example a process without personal data? Even if you only do the impact analysis, it will help to acknowledge the legal aspects."	Design principle 1 (Research legal implications)
	PR.4	"I would also look very strongly into who are going to be the participants in the blockchains. Who will participate and who will host the nodes? You have to check that early. Elsewise you cannot check who has which legal obligations. I would do that together with the process selection. You got to have room there to look to the parties. Which parties exchange which information?"	Define participants
	PR.5	"You should also define the smart contract itself. Then you know which legislation is applicable. What kind of legal product is this? Does it push a process? Does it grant a subsidy?"	Define contract types
	PR.6	"You do not have a place for legal. I do not find research legal implications political. Political is more about political support. The first and third design principle would also be a part of that."	Framework feedback
	PR.7	"Very nice and very recognizable. A good summary."	Framework feedback
	PR.8	"When a government places subsidy in the blockchain or the disabled parking permit, you have power under public law to make a decision about a citizen. If that is the case you have the obligation of effective and published justifications, and even more rules apply."	Translate code to language
	PR.9	"Is the framework different for the commercial sector: yes. The government also has to comply to the general properties of proper governance"	Framework feedback

	PR.10	"The public sector and the Dutch Supreme Court have the opinion you should be able to translate code into language and that is something different. That is really difficult. We are working together with multiple parties to figure that out. The judge demands you, based on the PAS-ruling, to translate code into language that is understandable for a citizen, so he can check if each step is done correctly. That is a very important technical requirement" … "When you automate decision making, you have to make your decision available."	Translate code to language
ICTU	I.1	"The government has as reflex to make another database when something does not work. So we have 600 copies of you and me and nobody knows that is the correct one." … "So if we allow you to manage your own information and the technology guarantees that the government always has access to that information thanks to the blockchain, I do not to manage 600 copies. I am not troubled by the logistics and have no data privacy risks, because I do not have the data. That is a very different way of thinking compared to how the government works now."	Design principle 16 (Examine shifting role of the government)
	I.2	"The blockchain enables me to be sovereign again about who I am and what I want to share about my identity. And in such a way there cannot be intervention. With blockchain I can get a self-sovereign solution: a self-sovereign identity. That is an identity solution in blockchain technology, that is not managed by the government, which gives me a digital existence."	Design principle 16 (Examine shifting role of the government)
	I.3	"You need censorship resistance. You have to be able to protect your own privacy, your own human being, against misbehaving governments. In our case it is alright, but Saddam Hussein for example burned down millions of birth certificates, meaning millions of Iraqis cannot prove they exist."	Design principle 16 (Examine shifting role of the government)
	I.4	"Spend public money two times: do I think that is a good idea? No, I do not think that is a good idea, so development costs for blockchain need open source."	Design principle 20 (Open source coding)
	I.5	"The hardest issue in blockchain technology is private key management. And not do I manage it technological, but can I manage it so we are still comfortable and everyone understands it. That is crucial."	Design principle 34 (Good UI/UX design)
	I.6	"My hypothesis is that you should ignore regulation parties as we know them now, such as Authority Financial Markets and Authority Personal Data, when implementing blockchain, because they are organizations that are founded to fight a certain problem, such as fraud or criminality. Organizations that exist, because a problem exists that needs to be solved. They are inclined to maintain themselves. Everyone is panicking due to the new GDPR, but if you give you back your own privacy, why do I need a government that makes a GDPR that manages how governmental organizations correctly handle your data. My conviction is that if we build from scratch again and embrace the technology, we need a different form of regulation than the current."	Design principle 1 (Research legal implications)
	I.7	"For me there is only one solution: a public blockchain, but starting on the private blockchain is a good idea. How do I prevent in my design framework that where I start is where I end? That is what I expect from a decent framework."	Framework feedback
	I.8	"So you are talking with someone who has a viewpoint from the public domain and that is expressly different than someone who works in a commercial company." … "Public services are about that: that we make a decent society, with something of solidarity in it. So the constitutional properties are very crucial and that is what makes public services special. There is no freedom of legal position when it comes to you and the government. At the bank or car fabricant, you can change from provider if you do not like the services. That is different for the government. If you do not like the public service, you cannot change government."	Framework feedback

	I.9	"Showing a passport for a parking license at the town hall has an intention. But the fact that I need to show my passport has become an object in an information system and a check mark for taking the service parking licensing. What is missing here is a dialogue." … "We accept that those realities are not relating to each other. The information area is developing toward intention." … "Nobody wants to break down the intention behind a law, but still we do it every day. Back to blockchain: I want to invite you to add such perspectives to your framework. It matters if I am a lawyer or need someone to put on my knee stocking." … "Look for perspectives where the framework is maneuvering."	Reason processes from the actual intention
	I.10	"You know the donut economy: there is more than money and growth. We see ourselves in the climate discussion, we are destroying natural resources. If we are successful in implementing public blockchain in governmental services, we will destroy percentages of the gross national product. So what is happening? I am talking about two perspectives where you can look through: I am going back from a 40-hour workweek to 16, I accept that this is the reality, what does it mean for my framework? I notice that in the current landscape between the market and the government, there are many parties who use the government as cash cow, with a vendor lock-in, with intellectual property, so every municipality pays for his own products and we do that 380 times. But what if one municipality, Zuidhorn for example, does a onetime investment for the Child Package, and it is reused in 380 municipalities. As tax payer you do not have to pay development costs 379 times. Multiply those 379 with the cases where reuse is possible and you can sense how many business opportunities are destroyed. Many software companies that have the government as cash cow now will be out of business."	Design principle 16 (Examine shifting role of the government)
	I.11	"I completely disagree. There is only one secure option and that is radically transparent and open source without compromises."	Dilemma: security & open source coding
	I.12	"I have much faith in the development of Bitcoin. I will tell you something awry: I do not see a future for Ethereum. I think the fundament is wrong. The single global computing surface, where the execution of a smart contract is an economic consideration, because you have to pay gas. Also the conviction in the business logic is that a contract can be Turing-complete, that you can program with every fourth generation programming language, you can also program in Ethereum. I do not believe in the execution of a protocol in a network that has a Turing-complete business logic. I think it is too complex to do it faultless. I think it is legally too complex and I think that there are very good reasons to manage that on premise at the party who is made for it. I think in limited business logic, more on transaction levels, such as for example transfers on certain times or an unspent transaction output."	Dilemma: scalability & transaction speed
	I.13	"Think about on premise data storage in combination with decentralized control, by you and me, like for example Ocean Protocol is currently developing. Understand if such a combination obtains a position in your framework and/or design principles, and how that would look like."	Framework feedback
Blockchain-pilots.nl	B.1	"We see that most people think about that in the prototype phase and need to have incorporated that at the implementation phase."	Design principle 1 (Research legal implications)
	B.2	"That also correlates very much with 1 (legal implications). If they do that, they probably also define clear policies and legislation."	Design principle 3 (Define clear policies and legislation)
	B.3	"That is of course an absolute must to get started."	Design principle 4 (Invest in blockchain knowledge)

	B.4	"You always need budget to do something, but not too much. There are always free activities you can do."	Design principle 5 (Allocate budget)
	B.5	"That is always applicable. Especially the societal apart, for example that you have the philosophy that it is important that data ownership should be more at the citizen instead of storing it in silo's."	Design principle 6 (Profitability)
	B.6	"Experts are necessary everywhere indeed."	Design principle 7 (Find experts)
	B.7	"I think that is correct. Optionally in the first part. Sometimes we tell them, not yet. The moment you work with a large group in the first phase, it is not the most efficient. You need tight steering. I often try to keep the pilot groups somewhat smaller."	Design principle 8 (Cooperate with other organizations)
	B.8	"Yes, you are right. Important from the second phase."	Design principle 10 (Share results)
	B.9	"In my opinion already in the conceptualization phase. If you do not have them involved, you will never have the process description clear. Then I cannot instruct the experts and we will build something that cannot connect to the reality."	Design principle 11 (Multidisciplinary team)
	B.10	"That is very important of course. We give much attention to that. If you do not do that, you have a limited amount of very enthusiastic employees, but if they cannot communicate that it will stop there."	Design principle 12 (Communicate significance)
	B.11	"That is not one that is specifically examined now, because it is still small. If you look at the subsidy process, where many processes are manual now, and replace them with smart contracts, it can be done in two minutes. You can sense that those persons might have to do something different. Often when you have defined a process, those people will ask what they are going to do then. Well, then you have a conversation. The moment your function is overtaken by technology, you should prepare to carry out your function in a different method."	Design principle 13 (Examine impact on jobs)
	B.12	"With us, in the most cases, they are already involved in the first session. If that is not the case, we put attention to that, else it stops there."	Design principle 14 (Involve supervisor)
	B.13	"I think this belongs with the multi-disciplinary team, it is about the same."	Design principle 15 (Cooperate internally)
	B.14	"That shows more or less from the process description. If you do that correctly and go from a centrally organized process to a decentralized process, you will see that as well. That will show up in the end. Some governmental organizations say that they want to focus on that. With others it is just the result of the pilot."	Design principle 16 (Examine shifting role of the government)
	B.15	"What is the implications for the citizen? And for the government?"	Design principle 17 (Understand implications)
	B.16	"That actually just comes at the actual product. It is still somewhat intangible for the most participating employees."	Design principle 18 (Define responsibilities)
	B.17	"That is the case with the prototype first indeed."	Design principle 19 (Security)
	B.18	"Also with open source coding, but we tell that in the conceptualization phase already. We invite Steven Gort to tell what ICTU does."	Design principle 20 (Open source coding)
	B.19	"Yes, in the conceptualization phase."	Design principle 21 (Process selection)
	B.20	"That one as well." [referring to doing this in the conceptualization phase]	Design principle 22 (Map the process)
	B.21	"Our pilots our small projects of course."	Design principle 24 (Start with small projects)

	B.22	"I think it belongs to the prototype and starts at the actual product."	Design principle 25 (Risk assessment)
	B.23	"It is very early for that. We try to do that on a voluntary base through ICTU, to establish best practices. Questions we get now are: what is the blockchain of the government? It is too early for that, we cannot say much about that. It is absolutely important, but it is too early."	Design principle 26 (Establish standards)
	B.24	"We try to do that with everything of course, both conceptual as with code that everyone can see from each other, so you do not have to make the same mistakes."	Design principle 27 (Learn from prior development)
	B.25	"I think this can go under *legal implications*. This is just one of the most important legal questions."	Design principle 28 (Privacy)
	B.26	"Actually I think that will only be done at the actual product. With many prototypes I see that they just pick a blockchain, based on assumptions or the preferences of the developer. If you implement you will need to make a well-considered choice for the ledger."	Design principle 29 (Decide ledger type)
	B.27	"Back-ups, working product I think. Actually we did not discuss that so much. Security is of course guaranteed by the distributed copies in the network. You can assume that it is managed and you do not need an extra copy."	Design principle 30 (Consider back-ups)
	B.28	"Correct, maybe in the exploration phase. It is optional there I think. There are many questions about what we are going to do with it and what is the impact on us?"	Design principle 31 (Define project goals)
	B.29	"Is a big blockchain question of course. How scalable are blockchains at the moment? Not really, is the answer. You can see that many projects are waiting for that, until their process can run smooth and without high costs. That really comes between prototype and working product, when you choose for a ledger type. What is acceptable and what not? If you go for the Internet-of-Things and transactions between devices, for example millions of transactions a day, it will be expensive with Ethereum. It depends on the ledger type. At the prototype it is not yet that important, because at the moment no blockchain is scalable enough to have a large scale project. Zuidhorn is a good project, but is not yet on the public network of Ethereum. It is a small scale project in the sense only a limited amount of people and twelve stores are involved. If they want to do it for the entire Netherlands, you can ask if Ethereum is scalable enough."	Design principle 32 (Scalability)
	B.30	"We discuss it now and them, but it also correlates with scalability."	Design principle 33 (Transaction speed)
	B.31	"I agree with this as it is now."	Design principle 34 (Good UI/UX design)
	B.32	"It depends how you do the conceptualization phase, if you want to determine that early on or not. I manage a pilot now where you want to know very precise if it is possible to share certain income information in a very large network, without enabling every organization to see all information. The UWV[20] for example cannot see all information, it is simply not legally allowed. Certain things yes, but other things not. It makes sharing everything in a ledger very complex. It also depends on the process. That is of course fundamental to have clear when going towards a working product."	Design principle 35 (Determine authorizations)
	B.33	"Sometimes it is technology driven and sometimes it is problem driven. With us there is always a mix of wanting to know what blockchain can do and wanting to solve the problem. That always needs fitting. In a normal project where these elements also are applicable, you know very well how technology can help you. And then you start. So there is still a learning element in it."	Framework feedback

[20]Dutch Employee Insurance Agency.

	B.34	"What in the testing phase costs much time compared to the concept is that in the conceptualization phase you can act as if all stakeholders are involved. But if you test you need a good story and it would be a waste if you test it by yourself. It can be done, working with made up data, but you see that many ask other organizations if they want to be involved. Because if they do not want to cooperate, what is the point then?"	Design principle 9 (Involve stakeholders)
DApp.Design	DD.1	"He said that the coming time we will see that it is difficult to find people who can actually develop."	Lack of developers
	DD.2	"They said that the knowledge about blockchain is very bad at the management and IT."	Lack of developers
	DD.3	"You also need people who can communicate it to the managers, the people who spend the money."	Design principle 12 (Communicate significance)
	DD.4	"Yes that is there. At the moment we do not account for that. We saw multiple meetings where legal people joined. Our adagio is: build first. When we encounter legal issues, we address them." … "The problem I have as entrepreneur, when Airbnb had given a presentation in the Netherlands before they started, where housing corporations and lawyers were present, they would have said: this is not possible, if you rent a house you cannot sublet a room. Now they do not care, it is implemented and a problem for the big cities. Same goes for Uber." … "Unless it is legally forbidden, then you should not do it." … "It is good it is in here and definitely good when you go towards a working product. I actually think you should start accounting for it at the Proof of Concept."	Design principle 1 (Research legal implications)
	DD.5	"Yes, I find *define a vision* good that municipalities and particularly governments have a clear policies towards projects and innovation. Strangely enough, the private sector is behind on them. So they actually made a vision. As developer, I can only follow that vision: we want to innovate. So as developer we follow the vision of the municipalities and the governments in this case."	Design principle 2 (Define a vision)
	DD.6	"That is also applicable for Schiedam, that they did that beforehand."	Design principle 6 (Profitability)
	DD.7	"I totally agree with that, that is a problem. There are very few of them. That is why we started an initiative to train people." … "We notice that there are hardly any developers. We concluded that we have to train them ourselves."	Design principle 7 (Find experts)
	DD.8	"Yes, you should definitively do that." … "You cannot do it on your own. Also open source organizations. I dislike large IT organizations, they are really on the business case. I would say do it from the Proof of Concept."	Design principle 8 (Cooperate with other organizations)
	DD.9	"Yes, I think you should do that. It is a condition to make the process a success." … "I see it is only applicable from the working product. It could slow down the process." … "I notice that the entire IT sector is moving towards DevOps[21]. Everyone needs knowledge from different fields." … "You should know the entire slang of IT." … "But I agree. You involve stakeholders when you have something to show."	Design principle 9 (Involve stakeholders)
	DD.10	"I totally agree. It is share, share, share. It is interesting from the second column (conceptualization)."	Design principle 10 (Share results)
	DD.11	"At FBA for example I do not have knowledge about the financial background. People there know everything about the substance and I am constantly e-mailing them." … "We have blockchain knowledge, but we need to hear from someone else what we need to build." … "I would say, multidisciplinary team from the start. Maybe you should scale up. Start small in the conceptualization phase and scale up. You want to solve something and you should understand the problem."	Design principle 11 (Multidisciplinary team)

[21] Development and Operations.

	DD.12	"I noticed at a certain municipality that the project team already had four or five meetings before we joined. Other organizations who cooperated did not see the merit. With our experience it is wise to involve us from the start, so also the correct project team can be made. At the end it did not succeed. I think if you want to communicate the significance, you should do that from the start."	Design principle 12 (Communicate significance)
	DD.13	"My experience is that people want to know: what is in it for me? If they sense that it will impact their job in the future, you have a problem. I did a project where people really needed to be educated about the added value of the project. I think that it is important to communicate." … "I would not start with that too early, you do not want to cause commotion. The working product is a good moment to show the pros and cons."	Design principle 13 (Examine impact on jobs)
	DD.14	"Yes, I agree with that."	Design principle 14 (Involve supervisor)
	DD.15	"Why do you have this one? I think this is culture. I would almost say, scrap it. I think this is an effect. The cause is that we start a project, the effect is that you have to cooperate."	Design principle 15 (Cooperate internally)
	DD.16	"Yes, I agree you do that the last moment. If you do that beforehand, you get long discussions. The moment something is build you can start the discussion." … "It is not something we are troubled with. Yes, we build things that changes processes and of course you should examine that. But do it as late as possible. Actually, when it is done, you are already experiencing it."	Design principle 16 (Examine shifting role of the government)
	DD.17	"I think you should do that at the prototype already. The prototype already more or less shows the implications. The moment you have the prototype you already think about that."	Design principle 17 (Understand implications)
	DD.18	"I do not agree. For Schiedam we will build a prototype, where we do not account for security. In IT you have different roles: in one role you can do this and in the other you cannot. This is RBAC[22]. Everything around it you will think about with the working product. The prototype is quick-and-dirty. The prototype is always made in a secured environment."	Design principle 19 (Security)
	DD.19	"Yes, totally agree."	Design principle 20 (Open source coding)
	DD.20	"I get the question now: why do you not apply blockchain? Why not a database? I think it will be the other way around in a few years."	Assess applicability of blockchain
	DD.21	"Yes, from the Proof of Concept onwards."	Design principle 22 (Map the process)
	DD.22	"I would call it build. Developing is broader. You already developed it, and now we are going to build it."	Design principle 23 (Prototype development)
	DD.23	"I agree that you should start small. Nice about blockchain is that you can scale good. The scaling problems of the central computer are gone. If you made it for one party, the entire Netherlands can use it. One of the large problems in the current IT is how to scale it. Everyone struggles with it: Google and IBM. Data centers are not scalable. Yes, you can build more, but that is not the case with swarm theory."	Design principle 24 (Start with small projects)
	DD.24	"I agree you do that with the working product."	Design principle 25 (Risk assessment)
	DD.25	"The downside of standards is that you slow down development." … "Okay, I agree. I would leave it like that."	Design principle 26 (Establish standards)
	DD.26	"You should certainly do that." … "Learn from what is already made."	Design principle 27 (Learn from prior development)

[22] Role-based access control.

	DD.27	”We choose for a public ledger now, Ethereum. Private solutions exist of course. At the moment you account for security, we should think about the constraints.” … “I know the privacy laws. Since the last version of Ethereum, zkSNARKs[23] are introduced. ING made a better, open source version. They are lobbying to introduce that to nodes. Zero knowledge is the proof that it is you or that you have certain information, without someone seeing the content. It provides privacy to people. I am strongly considering to already introduce that in the prototype, because it is technical. You should have it built in there already.”	Design principle 28 (Privacy)
	DD.28	“This has to do with privacy as well. I noticed that companies use private chains. So you see a split in the blockchain market. Actually you should tell what the selection process is. So I would say ledger type selection.”	Design principle 29 (Decide ledger type)
	DD.29	“Our design principle is no back-ups, because all nodes in the blockchain are each other’s back-up: do not do it. It is not in the characteristics of a DApp. A DApp is nothing more than an application in a computer or phone. It is yours. You connect with a ledger and is accessible from everywhere. Many central principles are not valid here anymore.”	Design principle 30 (Consider back-ups)
	DD.30	“At Schiedam we worked on basis of scrum. We show a Minimum Viable Product each time. The municipality can then decide when they think it is sufficient.” … “If you are talking about goals: of course. But those goals vary. I totally agree.”	Design principle 31 (Define project goals)
	DD.31	“Blockchain has scalability as characteristic. But, totally agree, you should think of it. It is something you should consider in your prototype, because the design determines if it is scalable.”	Design principle 32 (Scalability)
	DD.32	“This is one of the problems. If I see the developments at the moment, this is one of the major problems in blockchain. They are developing this full speed. This will be solved, this year. But not now. You can do fifteen transactions per second, which is too slow. I have an example in which two or three transactions per day are necessary, it is not a problem for that process.”	Design principle 33 (Transaction speed)
	DD.33	”Yes, I agree, you do this from the working product. I do not think you should do that from the prototype. You should show the functioning of the prototype as fast as possible. It does not have to look nice.” … “I show the prototype first and we will make it nicely looking afterwards. The basics of the UI though, is already in the design.” … “I think good is too general, you can better use *basic*, that it complies to certain standards.”	Design principle 34 (Good UI/UX design)
	DD.34	“Yes, I agree. You do not do that at the prototype, but at the working product. Maybe you should put RBAC with it.”	Design principle 35 (Determine authorizations)
	DD.35	“Then you are talking more about revenue models, return and investment. We are for the first time in the public sector with Schiedam. We started with the business case and that was completely wrong. Governments and municipalities are not about business cases, but about helping people.”	Framework feedback
	DD.36	“It is not all black and white. That is why these kind of models are difficult, it depends on the idea behind it.” … “I would like to use the model to show clients our approach: this is the process and this is the model how we do it. It is a comprehensive overview.” … “You see that blockchain is a large field where much is yet to be build. I think that this, when talking about the organizing part, is a very good document to steer with.”	Framework feedback
	DD.37	“You could hack very good with smart contracts first. Many people without coding knowledge did it unsafe. There was money in those contracts. With smart use of software you could extract the contract. But we did not do that. Others did. And they stole millions by doing that.”	Design principle 19 (Security)

[23] zkSNARKs = zero knowledge proof.

Groningen	G.1	"That is something we are still looking into. What is our policy exactly? Do we bump into certain legislation? What are the boundaries? I get the question now and then if giving out coupons is against the participation law. That is not a blockchain question though, but also other legislation, like privacy and security. That is covered already. From the start our Security Officer made sure of that."	Design principle 3 (Define clear policies and legislation)
	G.2	"That has been mediocre, because we are just working with it. I know some of it, how the network and transparency work, but it just passes me a bit. For us it is just: John Doe goes swimming, a swimming token is withdrawn from his wallet and it gets paid then"	Design principle 4 (Invest in blockchain knowledge)
	G.3	"We have budget for the Stadjerspas. Three or four years ago it was sufficient. Amongst others due to the new system, because it became user-friendly and functions well, the number of subscriptions has grown. Three years ago we had 3,000 subscription, now we have around 20,000 and we will grow towards 23,000. That pressures the budget."	Design principle 5 (Allocate budget)
	G.4	"Yes, we do that. We have an assessment framework for that. All the discounts on the app need a relation with participation or financial alleviation. Foremost to ensure people will leave their isolation and are more socially involved. It is not that they get discount for nothing, there is an idea behind it. Does it fit the vision we want?"	Design principle 2 (Define a vision)
	G.5	"We have legal experts on both substance from offers as the Security Officer. We have them inside the municipality and are on top of it."	Design principle 7 (Find experts)
	G.6	"Of course we do that often. With the organization with who we offer discounts together and other municipalities. It is one large cooperation."	Design principle 8 (Cooperate with other organizations)
	G.7	"Yes, I am working on summarizing the results of 2017, because we are not really sharing that with other organizations yet. That is not because we do not want to be transparent and maybe we will do that. I really want to do it, but I just did not have the time yet."	Design principle 10 (Share results)
	G.8	"We are working on the Stadjerspas with a team of four persons: three employees and me, for the administration and calls from members, and for the addition and deletion of discounts. That is part time and a sub part of a larger team on low income policy.	Design principle 11 (Multidisciplinary team)
	G.9	"I do not think so, because we did not shrink. We have the system of Stadjerspas that works with blockchain and we have our own administration system. Actually, that is still developing. I expect that if it runs smoothly we can do it with the current team. There are no plans to change that."	Design principle 13 (Examine impact on jobs)
	G.10	"We are cooperating internally much. If it is about swimming, it is also concerning the sports department. We have a culture department, where they find it of importance that everyone uses the library. We are the system that enables that. Within the poverty policy department, we are the tool to get the discounts to the people."	Design principle 15 (Cooperate internally)
	G.11	"We want to be like that, an organization that facilitates ideas from the population. We like to do that."	Design principle 16 (Examine shifting role of the government)
	G.12	"That is hard to measure. We notice from the reaction from people that they are enthusiastic about the card."	Design principle 17 (Understand implications)
	G.13	"When there is a hack in the system and it is hosted by DutchChain, it is their problem. It is their system. However, there is nothing to steal. We have all personal data within the municipality. We thought it through."	Design principle 18 (Define responsibilities)
	G.14	"They made a prototype for us to play with first. Afterwards we made it live."	Design principle 23 (Prototype development)

	G.15	"No, they did it quick-and-dirty. I did ask for the risks of blockchain, but we did not board it up."	Design principle 25 (Risk assessment)
	G.16	"We did not work on that."	Design principle 26 (Establish standards)
	G.17	"Yes, of course. We are currently developing our insights, both on substance and with the systems. There were some teething problems. It is still not completely finished."	Design principle 27 (Learn from prior development)
	G.18	"DutchChain definitively made a choice in that. I heard them say Ethereum."	Design principle 29 (Decide ledger type)
	G.19	"Yes, it works for the user, except for some teething problems, and it looks good."	Design principle 34 (Good UI/UX design)
	G.20	"That is settled well. What they can access, what can they do and what can they not."	Design principle 35 (Determine authorizations)
	G.21	"Our exploration was not on blockchain, but on substance. We had many complaints on the old system. We also did a client research, which problems do you encounter? What do you want to improve? Based on that we made a design brief about how we wanted to have the system function. Blockchain was not really involved then. It could have been a central database as well. It was not a goal to use blockchain."	Framework feedback
	G.22	"DutchChain tries to sell the system we have here to other municipalities as well."	Framework feedback
	G.23	"Blockchain was not a main goal. Blockchain was a means to facilitate the process we wanted. It just crossed our path as solution. We could have chosen something else." … "First we decided that the Stadjerspas had to change and blockchain came after that."	Framework feedback
	G.24	"There is not much difference. Of course, it is a political instrument for us as municipality to show that we do something extra for people with a low budget. We enable them to participate more. For another organization it might be about selling a product."	Framework feedback (Private vs. public sector)
Forus	F.1	"I think you should account for that from the start. On the other hand, it should not be that current legislation stops you from your thinking process. What technology does is changing the fundament. So I think you should think about it in the first phase." … "You think about it, but it is the question how deep you go. You do not have the intention to break the law." … " You can then later, with the prototype, start a discussion. You know by then: this are the discussion points between the prototype and the legislation. An example: for selling land you need a physical signature. When you automate that you cannot do that anymore. It does not mean it should stop you in your thinking process. You would like to sell the land with an app, without a notary or papers." … "If you show something nice with the prototype and show that it works, you can make a proposal to change legislation."	Design principle 1 (Research legal implications)
	F.2	"I think that is the most important of all. You must know why you want to use blockchain. Based on that vision you can account for the scope of your project: do you analyze one project?" … "Do you map the process in blockchain? How does the process change if there is not a central party anymore? That is not the same as translating each step in a smart contract." … "You need a broader vision for the entire organization. From there you define your future role, where things are automated. You can *blockchainify*[24], but it has to make sense. When you work out one process, you notice it touches more fields. You have to account for that in your vision and should not be naïve. It is also important who brings up the idea. Is it a commercial party who offers it, while it is not necessary?" … "There	Design principle 2 (Define a vision)

[24] Blockchainification refers to applying blockchain to a process.

		is a clear difference between blockchain and digitalization. Many processes benefit from digitalization already and blockchain is not always making things better.” … “In 99% of the cases other technology can be sufficient, but the addition of blockchain, and a crucial part of the vision, is decentralization and automation of control and trust. That is what smart contracts do.”	
	F.3	“You should definitely determine somewhere if blockchain is applicable to the process. Even if it is just a pilot, sometimes we are talking about hundreds of thousands of euros.” … “Blockchain can definitely be revolutionary for a process, but not per definition.”	Assess applicability of blockchain
	F.4	“Yes, from the very start. For someone to be able to judge if a prototype is useful, he has to know the basics of blockchain technology and that needs investment.”	Design principle 4 (Invest in blockchain knowledge)
	F.5	“That is important, but in practice difficult, because it is still early in the blockchain field. Actually, there are not many parties who know much about it. It will take a while before the principles of decentralization work through. It means there is a lack of experts, they are hard to find. And indeed, start as early as possible.”	Design principle 7 (Find experts); Lack of developers
	F.6	“Indeed, possible at the start.”	Design principle 8 (Cooperate with other organizations)
	F.7	“I would actually do that early. We contacted everyone who was important for the process relatively early. Also the one who manually keeps track of the vouchers. You can develop the product together. You involve those who are going to use the system in the first phase in order to get constant feedback.” … “The concept of the Kindpakket came from the organization. They have issues and encounter them. Everyone within the municipality of Zuidhorn also knows how blockchain works.”	Design principle 9 (Involve stakeholders)
	F.8	“We started with a hackathon. We shared the result with the organization. The results helped us a lot. With the demo we could move away from the abstract and show something tangible where people become enthusiastic about.” … “Share results: yes, very fast. But, not everything, especially the prototype.”	Design principle 10 (Share results)
	F.9	“Crucial from the start. You need people who can think conceptually, you need coders and you need people who can visualize. You also want your team to consist of stakeholders.” … “Actually also someone who was not that positive. It is pleasant to have someone like that in the room. It offers a view on the whole, which you do not have yourself.”	Design principle 11 (Multidisciplinary team)
	F.10	“You can also invest time on your own, so the moment you involve your supervisor, you can explain him the idea.”	Design principle 14 (Involve supervisor)
	F.11	“There is an IT-department in Zuidhorn, but you should consider well what you want to know from a department. On the on hand you want enthusiasm, but on the other hand you should not waste too much energy. Maybe it is partially covered by other principles.”	Design principle 15 (Cooperate internally)
	F.12	“The advantage for us was that that process was already in motion at Zuidhorn.” … “It also perfectly fits *define a vision*.” … “They for example want to work without a town hall, so employees go the people’s home.” … “That is also decentralization.”	Design principle 16 (Examine shifting role of the government)
	F.13	“I think you cannot understand it in the first phase.” … “I think that *understanding implications* is more a side effect. You want to grasp the effect of blockchain by doing. The effect of building is that you begin to understand the implications. You do not have to do it actively, it just happens.”	Design principle 17 (Understand implications)

	F.14	"In our implementation offers we did mention that. Based on the GIBIT[25]. If you look at blockchain, it is something that is developing, where the responsibilities are changing as well." … "Taking away power from central parties can offer many advantages, because the centralization of power can lead to corruption. With this technology it is possible to make technology that disallows using too much power by design. That discussion is outside the scope of a pilot." … "You cannot say beforehand who is responsible, that is too naïve. It should be a part of your pilot or product. Actually, you should tell in the workshops already that responsibilities are continually changing."	Design principle 18 (Define responsibilities)
	F.15	"It also depends on the scope of your project. The question then is how far you will go. Are we going to decentralize everything? I do not think so. Determining your scope is important, so everyone knows what is going to happen."	Design principle 21 (Process selection)
	F.16	"Yes, you should do it from the second phase."	Design principle 22 (Map the process)
	F.17	"Yes, absolutely. I think it is important you start small as fast as possible."	Design principle 24 (Start with small projects)
	F.18	"We constantly are discussing that. You should never be guided by fear, but you have to account for it." … "That is for example the person in the group who noticed many negative points." … "What is also important for us, what if my pilot fails, what are the consequences then? Are we eliminating ourselves then?"	Design principle 25 (Risk assessment)
	F.19	"You can see if there are standards that you can use, but establishing standards is something you will discuss very late." … "Actually I think of Ethereum as a sort of standard for decentralized development. You can build your own blockchain, but it will not become standard." … "Establishing standards is an ambitious goal." … "I think it is more an effect. You could look at other standards."	Design principle 26 (Establish standards)
	F.20	"Yes, absolutely. I would make something continuous of it."	Design principle 27 (Learn from prior development)
	F.21	"I would not put that under technology, it is more something general."	Design principle 31 (Define project goals)
	F.22	"Crucial." … "With the Kindpakket, that we could show something, helped us very much in other phases and conversations. That you have a product to communicate with." … "You can use that to start the discussion. With the working product it is crucial. The government does not have that incentive now, because there is no freedom of choice. If you do not like the tax authority, you have though luck. Until other parties come up who can overtake those functions. If you look at identity management, you got DigiD at the Dutch government. But Google and Facebook have real identity solutions that function globally. I think if you do not show as government it can be done in a different way, you will register your child at Google or Microsoft at some moment in time."	Design principle 34 (Good UI/UX design)
	F.23	"We want complete open source, but Kindpakket is not open source because of security. We want to do that." … "It depends on scale. You need enough eyes to look at the code, before giving it to the community. And the community has to be strong enough to do that." … "It also involves users having a wallet with money on it and that needs a high level of security." … "We are working each day to make it open source. In the long term I believe that open source coding is safe." … "The private sector probably does not want that, because they want to sell a product. We are a market party, but not a commercial party."	Dilemma: security & open source coding; difference between private & public sector

[25] Guideline with a checklist for tendering IT.

	F.24	"We have approximately 200 children in the system and until now there have been around 500 financial transactions in a few months' time." … "That is not a problem now, but you should account for it when you apply Kindpakket in for example Amsterdam or five municipalities." … "We are constantly looking at the boundaries of what is possible with the current technology."	Dilemma: scalability & transaction speed
	F.25	"The nice thing about a public chain is that it is a back-up." ... "We have that with Kindpakket at the moment. Because of the trade-offs we are still on a private blockchain. It also depends on the ledger type. Storage can be done decentralized with IPFS[26]. If you really do it decentralized with something like IPFS you are done, but it depends on your ledger type."	Dilemma: consider back-ups & decide ledger type
	F.26	"Of course. There is much investing in Zuidhorn I would say. It is a relatively large investment. And if you would only look what it would mean for the Kindpakket and what do we save with it, I think it is currently not balanced." … "But it does comply to the vision." … "You should account for a sort of business case. I think that misses in many municipalities. Where is my return on investment? It does not always have to be in euros." … "It goes to expansion. Kindpakket is not meant to work only in Zuidhorn. It will be implemented in other municipalities as well. We are talking about things like kickback, so Zuidhorn can retrieve a part of the investment back. Then Zuidhorn has done a relatively normal investment, while others still benefit."	Dilemma: allocate budget & profitability
	F.27	"In our case it was pleasant she does not lose her job, but her function changes." … "On large scale we should accept that people will lose their job. I expect that we will have more free time." … "For the lady who keeps the coupons it was scary at first, she did everything manually. Now there is a CSV-parser that automatically scans the file. She has a program on her computer now, with which she is very happy. You take something from her, but also give something back. Because we involved everyone, there was less resistance."	Dilemma: communicate significance & examine impact on jobs
	F.28	"Yes, there certainly is. We see that also with Kindpakket. We want to use a public blockchain, but cannot do so due to privacy problems. That is why we are actively researching zero knowledge solutions, which enables privacy on the blockchain. That is something of which we hope it will change in time." … "I think it also depends on your long term vision."	Dilemma: privacy & decide ledger type
	F.29	"If you use a private ledger, the one who uses the private ledger carries responsibility for the technology and you can adapt things if you would like to. You can fork internally and no one would notice. With a public ledger, the miners carry responsibility and the consensus algorithm guarantees that responsibility."	Dilemma: responsibilities & decide ledger type
	F.30	"We think that who owns the data is the one who the data is about. You will get an app where you manage your own data. Then there are no thousands of databases, where you do not know who knows what of you. What you really want is that you manage your own data, encrypted on a network. When you for example go to the general practitioner, you can provide him access to your data. I think the power should be with the end user. We are not there yet. Then you will give the authorization to the people who can comply."	Design principle 35 (Determine authorizations)

[26] InterPlanetary File System.