BLOCKCHAIN TECHNOLOGY FOR GOVERNMENTAL PROCESSES

THE DESIGN OF A BLOCKCHAIN ASSESSMENT TOOL: A DESIGN SCIENCE APPROACH

David Allessie

Master Thesis Report

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THE DESIGN OF A BLOCKCHAIN ASSESSMENT TOOL: A DESIGN SCIENCE APPROACH.

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by

David Allessie

Student number: 4172779

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Graduation committee

Chairperson: Prof.dr.ir. M.F.W.H.A (Marijn) Janssen, Section Information and Communication Technology
First Supervisor: Drs. J. (Jolien) Ubacht, Section Information and Communication Technology
Second Supervisor: Dr. S. (Scott) Cunningham, Section Policy Analysis
External Supervisor: Ir. G. (Guido) van der Harst, Gartner Consulting

FOREWORD

Curiosity drove me to read ‘The trust machine’ by the Economist in 2015 (The Economist, 2015). Never did I expect to write a full Master’s thesis on this exciting technology. After various discussions with Guido, my supervisor at Gartner, I decided to take the leap in February 2017. And what a journey it has been. This thesis drove me to both the heart of the technology and the heart of European decision-making on this topic. From participating in the first Dutch Blockchain Hackathon to being part of the first Blockchain Workshop hosted by the European Parliament, there has not been a single 'dull' moment in the last four months. The discussions I have had with experts in this field fueled my excitement to research this technology for governments. The attitudes towards this technology range from people convinced of a new world order enabled by blockchains to people seeing no benefits from blockchain at all. My view? *There is probably truth in both.*

This journey was made possible by a number of exceptional people. I would sincerely like to thank my first supervisor Jolien for her time and dedication in this research. Her knowledge on the socio-technical consequences of bottom-up platforms resulted in numerous fruitful brainstorms and her guidance was indispensable for this thesis. Even in the busiest of times she helped me if needed, for which I owe her a lot. Also, I would like to thank Scott for his expertise and the various enjoyable discussions while enjoying the TPM coffee. In addition, I would like to thank Marijn for his perspectives and insights in the world of e-government, which helped me throughout my research.

Without Gartner, this thesis would not have been possible, for which I am very grateful. I would especially like to thank Guido for supervising me on behalf of Gartner and offering me feedback throughout the process. I will miss both the spot-on discussions on blockchain and the sing-alongs on the way back from Brussels. To the whole Amsterdam and Brussels office: *it has been a pleasure!*

Lastly, I would sincerely like to thank my parents, Marc and Erica, my sister Rosa, and my friends for their support throughout my studies. Their support allowed me to explore the world, develop as a person and study at the same time. Even in the most difficult or stressful times, the 'nasi' made by my mother always worked its wonders. A last big thank you goes out to all my friends who deal with my shenanigans and crazy ideas on a daily basis. You made this journey possible!

Yours sincerely,

David Allessie

June 14th, 2017

SUMMARY

Blockchain is a technology that is able to register digital assets and the transactions of these assets in a distributed way in a peer-to-peer (P2P) network. Blockchain technology uses cryptography to make it impossible to alter transactions performed in the past. A transaction is verified by the network by a 'consensus mechanism', which is a mechanism that allows users in the P2P network to validate the transactions and update the registry in the entire network. Once validated, the transaction is locked into a block of data that is linked to the block previously validated resulting in an immutable chain of blocks containing the transaction data, hence the 'blockchain'. This technology is fundamentally different from existing information registration and exchange infrastructures and has the potential to reshape the way governments are able to interact with citizens, economic operators, and each other (Atzori, 2015).

Traditionally, to ensure the data integrity of data and to avoid fraud, society has formed a number of intermediaries, like banks, to act as a centralized authority keeping track of all transactions (Swan, 2015b). In blockchain systems, the transaction logs are immutable and digital assets can per definition only be send once. Therefore, this technology can have significant impact on institutions as we know them today. It can change the way how society interacts and runs economies (Davidson, De Filippi, & Potts, 2016b). Blockchain technology has the potential to provide benefits in governments and can present the next step in e-government development, as they enable *reduced costs and complexity*, *shared trusted processes*, *improved discoverability of audit trials* and *ensured trusted recordkeeping* (Palfreyman, 2015). However, literature on blockchain technology for e-government is scarce and a systematic analysis of the value of blockchain technology for the processes of public administrations is lacking.

The European Union is exploring the possibilities of blockchain for their services and processes as a bottom-up approach to the coordination of citizens and economic administrators. Blockchain enables the EU to achieve their *subsidiary* principle, as it enables the services to be provided in a distributed way at the lowest level of government while facilitating a better exchange of information between citizens and economic operators. However, the multi-actor complexity and the systems complexity of blockchain technology create unstructured decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology, resulting in a proliferation of blockchain experiments that do not provide significant value (Ametaro, 2017). In addition, different goals of governmental actors create different attitudes towards blockchain in the EU. In order to fully capture the potential of blockchain technology, enhanced decision-making in this area by EU Institutions and Bodies is needed.

A number of knowledge gaps cause this unstructured decision-making. First, the way blockchain technology challenges the role of public administrations is unclear. Second, insight in the technological and multi-actor complexity of governmental blockchain applications that can cause unintended outcomes is lacking. Third, awareness on the fit with blockchain technology for governmental processes and the socio-technical effects that blockchain implementations in governments can present is underdeveloped. Lastly, blockchain is often viewed as a one-size-fits-all solution, while the blockchain type and the consensus mechanism each impact the systems performance. An assessment tool is needed that provides insight into the value of blockchain in governments and allows for the structural assessment of the fit with blockchain for an information exchange or registration process.

This thesis aims to enhance decision-making in EU Institutions and Bodies regarding the value of experimenting with blockchain technology to improve their information exchange or registration processes. It addresses this objective by designing a *blockchain assessment tool* that assesses the fit between the information registration or exchange process, the organization and blockchain technology. It also provides insight into the design and effects of the implementation of blockchain. The Design Science approach as defined by Johannesson and Perjons (2014) is used as a guideline, to combine insights from both empery and established literature in the design of the *blockchain assessment tool*. In order to achieve the objective of this study, the following main research question is formulated:

*How can a **blockchain assessment tool** enhance decision-making by EU Institutions and Bodies regarding the experimentation of blockchain technology to improve their information exchange or registration processes?*

The Design Science approach is executed in 7 steps: *1) Problem Exploration, 2) Problem Explication, 3) Requirements Definition, 4) Artefact Design, 5) Artefact Demonstration, 6) Artefact Evaluation*, and 7) *Research Conclusion*. In the problem exploration, the problem as outlined above is identified and the research approach is determined. The problem explication phase presents the six relevant elements important in the *blockchain assessment tool* using a review of literature. Departing from an e-government perspective, but including New Institutional Economics, Public Choice and Complex Multi-Actor Systems perspectives, the systematic review of literature provides six elements that are important in the *blockchain assessment tool*, as they are of relevance for EU Institutions and Bodies when deciding to experiment with blockchain technology.

1) *Complexities*. The multi-actor nature and the systems complexity create uncertainties in blockchain implementation in governmental organizations, emerging from the multi-actor nature, the legacy systems, the nature of interactions, the public interest involved and the uncertainties of the governmental blockchain implementation.
2) *Process factors*. To investigate the applicability of blockchain for governmental processes, a number process factors determine the fit between the process and blockchain technology. These factors refer to the general context, prioritization factors, process characteristics and data and processing power.
3) *Organizational factors*. Various organizational factors determine public organization's ability to adopt blockchain technology successfully. These factors can be divided in five domains: support factors, perceived technology factors, organizational factors, collaboration factors and external factors.
4) *Decision-making*. Decision-making in EU Institutions and Bodies in this area is unique and complex with different actors, activities, roles and organizations involved, and to enhance this process, the blockchain assessment should be tailored to this decision-making process.
5) *Ripple effects*. Governmental blockchain use cases can cause socio-technical effects on multiple layers of institutions, and insights in these effects allow decision-makers to avoid unintended effects that might include a changing role of governments and diminishing geographic boundaries. These effects can be divided in three layers: 1. *primary effects* (on the organization itself), 2. *secondary effects* (on the actors in the network) and 3. *tertiary effects* (on society).
6) *Design features*. The different blockchain types (permissionless/permissioned, public/private) and consensus mechanisms impact the systems performance on the following process criteria; system reliance, control, actor transparency, external transparency, data assurance, security, scalability and energy efficiency of the system.

The elements are used as a basis for the design of the *blockchain assessment tool*. Figure A provides an overview of these elements.

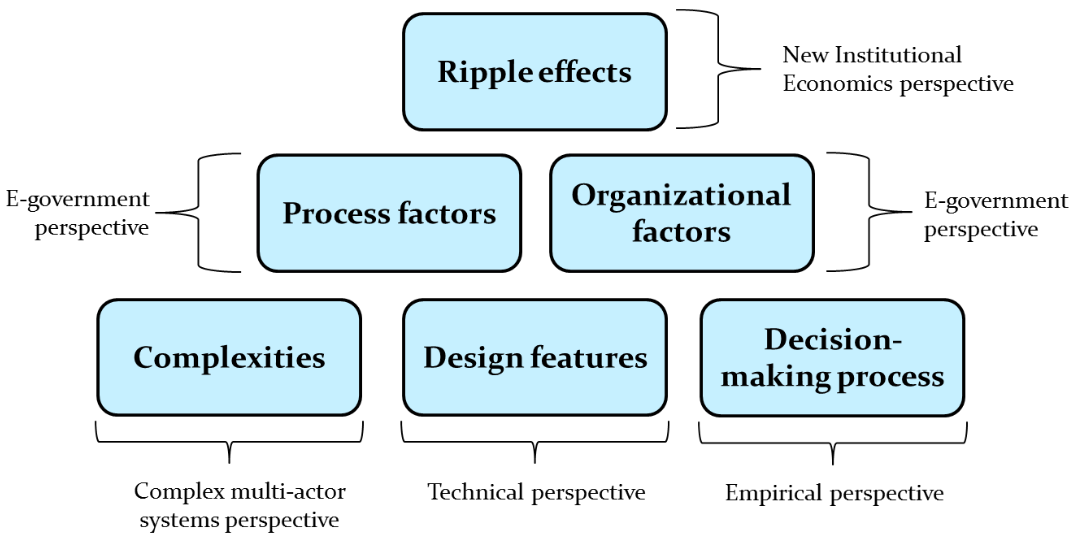

Figure A. Overview of the six elements for the blockchain assessment tool

In the requirements definition phase, empirical data on the six elements is gathered using 11 explorative interviews. Using both Qualitative Data Analysis and Matrix Prioritization Analysis, the elements are concretized and translated into requirements for the *blockchain assessment tool*. Based on these requirements, the *blockchain assessment tool* is designed using a Morphological Chart to structure the design process. Two case studies demonstrate the designed *blockchain assessment tool*, and 5 expert evaluation interviews are conducted to evaluate the *blockchain assessment tool*. On the basis of the Design Science approach, the *blockchain assessment tool* is designed. The *blockchain assessment tool* consists of three steps that allow a user to assess the blockchain fit, create a high-level blockchain design and to map the ripple effects. The users of the tool, decision-makers in EU Institutions and Bodies can follow the steps in sequence or iteratively, allowing the decision-maker to learn throughout the process. Figure B presents the visual representation.

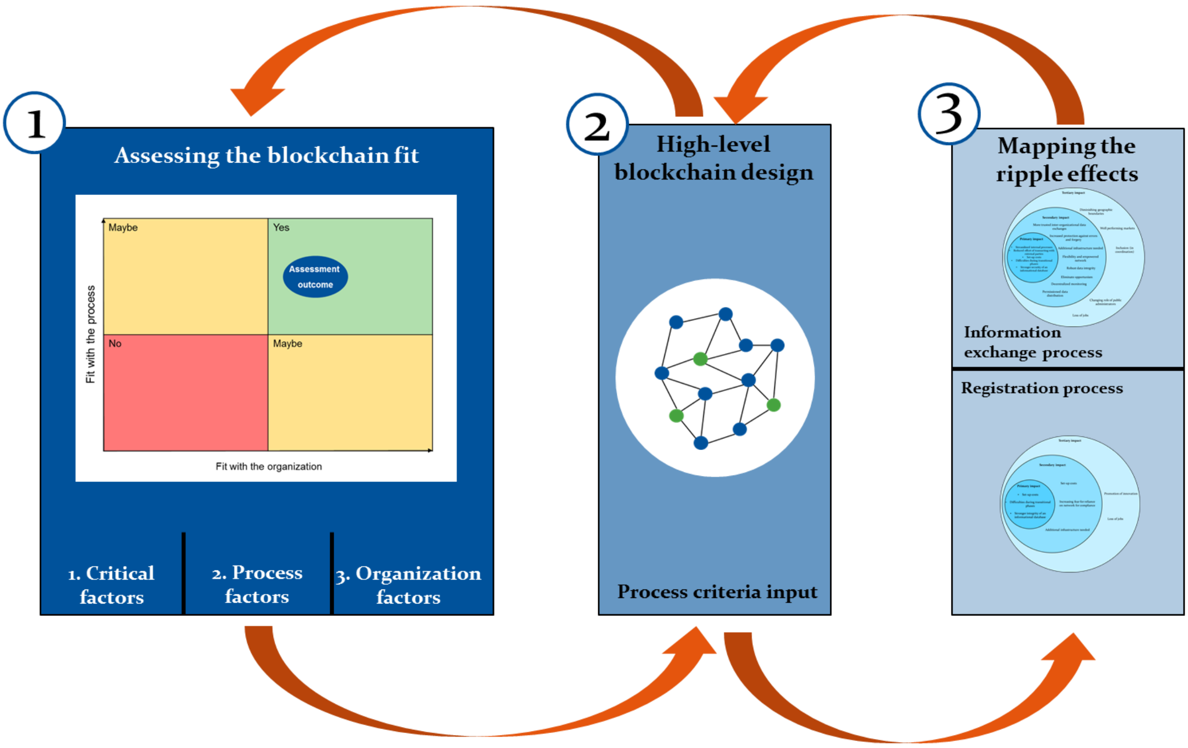

Figure B. Blockchain assessment tool application process

The first step of the tool assesses the fit between the process, the organization and blockchain technology. The blockchain assessment tool provides a blockchain process fit score based on statements that the decision-maker answers. The statements are divided into three parts:

1. *Critical factors.* The critical factors assess whether the blockchain use case makes sense. These critical factors are displayed in the beginning, so that if these are negatively assessed, this is known early in the decision-making process.
2. *Process factors*. The process factors assess the fit between the information exchange or registration process and blockchain technology, which are mapped in four factor domains: *general context, data and processing power, current process characteristics* and *prioritization factors*.
3. *Organizational factors.* The organizational factors assess the fit between the organization and blockchain technology. Five factor domains are used in this part*: support factors, perceived technology factors, organizational factors, collaboration factors* and *external factors*.

The complexities related to *the multi-actor nature, the legacy systems, the nature of interactions, the public interest involved* and the *uncertainties in the system* that refer to the process are incorporated in the process-blockchain fit statements and the ones referring to organizational factors are incorporated in the organization-blockchain fit statements.

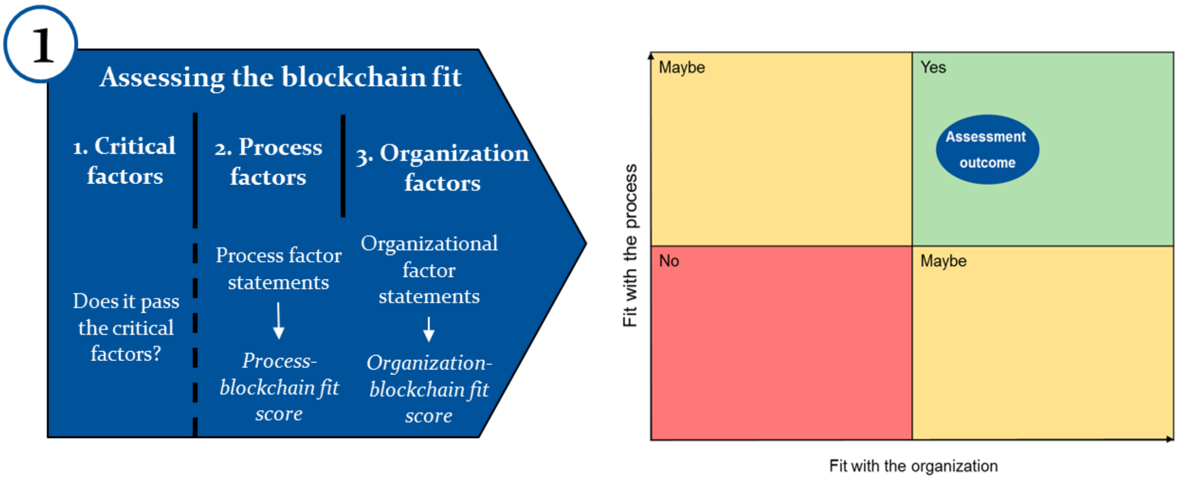

Figure C. Step 1 of the blockchain assessment tool: Assessing the blockchain fit

The second step of the tool allows for the high-level design of the type of blockchain application. As the design features of blockchain systems impact the systems performance which can be expressed with a number of process criteria, an appropriate design of the blockchain system must be chosen. Users of the tool can indicate their preferences on the following process criteria; *system reliance, control, actor transparency, external transparency, data assurance, security, scalability* and *energy efficiency*. This results in an advice on which blockchain type and consensus mechanism is the most appropriate for this process.

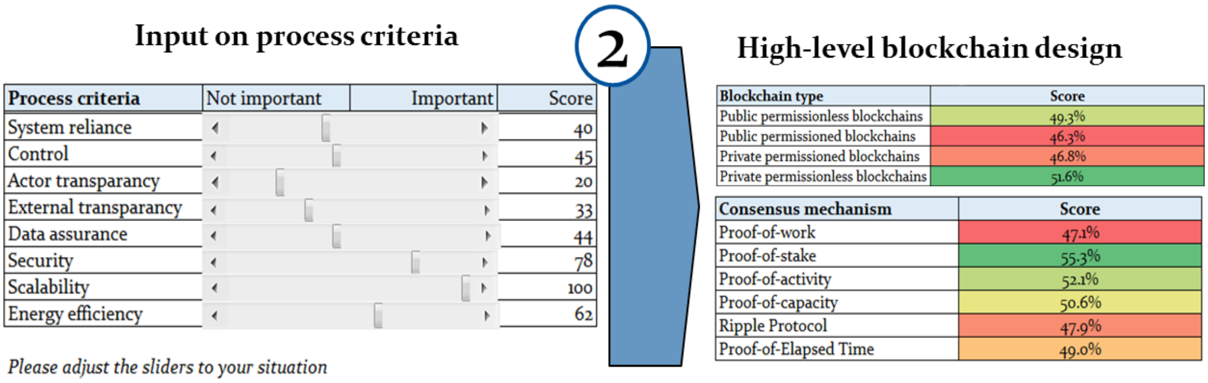

Figure D. Step 2 of the blockchain assessment tool: High-level blockchain design

The third step presents the potential effects of either the information exchange or registration process using blockchain technology. As a thought experiment, the decision-maker can estimate the effects on three layers: 1. *primary effects* (on the organization itself), 2. *secondary effects* (on the actors in the network) and 3. *tertiary effects* (on society). In this step, the decision-maker can map the effects based on his/her own assessment.

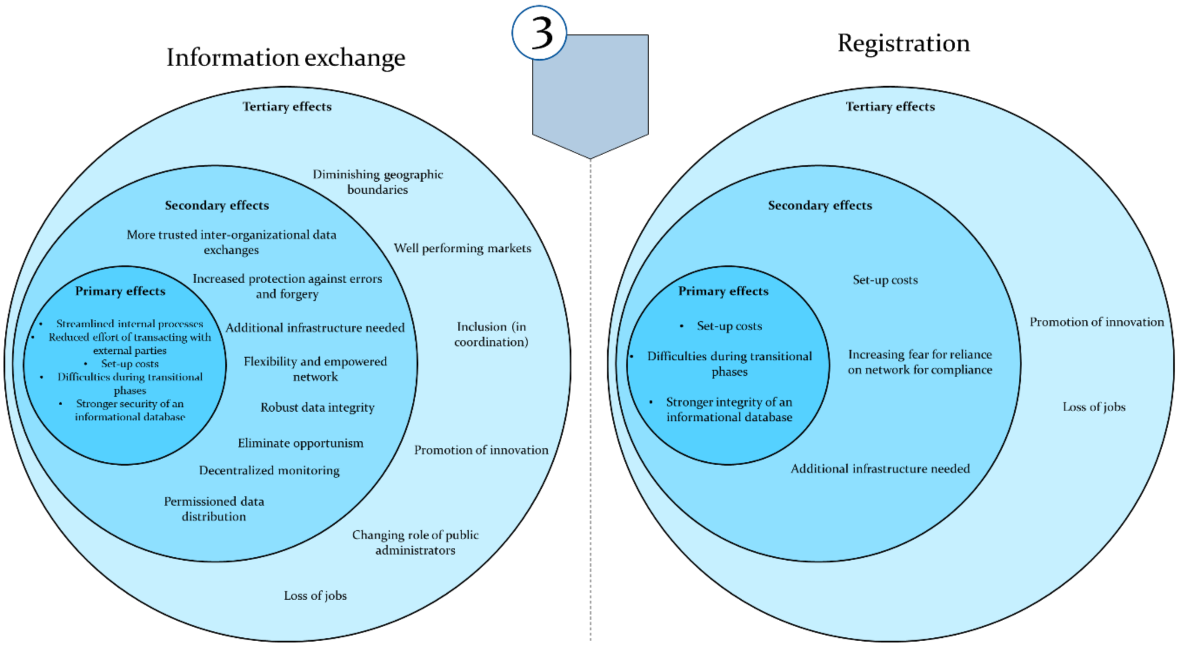

Figure E. Step 3 of the blockchain assessment tool: Mapping the ripple effects

The two case studies present a demonstration of how the *blockchain assessment tool* can illuminate the applicability of blockchain technology for an EU Institution or Body: a system that monitors the movements of excise goods under duty suspension called EMCS and an Emissions Trading System (ETS) based on blockchain. While the tool demonstrates that blockchain fits well for EMCS system, it also shows that an ETS on blockchain has some potential drawbacks because legal assessment tool does not allow for experimentation, the potential benefits are currently not outweighing the costs and there is no further independency between the actors caused by the interaction.

The two case studies also elucidate the differences of the effects caused by blockchain technology between the information exchange and registration processes. The *blockchain assessment tool* provides the insight that an information exchange process (EMCS) using blockchain technology could enable a changing role of the public administration: from an electronic intermediary towards a more supervisory role. For the registration process (ETS), this would present complete disintermediation in the public administration, which is believed to create a certain amount of fear of having to rely on a network when complying with regulations.

In the expert evaluation interviews, feedback was gathered on the design and usability of the *blockchain assessment tool*. It was found that the need, structure and logic of the blockchain assessment tool was well understood by experts in the field. The steps performed in this Design Science research approach answer the main research question: *How can a blockchain assessment tool enhance decision-making by EU Institutions and Bodies regarding the experimentation of blockchain technology to improve their information exchange or registration processes?*

Future work on the blockchain assessment is recommended to focus on improving the tool by adding a governance design block and incorporating the view of the citizen in the tool. Future research is suggested on the factors and ripple effects. The factors and effects in this thesis are based on existing literature and complemented by empirical research, but research into whether these effects are complete can improve the validity of the tool. In addition, future research is suggested on the trade-offs between the design features to provide a better view on the possible blockchain architectures. Also, more research into the openness and interoperability of blockchain systems could create more depth in the debate of permissionless versus permissioned blockchains in governments. Lastly, research into applying Value Sensitive Design for blockchains could enable the design of permissionless blockchain systems where authorities can be supervisors to protect public values in permissionless blockchains.

Keywords: *Blockchain, Design Science, E-government, EU Institutions, Technology Assessment Tool*

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TERMINOLOGY

Table A. Terminology of this thesis

Term used	Description
Artefact	The object that is to be designed in the design science research, designed to address the research gap.
Blockchain assessment tool	The tool designed in this thesis that assesses the fit between the process, the organization and blockchain technology and that provides insight into the design and effects of the implementation of blockchain.
Complexity	A complex element of blockchain implementation that is "difficult to describe, understand, predict, manage, design or change" (De Weck et al., 2011, p. 186).
Decision-making process	The process for making decisions and understanding the technology for the implementation of blockchain technology in an EU Institution or Body.
Design component	A component of the design of the blockchain assessment tool based on the requirements. The design of the blockchain assessment tool is a combination of all the design components.
Design features	The various options that architects have when designing blockchain systems.
Design Science research	Design Science research is the "study and creation of artefacts as they are developed and used by people with the goal of solving practical problems of general interest" (Johannesson & Perjons, 2014, p. 7)
Design space	The design space is a "space of possibilities" (MacLean, Young, Bellotti, & Moran, 1991)p.203 that displays the various design options that are able to satisfy the a number of predefined requirements.
E-government	"The use of information and communication technologies, particularly Internet, as a tool to achieve better government" (Field, 2003, p. 63).
Element	An overarching element that is of importance for blockchain implementation in governments and is therefore taken into account in the design of the blockchain assessment tool.
Evaluative expert interviews	Third round of interviews with various blockchain experts to evaluate the blockchain assessment tool.
Interactive case study interviews	Second round of interviews experts in EU Institutions and Bodies that are used to map and prioritize the ripple effects of a blockchain use case.
Explorative expert interviews	First round of interviews with experts in EU Institutions and Bodies whose findings are translated into requirements for the blockchain assessment tool.
Method Framework for Design Science research	A framework of methods to structure the design science research, in order to ensure quality of results and to present the research in a logical way (Johannesson & Perjons, 2014).
Morphological chart	A structure that allows for the generation of various design components based on the requirements of the artefact.
Organizational factor	A factor that refers to the elements of an organization that impact the ability to adopt blockchain technology in a governmental organization.
Process criteria	The criteria that determine the blockchain systems' performance *(system reliance, control, actor transparency, external transparency, data assurance, security, scalability* and *energy efficiency)*.
Process factor	A factor that refers to either the environment of the process or to the process itself, that assess the applicability of a blockchain system for the information exchange or registration process of the EU Institution or Body.
Requirement	A physical and functional need that the blockchain assessment tool must be able to perform.
Ripple effect	An effect on the public organization, the network involved or on society, caused by an implementation of blockchain for the information exchange or registration process of an EU Institution or Body.
Technology assessment tool	A tool that allows for the structural analysis and evaluation of a technology

I. PROBLEM IDENTIFICATION & RESEARCH APPROACH

Blockchain technology is an emerging technology that is able to facilitate direct interaction between citizens and economic operators in information registration and exchange processes. It can present a technological and institutional innovation when applied in governments. Blockchain systems are extremely complex as they encompass both multi-actor complexity and systems complexity, making experimentation with this technology by governments difficult. EU Institutions and Bodies are actively exploring the possibilities of blockchain technology for their processes, but decision-making regarding blockchain experimentation is still unstructured. To enable EU Institutions and Bodies to fully capture the potential of blockchain technology and enhance their decision-making in this area, this research designs a blockchain assessment tool that assesses the fit between the process, the organization and blockchain technology and that provides insight into the effects of the implementation of blockchain. A Design Science approach is used to structure the design process of the tool, as it uses both existing knowledge and empirical findings to design the tool to make it fit-for-purpose.

This chapter introduces the emergence of blockchain for governments (paragraph 1.1) and defines blockchain as an institutional innovation and as a complex multi-actor system (paragraph 1.2). The position of blockchain in e-government literature is examined and the exploration of the EU regarding blockchains is described in paragraph 1.3. The knowledge gaps regarding the experimentation with blockchain technology in EU Institutions and Bodies are introduced in paragraph 1.4. The need for a structural assessment of the fit with blockchain for an information exchange or registration process results in the objective of this thesis: the design of a blockchain assessment tool that facilitates EU Institutions and Bodies to enhance their decision-making regarding the experimentation with blockchain technology. The Design Science research approach of this research and the various steps to answer the research questions and design the blockchain assessment tool is introduced in paragraph 1.5. This chapter ends with a summary of the problem identification in paragraph 1.6.

1.1 THE EMERGENCE OF BLOCKCHAIN

The development of information technology (IT) has enabled governments to deliver services more directly to citizens, in a phenomenon called e-government. E-government is "the use of information and communication technologies, particularly Internet, as a tool to achieve better government" (Field, 2003, p. 63). The concept of e-government originated from the need for cost-reduction and effectiveness enhancement by governments. Nowadays, an effective e-government is acknowledged as a crucial factor in an effective government and a competitive society (Wimmer, Codagnone, & Janssen, 2008). E-government connects three distinct groups of stakeholders: *politicians, public institutions,* and *citizens, businesses and civil society* (Jansen, 2005). Traditionally, e-government initiatives have focused on one of the three dimensions connecting these groups; *e-democracy*, *e-service* and *e-administration*.

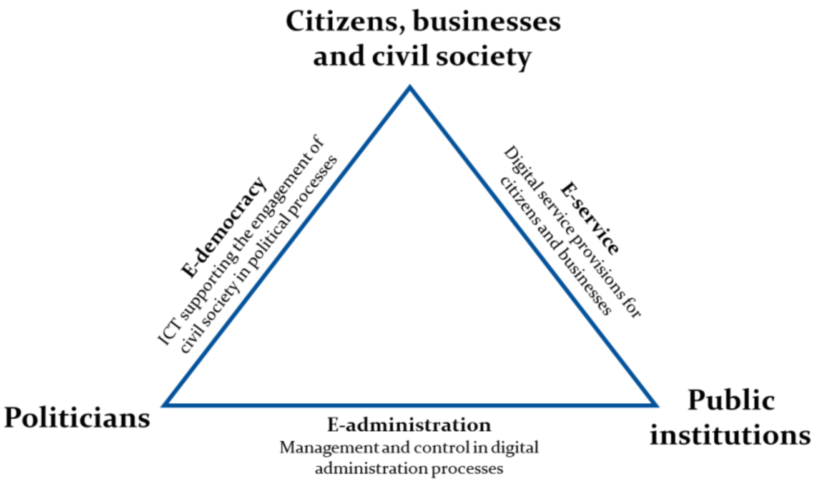

Figure 1. Three major dimensions in e-government initiatives [adopted from Jansen (2005)]

Now, a technology has emerged that opens up a world of possibilities in the field of e-government (Ølnes, 2015). This technology is a combination of existing technologies combined into a new information infrastructure, and is reshaping the way governments are able to interact with citizens, economic operators, and each other (Atzori, 2015). This technology holds the fundamental promise of facilitating direct interaction between citizens, and thereby providing administration without a governmental administrator and tailoring services provided by governments (Swan, 2015b). This facilitates the opportunity to rethink the current institutions in society. The technology enabling this revolution is *blockchain*.

Blockchain finds its origin in a paper published by an anonymous (group of) author(s) called Satoshi Nakamoto. In this paper, the idea of a Bitcoin was introduced as a purely peer-to-peer (P2P) electronic transaction network that allows for direct financial transactions instead of via a financial institution (Nakamoto, 2008). The infrastructure on which this network is based in called blockchain. To simplify, blockchain technology allows two actors in the system (called nodes) to transact in a P2P network and stores these transactions in a distributed way across the network (Back et al., 2014). It registers the owners of the assets that are transacted and the transaction itself. A transaction is verified by the network by a 'consensus mechanism', which is a mechanism that allows users in the P2P network to validate the transactions and update the registry in the entire network (Warburg, 2016). To ensure privacy, not everybody can view the full details of the transaction, as only the actors in the network that own the key to the encryption can view it. Every transaction is time stamped. Therefore, it can be built upon the previous transaction, forming a chain of blocks: hence the name 'blockchain'. Validation of the blocks is not done by a trusted intermediary, but via consensus algorithms that run on the computers in the P2P network. While the internet connects people, things and information, the blockchain connects transactions of value (Gartner, 2016a).

The blockchain addresses the 'double spending' problem. The double spending problem refers to the fact that digital information can be copied using the internet. If, for example, somebody would send a digital asset like a digital paper of ownership of a car to someone else, then there is a risk that the sender sends a copy over the internet and still keep the original paper of ownership (EVRY, 2016). Traditionally, this risk was mitigated by having trusted third parties, like banks, to act as a centralized authority keeping track of all transactions (Swan, 2015b). Blockchain technology shifts this responsibility of validating that the assets actually been send to the whole network, thereby eliminating the need for a centralized database. Every actor in the network has a copy of the record of transactions, and any change of ownership of the digital assets in the system requires validation from its users. More details on the process of transacting on a blockchain can be found in Appendix A.1 Transacting on blockchain technology and A.2 The mathematics behind transacting via blockchains.

The blockchain is considered to be a General Purpose Technology (GPT) by a number of researchers (Böhme, Christin, Edelman, & Moore, 2015; Swan, 2015a, 2015b; Tapscott & Tapscott, 2016a). The rise of a GPT can affect the entire economy and examples include the rise of the automobile, the computer and the Internet. However, when investigating the potential of blockchain, one must be aware of the hype currently surrounding it (Gartner, 2016b). In their 2016 Hype Cycle for Emerging Technologies, Gartner predicts a 5 to 10 year timespan until mainstream adoption, but with transformational benefit potential (Gartner, 2016b). They project that, like with most new technologies, blockchain technology cannot live up to the overinflated expectations, that interest will reduce and it will take a certain amount of time until the technology demonstrates real-world benefits and is accepted. Therefore, blockchain can be considered as a 'push' technology. A 'push' technology is where stakeholders are proactively looking for problems and use cases, and is the contrary of a 'pull' technology, where the problems in the marketplace create the need for a new technology (Martin, 1994). Researchers in this area should be aware of the current hype surrounding blockchain and should be critical towards its potential and value. Various definitions of blockchain technology exist, and the next section presents the definition of blockchain that is used in this thesis.

1.2 Defining blockchain

As there is little consensus on the definition of blockchain technology, the thesis of Meijer (2017), uses a literature review to construct an encompassing definition of blockchain technology. This definition incorporates the concepts of users, consensus mechanisms, the platform function, and two key attributes:

public/private and permissioned/permissionless. In addition, it incorporates the features that this technology displays from both distributed computing systems and a distributed database systems. Meijer (2017) presents the following definition:

> *"A blockchain is a distributed, shared, encrypted, chronological, irreversible and incorruptible database and computing system (public/private) with a consensus mechanism (permissioned/permissionless), that adds value by enabling direct interactions between users." (Meijer, 2017, pp. 6-7)*

Warburg (2016) presents an example to clarify the technology, using Wikipedia. Wikipedia is an open platform that stores images and words and the changes to this data over time (Warburg, 2016). On this platform, anybody can contribute by writing or rewriting pages on any topic, and the additions or adjustments are verified by specific users that have proven to be valuable to the platform. The blockchain differs from Wikipedia as it uses a consensus mechanism where certain mining nodes verify the transactions on the platform, while Wikipedia uses reputation mechanisms. Another difference is that on the blockchain, instead of just images and words, many different types of assets can be stored. Whereas Wikipedia only stores the history of custodianship, ownership and location of information on their platform, the blockchain can store the history of any type of value (Warburg, 2016). The blockchain can store any digital asset, including *information, "money, deeds, titles, music, art, scientific discoveries, intellectual property* and *votes*" (Tapscott & Tapscott, 2016b, p. 1). As this can have significant impact on the institutions that we know today, the next section analyses blockchain as an institutional innovation.

1.2.1 Blockchain as an institutional innovation

The blockchain is a novel technology that is not only a computer science innovation, but also an innovation that is radically changing the way how we interact and run economies (Davidson et al., 2016b). As humans, we have been forming and building institutions like legal institutions, corporations and marketplaces that facilitate our trade (North, 1990). The foundation of designing and creating these institutions is to lower uncertainty about the intentions and capabilities of the counter party and thereby increasing trust, so that we can exchange value. The emergence of the blockchain comprises an innovation that can be analyzed as a technological institution (Warburg, 2016). Traditionally, the formal institutions in society are either political (governments) or economic institutions (banks, corporations and other trusted intermediaries like notaries). Now, the technological institution called blockchain can radically change how humans exchange value. The blockchain can lower transaction uncertainty with technology alone and connect all sorts of value in society in a decentralized, autonomous way (Warburg, 2016).

Whereas in the past, the uncertainty about the intentions and capabilities of the counter party hindered interaction between citizens and economic operators, and required the design and creation of institutions like banks, governments and corporations, the blockchain can lower these uncertainties (Warburg, 2016). It does so by increasing trust in that the counterparty will keep the other end of the bargain by creating an immutable record of transaction that is stored locally at every participant in the system. In addition, it increases both transparency and privacy, as the record of transactions is known to all the actors in the system, but it is still mathematically anonymized using cryptography. Thereby, blockchains can be used in networks to collaborate and exchange more and more openly (Czepluch, Lollike, & Malone, 2015). Some authors argue it is a decentralized database with the efficiency of a centralized database, without having a centralized authority (Warburg, 2016). Therefore, the blockchain can be considered as a technological institution with all the benefits of other, real world institutions, yet realizing this in a decentralized, digital way. This new technology truly presents a paradigm shift in society as the user of blockchain puts his or her trust in math instead of putting his or her trust in people (Antonopoulos, 2014).

1.2.2 Blockchain as a complex multi-actor system

Blockchain is considered to be highly disruptive, as it affects how value is exchanged, how transactions can be regulated and how communities are able to organize their transactions. This can be primarily seen in the first and most famous application of blockchain: Bitcoin. The Bitcoin is a crypto-currency, meaning that it is a P2P payment system on which the Bitcoin is used as a currency, and where cryptography ensure the privacy of participants even though the ledger is fully transparent and the software is open-source. Blockchain systems are extremely complex as there is both multi-actor complexity and systems complexity

(Pruyt, 2010). Consequently, a *complex multi-actor system perspective*, as defined by Pruyt (2010), is used to analyze this technology.

Multi-actor complexities are characterized by issues that include “different actors with different perspectives and goals [and where the] interaction of actors might lead to complex decision-making processes and to unforeseen/unintended effects” (Pruyt, 2010, p. 511). *Systems complexity* refers to “a system with components and interconnections, interactions, or interdependencies that are difficult to describe, understand, predict, manage, design, or change” (De Weck et al., 2011, p. 186). From this perspective, it is argued that two types of complexities lead to high uncertainties regarding these systems, especially when implemented in a highly institutionalized environment like governments (Meijer, 2017), which is introduced in the next section.

1.3 BLOCKCHAIN FOR E-GOVERNMENT

Currently, the majority of blockchain applications is focused on the financial sector. However, an increase in interest of the public sector in this technology can be seen in the increase in literature and experimentation in this sector. Current experiments of blockchain technology in the public sector include archival records on an open distributed ledger in the USA, an e-residency program in Estonia with identities of citizens on blockchain, a land registration system on blockchain in Georgia and many more (Mougayar, 2016a). The main benefits of applying blockchain technology in governments, are argued to be *reduced costs and complexity*, *shared trusted processes*, *improved discoverability of audit trials* and *ensured trusted recordkeeping* (Palfreyman, 2015).

Before 2014, blockchain research was primarily focused on Bitcoin, and mainly concentrated on its technological, economic, and regulatory aspects (Böhme et al., 2015; Hendrickson, Hogan, & Luther, 2015; Ølnes, 2015; White, 2014). Yet, the narrow scope only focusing on the Bitcoin application of blockchain technology does not acknowledge the possibilities and applications of blockchain. Since 2015, blockchain technology is slowly emerging in e-government literature. As Ølnes (2015) argues in his review of literature on blockchain in e-government, too little research is dedicated towards the potential of this major technological breakthrough in the public sector and what it can do for future development in e-government, and “it is high time to do something about that” (Ølnes, 2015, p. 7)

In the last two years, more researchers have focused on exploring new fields of application for blockchain and examining the governance potential in these new areas (Yong & Feiyue, 2016). Current research indicates many opportunities for governments to utilize blockchain technology (Swan, 2015b; Tapscott & Tapscott, 2016a, 2016b), as they do not have a central administration blockchain-based systems can ensure the integrity of government records and services (Oja, 2016). Blockchain can enable governments to move away from being a registration actor towards a service providing actor. Looking beyond the blockchain’s initial use case, the Bitcoin, blockchain technology enables a completely different way of looking at data sharing, transparency and trust between governments and citizens given its fundamental differences with traditional data storage and digital transactions (Shrier, Larossi, Sharma, & Pentland, 2016; Yermack, 2015).

Methodology of the literature review on blockchain in governments

For the Problem Identification, an initial literature study was performed into the potential of blockchain technology in governments. Academic databases Google Scholar and Scopus were used with the following keywords: *Blockchain, Blockchain Technology, E-government, Complex Systems, Institutions, European Union.* This resulted in the scientific articles used in Chapter 1. Due to the novelty of this technology, semi-academic articles and corporates reports were found using web searches. In addition, to identify the current state of affairs in the European Union regarding blockchain, reports published by EU institutions were used.

1.3.1 Primary processes of public administrations

Current literature points to two primary governmental processes that can be improved by blockchain: *information/asset exchange* and *registration* (Atzori, 2015; Davidson et al., 2016b). This thesis investigates the potential of blockchain technology for these two primary processes in public administrations: *information exchange* and *registration*. Public administrations facilitate the *exchange of information* between actors to regulate networks, in order to coordinate interaction and ensure a high level of data quality in the system. These networks often involve reasons for regulation like tax collection, the fact that the service in the network is essential for the welfare of citizens and to ensure social inclusion. Examples of these information exchange processes include the facilitation of trade information between traders, the exchange of criminality information, the distribution of grants, the exchange of information in infrastructures like energy and roads and the exchange of information regarding academic degrees. The *registration* process is provided by public administrations also to check whether actors in a networks comply with regulations. These checks are put in place to regulate the network, and avoid fraud and abuse in these networks. In addition, registration allows for the design of effective policies, which for example can be seen in the case of civil registration. If the number of births and deaths is registered accurately, effective public health policies can be designed. Other examples of registration in governments include land registration, vehicle registration, civil registration and property registration.

1.3.2 Blockchain in the European Union

EU Institutions and Bodies are, like many other parties in the public sector, exploring the possibilities of blockchain for their primary processes (Bucher, 2016; Van Zuidam, 2016; Yermack, 2015). Blockchain can enable a more bottom-up approach to the coordination of citizens and economic administrators, relying on more horizontal coordination mechanisms than hierarchical ones. From a governance perspective, the governance mechanisms in place in blockchain systems challenge the way society has originally constructed the authority of governments and its relation with citizens (Atzori, 2015). The European Union is a supra-national government that develops systems and policies in to exchange information between citizens and economic operators in and between Member States, in policies areas like customs, criminality, supply chain, agriculture and education. The EU also provides a number of EU-wide registries like the EU Clinical Trials Register, EU Shipping Register, EU ETS registry and a number of patient registries. The information exchange and registration processes of EU Institutions and Bodies can benefit from blockchain technology as this technology facilitates direct asset transactions, automatic execution of tasks by smart contracts, the decentralization of process governance and increased transparency and audibility caused by the hashing function of blockchain systems (Ølnes, 2015; Swan, 2015b; Tapscott & Tapscott, 2016a).

In addition, the European Union has one principle that increases the interest of the EU towards blockchain technology more than national governments: the *subsidiarity* principle. The subsidiarity principle is one of the three general principles of EU law making: attribution, proportionality and subsidiarity. The subsidiarity principle encompasses that functions and services must be provided at the lowest level of governments possible (EU, national, regional or local), only being provided by higher levels of governments if necessary. Blockchain enables the services to be provided in a distributed way at the lowest level of government while facilitating a better exchange of information between citizens and economic operators.

Different attitudes depending on the governmental actor type can emerge. Strom (1990) presents a classification of three governmental actor types: vote-seeking actors, policy-seeking actors and office-seeking actors. Vote-seeking actors seek to maximize their electoral support in order to gain control in a government (Strom, 1990). Policy-seeking actors look to maximize control and effect on public policy (Strom, 1990). Office-seeking actors look to maximize the internal control in the public administrations rather than win over votes (Strom, 1990). The vote-seeking actors are likely looking for blockchain technology as a way to showcase their innovative character as this technology is entering mainstream media. The policy-seeking actors might have a less positive attitude towards blockchain, as this technology has the potential to distribute (part of the) power and control on public policy and service towards citizens and economic operators. The office-seeking actors are more likely to have a negative attitude towards this technology, because blockchain technology has the potential to reshape institutions and public organizations as we know them today. The distribution of control in information exchange or registration processes traditionally provided by public administrations contradicts the goals of office-seeking actors that aim to control the executive branch of governments.

1.4 Research problem

Given the multi-actor complexity and the systems complexity, decision-makers in the EU Institutions and Bodies must be aware of the impact of this technology on the trust and governance in these systems as well as the institutional and technical uncertainties these present, before adopting blockchain technology for their processes. Institutional uncertainties refer to the uncertainty of how this technology will fit and shape current institutions and processes, and technical uncertainties refer to the uncertainty on the maturity of the technology. The distributed nature of blockchain systems can create uncertainties regarding the control in the network. The impact of blockchain technology has the potential to alter governance structures (Davidson, De Filippi, & Potts, 2016a). In other words, the way governments structure their operations, thereby impacting existing institutions and the power positions in these systems (Pierson, 2000). The changes in checks and control in the processes in blockchain systems potentially enables a changing role of public administrations (Atzori, 2015). The decentralized character of blockchain might cause certain public organizations to lose power, as the registration information exchange processes are distributed to the lowest level of government. The attitude of the decision-maker towards blockchain can differ depending on the goals and aims of the actor.

At the moment of writing (May 2017), blockchain technology is still rather immature. A measurement for technology maturity that is often used, is the Technology Readiness Level (TRL), originally designed by NASA. Blockchain is at TRL4 or TRL5, meaning that the technology is currently validated in both labs and relevant environments, resulting in the growing number of proof-of-concepts and pilots. The current generation of blockchain has limitations in terms of scalability, flexibility and governance. In addition, current legacy systems in place also facilitate complexity, as the system is different compared to traditional systems in all technical layers (Mougayar, 2016b). This creates technical uncertainty which EU Institutions and Bodies should be aware of regarding blockchain implementation. Therefore, EU Institutions and Bodies should not immediately look for a market-ready full-scale blockchain system implementation but rather decide whether to experiment with this technology for their information exchange or registration process or not.

The increasingly positive attitude of the EU towards blockchain technology can be seen in a report by Boucher, Nascimento & Kritikos (2017) for the European Parliament: *"Blockchains shift some control over daily interactions with technology away from central elites redistributing it among users."* (Boucher, Nascimento, & Kritikos, 2017, p. 4). While an increase in interest in blockchain can be seen in the increase of reports published by EU Institutions and Bodies, the tentative reflection on in which areas and organization the blockchain technology would fit has only started in 2017, as the Scientific Foresight Unit of the European Parliament mentions in their first in-depth analysis on blockchain technology for the EU (Boucher et al., 2017). Decision-making regarding the experimentation with blockchain technology by EU Institutions and Bodies is still unstructured, resulting in a proliferation of blockchain experiments that do not provide significant value (Ametaro, 2017). Different goals of the various actor types that can be found in governments result in divergent attitudes towards blockchain technology. Enhanced decision-making regarding the value of experimenting with blockchain technology to improve their information exchange or registration processes enables a structural deliberation of the applicability of blockchain technology and the experimentation of blockchain in processes where it can provide benefit. As blockchain technology is highly complex from a multi-actor perspective and a systems perspective, enhanced decision-making in this area by EU Institutions and Bodies is needed to fully capture the potential of blockchain technology. The next paragraph presents the knowledge gaps of this thesis.

1.4.1 Knowledge gaps

Although an increase in research that focuses on exploring various use cases for applying blockchain in governments and the EU is apparent, a number of knowledge gaps appear.

First, the way blockchain technology challenges the role of public administrations is unclear. The distributed nature of this technology is fundamentally different than traditional ways of registration or the facilitation of information exchange provided by governments. Public administrations traditionally rely on control in these processes, but blockchain can potentially shift this control more towards citizens and economic operators (Boucher et al., 2017).

Second, insight in the technological and multi-actor complexity of governmental blockchain applications that can cause unintended outcomes is lacking, as a complex multi-actor perspective on blockchain is not made explicit in literature. However, the implementation of blockchain technology in governments constitutes of a number of complexities. These complexities present technological and institutional uncertainties in governmental blockchain applications, and need to be considered to avoid unintended outcomes in blockchain experimentation in governments.

Third, awareness on the fit with blockchain technology for governmental processes and the socio-technical effects that blockchain implementations in governments can present is underdeveloped. To structurally assess the applicability of blockchain technology for governmental use cases, factors are needed to determine the fit between blockchain technology and governmental processes. These are not explicitly mentioned in current literature and need to be explored. In addition, it is unclear what organizational factors determine the ability to adopt blockchain technology in public organizations and how the decision for experimenting with blockchain technology is reached in EU Institutions and Bodies is reached. An overview of the effects of blockchain implementations in governments is needed to anticipate the consequences of this technology for the EU.

Lastly, an overly simplistic view on the design of blockchain systems is dominant in research investigating blockchain use cases in governments. Blockchain systems can differ in terms of openness of participation, openness of validation and the way the validation mechanism works. The way the blockchain system is designed impacts the systems performance, so blockchain systems cannot be considered a one-size-fits-all solution. Research exploring potential use cases of blockchain ignore the different design features of blockchain and their impact on the systems performance. To fully estimate the impact of blockchain technology in governmental processes, the design features of blockchain systems need to be considered in the decision-making process.

These knowledge gaps and the different attitudes towards blockchain of various governmental actors lead to unstructured decision-making on blockchain experimentation in EU Institutions and Bodies, resulting in blockchain experiments that do not provide significant value (Ametaro, 2017). An assessment tool is needed that provides insight into the value of blockchain for these processes allows for the structural assessment of the fit with blockchain for an information exchange or registration process. These knowledge gaps are combined in the following main research gap:

Blockchain technology has the potential to improve information exchange and registration processes in EU Institutions and Bodies, but an assessment tool that provides insight into the value of blockchain for these processes is lacking.

To enable EU Institutions and Bodies to assess the fit of blockchain technology for their information exchange and registration processes, a tool is needed tool that provides insight into the fit for blockchain for this process and organization and its effects. Therefore, this thesis addresses the following research objective:

To enhance decision-making in EU Institutions and Bodies regarding the value of experimenting with blockchain technology to improve their information exchange or registration processes, by designing a blockchain assessment tool that assesses the fit between the process, the organization and blockchain technology and that provides insight into the effects of the implementation of blockchain.

This research will present a scientific contribution, as it contributes to e-government and blockchain literature. This research also has societal relevance, as enhanced decision-making of EU Institutions and Bodies provides value for both the EU and society. The blockchain assessment tool will be the practical deliverable of this research. The scientific relevance, societal relevance and practical deliverable will be elaborated in the following paragraphs.

1.4.2 Scientific relevance

While the benefits of blockchain technology for government are often mentioned, e-government literature analyzing blockchain technology is still scarce. This thesis will contribute to e-government literature as it explores blockchain technology as the next step in e-government. Also, it contributes to blockchain literature by systematically analyzing the potential of blockchain technology for governments, whereas blockchain literature currently mainly focused on other sectors (Yong & Feiyue, 2016). A complex multi-actor system perspective on blockchain is currently not offered in literature, to which this research contributes as well. The elements that are incorporated in the blockchain assessment tool are drawn from Public Choice Theories, New Institutional Economics, E-government, and Complex Systems literature. These four domains refer the knowledge gaps that this research addresses, and complement each other for the purpose of this research. The blockchain assessment tool will be based on literature, yet supported by practice.

1.4.3 Societal relevance

This thesis will be relevant for both EU Institutions and Bodies, and for citizens and economic operators. Enhanced decision-making in EU Institutions and Bodies regarding the experimentation of blockchain technology to support their processes allows for the appropriate allocation of tax payers' money and avoids the high costs involved in unsuccessful blockchain experimentation and implementation. Better informed decisions in this area also include the critical reflection of the negative effects of this technology that is currently 'pushed' towards the marketplace, as this technology can present a changing role for public administrators. For citizens and economic operators this research is relevant as it explores the fit between blockchain technology and e-government processes. Blockchain systems can contribute to a more effective EU if applied in a good fit between process and technology, and this research explores this fit.

1.4.4 Practical deliverable

This thesis will produce the following main practical deliverable:

A blockchain assessment tool that facilitates EU Institutions and Bodies to enhance their decision-making regarding the experimentation with blockchain technology to improve their information exchange and registration processes.

A technology assessment tool in this thesis is defined as a tool that allows for the structural analysis and evaluation of a technology. The blockchain assessment tool will be a technology assessment tool tailored for blockchain technology for EU Institutions and Bodies. The intended users of the blockchain assessment are decision-makers in EU Institutions and Bodies, responsible for developing policies or for facilitating information exchange or registration processes. Both executive EU agencies and Directorate-Generals (DGs) of the European Commission fall under this definition. Executive agencies have a constituent document or founding regulation in which their mandate, objectives, tasks and organizational structure are set out (Groenleer, 2009). Directorate-Generals of the EC are branches of the EC dedicated to a specific field of expertise and are responsible for proposing and implementing policy within their designed field of expertise. The objectives of the DGs go beyond proposing new- or improvements to executive tasks of the EU, but this research focusses on the *information exchange and registration* processes alone. Appendix A.3 EU Institutions and Bodies provides an overview of all agencies and DGs that fall under this definition.

1.4.5 Research problem summary

Summarizing, it is stated that blockchain technology can provide benefits to EU Institutions and Bodies, citizens and economic operators but multi-actor complexity and the systems complexity makes decision-making in this area a difficult task. Unstructured decision-making is resulting in a proliferation of blockchain experiments that do not provide significant value and multiple attitudes towards this technology exist between different governmental actor types. There however no assessment tool that provides insight into the value of blockchain for the information exchange and registration processes of EU Institutions and Bodies. This research is aimed at the design of such a blockchain assessment tool, that assesses the fit between the process, the organization and blockchain technology and that provides insight into the effects of the implementation of blockchain. The following paragraph elaborates on the design of the research that is used to develop this tool.

1.5 Research design

This research is design-oriented, as it intends to develop an assessment tool to support the decision-making regarding the experimentation of blockchain technology of EU Institutions and Bodies. Therefore, the Design Science approach as defined by Johannesson and Perjons (2014) is used as a guideline. In a Design Science study, the goal is develop an artefact that is fit for purpose, using the existing knowledge and theories as a departure point and exploring the environment in which the artefact will be functioning (Johannesson & Perjons, 2014). A Design Science study produces both an artefact that addresses the research problem and knowledge both the artefact itself and the environment of this artefact (Johannesson & Perjons, 2014). The next paragraphs will introduce the research questions, elaborate on the research approach, the research strategy and the steps that result in the design of the blockchain assessment tool in this research.

1.5.1 Research questions

Based on the research problem formulation, the following main research question is constructed:

How can a blockchain assessment tool enhance the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology to improve their information exchange or registration processes?

The following sub-questions will help answer the main research question, and correspond to the Design Science approach that is used to develop the blockchain assessment tool in this research:

1. *What is currently known about the potential of blockchain technology in governments?*
2. *What are the elements that need to be incorporated in the design of a blockchain assessment tool for EU Institutions and Bodies?*
3. *What are the requirements for a blockchain assessment tool that supports decision-making regarding blockchain experimentation in EU Institutions and Bodies?*
4. *How does a blockchain assessment tool for EU Institutions and Bodies look like?*
5. *How can the feasibility of the blockchain assessment tool be demonstrated?*
6. *How can the blockchain assessment tool be evaluated?*

The following paragraph discusses the approach that is used to answer these questions.

1.5.2 Research approach

The Design Science Research Cycle as introduced by Hevner (2007) is at the basis of the Design Science approach by Johannesson & Perjons (2014). The Design Science Research Cycle consists of three cycles: the Relevance Cycle, the Rigor Cycle and the Design Cycle (Hevner, 2007). The Rigor Cycle is where this research departs: the selection of the kernel theories that are used as a lens for the design: E-government, Public Choice, New Institutional Economics and Complex Multi-Actor Systems theories (Johannesson & Perjons, 2014). The Relevance Cycle concerns the empirical side of the research domain, which is where this thesis uses explorative interviews to define the requirements for the blockchain assessment tool, as well as for the evaluation of the design. The Design Cycle draws insights from both the knowledge base and environment, in which the design of the blockchain assessment tool is created. Figure 2 presents the Design Science Research Cycle and how this thesis will connect to it.

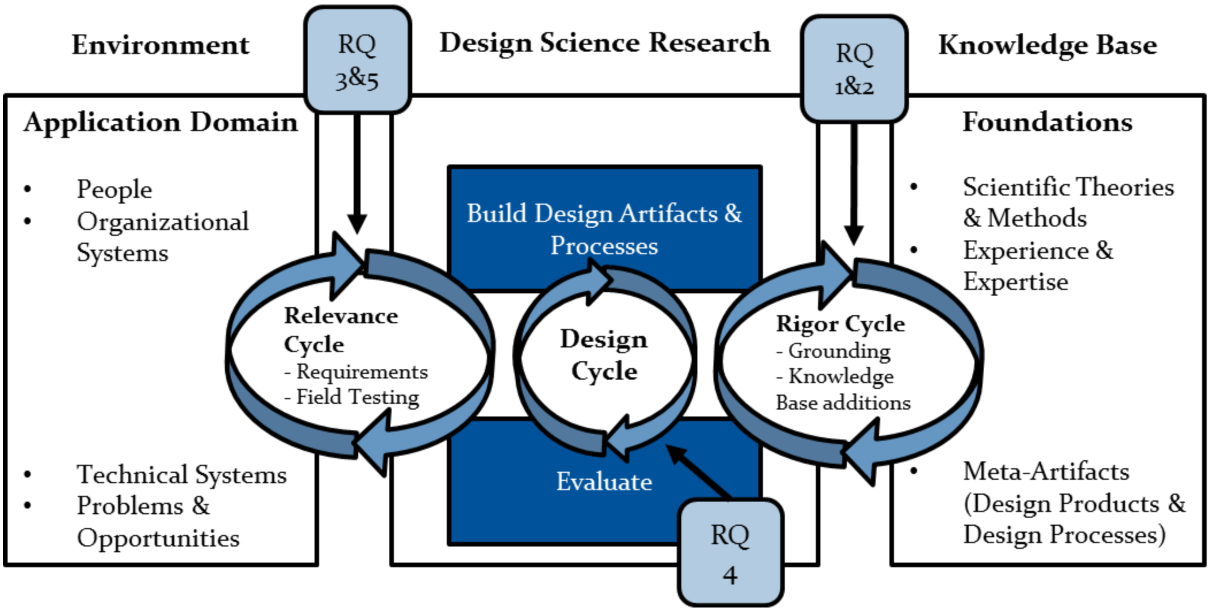

Figure 2. Design Science Research Cycle and the research questions [adjusted from Hevner (2007)]

To structure this design-oriented research, the Method Framework for Design Science research as presented by Johannesson & Perjons (2014) is used to ensure quality of results and support in presenting the research in a logical way (Johannesson & Perjons, 2014). This framework consists of the following high-level activities*: 1) Explicate Problem, 2) Define Requirements, 3) Design and Develop Artefact, 4) Demonstrate Artefact* and *5) Evaluate Artefact*. The *Explicate Problem* activity is explicates the research problem and investigates what is already known about this problem. The *Define Requirements* activity transforms this problem into requirements of the proposed artefact. The *Design and Develop Artefact* is the activity where the artefact is designed that fulfils the defined requirements. The fourth activity called *Demonstrate Artefact* demonstrates the feasibility of the artefact, in the form of an "illustrative or real-life case" (Johannesson & Perjons, 2014, p. 76). The last activity of the Method Framework for Design Science, *Evaluate Artefact*, focusses on assessing how well the artefact fulfils the requirements and how well it solves the research problem (Johannesson & Perjons, 2014). The next paragraph discusses how this approach is used in this research.

1.5.3 Research strategy and steps

Departing from the five activities as defined in the framework by Johannesson & Perjons (2014), this thesis uses seven steps instead of five to answer the research questions, design the blockchain assessment tool and conclude the research. The Method Framework for Design Science departs from an initially defined problem. This thesis adds a step to also structure the problem exploration process. In addition, the Method Framework for Design Science does contain an evaluation step, yet this step only evaluates the designed artefact. This thesis also uses this step, but adds a separate conclusion step, which answers the research questions of this thesis. An overview of the research strategy and the steps that are used in the research are discussed in the next paragraphs.

A research strategy is an overview of the steps and methods to perform the research study (Johannesson & Perjons, 2014). This research uses a literature review, expert interviews, Qualitative Data Analysis, Matrix Prioritization Analysis, case studies and expert validation interviews as research methods. The overview of the research strategy is presented in Table 1. The different research steps are described in more detail in the next paragraphs.

Table 1. Overview of research strategy of this thesis

Research step	Chapter	Design Science Method Framework activity	Sub-question	Deliverable	Research strategy or method	Data collection method
1. Problem Exploration	I. Problem Identification	1. Explicate Problem	*None*	Overview of potential of blockchain technology for governments; Identified issues of EU Institutions and Bodies regarding their executive processes; Defined scope	Literature review	Literature and reports
				Research approach	Design Science Method Framework	Method defining
2. Problem Explication	II. Theoretical Background	1. Explicate Problem	*1. What is currently known about the potential of blockchain technology in governments?*	Overview of literature on blockchain technology adoption in governments	Literature review	Literature review
			2. What are the elements that need to be incorporated in the design of a blockchain assessment tool for EU Institutions and Bodies?	Elements that are important for designing a blockchain assessment tool for EU Institutions and Bodies		
3. Requirements Definition	III. Requirements Definition	2. Define Requirements	*3. What are the requirements for a blockchain assessment tool that supports decision-making regarding blockchain experimentation in EU Institutions and Bodies?*	Empirical data on decision-making process and blockchain assessment factors	Expert interviews	Explorative expert interviews
				Formulated requirements and content of the assessment tool	Qualitative Data Analysis & Matrix Prioritization Analysis	Literature review
4. Artefact Design	IV. Design	3. Design and Develop Artefact	*4. How does a blockchain assessment tool for EU Institutions and Bodies look like?*	Design of blockchain assessment tool	Case study	Creative methods; Morphological Design Space chart
5. Artefact Demonstration	V. Demonstration	4. Demonstrate Artefact	*5. How can the feasibility of the blockchain assessment tool be demonstrated?*	Extra requirements from case studies; Demonstrated blockchain assessment tool	Case study	Desk research and evaluative expert interview
6. Artefact Evaluation	VI. Evaluation	5. Evaluate Artefact	*6. How can the blockchain assessment tool be evaluated?*	Evaluated blockchain assessment tool by experts in the field	Expert evaluation interviews	Logical expert evaluation interviews
7. Research Conclusion	VII. Conclusion	Not existent	*MQ: How can a blockchain assessment tool enhance the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology to improve their information exchange or registration processes?*	Answers to the research questions; Reflection; Recommendations for future research	Synthesis and generalization	Findings from conducted research

Step 1: Problem Exploration

The first step of this research explores the problem at hand. This step is done in Chapter I Problem Identification & Research Approach. This chapter presents the knowledge gaps regarding the experimentation with blockchain technology in EU Institutions and Bodies, the research question and the projected artefact to address the scientific and societal knowledge gap. This step is part of the *Explicate Problem* activity within the Method Framework for Design Science research by Johannesson & Perjons (2014).

Step 2: Problem Explication

The second step is also part of the *Explicate Problem* activity within the Method Framework for Design Science research. This step explores what is currently known about the problem in the knowledge base. The research methodology that this step uses is a literature review and aims to answer the first research question: *What is currently known about the potential of blockchain technology in governments?* A drawback of a literature review in this novel topic is that a full overview of all literature is difficult to guarantee due to the novelty of the topic and the fragmented literature using several theoretical lenses.

This is mitigated by departing the research from the four knowledge gaps identified in the problem exploration. Therefore, the literature review is divided into four separate sections, blockchain challenging the role of governments, blockchain as a complex multi-actor system, blockchain for e-governments and blockchain system design.

Explicating the problem even further, based on the literature review, this step also answers the second research question: *What are the elements that need to be incorporated in the design of a blockchain assessment tool for EU Institutions and Bodies?* The focus of this phase is on investigating the different elements that are described in literature that are of importance to consider for the experimentation with blockchain technology and that can address the research problem. These elements form the basis of the requirements and content of the blockchain assessment tool and make sure the tool is embedded in the body of knowledge. This step is found in Chapter II Theoretical Background.

Step 3: Requirements Definition

Next, the third steps draws insights on the identified elements from the environment. This step uses empirical data to 'concretize' the elements which are used as the content of the blockchain assessment tool. Based on these concretized elements, the requirements of the tool are formulated. A requirement is a "property of an artefact that is deemed as desirable by stakeholders in a practice and that is to be used for guiding the design and development of the artefact" (Johannesson & Perjons, 2014, p. 103). This includes both functional and non-functional design requirements for the blockchain assessment tool. This phase answers research question 3: *What are the requirements for a blockchain assessment tool that supports decision-making regarding blockchain experimentation in EU Institutions and Bodes?* For this step, empirical data is gathered using explorative interviews with experts from EU Institutions and Bodies. The protocols of the explorative interviews are based on the elements found in the theoretical background. Based on these explorative interviews, the elements identified in literature are made concrete using Qualitative Data Analysis and a Matrix Prioritization Analysis, which is explained in Chapter III Requirements Definition. The requirements of the blockchain assessment tool are formulated based on these concretized elements.

Step 4: Artefact Design

The *Design and Develop Artefact* activity as outlined by Johannesson & Perjons is described to "create an artefact that addresses the explicated problem and fulfills the defined requirements" (Johannesson & Perjons, 2014, p. 117). In this thesis, this step answers research question 4: *How does a blockchain assessment tool for EU Institutions and Bodies look like?* The blockchain assessment tool is designed on the basis on the concretized elements and defined requirements in step 3, and this step uses a Morphological Chart to structure the design process. Chapter IV Design describes this step.

Step 5: Artefact Demonstration

Step 5 demonstrates the designed blockchain assessment tool. This demonstration step is found in the Method Framework for Design Science research as the *Demonstrate Artefact* activity. In this step, two cases are described on which the blockchain assessment tool is used for a registration and an information exchange process for an EU Institutions or Body. Both desk research and interactive case study interviews are used for the case studies. This step answers research question 5*: How can the feasibility of the blockchain assessment tool be demonstrated?* The demonstration of the designed blockchain assessment tool is described in Chapter V Evaluation.

Step 6: Artefact Evaluation

Step 6 of this thesis evaluates the blockchain assessment tool. This step uses expert evaluation interviews to evaluate the design of the blockchain assessment tool. Using the expert evaluation interviews, the quality and appropriateness of the designed blockchain assessment is evaluated. This step answers the sixth research question: *How can the blockchain assessment tool be evaluated?* The evaluation step is described in Chapter VI Evaluation.

Step 7: Research Conclusion

The final step of this thesis is concludes the research, answering the main research question: *How can a blockchain assessment tool support the decision-making regarding the experimentation of blockchain technology of EU Institutions and Bodies in pursuance of executing their information exchange or registration processes?* The main research question is answered in Chapter VII Conclusions by answering all research questions of this thesis, generalizing the findings and confronting them with existing literature. In this chapter also a reflection on the research is projected and suggestions for future research are presented.

1.5.4 RESEARCH FLOW DIAGRAM

A visual overview of the different research steps, the chapters and how this aligns with the Method Framework for Design Science is now presented. This research flow diagram displays the input and the output of each of the research activities. It also displays the research steps, the chapters and the research questions. The research flow diagram is visualized in Figure 3 on the next page.

1.6 SUMMARY OF CHAPTER I

This chapter presented the knowledge gaps regarding the experimentation with blockchain technology in EU Institutions and Bodies. The multi-actor complexity and the systems complexity of blockchain technology makes decision-making in this subject a difficult task, resulting in a proliferation of blockchain experiments that do not provide significant value. To capture the benefits of blockchain in processes where this technology is applicable in the EU, a blockchain assessment tool is needed that allows for the structural assessment of the fit with blockchain for an information exchange or registration process. This tool will enhance decision-making regarding the experimentation with blockchain technology in EU Institutions and Bodies. This chapter also described the research design that this research uses to address the research question. Departing from the Method Framework for Design Science research as outlined by Johannesson & Perjons (2014), this research will use seven steps to answer the research questions and design the blockchain assessment tool: *1. Problem Exploration, 2. Problem Explication, 3. Requirements Definition, 4. Artefact Design, 5. Artefact Demonstration, 6. Artefact Evaluation* and *7. Research Conclusion*. The next chapter will present the second step of this research: Problem Explication, which consists of a literature review on the potential of blockchain technology in governments.

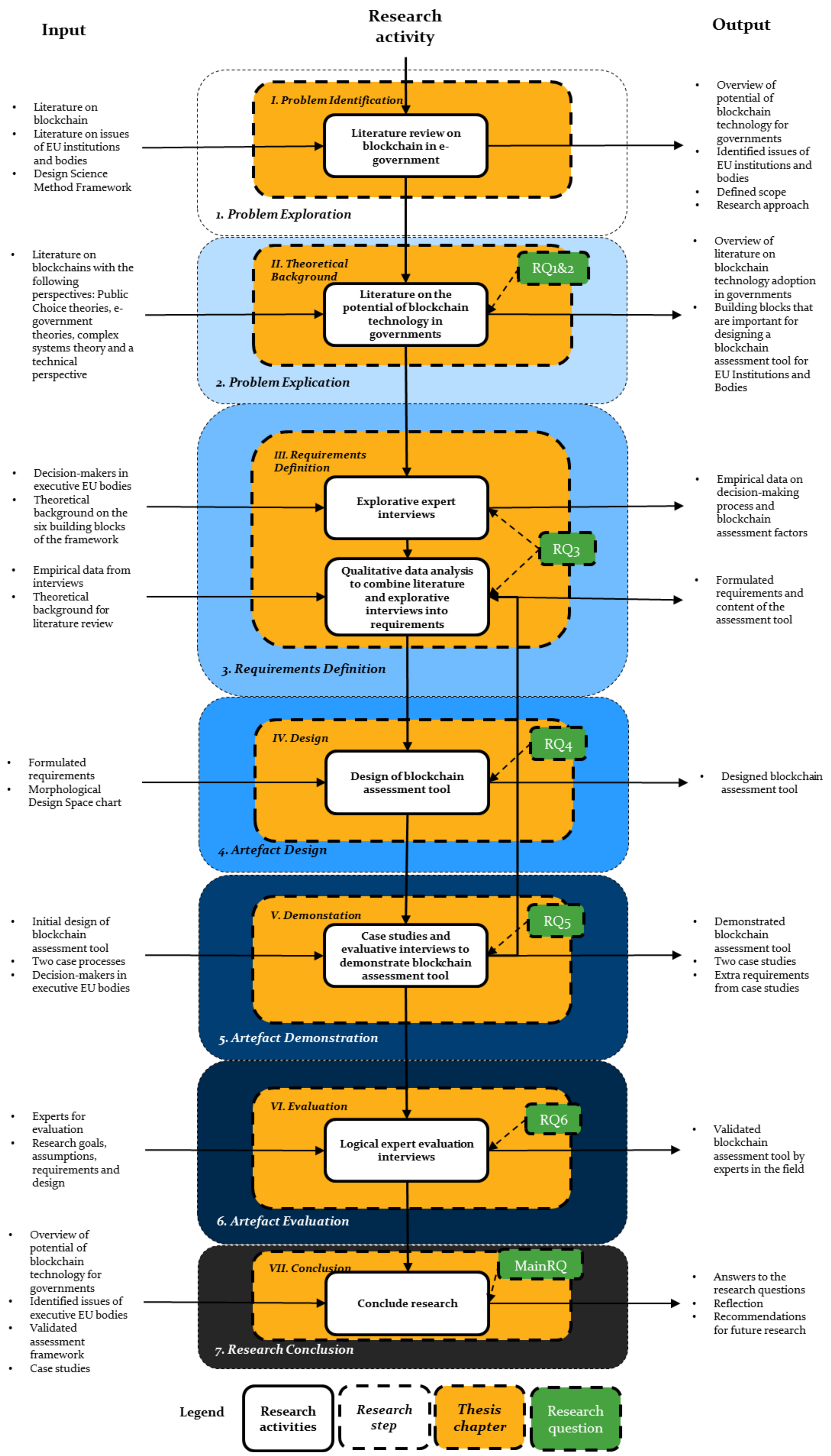

Figure 3. Research Flow Diagram

II. THEORETICAL BACKGROUND

The previous chapter introduced research problem and the research approach of this thesis. This chapter presents the theoretical background of this thesis, and is part of the Problem Explication step of this research. The aim of this chapter is to identify the elements that need to be included in the blockchain assessment tool. This chapter answers the first two research questions: **What is currently known about the potential of blockchain technology in governments?** and **What are the elements that need to be incorporated in the design of a blockchain assessment tool for EU Institutions and Bodies?** Using a literature review, an overview of literature on blockchain technology adoption in governments in provided. Paragraph 2.1 provides the structure of the theoretical background. The knowledge gaps identified in the problem identification are used as a departure point. Therefore, the literature review is divided in four different sections: blockchain challenging the role of governments (paragraph 2.2), blockchain as a complex multi-actor system (paragraph 2.3), blockchain for e-governments (paragraph 2.4), and blockchain system design (paragraph 2.5). Based on these literature reviews, the elements that are important for designing a blockchain assessment tool for EU Institutions and Bodies are summarized in paragraph 2.6. These elements will serve as a basis for the Requirements Definition step of this research that is described in Chapter III. This chapter concludes with answers to the first and second research questions in paragraph 2.7.

2.1 THEORETICAL BACKGROUND OVERVIEW

Literature that investigates the potential of blockchain systems in governments is at the moment of writing limited and widely dispersed and the various lenses analyzing blockchain technology has led to fragmented literature. As described in Chapter I Problem Identification, a number of knowledge gaps appear when investigating the potential of blockchain technology in governments. The theoretical background departs from these knowledge gaps to provide an overview of what is currently known about the potential of blockchain technology in governments. The aim of this overview is to identify the elements that need to be included in the blockchain assessment tool. The knowledge gaps and their corresponding choice of perspective are elaborated in the following paragraphs.

First, because it is unclear how blockchain technology challenges the role of public administrations, it is essential to reflect on why we have governments and public administrations and how blockchain can contribute to the disintermediation of public administrations and governmental services. To explore the way blockchain technology challenges the role of public administrations, a literature review on blockchain challenging the role of governments is presented in paragraph 2.2 Blockchain challenging the role of governments. A Public Choice perspective is used in this review of literature, because Public Choice theories reflect on the foundations of governments and analyses why and how structures like bureaucracies are formed. Blockchains have the potential the disintermediate a number of governmental processes. To investigate the intermediary role of public administrations, Transaction Costs Theory is used. Using these two perspectives allows for the analysis of the dis- and re-intermediation in public administrations that is caused by blockchain technology, and what this means for the role of these organizations.

Second, a complex multi-actor perspective on blockchain technology is lacking. Analyzing blockchain systems as complex multi-actor systems allows for the anticipation of behavior in these systems and can avoid unforeseen outcomes in blockchain experimentation. A literature review is performed on blockchain as a complex system to explicate the complexities involved in the implementation of blockchain. This is presented in 2.3 Blockchain as a complex multi-actor system. A complex systems perspective is used in this review of literature, because this technology constitutes of both multi-actor complexity and systems complexity (Pruyt, 2010).

Third, because awareness on the blockchain fit and its socio-technical effects for governments is not developed, blockchain for e-government literature is explored to identify factors to determine the fit between blockchain technology and governmental processes. E-government literature analyzed factors that determine the ability to adopt IT innovations in public organizations, but these factors are not investigated for blockchain technology. This literature also present a basis for analyzing how decisions regarding IT innovation adoption in public organizations are reached. This literature is complemented with a New Institutional Economics (NIE) perspective to anticipate the effects of experimenting with this technology by governments. This perspective is used because it allows the analysis of blockchain as a new institutional technology of governance. NIE allows for the analysis of the effects of a technological configuration like blockchain technology on the institutional layers of society. This theoretical background of blockchain in e-government theories is described in 2.4 Blockchain for e-governments.

Lastly, as blockchain systems contain several design features, it needs to be investigated how these impact the systems performance. A technical perspective is used to explore this impact, as this allows for a descriptive and objective analysis of the design features. Blockchain systems design is analyzed mostly by empirical reports, so both academic and semi-academic resources are used in the review of literature on the design features of blockchain systems, which is presented in 2.5 Blockchain system design.

For each of the four theoretical background sections, the literature review procedure is outlined in the section of this chapter. The theoretical background sections present the various elements that need to be included in the blockchain assessment tool. In this way, the overview of literature on blockchain technology adoption in governments is translated into elements of importance for the blockchain assessment tool, which are summarized in 2.6 Elements of the blockchain assessment tool. Figure 4 provides a readers guide to the theoretical background presented in this chapter.

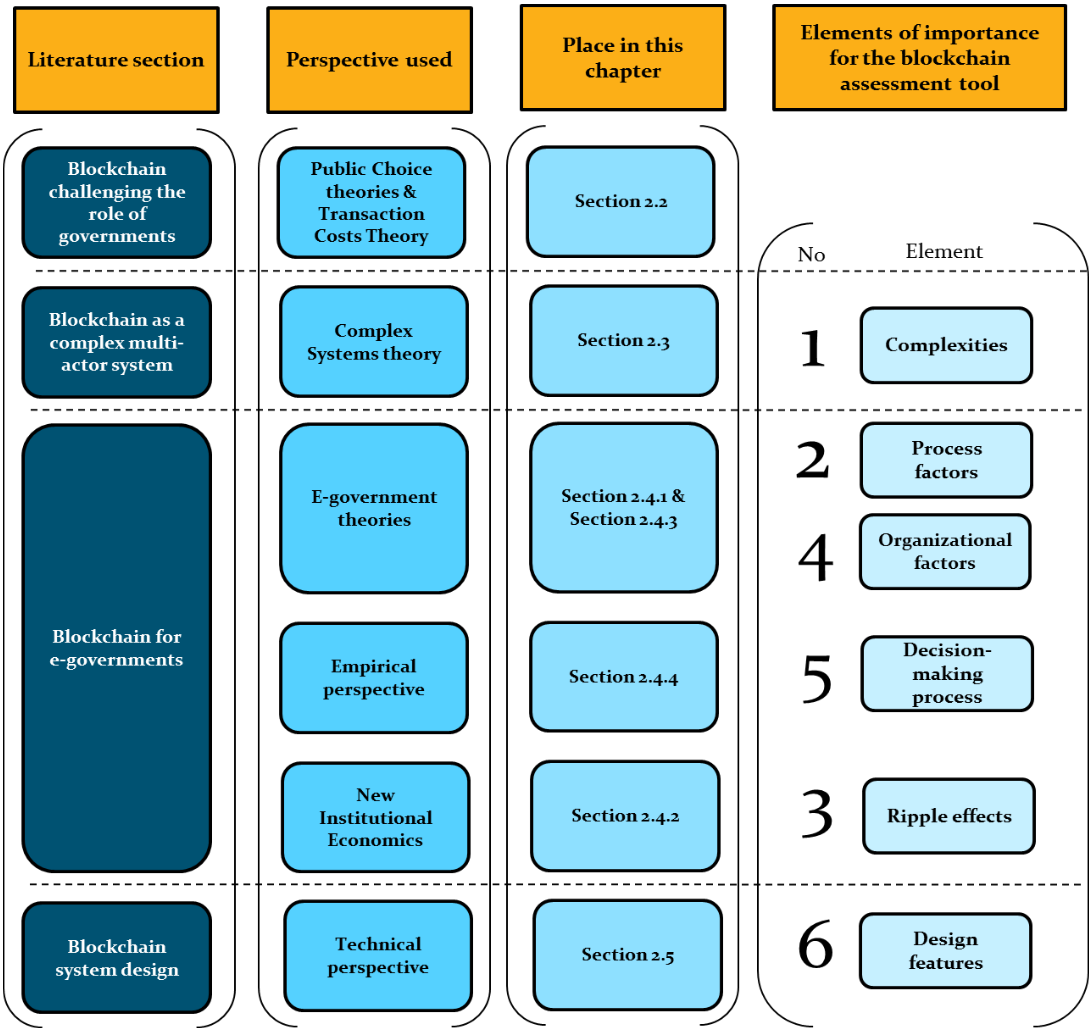

Figure 4. Reader's guide to Chapter II Theoretical Background

2.2 Blockchain challenging the role of governments

Methodology of the literature review on blockchain challenging the role of governments

For the review of literature on blockchain in governments challenging the role of governments, both Public Choice and New Institutional Economics perspectives are used. Academic databases Google Scholar and Scopus were used with the following keywords: *Blockchain, Intermediation, Disintermediation, Re-intermediation, E-government, Peer-to-Peer Technology, and Public Choice.* After a selection on relevance for this thesis, the final papers that this section analyses were selected.

This section reflects on why governments and public administrations are created from a Public Choice perspective, and how blockchain can contribute to the disintermediation of public administrations and governmental services from a New Institutional Economics perspective. Public Choice theory refers to the perspective of using "economic tools to deal with traditional problems of political science" (Tullock, 1987, p. 10). From this perspective, the main reason why central public administrations are originally created is to maximize some sort of welfare function for society (Tullock, 1987). Also, central public administrations are created to protect social values, promote the common good and protect collective right (Atzori, 2015; Green, 1991; Scammell, 2000). Public administrations create policies in order to avoid individual exploitation or short term gains instead of long term protection in these policy areas. In other words, a government facilitates coordination in society to smoothen the tensions between the short term individual interest and the collective good, with the goal of finding compromises between the two (Atzori, 2015; Dahl, 1989). These governments in turn are often divided into public administrations that are organizations responsible for the implementation of a certain government policy (Slunge, Nooteboom, Ekbom, Dijkstra, & Verheem, 2011). From a Public Choice perspective, governments tend to centralize over time because this is the most efficient structure to establish and enforce rules, but this centralization of power also becomes vulnerable to exploitation, corruption, and rent-seeking (Davidson et al., 2016a). To provide coordination in the most efficient way, public administrations have developed towards bureaucracies, referring to the processes and organized hierarchies to provide governmental services for citizens.

2.2.1 Theories of Bureaucracy

Bureaucracies, as introduced by Weber (1922), are administrative systems governing any large institution (Weber, 1922). Opponents of bureaucracies highlight the inefficiencies and limited flexibilities of these bureaucracies to provide services that are requested by civilians, causing a gap between the governmental services that citizens desire and the governmental services that are provided (Atzori, 2015; Johnson & Libecap, 1994). The hierarchical structures of these bureaucracies are also argued to facilitate the centralization of the power towards a few top civil servants, causing a lack transparency, the possibility of being corrupt and the potential misuse of power (Antonopoulos, 2016). On the contrary, proponents argue a rational and systematic control is needed to facilitate coordination between humans (Weber, 1922). Weber (1992) argues that bureaucracies can avoid favoritism and enhance the efficiency of interactions in society.

As outlined above, centralized institutions like the government and bureaucracy, have emerged for the "purpose of reaching consensus and coordination between heterogeneous or distant groups of people, facilitating their mutual interactions" (Atzori, 2015, p. 6). In an article analyzing blockchain as an alternative model of governance, Atzori (2015) draws a parallel between a bureaucracy and a 'Single-Point-of-Failure'. A Single-Point-of-Failure is an element of a system that is critical for the functioning of a system. If this point fails, the whole system fails. This term is often used in information systems, as centralization of data storage presents advantages in terms of efficiency and centralized control, but often also reflects a critical failure point: if the central database fails, the whole IT system fails. Atzori (2015) even argues that this "concentration of power is a fundamental issue for citizens to achieve political efficacy, equality, transparency, and freedom" (Atzori, 2015, p. 7). She argues that blockchain has the potential to present a power shift from these institutions to the citizens. This power shift is argued to emerge from the ability of blockchain systems to provide a range of services traditionally provided by governments, but can now be provided with opt-in and opt-out opportunities making these services voluntary instead of hierarchical (Atzori, 2015).

2.2.2 *GOVERNMENTAL DECENTRALIZATION TRENDS*

Several theories and concepts have been developed throughout history that present ways of decentralizing the central power of governments (Atzori, 2015). These trends investigate ways to provide more distributed power to citizens, and range from *Proudhon's social contract* developed in 1989 to IT as a source of decentralization in the 1990s. The following overview is constructed on the work of Atzori (2015), and Figure 5 provides a visual overview.

- *Proudhon's social contract*: the concept that a society can be constructed and run efficiently on the basis on individual contracts between citizens, completely abolishing any governmental structure (Proudhon, 1923).
- *Marxism*: a view on society that the centralized authorities like the government but also the elite are oppressing the lower classes, and that coercion (hierarchical pressure) is the source of all evil (Atzori, 2015). The Marxism doctrine includes the idea that the government will gradually diminish once the production processes in society are organized based on freedom and equality. Marxism has resulted in various forms of socialistic states, some more idealistically referring to the Marxism's principles than others. From an ideological perspective of this doctrine, the members of society will at some point be able to administer the society themselves (Engels, 1884).
- *New models of governance*: a trend towards decentralization of the government can be distinguished in the last decades (Paquet & Wilson, 2015). This trend looks at different models of governance, rethinking the way citizens and governments interact. The following new models of governance have been formed since the 1970s:
    - *Deliberative democracy*: a democratic model that emerged in the 1980s to enable self-governance in places where traditional representative democracy fails (Atzori, 2015). Deliberative democracy consists of the idea that the representative democracy is not complete and that the participation of citizens should be more systematically included. This inclusion can be achieved by incorporating citizens directly in political decision-making processes, improving transparency how political decisions emerge and promoting the participation of citizens in the governance of the country (Bohman, 1997).
    - *New Public Management*: a new framework of decentralized governing practice formed in the 1970s, with a clear priority of the techniques used instead of the purpose of the governmental services (Rosenbloom & Kravchuk, 2014). This framework was argued to better meet citizens' needs, as well as the improvement of efficiency and reduction of the costs of governmental services, but the emphasis of efficiency was also argued to lead to 'corporatization' of public organizations (Atzori, 2015).
    - *Consensus oriented governance models*: these models of governance argue the power of networks and the private sector instead of a central authority. Self-organization and resilience are key characteristics of networks that enable the power shift from public administrators to networks (De Bruijn & Ten Heuvelhof, 1997; Kooiman, 1993). These governance models have emerged since control and social coordination have become so complex that the government needs to involve other actors to facilitate this (Atzori, 2015)
- *IT as a source of governance decentralization*: a trend towards IT enabling more direct interaction between citizens. Peer-to-peer networks enable participation in social movements and the forming of autonomous communities, but also a "growing distrust of government actors" (Atzori, 2015, p. 14). In a more fundamental form, this trend can be found in manifesto's from Crypto Anarchy theorists May (1992) and Hughes (1993). These manifesto's place great emphasis on the openness of societies and that openness in modern day societies need to be achieved by digital freedom of speech, the protection of privacy on the internet and anonymity in economic transaction systems (Hughes, 1993; May, 1992)
    - *E-governance*: E-governance is not as much of a trend of decentralization, because the provision of these e-governance services is still centralized, yet it is a trend that does try to tailor the services of governments to citizens and bridge the gap between governments and citizens (Molnar, Janssen, & Weerakkody, 2015).

- *Blockchain*: Blockchain builds upon these trends as this technology can enable disintermediation of institutions and decentralize services. This is elaborated by first introducing the role of public administrators as intermediaries and then analyzing the possibility of disintermediation of public administrators by blockchain technology in the next section.

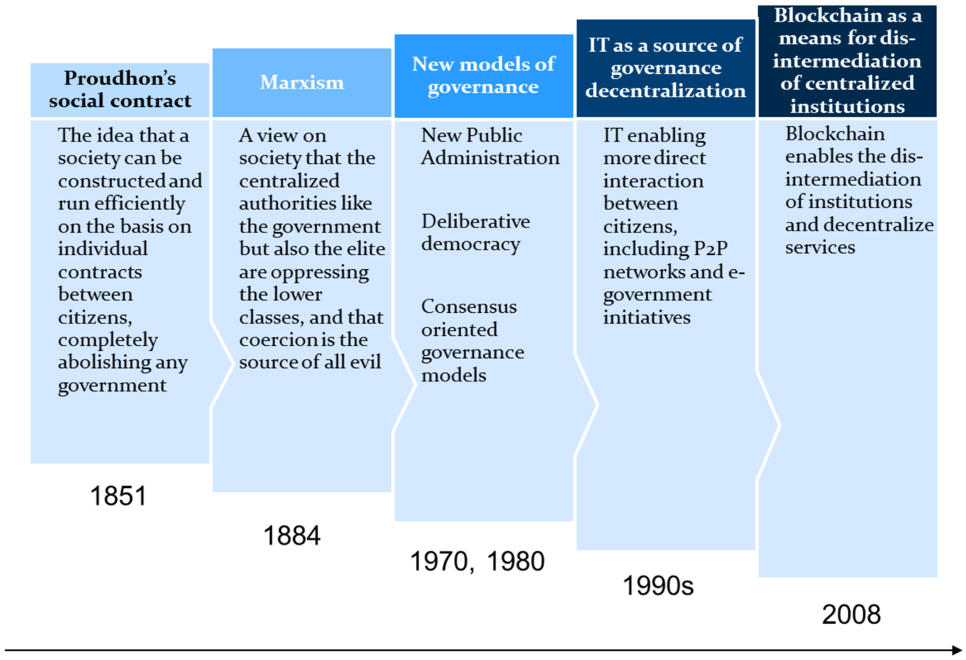

Figure 5. Trends towards governmental decentralization throughout history [constructed on the basis of Atzori (2015)]

2.2.3 PUBLIC ADMINISTRATIONS AS INTERMEDIARIES

This section presents the role of public administrations as intermediaries in a network setting. Janssen (2009) defines three actor types in organizational network settings: *intermediary, service provider* and *service requester* (Janssen, 2009). Service providers in this context are any citizen or economic operator providing a service that requires compliance to the authorities, like sending a package across borders, building a house or selling land or property. Service requesters are citizens or economic operators on the receiving end of this service. Janssen (2009) defines an intermediary as "an organization aimed at bringing together demand and supply" (Janssen, 2009, p. 1320). Public administrators traditionally take on the role of intermediaries in a network to facilitate coordination between citizens/economic operators, in order to protect the common good, reduce opportunism and avoid the abuse of the network (Atzori, 2015; Klievink & Janssen, 2008). This intermediation of public administrations have resulted in silos of data: different public administrators managing their own databases in order to have control on the data for which they are responsible and to be the trusted intermediary in providing this service (Boucher et al., 2017).

There are generally two possible ways a public administrator can coordinate between the providing citizen/economic operator and the receiving citizen/economic operator: bilateral or intermediated contact (Janssen, 2009). Figure 6 shows three possibilities; complete intermediation, partial intermediation and no intermediation. These intermediaries might not be involved in the actual transaction of a real-life product, but they can also just facilitate the market transaction by providing the registration or facilitate the exchange of information (Garbade, 1982). This is generally the case in public administrations, as they facilitate the information exchange or registration, without being involved in the physical transaction.

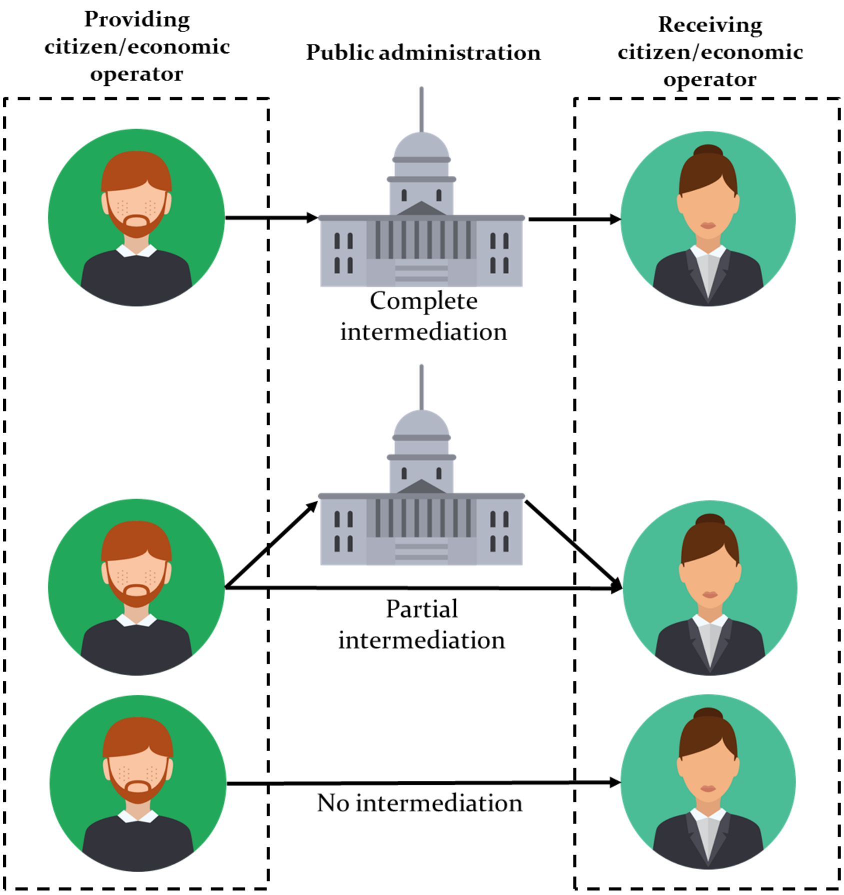

Figure 6. Levels of intermediation by public administrations [based on Janssen & Sol (2000)]

One perspective that explains the emergence of intermediaries is Transaction Cost Theory that is part of the New Institutional Economics perspective (Malone, Yates, & Benjamin, 1987; Sarkar, Butler, & Steinfield, 1995). This perspective analyses the costs of transacting between two parties. If these transaction costs are too high for a transaction to occur, then intermediaries can emerge to bring these parties together and lower the transactions costs. However, Transaction Costs Theory is often criticized for not taking into account more complex elements and situational characteristics like trust, relationships and the need for information collection (Janssen, 2009). Various authors including Chircu & Kauffman (1999), Janssen & Verbraek (2005) and Malone et al (1987) have looked into the re- and disintermediation of these intermediaries, yet no consensus is presented on the value that intermediaries can bring in networks (Janssen, 2009). Blockchain can present the next step in the discussion in the re- and disintermediation of electronic intermediaries, as the role of public administrators in the field of registration and data exchange will change by this technology. Next, it is discussed how blockchain technology can present the shift in power in networks that are governed by public administrations.

2.2.4 Power shifts by blockchains

In this section, the power shifts in blockchain networks for public administrations are analyzed and the implications of this are discussed. Two main types of blockchains are investigated: permissionless blockchains and permissioned blockchains. The difference lies in the participation in the consensus mechanism: permissionless blockchains allow all nodes to participate in the consensus mechanism, while permissioned have the transaction consensus mechanism performed by a given set of participating nodes, based on criteria that the architect of the permissioned blockchain can determine. More on the different blockchain types and consensus mechanism is presented in section 2.5.1 Impact on process criteria.

2.2.4.1 Permissionless blockchains

For permissionless blockchains, like Bitcoin, processes facilitated by these open blockchain system would present a power transfer of public administrators to a 'techno-elite'. The techno-elite is an elite group of powerful developers with the skills and resources to build and contribute to these open blockchain systems. Providing governmental services on these permissionless blockchain systems allows this techno-elite to have a power over the way governmental services are provided. This power emerges out of technical skill instead of the traditional formal legitimacy that public servants have, as they are chosen in a transparent process (Atzori, 2015). This type of blockchains also presents a number of other problems, including a trend towards centralization with the introduction of 'mining-pools', where validation nodes connect together, creating miner corporations that have significant validation power in the network. Also, this blockchain type might favor short-term individualistic preferences over the long-term protection of the common good. The majority rule might undermine the minority vote, causing a potential lack of service continuity (Atzori, 2015). If public administrations would provide government services on permissionless blockchains, this would present a complete power shift in control in the network.

Therefore, governmental services are not fully suited for public permissionless blockchains. Governmental services "require high performance and a high degree of reliability, accessibility and predictability, and being not tolerant of any service interruption or failure" (Atzori, 2015, p. 18). This is the reason why these infrastructures and processes have to be regulated: continuity is required to protect the common good and facilitate interaction in society. Failing to do so might have large effects and impact the lives of the citizens (Atzori, 2015). Creating policies and regulating these infrastructures and processes is traditionally performed by civil servants that are transparently chosen by a formalized process, which is not guaranteed in permissionless blockchains. This presents a power shift from public administrators to a dominant techno-elite. When public services are provided by permissionless blockchains, public administrators can become completely obsolete as the governance of the service will be in the control of the network. In these permissionless blockchain systems, there are only limited ways of interfering in the process as a government.

2.2.4.2 Permissioned blockchains

Permissioned blockchains can however provide these securities that permissionless blockchains do not guarantee. Human intervention is still possible in order to guarantee coordination, reliability and security in governmental services. These permissioned blockchains do not have the speculative verification mechanisms as is the case in permissionless blockchains, and compared to centralized databases it provides efficiency, security and data integrity advantages.

These blockchains are still somewhat centralized in terms of control, as they are closed systems and the architect of the system can impose participation rules. This form of centralized control in a decentralized architectures is necessary when protecting the common goods and citizens' rights (Atzori, 2015). In addition, the control in the hands of public officers that are legitimated through formal, accountable and transparent procedures, instead of the techno-elite as is the case in permissionless blockchains (Atzori, 2015). In permissioned blockchains, when the public administration is still in (partial) control, the protection against this tyranny of the majority is guaranteed, as opposed to the case in permissionless blockchain systems (Atzori, 2015).

2.2.5 Dis- and Re-intermediation in public administrations using blockchain

Given these potential power shifts, it is discussed to what extend blockchain technology is able to disintermediate in processes traditionally provided by public administrations. Governments traditionally use hierarchical power or 'coercion' to provide services. Blockchain technology can provide these services in a more bottom-up or disintermediated way. No hierarchical power or force is necessary for the services to be provided, allowing for a "more horizontal and distributed diffusion of authority" (Atzori, 2015, p. 7). For public administrators, when implementing a permissioned blockchain system, it can present a change in roles; from the intermediary that is in control of validating the quality of the data and facilitating the data exchange, towards a disintermediated supervisory role where the public administrator does not place itself in the middle of the data transaction process, but only provides semantic validation where needed. In this context, data quality is defined as *the accuracy of the representation of what it represents in the real-world construct.*

Hence, there will still be a need for a public administrator to act as a trusted intermediary, as this facilitates coordination in society and markets (to eliminate opportunism) and protects the common good (Davidson et al., 2016a). Yet currently, the execution of being the trusted intermediary is done by placing the public administrator in the middle of the data exchange or registration process by facilitating the data storage and exchange in systems fully in their control, in the form of full intermediation. The implementation of permissioned blockchains can allow public administrators to provide this level of trust and protect the common good while *largely distributing the control* to the network.

2.2.5.1 The gate-keeping role

It is explicitly stated that using permissioned blockchains enables '*largely distributing the control*' and not complete disintermediation. This is because blockchains are not able to provide a validation mechanism that also includes the *semantics* of the data. Blockchains have evolved to already facilitate business rules in the form of smart contracts (Norta, 2015). Once these systems are able to take the next step and also provide semantic validation (*validating whether the data that is exchanged is also semantically correct),* then the control can be *completely* disintermediated. The reasons for public administrators to currently scrutinize data input and requests, being a gatekeeper in this process, is to avoid fraud and opportunism, and to protect the common good (Boucher et al., 2017). Current blockchain technology does not facilitate the elimination of this gatekeeper role.

Current blockchain systems that are successful, like Bitcoin, do not require semantic data validation on top of the consensus mechanism. Given the relative simplicity of a payment system that includes one currency like Bitcoin, these systems are able to provide full data quality validation disintermediation. In these systems, the blockchain system is able to provide the data quality validation in a network setting. The way this works is, very simply put, that each transaction is validated if the following two conditions are met:

I. *The sender has sufficient amount of funds to send the amount of Bitcoin*
II. *The sender knows the address of the receiver*

Looking at a more complex data or asset exchange or registration system, where also the semantics of the data is of value, there is still a need for an intermediary to provide this data quality check. The verification on the blockchain is only done on the technical requirements of the protocol, so it records the time and details of the transaction. In current blockchain systems, if the transaction ticks all the technical requirement boxes, than the transaction will become part of the transaction history that is immutable. The semantics of the content of the transaction is not checked in this process (Boucher et al., 2017). Therefore, the quality of the data in the system cannot be verified with a blockchain system alone.

Concluding, blockchain technology alone cannot be an alternative for the current data accepting and sharing controls of public administrators given the current limitations of providing semantic validation. However, it can change the role of public administration from an electronic intermediary to a disintermediate semantic supervisor in a registration or data exchange process. There will still be a need for a public administrator to act as a trusted intermediary, as this facilitates coordination in society and markets (to eliminate opportunism) and protects the common goods. Yet currently, the execution of being the trusted intermediary by placing themselves in the middle of the data exchange process by facilitating the data storage and exchange in systems fully in their control, in the form of an electronic intermediary. The implementation of permissioned blockchains can allow public administrators to provide this level of trust and protect the common good while largely distributing the control to the network. The re- and disintermediation of public administrations by blockchain technology is presented in Figure 7.

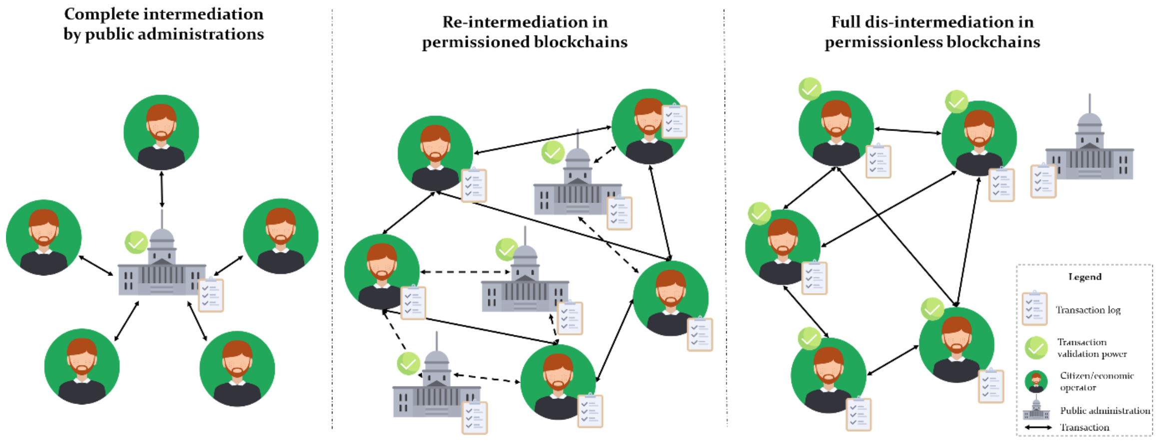

Figure 7. Re- and disintermediation of public administrations by blockchain technology

2.3 BLOCKCHAIN AS A COMPLEX MULTI-ACTOR SYSTEM

As introduced in Chapter I Problem Identification, blockchain is an extremely complex technology as there is both multi-actor complexity and systems complexity (Pruyt, 2010). This section will present the theoretical background on blockchain that is analyzed using complex systems theory. First, blockchain as a complex system will be defined. Then, the domains of where complexities can emerge are defined in blockchain implementation by public administrations.

2.3.1 DEFINING BLOCKCHAIN AS A COMPLEX SYSTEM

Complex systems theory argues that the unpredictable and complex features of certain technical system requires a perspective that goes beyond a linear engineering perspective (Rouse, 2007). Complex systems exhibit non-linear dynamic behavior, in contrast to linear stable behavior of non-complex systems (Bauer & Herder, 2009). Helbing (2015) highlights the importance not to mistake complex systems with complicated systems. Complicated systems are systems with various interrelating elements, but the behavior of these system can be attributed to properties of the single parts of the system in isolation (Helbing, 2015). In complex systems, the behavior that emerges in the system in not merely the total of the behavior of the individual parts (Helbing, 2015). De Weck et al. (2011) present a definition of a complex system:

Methodology of the literature review on blockchain as a complex multi-actor system

For the review of literature on blockchain as a complex multi-actor system, Complex Systems literature is used. First academic databases Google Scholar and Scopus were used with the following keywords: *Blockchain*, *Complex System*, *Uncertainty*, and *Multi-Actor Systems*. Then, the selection of papers was made on primary works and the inclusion of multi-actor complexity in the paper. No papers were found that explicitly use a Complex Systems perspective to analyze blockchain technology.

Complex system is "a system with components and interconnections, interactions, or interdependencies that are difficult to describe, understand, predict, manage, design, or change" (De Weck et al., 2011, p. 186)

These complex systems involve a large numbers of interacting elements and all these elements contain attributes that are of interest to many stakeholders in the system. These stakeholders each have often conflicting objectives and interests (Rouse, 2007). Rouse (2007) argues that the behavior of actors in a system can be unpredictable in these systems, highlighting the importance for a well-defined decentralized governance model in blockchain systems. An example of unpredictable behavior in a blockchain system resulting in undesirable outcomes is the Decentralized Autonomous Organization (DAO). The DAO was a completely decentralized investment fund based on the smart contracts of blockchain, yet it was hacked in June 2017. Somebody found an error in the 'airtight' smart contracts and was able to steal 50 million worth of the digital currency Ether that was used in the DAO, showing that even the most rigid contract options cannot entirely mitigate the complexities of the decentralized systems based on blockchain. In complex systems theory, it is argued that in complex systems there are certain elements where a small shift in one thing can produce big changes in the whole system (Meadows, 1997). In the case of the DAO based on a blockchain system, this element was a smart contract that was not written completely airtight, caused shift in the whole system.

The emergent behavior of the complex system as a whole is not just the sum of the behavior of the subsystems combined because the subsystems have a degree of autonomy (De Bruijn & Herder, 2009; Rouse, 2007). The subsystems of complex system are autonomous to a certain extent, as each of subsystem has its own objectives (Sage & Cuppan, 2001). This can be true for blockchain systems as well, especially for permissionless blockchain systems. In these systems everyone can participate in the consensus mechanisms. There is inherently no central administrator in blockchain systems, so the participating actors (nodes) have a form of autonomy and their own objectives.

2.3.2 Complexity in blockchain implementations

Next, the domains where complexities can occur are investigated. In order to minimize making decisions on blockchain experimentation that result in unintended consequences, it is important to identify the domains of complexities. Rouse (2007) identified domains where complexity arises in complex systems. These issues include the multi-actor nature and the nature of interactions. Pierson (2000) conceptualizes the concept of path dependency, relating to the difficulties of connecting blockchain systems to legacy systems as this will impact existing institutional structures in governments. Perez, Drechsler, Kattel, & Reinert (2011) present the concept of a Techno-Economic Paradigm Shift, arguing that technological and institutional challenges can hinder the large-scale adoption of a new adoption of a technology reshaping economic interaction. Koppenjan & Groenewegen (2005) present the argument of strategic uncertainty in complex multi-actor systems, which refers to uncertainty about the intent and strategies of other actors in the complex system. In these systems, it might not be clear which actors are willing to participate, and if they participate if they will adhere to the rules of the game (Olson, 1965). In conclusion, the complexity in blockchain systems implementation in governments are argued to arrive from the multi-actor nature, the legacy systems in place, the nature of the interactions in the system, the public interest involved, and the uncertainty involved in the system. The next paragraphs will elaborate on these domains of complexity in blockchain systems.

2.3.2.1 Multi-actor nature

The multi-stakeholder nature of complex systems is an important contributor to the complexity (Rouse, 2007). This can be seen in the distributed nature and the different actors involved of blockchain systems. In a blockchain system, there are participating nodes who participate in the transactions and validating nodes who validate each transaction in the system. In networks regulated by public administrations, another actor is in play: the regulator. These actors each have their own interest and objectives in the blockchain system, causing multi-actor complexities.

2.3.2.2 Nature of interactions

A substantial part of the complexity is caused by the frequency and nature of interactions within a system (Rouse, 2007). As governmental organizations look to implement blockchain for their processes, it has the potential to alter the relation and interaction between governments and citizens (Atzori, 2015). It could result in direct interaction with citizens (for example in a blockchain-based public participation system) or with economic operators (for example in a blockchain-based customs tax collection system). This changes the dynamics and nature of the interaction in a system. In addition, the complexity also stems from the process nature of a blockchain; the processes will always involve a network and a chain of interactions (ENISA, 2016).

2.3.2.3 Legacy systems in place

Legacy systems already in place also facilitate complexity in these systems (Rouse, 2007). If the context in which the system is to be designed already contains already systems that emerged throughout the history and are difficult to change or to create interoperability with. In blockchain systems, interoperability with legacy systems is an issue, as the system is different compared to traditional systems in all technical layers (Mougayar, 2016b). Integration and coupling are presented as challenges in this field (Rouse, 2007). A closely related concept is Institutional Stickiness. Institutional Stickiness is a concept that deems to explain why institutional structures are difficult to change. As argued above, blockchain technology has the potential to alter governance structures and the way governments structure their operations, thereby impacting existing institutions (Davidson et al., 2016a). Pierson (2000) argues that when the system has actors with powerful positions, it is hard to change these institutional structures making blockchain implementation difficult (Pierson, 2000).

2.3.2.4 Public interest involved
Complex systems generally have a public interest or stake of some sort, which is more or less inherent to large scale systems (Koppenjan & Groenewegen, 2005). A legal framework is in place to preserve this public interest, creating technological and institutional challenges. The concept of Techno-Economic Paradigm Shifts explains that both technological and institutional challenges must be overcome before a Techno-Economic Paradigm Shift can take place. A Techno-Economic Paradigm Shift is the combination of a new technology, shaping new economic interaction, with the potential of shaping societal change. In the light of this concept, the socio-institutional assessment tool is considered one of the most important barriers for the diffusion of technology, for example blockchain technology (Perez, Drechsler, Kattel, & Reinert, 2011). When analyzing the potential of blockchain technology for governmental services this is critical as well, as the public interest needs to be served.

2.3.2.5 Uncertainties
In complex systems, strategic uncertainty of actors behavior creates complexity in a system (Koppenjan & Groenewegen, 2005). In blockchain systems, uncertainties can arise in two forms: in technological uncertainties and institutional uncertainties. Technical uncertainties refer to the uncertainty on the maturity of the technology, and institutional uncertainties refer to the uncertainty of how this technology will fit and shape current institutions. Based on the identification of complexities in blockchain systems, the next paragraph identifies the first element that will be included in the blockchain assessment tool.

2.3.3 Element 1: Complexities
In conclusion, the implementation of blockchain technology in governments constitutes of a number of complexities. These complexities are caused by the multi-actor nature, the legacy systems in place, the nature of the interactions in the system, the public interest involved, and the uncertainty involved in the system. The complexity impacts the span of control of designers and developers of these systems: they must be aware that a linear design of a system does not necessary result in the intended outcomes. Therefore, in blockchain systems design and analysis, it is critical to take the complexities involved in implementing blockchain in public administrations into account. This results in the first element of the blockchain assessment tool: *Complexities*. This element is defined in the textbox below.

Element 1: COMPLEXITIES

The element of the blockchain assessment framework is the complexities involved in blockchain implementation in governmental organizations. The definition of complexity in this thesis is;

A complex element of the blockchain implementation that is "difficult to describe, understand, predict, manage, design or change" (De Weck, Roos, & Magee, 2011, p. 186). These complexities arise from the multi-actor nature, the nature of the interactions in the system, the legacy systems in place, the public interest involved, and the uncertainty involved in the implementation of blockchain technology.

2.4 BLOCKCHAIN FOR E-GOVERNMENTS

Next, blockchain for e-governments is investigated. The e-government perspective is complemented with the New Institutional Economics perspective to investigate the potential and effects of blockchain in e-governments. First, a literature review on the potential blockchain for governmental processes is described. Then, the effects of implementing blockchain technology in governmental processes is investigated. Lastly, factors to determine the capability of governmental organizations to adopt IT innovations and the decision-making process for the adoption are analyzed using an e-government perspective. First, the definition of e-government is presented.

> **Methodology of the literature review on blockchain for e-governments**
>
> For the review of literature on blockchain for e-governments, both e-government and New Institutional Economics perspectives are used. Academic databases Google Scholar and Scopus were used with the following keywords: *Blockchain, E-government, Governmental Processes, IT Adoption, and Public Organization.* Then, two selections of papers were made on the topics of blockchain for governmental processes and IT innovation adoption in public organizations. The overviews of the selections of papers used in the literature review are presented throughout this section.

E-government is defined as "the use of information and communication technologies, particularly Internet, as a tool to achieve better government" (Field, 2003, p. 63). The use of IT technology is argued to reduce costs, improve performance, increase speed of delivery and the effectiveness of the implementation (Almarabeh & AbuAli, 2010, p. 1). In the early 2000s, it was claimed that e-government has the potential to change the relationship between public administrations and the public (IPCS, 2003). The same claim is nowadays made about blockchain; as it argued to change the way governments and citizens interact (Atzori, 2015).

2.4.1 RESEARCH ON BLOCKCHAIN FOR GOVERNMENTAL PROCESSES

Blockchain technology is well suited to have public services built upon it, since many public services are based on a database or registry (land registry, the chamber of commerce, civil status registry, vehicle registration, tax, social insurance and others). Table 2 provides an overview of the literature that examines blockchain for governments and governmental processes.

Table 2. Research overview on governmental processes and blockchain

Title	Author	Year
Blockchain Technology and Decentralized Governance Is the State Still Necessary?	Atzori	2015
Government-as-a-service	Van Zuidam	2016
Blockchain a blueprint for a new economy	Swan	2015
Fundamenteel anders kijken naar de vraagstukken van de overheid	ICTU	2016
Public Sector Innovation Using the Bitcoin Blockchain Technology	Ølnes	2015
The Impact of the Blockchain Goes Beyond Financial Services	Tapscott & Tapscott	2016
Where Is Current Research on Blockchain Technology?—A Systematic Review	Yli-Huumo, Ko, Choi, Park, & Smolander	2016
Economics of Blockchain	Davidson, de Filippi and Pots	2016

A number of authors investigate the benefits of blockchain for governments. Atzori (2015) argues that blockchain could be used to store any type of governmental documents, making governmental registration decentralized, efficient and cost-effective (Atzori, 2015). She argues that the blockchain can bring value to governmental processes in terms of automation, transparency and auditability (Atzori, 2015). By some idealists, the idea the blockchain can improve government services is expanded to the idea that blockchain can dismiss the government as a whole by some projects (for example Bitnation[1]). Yet most authors present to argument that blockchain can be used to promote better governance (Atzori, 2015). Swan (2015) argues that blockchain-based systems can replace numerous services traditionally provided by governments, making these services more tailor-made due to the decentralized governance of these services (Swan, 2015b). Atzori (2015) notes that the services of governments can become more

[1] Via https://bitnation.com

global and border-less. Swan notes in this area that the blockchain can lift restrictions on geographic factors of government services, and even create the potential for multiple government 'providers' (Swan, 2015b). Van Zuidam (2016) expands this idea by introducing the concept of 'government-as-a-service'. This concept refers to government services, performed using blockchain technology, that are desirable in many places in the world, to enhance the coordination in society and to enlarge the trust of citizens and companies in (governmental) systems (Van Zuidam, 2016).

Another stream of research focusses on the transformational power of blockchains in governments, Tapscott & Tapscott (2016) analyze blockchain technology from an economic perspective, arguing that the blockchain could transform business, government, and society (Tapscott & Tapscott, 2016b). Davidson, de Filippi and Potts (2016) use Public Choice and Institutional Economics perspectives to analyze blockchain innovation, and suggest the governance-centered economics lens is promising as it as a new technology for creating spontaneous organizations. Perceiving governments as a pure centralized solution, they present blockchain to counter all problems of trust and its abuse (Davidson et al., 2016b). In his article, Ølnes (2015) mainly focusses on blockchain use cases for the registration process, stating that blockchain presents a "decentralized, permanent, and utterly secure store for all types of information assets" (Ølnes, 2015, p. 7). Swan (2015) also focusses on blockchain use cases for the registering process. She argues in her book that blockchain changes the relationship of between governments and citizens, as well as the relationship between the citizens.

2.4.1.1 Literature presenting factors determining a blockchain-process fit

Another stream of literature analyses *prioritization factors*, referring to factors of the process that are deemed important by governments, and how this can relate to the choice for blockchain. ICTU published a whitepaper in 2016 on blockchain, reflecting how this can fundamentally change the way the government can approach their operations. ICTU presents the following criteria of when a government process can benefit from blockchain technology (ICTU, 2016):

1. Privacy: when the citizen desires control of their own data
2. Productivity: when the services use data from different data silos and services
3. Power: where all parties involved benefit from an efficient and fair platform, so that the hosting and verification of the platform services can be performed in a distributed way

Also, research has focused on identifying the *process characteristics of current processes* for the potential of blockchain. Van Zuidam (2016) argues the following criteria of when a government process can benefit from blockchain technology:

1. Where there were previously no solutions available yet (for example: the lack of a chamber of commerce or a land registry institution) or the knowledge for a good solution is not yet present (for example, in developing countries)
2. Where public services do exist but are plagued by corruption (where the trust in the system is relatively low)
3. Where the current solution is very rigid and laborious (often legacy systems). Consider far-reaching, potentially complex bureaucracy, often in place to prevent corruption

Lastly, a technical review article focusses on the *data and processing criteria* for the potential of blockchain. Yli-Huumo, Ko, Choi, Park, & Smolander (2016) use a more technical lens to analyze when blockchain can be applied in specific use cases. Based on a systemic literature review of 41 peer-reviewed papers, they synthesize the current challenges in blockchain literature. They argue, as of the moment of writing, that there are still unaddressed challenges in the following areas; authentication, latency, throughput, usability, versioning, size and bandwidth, 51% attack and security incidents (Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). While recognizing the fact that this technology is likely to develop, they present evidence that a government process can benefit from blockchain technology in the following situations:

1. When privacy is important in the process
2. When security is not the prime concern
3. When the throughput of data in the process is low
4. When latency is not the prime concern

5. When the network is able to provide enough bandwidth and computing power

An overview of the process factors found in literature are displayed in Table 3. Based on the analysis of literature presenting factors determining a blockchain-process fit, the next paragraph identifies the second element that will be included in the blockchain assessment tool.

Table 3. Process factors identified in literature

Domain	Factor defining fit between blockchain and process	Derived from
General context	Low institutionalized environment Low trust in current process Laborious processes	Van Zuidam (2016)
Process characteristics	High user data control requirements Data silos Platform tendency	ICTU (2016)
Data and processing power	High importance of privacy Low importance of security Low throughput of data Low importance of latency High availability of bandwidth and computing power	Yli-Huumo, Ko, Choi, Park, & Smolander (2016)

2.4.2.1 Element 2: Process Factors

In conclusion, it is important to determine the fit between the governmental process and blockchain. The literature review found a number of authors presenting factors for determining a blockchain-process fit. Research has so far focused on *general context, data and processing power* and *process characteristics*. To enhance decision-making regarding blockchain experimentation in EU Institutions and Bodies, it is argued that the factors that define the fit between the process and blockchain technology need to be considered. This results in the second element of the blockchain assessment tool: *Process Factors*. This element is elaborated in the textbox below.

ELEMENT 2: PROCESS FACTORS

The element of the blockchain assessment framework are the process factors for determining the blockchain-process fit in the EU Institution or Body. The definition of process factors in this thesis are:

Factors that refer to either the environment of the process or to the process itself, that assess the applicability of a blockchain system for the information exchange or registration process of the EU Institution or Body.

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2.4.2 RESEARCH ON EFFECTS OF BLOCKCHAIN

The same literature, as displayed in Table 2, also investigates the effects of blockchain. The implementation of blockchain by EU Institutions and Bodies potentially has big effects on the organization itself, the network involved and on values in society. Blockchain is not just a new way of storing data, but a new way of economic coordination. Davidson et al (2016b) presents the argument that society has governments, firms, markets, relational contracting, and *blockchains*. The New Institutional Economics lens will elaborate on this concept, as blockchain can be analyzed as a revolutionary new institutional technology of governance.

New institutional economics theory focuses on the development of certain units of analysis, given sets of formal and informal rules surrounding it (Coase, 1984; Williamson, 2000). This theory can be used to analyze the effects of blockchain technology on society. Williamson (1970) created a framework with four layers of institutions that influence the functioning of complex (technological) systems (Williamson, 1979). The four layer model is presented in Figure 8. It assumes that a change in one layer of institutions can affect other layers of institutions (Williamson, 1979, 2000).

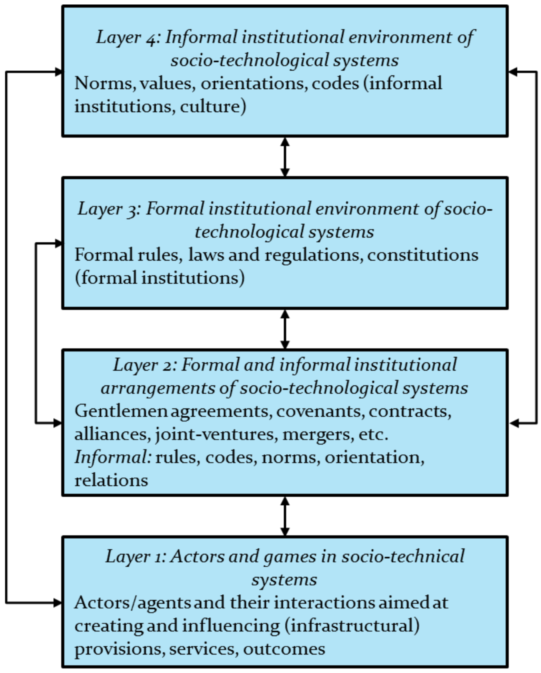


Figure 8. Williamsons' four layer institutional model [by Williamson (1979)]

Based on this model, Künneke, Groenewegen & Auger (2009) developed a dynamic layer model to analyze the effects of a technological configuration on the institutional layers or policy configuration, as can be seen in Figure 9. The dynamic layer model developed by Künneke et al. (2009) identifies general characteristics of infrastructures and the specific relation or logic that underlies their relation. This model allows for the exploration and identification of the effects of the specific institutional, technical and policy configuration of blockchain.

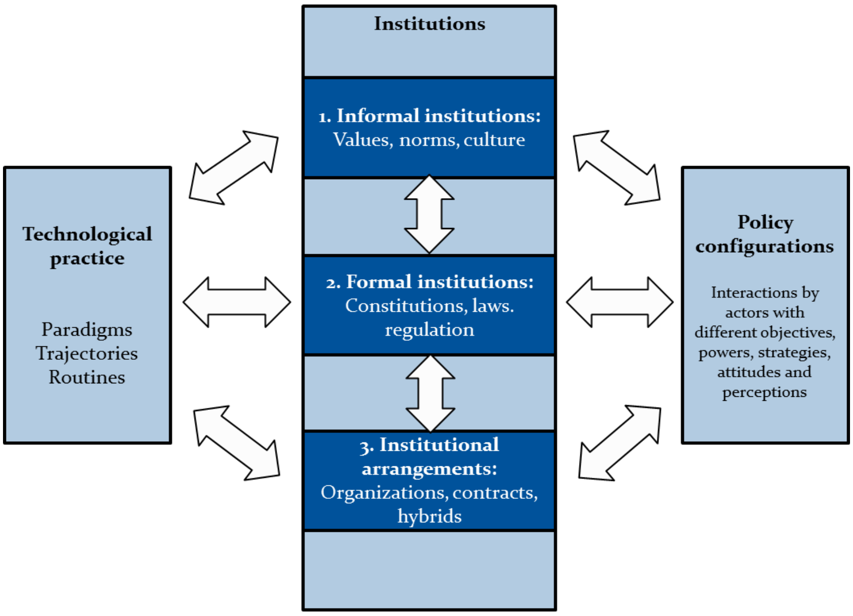


Figure 9. Dynamic Layer Model [by Künneke et al. (2009)]

2.4.2.1 Explanation of the conceptual framework

Informal institutions refer to the values, norms and culture of the system, and rarely ever change. There are only limited opportunities for governments to change or influences these institutions directly, and is mostly done by changing the formal institutions: which refer to constitutions, laws and regulations. Often referred to as the 'rules of the game', the formal institutions include the formal assignment of property rights, (democratic) procedures and structures of political decision-making, the juridicary and bureaucratic organizational structures (Künneke, 2012). These formal institutions influence the institutional arrangements, which refer to the structures of how the 'game is played'. These structures describe the way stakeholders in the system can interact and realize their objectives, and include organizations, contracts and hybrids. The institutional arrangements change more frequently than informal institutions and formal institutions. These institutional layers are interrelated in the way that the institutional arrangements are largely defined by the formal institutions, which in turn are based about the informal institutions. Not only this top-down relationship is argued by Künneke et al. (2009), but the bottom-up relationships as well, arguing the possibility of newly emerging institutional arrangements to present changes to formal institutions and even informal institutions (Künneke, Groenewegen, & Auger, 2009).

The policy configurations element of the framework concerns the interactions among actors that have different objectives, powers, strategies, attitudes and perceptions, which are framed by the institutions and technological configurations and are very case specific. The technological practice element of the framework is defined as "the way in which technological artefacts are planned and created in order to meet human needs" (Künneke et al., 2009, p. 245), and consists of paradigms, trajectories and routines.

The framework uses the notion that changing technological paradigms are interrelated with institutional change. In informal institutions for example the societal changes by the industrialization of the economy. The development of technology is paired with changing formal institutions and institutional arrangements, like the introduction of high-speed train connections was paired with new safety standards (formal institutions) and new public-private partnerships (institutional arrangements). The technological practice and policy configurations are interrelated as well; changes in perceptions or objectives of actors can influence the requirements of the technological practice. For example, more preference towards user driven services for citizens provide requirements of more decentralized control of the technological practice (Künneke, 2012).

2.4.2.2 Example: applying the framework to Bitcoin

The changes in logic between the technological practice, the different layers of institutions and the policy configurations can be seen in Bitcoin, a permissionless blockchain. Bitcoin is a as a cryptocurrency and an electronic payment system based on blockchain technology, and was created by an anonymous (group of) author(s) under the name of Satoshi Nakamoto in 2008. It was created to facilitate payments while avoiding intermediaries like banks that require fees for processing payments, with the objective of creating a more bottom-up, peer-to-peer economic system. In combination with the economic crisis of 2008, these changes in objectives facilitated a change in technological practice.

Though the direct effect of Bitcoin on informal institutions is difficult to argue, the Bitcoin itself stresses individual responsibility in contrast to relying on intermediaries like banks to facilitate services. The consensus-based governance structure of the Bitcoin system contrasts with the traditional figuration of economic systems and limits the possibilities of protecting the public values, the common good and collective rights.

The Bitcoin system in turn initially caused resistance by regulators, legislators and the media, as it became clear that the cryptocurrency was often used for criminal activity given its mathematical guarantee for anonymity. The prevention of criminal activity is one of the values that law makers intend to safeguard, which is why a number of formal institutions changed in the form of laws. Even though the initial reaction of many governments was to ban the use of Bitcoin, more and more countries are legalizing the use of the currency, for example in Japan. Japan now officially accepts Bitcoin as a payment method (Garber, 2017), displaying the increasingly positive sentiment regarding this cryptocurrency.

Bitcoin is not any national system and there is no central owner, the organization of the system is described as self-organizing based on a common interest. This results in a broad variety of institutional arrangements based on consensus of the actors. This can be seen in the Bitcoin network regarding the software version that the nodes are using. In 2013, there was a small technical failure causing to different ledgers to exist at the same time. Consensus needed to be reached on which software version to use in order to restore the error. Eventually, this error was resolved as the majority downgraded to a previous version of the software. This resolved the error and operation with one true Bitcoin ledger continued.

2.4.2.3 The effects of blockchains in the EU

For permissionless blockchains, these effects are more impactful then in permissioned blockchains, because permissionless blockchain do not guarantee the protection of the common good and facilitate the necessary interaction in society. A permissioned blockchain allows governments to keep the necessary control over these networks, allowing public administrations to provide the necessary checks and balances. Therefore, permissioned blockchains are better suited to provide direct protection for these informal institutions.

Though the implementation of permissioned blockchains in public administrations might at first sight only present effects on the organization itself and the network of the service involved, yet it can have impact on the fundamental norms, values and culture as well. Decision-makers in EU Institutions and Bodies need to be aware of this when deciding to experiment with blockchain technology.

In order to create insights in these effects, this thesis will investigate the ripple effects of EU Institutions and Bodies implementing blockchain technology. The Dynamic Layer Model by Künneke et al. (2009) enables the analysis of the effects of a technological configuration on the institutional layers, in this case blockchain technology. In Figure 10, these effects are shown by the arrows. This thesis does not aim to analyze the legal framework, so the only effects of blockchain on the informal institutions and the effects of blockchain on the institutional arrangements are investigated. The effects on the institutional arrangements (organizations, contracts and hybrids) can be two-fold: it can have effect on the public administration setting up the blockchain system and the actors involved in the network. The following layers of effects are analyzed:

1. *Primary effects*: on the organization itself. These effects look at the direct effects on the organization experimentation with the blockchain solution.
2. *Secondary effects*: on the actors in the network. These effects look at the effects on the actors in the network.
3. *Tertiary effects*: impact on society. These effects look at how the blockchain implementation might drive changes to values of society.

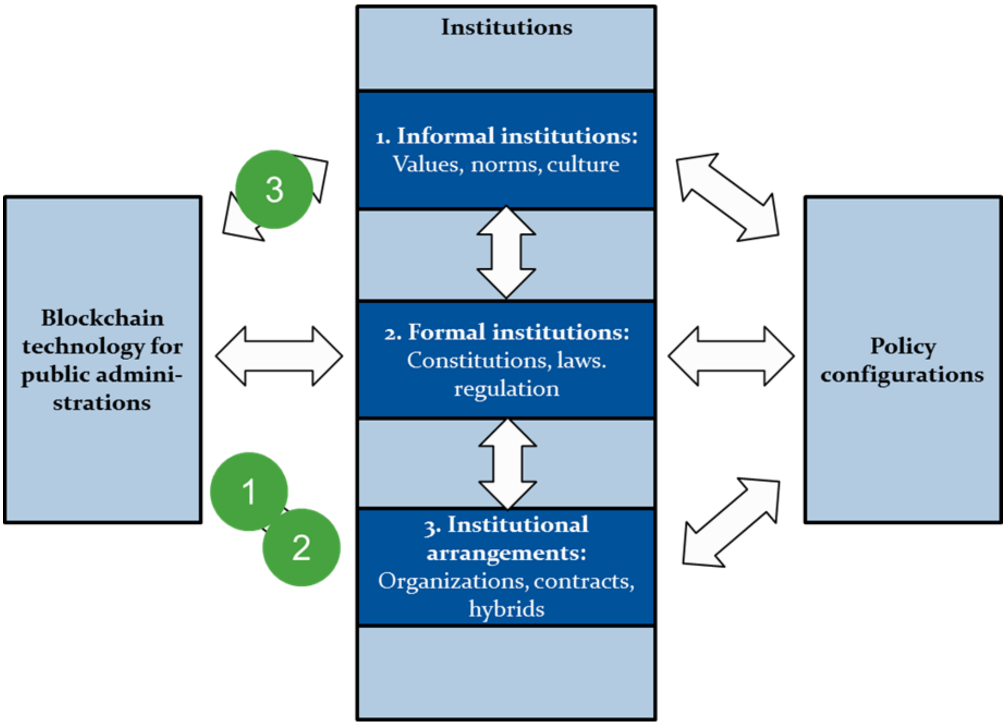


Figure 10. The effects of blockchain in the Dynamic Layer Model [adopted from Künneke et al. (2009)]

Using the dynamic layer model of Künneke et al. (2009) as a basis, these three levels of effects can be mapped for each blockchain implementation. Boucher et al. (2017) present an in-depth analysis on how blockchain technology could change the EU. Primarily focusing on the impact on the public administrators and the network involved, they present a number of effects of blockchain implementation in EU public administrations, including streamlined internal processes, difficulties during transitional phases with legacy systems and the increased protection against errors and forgery. Yet, they also warn for this technology to exacerbate the digital divide. Using a more economic lens, Davidson et al. (2016) provide the analysis that blockchains lower transaction costs and decentralize the control on the transactions. Meijer (2017) uses a Grounded Theory approach to conceptualize the impact of blockchain implementation and presents the argument that a blockchain causes a disintermediation of control by the network. Buterin (2015) argues that given the decentralized governance in blockchain systems, the network is more flexible and the participants are more empowered. Yli-Huumo et al. (2016) argue the increase in data integrity and ICTU (2016) presents the argument that blockchains can enable a self-sovereign identity, allowing for opt-in governmental services and purely local storage of personal data. Ølnes (2015) argues that blockchain implementations promote innovation, and according to Swan (2015) and Tapscott & Tapscott (2016), a blockchain presents a more level-playing field than other information infrastructures. Atzori (2015) argues the changing role of public administrators in blockchain systems, as outlined in 2.2 Blockchain challenging the role of governments. The overview of the effects found in literature are summarized in Table 4.

Table 4. Identified ripple effects of blockchains in literature

Effect	Type	Sources
Streamlined internal processes	Primary	Boucher, Nascimento, & Kritikos (2017)
Reduced effort of transacting with external parties	Primary	Davidson, De Filippi, & Potts (2016a)
Set-up costs	Primary	Boucher, Nascimento, & Kritikos (2017)
Difficulties during transitional phases	Primary	Boucher, Nascimento, & Kritikos (2017)
Disintermediation of control by network	Primary	Meijer (2017)
Stronger security of an informational database	Primary	Davidson, De Filippi, & Potts (2016a)
More trusted inter-organizational data exchanges	Secondary	Boucher, Nascimento, & Kritikos (2017)
Increased protection against errors and forgery	Secondary	Boucher, Nascimento, & Kritikos (2017)
Additional infrastructure needed	Secondary	Boucher, Nascimento, & Kritikos (2017)
Flexibility and empowered network	Secondary	Buterin (2015)
Decentralized control on transactions	Secondary	Davidson, De Filippi, & Potts (2016a)
Robust data integrity	Secondary	Davidson, De Filippi, & Potts (2016a) & Yli-Huumo, Ko, Choi, Park, & Smolander (2016)
Eliminate opportunism	Secondary	Davidson, De Filippi, & Potts (2016a)
Decentralized monitoring	Secondary	Davidson, De Filippi, & Potts (2016b)
Self-sovereign identity	Secondary	ICTU (2016)
Permissioned data distribution	Secondary	ICTU (2016)
Exacerbate the existing digital divide	Tertairy	Boucher, Nascimento, & Kritikos (2017)
Diminishing geographic boundaries	Tertairy	Davidson, De Filippi, & Potts (2016a)
Well performing markets	Tertairy	Davidson, De Filippi, & Potts (2016a)
Inclusion (in coordination)	Tertairy	Davidson, De Filippi, & Potts (2016a)
Protection against the tyranny of the majority	Tertairy	Davidson, De Filippi, & Potts (2016b)
Promoting of innovation	Tertiary	Ølnes (2015)
Level playing field	Tertiary	Boucher, Nascimento, & Kritikos (2017), Swan (2015) & Tapscott & Tapscott (2016)
Changing role for public administrators	Tertiary	Atzori (2015) & Davidson, De Filippi, & Potts (2016a)

Based on the analysis of literature presenting the effects of blockchain implementation in governments, the next paragraph identifies the third element that will be included in the blockchain assessment tool.

2.4.2.4 Elements 3: Ripple effects

In conclusion, given the institutional change that blockchains might present, it is critical to take into account the effects of blockchains when deciding to experiment with blockchain technology as an EU Institution or Body. This results in the third element of the blockchain assessment tool: *Ripple Effects*. This element is elaborated in the textbox below.

The element for the blockchain assessment framework are the ripple effects caused by the implementation of blockchain by the EU Institution or Body. The definition of ripple effects in this thesis are:

Effects on the public organization, the network involved and on society, caused by an implementation of blockchain for the information exchange or registration process of an EU Institution or Body.

2.4.3 RESEARCH ON IT INNOVATION ADOPTION IN GOVERNMENTAL ORGANIZATIONS

Next, literature on IT innovation adoption in governmental organizations is reviewed. A major work in this field is Kamal (2006), who investigated numerous factors influencing the ability of public organizations to adopt IT innovations. Using an interpretive and qualitative multiple case study approach of IT innovations in public organizations presented in normative literature, Kamal (2006) identified a total of 22 factors for IT innovation adoption specifically in public organizations, as presented in Figure 11.

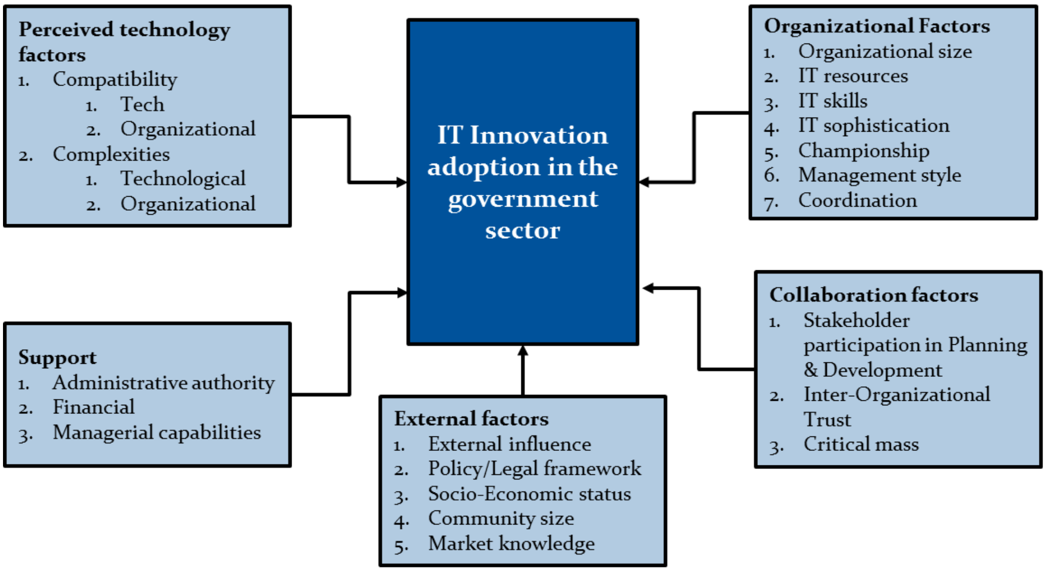


Figure 11. Factors impacting successful IT innovation adoption in the government sector [adjusted from Kamal (2006)]

Kamal (2006) analyzed 24 articles that assess these factors and analyzed their impact on IT innovation adoption in government organizations, which are displayed in Figure 11. These factors refer to IT innovation adoption, and no research has been performed to investigate which are relevant for adopting blockchain technology. Table 5 summarizes these factors.

Table 5. Factors influencing IT innovation adoption in the government sector [adjusted from Kamal (2006)]

Domain	Factor	Impact on IT innovation adoption	References
Support factors	*Administrative authority*	+	Tolbert and Zucker (1983), Kim and Bretschneider (2004), Miller (1983), Moon and Bretschneider (1997)
	Financial	+	Mohr (1969), Ross and Beath (2002), Sambamurthy and Zmud (1999), Kim and Bretschneider (2004)
	Managerial capabilities	+	Mohr (1969), Daft (1978), Kim and Bretschneider (2004), Perry and Danzinger (1980)
	Compatibility: technological	+	Tornatzky and Fleischer (1990), Dasgupta (1997), Caudle et al. (1991), Dawes (1996), Landbergen and Wolken (2001)

Perceived technology factors	*Compatibility: organizational*	+	Landbergen and Wolken (2001), Premkumar and Ramamurthy (1995), Damanpour (1991), Newcomer and Caudle (1991), Norris (1991), Akbulut (2002)
	Complexities: technological	-	Akbulut (2002), Chwelos et al. (2001), Clegg et al. (1997)
	Complexities: organizational	-	Akbulut (2002), Chwelos et al. (2001), Clegg et al. (1997)
Organizational factors	*Organizational size*	+	Rogers (1995), Mohr (1969), Moch and Morse (1977), Damanpour (1992)
	IT resources	+	Akbulut (2002), Newcomer and Caudle (1991)
	IT skills	+	Perry and Danzinger (1980), Norris (1999)
	IT sophistication	+	Chwelos et al. (2001)
	Championship	+	Reich and Benbasat (1996), Beath (1991), Garfield (2000), Norris (1999), Rogers (1995), Rockart (1988)
	Management style	+	Johannessen (1994), Quinn (1986)
	Coordination	+	Johannessen (1994)
Collaboration factors	*Stakeholder participation in Planning & Development*	+	Heeks (1999)
	Inter-Organizational Trust	+	Dawes (1996), Landbergen and Wolken (2001)
	Critical mass	+	Bingham (1976), Bouchard (1993), Chwelos et al. (2001)
External factors	*External influence*	+	Themistocleous et al. (2004), Akbulut (2002), Bingham (1976)
	Policy/Legal assessment tool	+	Landbergen and Wolken (2001)
	Socio-Economic status	+	Bingham (1976)
	Community size	+	Akbulut (2002), Bingham (1976), Brudney and Seldon (1995), Norris (1999)
	Market knowledge	+	Rothwell (1977), Lee and Treacy (1998), Johannessen (1994)

Based on the work of Kamal (2006), the next paragraph identifies the fourth element that will be included in the blockchain assessment tool.

2.4.3.1 Elements 4: Organizational factors

In conclusion, a number of factors determine the importance of the ability of a governmental organization to adopt IT innovation for the success of that adoption. Therefore, an important element for blockchain adoption in governmental organization are the organizational factors. This results in the fourth element of the blockchain assessment tool: *Organizational Factors*. This element is elaborated in the textbox below.

Element 4: Organizational Factors

The fourth element for the blockchain assessment framework are the organizational factors that determine the ability of the EU Institution or Body to adopt blockchain. The definition of organizational factors in this thesis are:

Factors that refer to the support, technological compatibility, organizational, collaboration and external elements of an organization, that impact the ability to adopt an IT innovation in a governmental organization.

2.4.4 LITERATURE ON IT INNOVATION ADOPTION PROCESS IN GOVERNMENTS

The IT innovation adoption process in this thesis is defined in the way Rogers (1995) defines the innovation adoption process: the "process through which an individual or other decision-making authority passes from first knowledge of innovation first knowledge of innovation, to forming an attitude towards innovation, to a decision to adopt or reject, to implementation of new idea, and to confirmation of this decision" (Rogers, 1995, p. 162). The process leading to the institutionalization of the usage of the new technology is considered to be a temporal sequences of steps, yet there is no consensus on what these steps are and in what order they should be taken (Kamal, 2006).

Kamal (2006) created an overview of the different IT innovation processes that are identified in literature, which is presented in Table 6. These IT innovation adoption models and processes predominantly stem from research on organizations in the private sectors. These models use various perspectives, yet they all explain IT innovation adoption or diffusion in a process form in an organization (Kamal, 2006). The biggest differences are the unit of analysis; some models only consider the organization as a whole, others also include the importance of individual actions in IT innovation adoption (Becker & Whisler, 1967).

Table 6. IT innovation adoption models and processes [adopted from Kamal (2005)]

IT innovation adoption model or process	Author
Change model	Lewin (1952)
Stages of innovation adoption	Becker and Whisler (1967)
Two stage innovation adoption model	Zaltman et al. (1973)
Organizational innovation model	Pierce and Delbecq (1977)
Innovation adoption	Rogers (1983)
Technology acceptance model	Davis (1989)
The research model	Agarwal and Prashad (1998)
IT adoption model	Dixon (1999)
Four phase innovation adoption process	Darmawan (2001)
Innovation adoption and implementation	Gallivan (2001)
Organization innovation adoption	Frambach and Schillewaert (2002)

Kamal (2006) noted that these models all explain only one part of the IT innovation adoption process and no single comprehensive model was yet created (Kamal, 2006). Based on these 11 models, Kamal (2006) created an 8-stage innovation adoption process model, represented in Figure 12.

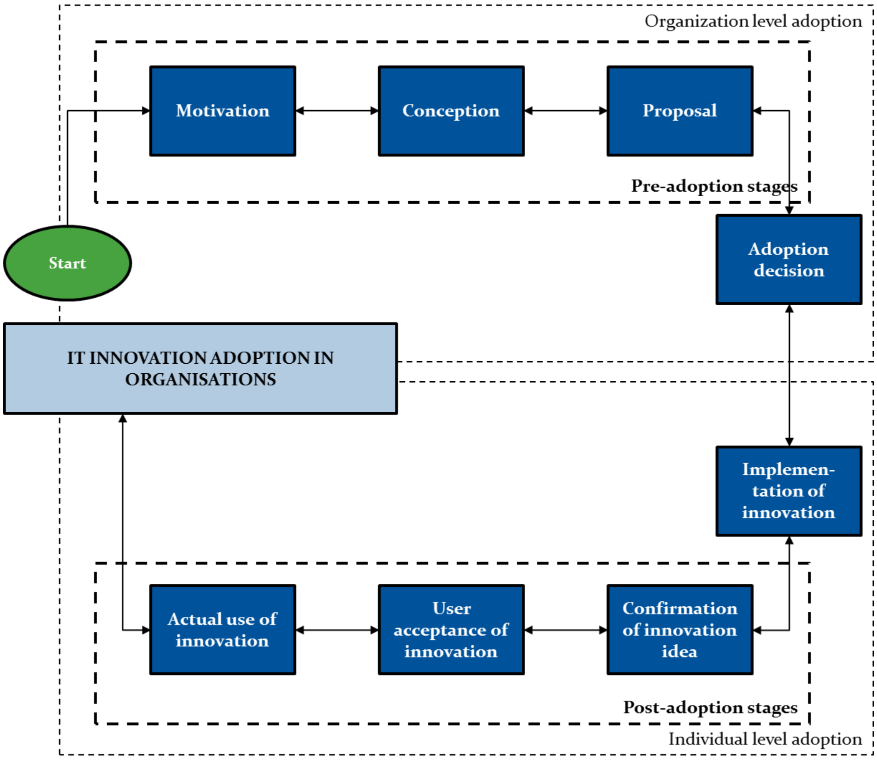


Figure 12. IT innovation adoption process model by Kamal (2006)

The stages in model created by Kamal (2006) are adopted from other models from other authors, and presented in Table 7.

Table 7. Stages in IT innovation adoption process model [adjusted from Kamal (2006)]

Stage	Adopted from
Motivation towards innovation	Pierce and Delbecq (1977), Darmawan (2001), Agarwal and Prashad (1998), Rogers (1983), Frambach and Schillewaert (2002)
Specific conception about innovation	Agarwal and Prashad (1998), Davis (1989), Rogers (1983)
A formal proposal of the rest of the organization about innovation adoption	Becker and Whisler (1967), Dixon (1999)
Actual adoption decision stage	Pierce and Delbecq (1977), Darmawan (2001), Agarwal and Prashad (1998), Rogers (1983), Frambach and Schillewaert (2002), Becker and Whisler (1967)
Implementation of innovation in the organization	Added by Kamal (2006)
Confirmation of innovation idea	Added by Kamal (2006)
User acceptance of the technology	Added by Kamal (2006)
Integrating innovative technology with other information system applications	Added by Kamal (2006)

The objective of this research is to design a tool that provides insight into the value of blockchain. Therefore, the assessment tool that is designed in this thesis focusses on the motivation, conception and proposals stages. The stages that follow after these stage are more formal stages decision-making stages that do not require an initial insight in the value of blockchain. The conception stage is the phase where the members of the organization are learning about the technology and form an attitude towards it (Agarwal & Prasad, 1998). In the proposal stage, the idea of experimenting with the innovation is proposed to other stakeholders in the organization (Becker & Whisler, 1967). Kamal (2008) also presents the argument that there is not merely one decision-making process for IT innovation adoption, as the decision-making processes can vary. In addition, the success of the adoption of the innovation depends on various authors in and around the public organization. Mulgan and Albury (2003) argue that the most important actors are knowledge engineers, ministers and political leaders, directors of the organizations and experts. Each of these actors have their own interest and power in the IT adoption process (Mulgan & Albury, 2003). Yet it is not only this intra-organizational multi-actor complexity creates difficulties in implementing blockchain technology in a governmental organizations, as different organizations, different type of users and data owners all participate in a system with a distributed governance (Böhme et al., 2015; Davidson et al., 2016a). Based on the review of literature on IT innovation adoption processes in governments, the next paragraph identifies the fifth element that will be included in the blockchain assessment tool.

2.4.4.1 Elements 5: Decision-making process

In conclusion, as there is not merely one decision-making process for IT innovation adoption. The process of how a decision on blockchain experimentation is reached needs to be considered when designing the blockchain assessment tool. It is impossible to retrieve a complete overview on the decision-making process regarding blockchain experimentation in EU Institutions and Bodies in literature, so empirical data needs to be gathered to fit the blockchain assessment tool in this process. The high-level IT innovation adoption model by Kamal (2008) can be used as a basis for this. This results in the fifth element of the blockchain assessment tool: *Decision-making Process*. This is elaborated in the textbox below.

ELEMENT 5: DECISION-MAKING PROCESS

The fifth element of the blockchain assessment framework is the process how the EU Institution or Body coming to the decision of deciding about experimentation with blockchain. The definition of the decision-making in this thesis is:

The process of understanding blockchain technology and making decisions regarding the experimentation with blockchain technology.

2.5 Blockchain system design

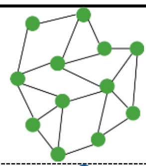
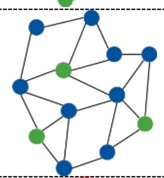
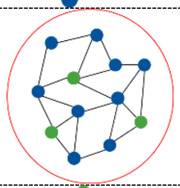
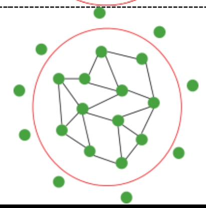
So far, this theoretical background has identified five elements that are included in the blockchain assessment tool: *complexities, process factors, ripple effect, organizational factor* and the *decision-making process*. Next, a technical perspective is used to identify the impact of the different blockchain types and design features on the performance of the system. Currently, literature investigating use cases for blockchain technology consider blockchain as a one-size-fits-all technological solution for a certain problem, ignoring the various design features of blockchain systems. In general, four major blockchain types can be distinguished: public permissionless blockchains, public permissioned blockchains, private permissioned blockchains and private permissionless blockchains (BitFuri Group, 2015; Buterin, 2014; Walport, 2016).

Methodology of the literature review on blockchain system design

For the literature review on blockchain system design, a technical perspective is used. Both academic and semi-academic research was used. Using Google Scholar, Scopus and Google Web search, the following keyword were used: *Blockchain, Blockchain Design, Blockchain type, Consensus Mechanism, Process Criteria.* This resulted in the articles as presented in Table 9.

Table 8 presents an overview of the four types of blockchains as defined by BitFuri Group (2015), Buterin (2014) and Walport (2016). In the table, a visualization of the blockchain system is added. The green dots are the validating nodes, meaning that they are able to validate the transactions in the system and participate in the consensus mechanism. The blue dots are participants in the network in the sense that they are able to transacts, but they are not able to participate in the validation mechanism. The blue dots are not participating in the consensus mechanism. A red ring means that only the nodes in within the ring can see the transaction history. The visualizations without a ring means that everyone with a connection to the internet is able to see the transaction history of the blockchain.

Table 8. Overview of blockchain types

Blockchain type	Explanation	Example	Visualization
Public permissionless blockchains	In these blockchain systems, everybody can participate in the consensus mechanism of the blockchain. Also, everyone in the world with a connection to the internet is able to transact and see the full transaction log	Bitcoin, LiteCoin, Ethereum	
Public permissioned blockchains	These blockchain systems allow everyone with a connection to the internet to transact and see the transaction log of the blockchain, but only a restricted amount of nodes can participate in the consensus mechanism, allowing for a more controlled environments (Schwartz, Youngs, & Britto, 2014)	Ripple, private versions of Ethereum	
Private permissioned blockchains	These blockchain systems restrict both the ability to transact and view the transaction log to only the participating nodes in the system, and the architect or owner of the blockchain system is able to determine who can participate in the blockchain system and which node can participate in the consensus mechanism	Rubix, Hyperledger	
Permissionless private blockchains	These blockchain systems are restricted in who can transact and see the transaction log, but the consensus mechanism is open to anyone	No current use is known, due to contradicting properties	

Another significant design feature of a blockchain system is the consensus mechanism. A consensus mechanism is the protocol that determines how transactions are validated. KPMG (2016) present a formal definition: "A consensus mechanism is the way in which the majority (or, in some mechanisms, all) of the network members agree on the value of a piece of data or a proposed transaction, which then updates the ledger" (KPMG, 2016, p. 3). An overview of the high-level design features of blockchain systems is presented in Table 9.

Table 9. Design features of blockchain systems

Blockchain design axis	Design option	Explanation	Source
Data access	*Private*	Only a predefined set of entities can transact in the system. The transaction log is only available to the nodes in the system and not available for anyone outside the system	BitFuri Group (2015)
	Public	Anyone can transact view the transaction log and data. This data may still by encrypted and therefore by anonymized	BitFuri Group (2015)
Consensus participation	*Permissioned*	Only a selected amount of nodes can validate the transactions and therefor the consensus mechanism is limited to a predefined set of participants	BitFuri Group (2015)
	Permissionless	Anyone with the right hardware can participate in the consensus mechanism and validate the transactions in the blockchain systems.	BitFuri Group (2015)
Consensus mechanism	*Proof-of-work*	Uses computational power to validate new blocks of data and the first solver receives a newly issued (part of a) coin	KPMG (2016) & ENISA (2016)
	Proof-of-stake	Validation nodes voting on valid blocks based on their wealth (stake) and get rewarded with a transaction fee instead of newly issues coins	KPMG (2016) & ENISA (2016)
	Proof-of-activity	Combining both proof-of-work and proof-of-stake, thereby making in more difficult to rewrite history in these systems	KPMG (2016)
	Proof-of-capacity	Proof of Capacity is a consensus mechanism where miners with large free disk space are chosen to validate the transactions	KPMG (2016)
	Ripple Protocol	Using a predefined list of effective validating nodes, this protocol allows for fast transactions and requires a supermajority to provide validation	ENISA (2016)
	Proof-of-Elapsed Time	This transaction mechanism uses a lottery to fairly distribute the validation rewards to the participating nodes in comparison to Proof-of-Work, where the node with the most computing power and thereby first validates the transaction wins the reward	ENISA (2016)

2.5.1 IMPACT ON PROCESS CRITERIA

The different design features all have a certain impact on the system. Various researchers have looked into the impact of a specific design feature on process criteria including system reliance, control, actor transparency, external transparency, data assurance, security, scalability and energy efficiency of the system (Gartner, 2016a).

- **System reliance** - Refers to the level of reliance in the system of actors, where even if there is no explicit external governance as part of the operating model, the system should continue providing the intended level of assurance
- **Control** – Refers to the control on the counterparties in the system from perspective of the organization that is issuing the system
- **Actor transparency** - Refers to the transparency of the identity actors that are transacting in the system to the other actors in the system
- **External transparency** – Refers to the transparency of the transaction and actors in the system from an external perspective
- **Data assurance** - Refers to the recording and protection of the origin and history of all identity, attributes and certification hash records.
- **Security** - Refers to the confidentiality, integrity and availability of the ID of the participant
- **Scalability** - Refers to how the system performs under a large volume of read-and-write operations workload
- **Energy efficiency** - Refers to whether the system operates economically, thus serving a large population of user entities with minimal cost and waste.

2.5.1.1 Impact of different blockchain categories

Gartner (2016) investigated the architecture and the considerations of blockchain platforms. Looking at how blockchain systems can support reliance, assurance, provenance, security, scalability and efficiency, it is argued that private blockchain networks are more suitable to address these criteria (Gartner, 2016a) and an overview is presented in Table 10.

Table 10. Impact of different data access types of blockchain

Impact criterion/data access type	Public blockchain	Private blockchain
System reliance	++	+
Control	-	+
Actor transparency	-	++
External transparency	++	-
Data assurance	-	o
Security	+	+
Scalability	-	o
Energy efficiency	--	o

ENISA (2016) looked into the impact of various design features. Regarding consensus participation, ENISA states that permissioned blockchains increase reliance and security, yet the scalability can be a potential issue. On the contrary, permissionless blockchains provide advantages regarding transparency and scalability (ENISA, 2016). Based on these two reports, Table 11 was constructed, that represents the four major blockchain types and how they score on the impact criteria.

Table 11. Four major blockchain types scoring on criteria

Impact criterion/blockchain type	Public permissionless blockchains	Public permissionless blockchains	Private permissioned blockchains	Private permissionless blockchains
System reliance	++	++	++	++
Control	--	-	+	o
Actor transparency	o	-	++	++
External transparency	++	++	-	-
Data assurance	-	-	++	++
Security	+	++	++	+
Scalability	o	--	-	+
Energy efficiency	--	--	o	o

ENISA (2016) also investigated four different consensus protocols; proof-of-work, proof-of-stake, the Ripple Protocol and proof-of-elapsed time. In this report, it is argued that proof-of-work presents advantages regarding transparency, but is less scalable and energy efficient. Proof-of-work is less transparent but regarding performance it has advantages looking at the scalability and energy efficiency. The Ripple Protocol requires all participants to vote, providing a positive impact on the assurance criterion. The proof-of-elapsed time consensus mechanism is highly energy efficient (ENISA, 2016), but can be limited scalable. KPMG (2016) also investigated four consensus mechanisms: proof-of-work, proof-of-stake, proof-of-activity and proof-of-capacity. Proof-of-activity (also called delegated proof-of-stake) combines proof-of-work and proof-of-stake characteristics, presenting energy efficiency advantages without the transparency trade-off (KPMG, 2016). Proof-of-capacity is a relatively new protocol, and literature only suggest a significant disadvantage regarding energy efficiency. Table 12 provides an overview of the impact of the different consensus mechanisms as presented in ENISA (2016) and KPMG (2016).

Table 12. Impact of different consensus mechanisms

Consensus mechanism/impact	Positive impact	Negative impact
Proof-of-work	Data assurance	Scalability & energy efficiency
Proof-of-stake	Scalability & energy efficiency	-
Proof-of-activity	Energy efficiency	-
Proof-of-capacity	-	Energy efficiency
Ripple Protocol	Data assurance	Scalability
Proof-of-Elapsed Time	Energy efficiency	Scalability

2.5.1.2 Elements 6: Design features

In conclusion, the different blockchain design features impact the systems performance, causing not every blockchain design to fit every process. Therefore, it is important to reflect on the impact of these features on the process criteria. The review of literature provides all insights necessary for this element, as it is based on proven research. Therefore, the empirical data gathering in this thesis will not focus on this element. This results in the sixth element of the blockchain assessment tool: *Design Features*.

ELEMENT 6: DESIGN FEATURES

The sixth element of the blockchain assessment framework are the design features of blockchain systems and their impact on process criteria. The definition of design features in this thesis are:

Choices that a designer can make in the technical design of a blockchain-based system that impact the process criteria.

2.6 ELEMENTS OF THE BLOCKCHAIN ASSESSMENT TOOL

The theoretical background provided six elements that are important to incorporate in the blockchain assessment tool. These six elements are the basis for the empirical data gathering in Chapter III Requirements Definition. The six elements are summarized in Figure 13.

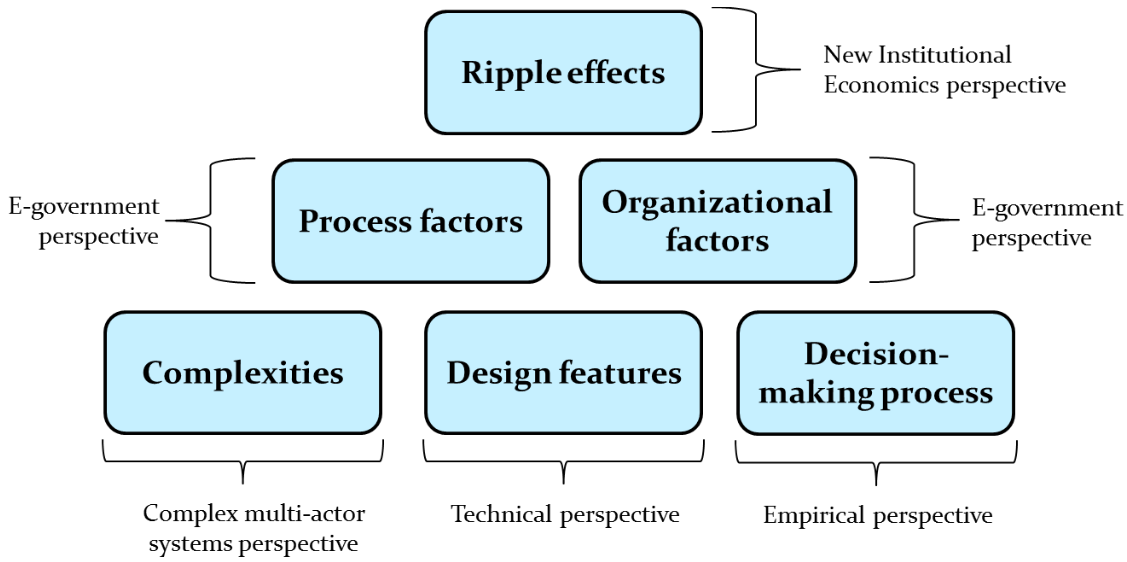


Figure 13. Overview of the six elements for the blockchain assessment tool

2.7 CONCLUSIONS OF CHAPTER II

Bases on the review of literature as outlined in this chapter, the first research question can be answered: *What is currently known about the potential of blockchain technology in governments?* Four main areas of research are found: 1) blockchain challenging the role of governments, 2) blockchain as a complex multi-actor system, 3) blockchain for e-governments, and 4) blockchain system design. Blockchain can change the role of public administration from an electronic intermediary to a supervisor in a registration or data exchange process, but won't completely make public administrations redundant. There will still be a need for a public administrator to act facilitate coordination in society and markets to eliminate opportunism and protects the common good. Blockchain can present the next step in e-government development as it can provide many benefits if applied in the right 'fit'. This fit is determined by the fit with the process for which the blockchain is used and the fit with the organization. Complexities in the experimentation with blockchain technology by governments are caused by from the multi-actor nature, the legacy systems in place, the nature of the interactions in the system, the public interest involved, and the uncertainty involved in the system. The design of blockchain impacts the performance of the system as blockchains are not one-size fits all solutions. Each blockchain type and consensus mechanism have their individual impact on the system performance.

The insights from these four literature review sections are used to answer the second research question: *What are the elements that need to be incorporated in the design of a blockchain assessment tool for EU Institutions and Bodies?* Six elements were found to be of importance for blockchain experimentation in EU Institutions and Bodies: *Complexities, Process Factors, Ripple Effects, Organizational Factors, Decision-making Process* and *Design Features*. It is critical to take the complexities involved in implementing blockchain in public administrations into account. Also, the factors that define the fit between the process and blockchain technology need to be considered as insight in this fit can enhance decision-making regarding blockchain experimentation in EU Institutions and Bodies. In addition, there are a number of organizational factors that determine the ability of a governmental organization to adopt blockchain technology. Given the institutional change that blockchains might present, it is critical to take into account the ripple effects of blockchains when deciding to experiment with blockchain technology as an EU Institution or Body. As there is not merely one decision-making process for IT innovation adoption, the process of how a decision on blockchain experimentation is reached needs to be considered as well. Lastly, as blockchain technology compromises of various types and design features, it is important to reflect on the impact of these features on the process criteria. These elements will now form the basis for the Requirements Definition step of this research that is described the next chapter.

III. Requirements Definition

This chapter is describes the Requirements Definition step of this research, presenting the research step that uses empirical research to draw insights from the environment. This step uses explorative interviews to make the elements that are defined in the previous chapter more concrete for the blockchain assessment tool. Based on these concrete elements, requirements are formulated for the blockchain assessment tool. This chapter answers research question 3: **What are the requirements for a blockchain assessment tool that supports decision-making regarding blockchain experimentation in EU Institutions and Bodies?** An overview of the requirements definition process is provided in paragraph 3.1. The explorative interviews consists of two approaches: explorative expert interviews (paragraph 3.2) and interactive case study interviews (paragraph 3.3). The design features element does not use explorative interviews to make this element more concrete, as the theoretical perspective used in the literature review provides a sound base. The concretization of the design features element is described in paragraph 3.4. The overview of the functional and non-functional requirements are presented in paragraph 3.5. The concretized elements and requirements are used in the design of the blockchain assessment tool, which is presented in the next chapter. This chapter end with a conclusion to the third research question in paragraph 3.6.

3.1 Requirements definition overview

Figure 14 presents an overview of how the literature review is translated into requirements. The theoretical background presented in the previous chapter provided the six elements for the blockchain assessment tool. Based on these elements, explorative interviews are conducted to gather empirical data, to concretize the elements. The explorative interviews use the elements found in the theoretical background as a basis to shape the interview format and questions. Semi-structured explorative expert interview are used to gather data in relation to the *complexities, process factors, organizational factors* and *decision-making process* involved in blockchain implementation. Interactive case study interviews are used to map and prioritize the *ripple effects* of blockchain implementation. Analyzing the data retrieved in the explorative expert interviews, a Qualitative Data Analysis is used to structure the qualitative data into clear findings. A Matrix Prioritization Analysis is used in the interactive case study interviews to prioritize the ripple effects of blockchain, whereby the effects identified in literature serve as a basis. Each of the concretized elements are then translated into requirements for the blockchain assessment tool.

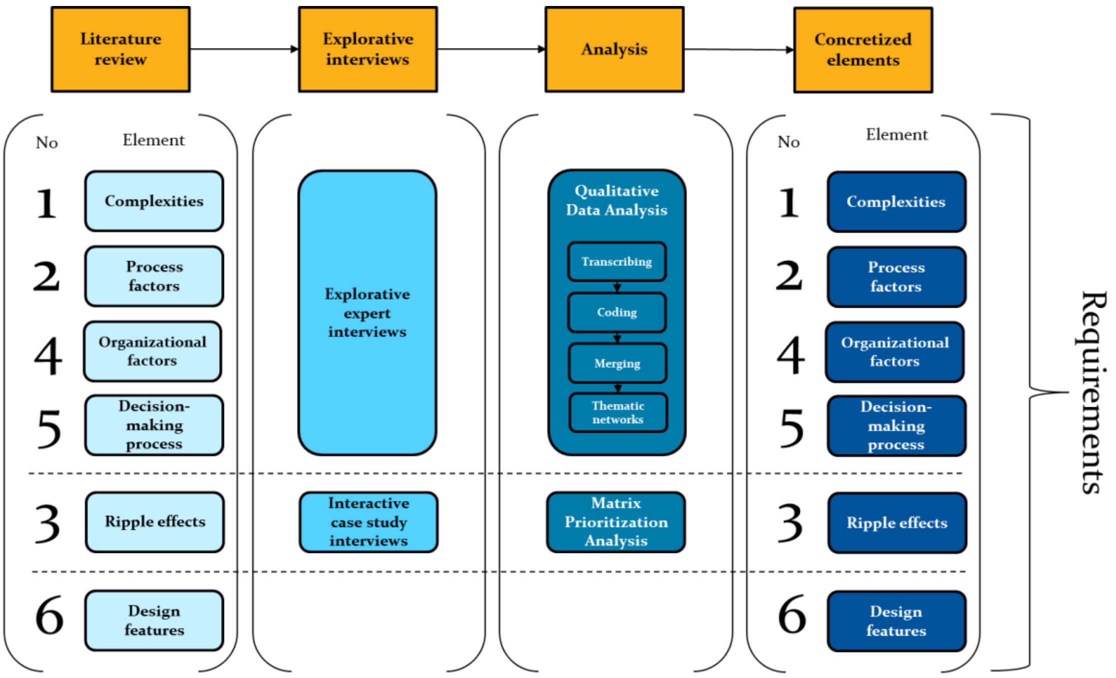


Figure 14. Overview of analysis towards requirements definition

The gather the empirical data to determine the requirements of the blockchain assessment tool, two types of interviews are used. The first round of interviews is of explorative nature, and the second round is focused on one specific case. Both interview type use the theoretical background as a basis to concretize the elements for the blockchain assessment tool. Table 13 presents an overview of the interview methods used in this chapter.

Table 13. Overview of interview methods in this chapter

Interview type	Explorative expert interview	Interactive case study interviews
Interview strategy	Exploratory	Exploratory
Method	Semi-structured questions and open answers	Effects mapping and prioritization
Amount of interviews	9	2
Objective	Concretize the complexity, process factors, organizational factors and decision-making process elements for the implementation of blockchain in EU Institutions and Bodies	Identify the applicable ripple effects of blockchain implementation in EU Institutions and Bodies
Input	- Theoretical background on the complexities, process factors, organizational factors and decision-making process - Semi-structured questions	- Theoretical background on ripple effects - Matrix Prioritization Analysis - EU Institution or Body investigating blockchain for a specific process
Output	- Empirical data on complexities, process factors, organizational factors and decision-making process - Concretized complexity, process factors, organizational factors and decision-making process elements for the blockchain assessment tool	- Empirical data on prioritized effects of blockchain - Concretized ripple effects element for the blockchain assessment tool
Interviewees	Decision-makers in EU Institutions and Bodies	Decision-makers in EU Institutions and Bodies

In the next sections, the concretization of the elements are described. First, the concretization of the *complexities, process factors, organizational factor* and the *decision-making process* elements is described, for which the explorative expert interviews and the Qualitative Data Analysis are used. Next, the concretization of the *ripple effects* elements is presented, for which the interactive case study interviews and the Matrix Prioritization Analysis is used. Lastly, the *design features* element is concretized based on the articles found in the literature review.

3.2 Concretizing the complexity, process factors, organizational factors and decision-making process elements

This section describes the concretization of the *complexities, process factors, organizational factor* and the *decision-making process* involved in the experimentation of blockchain technology by EU Institutions and Bodies. These elements were identified in the theoretical background, and explorative expert interviews are used to make them concrete for the blockchain assessment tool. First, the explorative interviews method is described. Second, it is described how the gathered data is analyzed. Lastly, the concretization of the *complexities, process factors, organizational factor* and the *decision-making process* elements are described.

3.2.1 Explorative expert interviews

Explorative expert interviews are used because knowledge required to concretize the *complexities, process factors, organizational factors* and the *decision-making process* involved in the experimentation of blockchain technology is partly embodied (tacit) knowledge and embedded knowledge in EU Institutions and Bodies (Johannesson & Perjons, 2014). The explorative expert interviews are constructed on the basis of concepts found in literature (Johannesson & Perjons, 2014). In this research, the respondents were interviewed about the *complexities, process factors, organizational factor* and the *decision-making process* elements. First, the interviewee selection is presented. Secondly, the interview protocol is described. Then, the analysis of the data gathered is described, for which a Qualitative Data Analysis approach is used. Lastly, the *complexities, process factors, organizational factor* and the *decision-making process* elements are concretized based on this analysis.

3.2.1.1 Interviewee selection

In order to gain the accurate knowledge from the environment domain, the interviewees must be in line with the research problem and objective, as well as the theoretical background in order to answer the research questions. To gain insights for the users for which the assessment tool is designed, it is critical that the interviewees are decision-makers or policy-makers for the executive processes of the EU. Both EU Institutions and Bodies and closely related forms are identified in this context. The assessment tool assesses the potential of blockchain for two governmental processes: *registration* and *information exchange*. To make the blockchain assessment tool applicable for both processes, the requirements are drawn from interviewees that are involved in a mix of these processes. The interviewees were selected on the following basis:

- The interviewee is an employee of an EU institution or agency
- The organization the interviewee works for is involved in or provides advice to an organization involved in an information registration or exchange process
- The interviewee is either policy-maker, IT manager or technology influencer in the organization, and the different actor types are evenly distributed in the sample
- The interviewee is familiar with blockchain technology
- The interviewee has been involved in an IT innovation adoption or decision-making process

The overview in Table 14 presents the 9 organizations that were interviewed for the explorative expert interviews. In total 6 interviews were conducted with employees involved in a process of registration with their organization and 8 of the interviews were conducted at organizations involved in a process of information exchange. The interviews took 1 hour and are of explorative nature, using a semi-structured research approach. For confidentiality reasons, the organization and interviewee names are anonymized.

Table 14. Explorative expert interviews overview

Organization number	EU Body type	Sector	Interview type	Process type	Actor type
1	Other institution	Economy and finance	1-on-1	Registration/Information exchange	IT manager
2	Directorate-General	Development and aid	1-on-1	Registration/Information exchange	EU policy-makers
3	Other institution	Law and crime	1-on-1	Information exchange	Technology influencer
4	Executive agency	Science and technology	1-on-1	Registration/Information exchange	Technology influencer
5	Directorate-General	Economy and finance	Collective	Information exchange	EU policy-makers and Technology influencers
6	Directorate-General	Climate and environment	1-on-1	Registration	IT manager
7	Executive agency	Agriculture, fisheries and food	Collective	Information exchange	IT managers and technology influencers
8	Directorate-General	Science and technology	Collective	Registration/Information exchange	EU policy-makers
9	Directorate-General	Science and technology	1-on-1	Registration/Information exchange	EU policy-maker

3.2.1.1 Explorative expert interview protocol

For the explorative expert interviews, a semi-structured interview protocol was used, that is based on the *complexities, process factors, organizational factor* and the *decision-making process* elements as identified in the previous chapter. The interview consisted of four sections: personal questions, questions about the current challenges the EU Institutions or Body is facing, the decision-making process for IT innovation adoption, and process- and organizational factors and complexities in blockchain experimentation in their organization. The full explorative expert interview protocol can be found in Appendix 3.2.1.1 Explorative expert interview protocol.

3.2.2 Qualitative Data Analysis

This thesis gathers qualitative data from both the knowledge base and the environment, using a literature review and expert interviews. The literature review served as a basis to identify the elements that are important for the blockchain assessment tool, and expert interviews are used to make these more concrete. To analyze the expert interview data, a qualitative data analysis approach is used. *Atlas.ti* is used to structure and code the data. This software is particularly suitable for this task, as it can help to systematically analyze unstructured data and uncover complex phenomena (Silver & Lewins, 2014). Atlas.ti is especially valuable to reveal meanings and relationships, as the user can code, semantically link and visualize qualitative data from different formats. The function of the semantic linking and visualization of the various concepts in this thesis is that it allows for the understanding of the relationship between concepts and the identification of new patterns (Silver & Lewins, 2014). The input for the qualitative data analysis are the explorative expert interviews. The coding of the interviews is done based on the transcripts of the interviews, and the initial code groups are based on the elements identified in the literature review. In addition, the articles that define the *process factors* (Table 3) and *organizational factors* (Table 5) complemented the coding for these elements, as literature already provides a number of potential process and organizational factors. The next paragraphs describe the steps in the qualitative data analysis.

3.2.2.1 Transcribing

First, the interviews are transcribed using the notes and audio recordings of the interviews. The interviews are transcribed as accurate as possible. The transcriptions were send back to the interviewees for validation. After consent, the transcripts are used for the coding phase. This transcripts are not included in this thesis due to confidentiality reasons. Also, the employee and company names are filtered out in this for confidentiality reasons. The articles found in the literature review that define the *process factors* (Table 3) and *organizational factors* (Table 5) are in written form already, so transcribing is not necessary for these documents.

3.2.2.2 Coding

The next phase is the coding phase. The documents are coded in the following code groups, which are related to the element as defined in the theoretical background. Table 15 provides an overview of the different elements that are coded.

Table 15. Overview of code groups in the qualitative data analysis

Element	Definition	Code group
Complexities	A complex element of the blockchain implementation that is "difficult to describe, understand, predict, manage, design or change" (De Weck et al., 2011, p. 186)	Complexities
Process factors	Factors that refer to either the environment of the process or to the process itself, that assess the applicability of a blockchain system for the information exchange or registration process of the EU Institution or Body	Process factors
Organizational factors	Factors that refer to the support, technological compatibility, organizational, collaboration and external elements of an organization, that impact the ability to adopt an IT innovation in a governmental organization	Organizational factors
Decision-decision making process	The process of understanding blockchain technology and making decisions regarding the experimentation with blockchain technology	Decision-making process

Both the insights from the knowledge base (literature review) and insights from the environment domain (expert interviews) can be combined in the coding process. The overview of all codes used is provided in Appendix C.2 Qualitative Data Analysis. Argumentation for the coding is necessary, to derive valuable insights in the next step: identifying and analyzing Thematic Networks. The identification and analysis of the Thematic Networks is done to understanding of the relationship between concepts and the identification of new patterns and to concretize the elements. Before these Thematic Networks can be created, the codes that are overlapping or redundant are merged.

3.2.2.3 Merging codes

The next step is merging codes that are overlapping or redundant. Some experts mean the same thing but use other wording, so this step is done carefully and systematically. Also, the overlap between the codes between the documents of the literature review for the *process factors* and the *organizational factors,* and the transcription are investigated. The output of this step is a list of codes and quotations for each code group. Appendix C.2 Qualitative Data Analysis presents an overview of all codes used and merged. Quotations are left out due to confidentiality reasons.

3.2.2.4 Creating Thematic Networks

The last step is identifying and analyzing Thematic Networks, meaning that a qualitative data analysis technique for conducting thematic analysis of qualitative data is performed. This allows this research to concretize the elements identified in the theoretical background. Based on the step-by-step guide by Attride-Stirling (2001), web-like illustrations that summarize the main themes in both the literature review and the interviews are created (Attride-Stirling, 2001). This method is chosen since it allow for the systematization of qualitative data, without it being too rigid for new field of research. This steps aims to transform the qualitative data into clear findings. This is achieved by 1) the merging of terms and 2) the mapping of the findings into a Thematic Network of the concepts. This is done for all the code groups. An overview of the Thematic Networks for each code group is presented in Appendix C.2 Qualitative Data Analysis. The insights of the Qualitative Data Analysis is presented for each code group is the following sections. For each of the four elements, the literature review insights are recapped, after which the concretization based on the explorative expert interviews is described.

3.2.3 COMPLEXITIES

The complexities inherent to blockchain systems create uncertainties when implementing this technology in EU Institutions and Bodies. The literature review used complex systems theory to identify areas where these complexities could arise. The explorative expert interviews focused on making these complexities concrete for blockchain in EU Institutions and Bodies. First, the insights from the literature are recapped, and after this empirical insights from the interviews are presented. Concluding, the complexities element is concretized based on the explorative expert interviews, and an overview of the complexities that are taken into account in the design of the blockchain assessment tool is presented.

3.2.3.1 Literature review insights

Using a complex systems lens, the complexity in blockchain systems are argued to emerge in the following areas:

- *Multi-actor nature* - The multi-stakeholder nature of complex systems, as well as its multi-objective nature complexity (Rouse, 2007).
- *Legacy systems* - Legacy systems already in place facilitate complexity in these systems (Rouse, 2007).
- *Nature of interactions* - The number and nature of interactions within a complex system (Rouse, 2007).
- *Public interest involved* - Complex systems generally have a public interest or stake of some sort, which is more or less inherent to large scale systems (Koppenjan & Groenewegen, 2005).
- *Uncertainties* - In blockchain systems, uncertainties can arise in two forms; in technological uncertainties and institutional uncertainties (Koppenjan & Groenewegen, 2005). Technical uncertainties refer to the uncertainty on the maturity of the technology, and institutional uncertainties refer to the uncertainty of how this technology will fit and shape current institutions.

3.2.3.2 Explorative expert interview insights

In the interviews that were conducted, only multi-actor applications of blockchain technology were examined by the interviewees. The decentralized characteristics are of blockchain technology are the drivers of the benefits that these organizations seek, while keeping the reliability and robustness of the systems. The added value of having a blockchain application for an internal process only is considered to be non-existent by the interviewees. Some experts argued that it could be a decentralized way of implementing a data container solutions.

"We are [only] looking at applications for inter organizational information exchange, so working with different organizations from different countries." - *Technology influencer at an EU organization in the Science and Technology sector.*

Complexity of interoperability between blockchains as well as the legacy IT systems in place was extensively mentioned in the explorative expert interviews. Integration with legacy systems is recognized as a large challenge. Many legacy systems are already years in place, and important institutions are based on these systems for reporting and risk management in the public sector. The highly institutionalized environments make blockchain experimentation a complex task.

"The problem here is definitely the legacy systems; it is not trivial to map the configuration [of the existing process] with the blockchain on a legacy system. We cannot rely on the blockchain for all the information exchange, we still need legacy systems for this." – *IT manager at an EU organization in the Economy and Finance sector*

The nature of interactions in blockchain systems are currently more of a hurdle than an enabling factor. It is argued that current blockchain systems are not developed enough to provided added value in systems where there are large volumes of transactions. What is of importance here is to keep an eye on the development of this technology. Many of the experts recognize the limitations in scalability of current blockchain systems, but argue that this will evolve in the future.

"[Blockchain applications are valuable in] providing information for backend services. So, in terms of situations where you don't have a lot of volume regarding transactions, but where you want to be sure that the information that you see is right and correct. Financial institutions look at thousands of transactions per second, which the technology cannot handle yet. This might evolve in the future and be solved, but right now it is still a problem" - *Technology influencer at an EU organization in the Law and Crime sector*

The complexity of having a public interest involved is mostly expressed through the fact that many organizations do not see it as their task to be a first-mover in this field. Development and experimentation is something for the private sector is the argumentation, and public administrations should be as cost-effective as possible.

"We are a public administration, so we are subject to audit and we are subject to public document legislation. Financial regulation imposes a lot of restrictions, which is fair since we are spending taxpayer's money, so we must use it effectively." – *IT manager at an EU organization in the Economy and Finance sector*

Uncertainties about the technology can be seen in the fact that many organizations expect the technology to evolve in the coming years. Yet almost all of the experts that were interviewed share an optimistic view on the potential development of blockchain technology. Institutional uncertainties are perceived to be of more importance. Many of the executive processes are the result of years of evolution and the stakeholders involved in these processes have their own interfaces; for example economic operators in customs systems, local authorities in many registration systems, and accounting departments in many of the financial systems. The way these institutional uncertainties in blockchain experimentation can be mitigated is by setting up proof-of-concepts that do not incorporate any of these existing institutionalized systems, allowing for the demonstration of the added value of these applications. Then, is the argumentation, the application can later grow in size and stakeholders involved, and become institutionalized along the way.

"Complexity originates out of sequential development of IT systems. We should take a more iterative approach; start small, just show the concept. You have to start with what the problems are that you are confronted with. In that way we can test the distribution and test the interfaces. Later, we can roll it out." – *Policy-maker at an EU organization in the Science and Technology sector.*

3.2.3.3 Concretizing the complexities element

The Qualitative Data Analysis based on the explorative expert interviews allows for the concretization of the complexities element. Table 16 provides an overview of the complexities in blockchain experimentation in EU Institutions and Bodies as identified in the explorative expert interviews that should be included in the blockchain assessment tool. The full Thematic Network for this code group can be found in Appendix C.2.1 Complexities .

Table 16. Complexities in blockchain experimentation in EU Institutions and Bodies

Complexity dimension	Complexity category
Multi-actor nature	*Trust in external actor data input*
	Information complexity
	Cross-organizational use-case
	Decentralized characteristics
Legacy systems	*Different interfaces*
	Different data sources
	Interoperability
	Legacy systems in place

Nature of interactions	*Scalability issues*	
	Low volume of transactions	
Public interest involved	*Tax payers money*	
	Cost-effectiveness	
Uncertainties	*High institutionalized environment*	
	Technological uncertainty	

For the *complexities element*, the following functional requirement is presented:

The blockchain assessment tool must take into account the ***multi-actor nature, legacy systems, nature of interactions, public interest involved*** *and u****ncertainties*** *involved in blockchain experimentation in EU Institutions or Bodies*

3.2.4 Process factors

Current literature provided several factors that define the fit between the process and blockchain technology, and the experts were asked in the explorative expert interviews about these process factors for which they deem blockchain-based systems applicable. First, the insights from the literature are recapped, and after this empirical insights from the interviews are presented. Concluding, the process factors element is concretized based on the explorative expert interviews and literature review, and an overview of the process factors that should be included in the blockchains assessment tool is presented.

3.2.4.1 Literature review insights

Current literature on governmental processes and blockchain is still rather limited, and focus on the various processes of the government for which blockchain technology can provide added value. Three articles provide factors that refer to either the environment of the process or to the process itself, that assess the applicability of a blockchain system for the governmental process. Table 3 provides an overview of these factors based on the literature review. Three general domains of factors that that define the fit between the process and blockchain technology are presented: factors that refer to the general context, factors that refer to the data and processing power and process prioritization factors.

3.2.4.2 Explorative expert interview insights

In the explorative expert interviews, a number of factors that determine the fit between a governmental process and blockchain were mentioned by the experts. This section described the factors on which there was the most debate, the threats that were most often mentioned and the process factors that are unique to the public sector. As became clear in the explorative expert interviews, there is little consensus on what blockchain systems can bring in terms of security. Some EU organizations are looking at the technology because they argue it will bring security advantages, whereas others argue that the same level of security can be provided in other systems like central or decentralized databases. The differences became apparent in the explorative expert interviews, and can be seen in the following quotes;

"This is the first technology that has security in mind from the ground up. Normal technology has security measures build on top. The blockchain has this build in, as it has the encryption in its architecture, which was missing from previous technologies." – Technology influencer at an EU organization in the Science and Technology sector.

This contrast is apparent in an interview with an IT manager in an EU organization when discussing the possibilities of blockchain for an application for the exchange of information:

"[…] I don't see how Blockchain would make the security any better in this case. Somebody must have a login in their computer and access the system, and they would have to send the message from the Member State to the system of this [organization][2]. Is the Blockchain going to guarantee the identity of the person sitting at the computer and sending the message? As of now, no." - Technology influencer at an EU organization in the Law and Crime sector.

[2] Organization name anonymized

In addition, in some interviews other trends like quantum computing were mentioned as possible threats to current security measures like the use of certificates, which could possible break the certificates in place. On the contrary, this exact trend could present troubles for the public-private key generation that is used in current blockchain systems.

"We might have problems in the future of blockchain regarding quantum computing, [...] because quantum computers might be able to break some asymmetric encryption algorithms. So even if the information is encrypted, somebody might be able to impersonate somebody else for some reason and read the data. But this is something to keep in mind that might come as a future challenge." - Technology influencer at an EU organization in the Science and Technology sector.

Another interesting insight is that many of the experts see the added value of blockchain to reduce bureaucratic processes, and mostly with the usage of smart contracts. But, many also see the low level of maturity of blockchain to add this level of automation, and are currently more interested in the distributed characteristics of blockchain. It became clear that EU Institutions and Bodies do not look to blockchain just to get a piece of the pie in the market that blockchain creates like many private organizations. They are not interested in being an intermediary for the reason of just being the intermediary, so they are looking at blockchain as a potential solution for current problems in their internal processes.

"Eliminating the manual labor of settling excel files, automatizing the backend system with smart contract could be highly valuable." - Technology influencer at an EU organization in the Science and Technology sector.

Lastly, an interesting insight which highlights the difference between the private sector and the public sector in this area, is the fact that many organization have no interest of being the middleman, whereas some private organizations do. This impacts the use cases for which these organizations look at blockchain

"I don't see any interest of us being the middleman, like banks are for example in the case of blockchain. The European Union does not have this role. Our aim is to be as transparent and invisible as possible, and to intervene as little as possible in the interactions between citizens and companies. From that point of view, I don't see the 'disruption' as in the financial industry also coming to the public sector" – Policy-maker at an EU organization in the Science and Technology sector.

3.2.4.3 Concretizing the process factors element

The Qualitative Data Analysis based on the literature review and explorative expert interviews allows for the determination of the process factors elements. The Thematic Network that was constructed on the explorative expert interview presents that finding that various factors that define the fit between the executive process and blockchain technology in EU Institutions and Bodies can be categorized in four domains: *general context, data and processing power, current process characteristics* and *prioritization factors*, as can be seen in Appendix C.2.2 Process factors codes. It also became clear that EU Institutions and Bodies by definition are not interested in being the middleman without any clear reason, so they are looking at blockchain as a potential solution for current problems in their processes. Table 17 provides an overview of all factors identified that define the fit between the process and blockchain technology. Using the explorative interview, the general context factors were largely extended and a new domain of factors was highlighted: prioritization factors.

Table 17. Factors that define the fit between the process and blockchain technology

Domain	Factors that define the fit between the process and blockchain technology
General context	Predictable actor behavior
	Limited trust in current process
	Platform tendency
	Low interest of governmental organization in being the middle-man
	No legacy systems in place
	Low institutionalized environment
	Ability to implement standards in network
	High information complexity
	Desired user control over data
Prioritization factors	Low trust in the data storage

	Low data protection requirements High availability of bandwidth Low throughput of data
Process characteristics	Traceability required Low amount of owner changes Transparency required Currently laborious executive process Interoperability possibility Inter-organizational information exchange
Data and processing power	Privacy of high priority Importance of control over the infrastructure Low importance of latency High importance of user experience

For the process factors elements the following functional requirement is presented:

The blockchain assessment tool must take into account the process factors that relate to the ***general context****,* ***prioritization factors****,* ***process characteristics*** *and* ***data and processing power*** *that define the fit between the process and blockchain technology*

3.2.5 ORGANIZATIONAL FACTORS

For EU Institutions and Bodies to be successful in blockchain experimentation, the organizations ability to adopt this innovation successfully depends on a number of factors. The literature review and the explorative expert interviews focused on identifying these factors. First, the insights from the literature are recapped, and after this empirical insights from the interviews are presented. Concluding, the organizational factors element is concretized based on the explorative expert interviews and literature review, and an overview of the organizational factors that should be included in the blockchains assessment tool is presented.

3.2.5.1 Literature review insights

The literature review focused on literature that assess technology usage in governmental organizations from an e-government perspective. Kamal (2006) analyzed this from an organizational alignment perspective and incorporate 24 articles that assess these factors and analyzed their impact on IT innovation adoption in government organizations. These factors can be mapped over five domains, and are argued to have either a positive or negative impact on the ability to adopt an IT innovation by the organization. Table 5 in Chapter II Theoretical Background presents an overview of these factors as a result of the literature review. Factors relating to the five main organizational factor domains that Kamal (2006) presents were asked in the explorative interviews. The next section discusses the insights of the explorative interviews relating to the organizational factors.

3.2.5.2 Explorative expert interview insights

As the factors identified in the literature review are applicable for IT innovation adoption in general (for example cloud, Big Data, Bring-Your-Own-Device, etc.), the explorative expert interviews focused on identifying which of these factors are applicable for blockchain adoption. This section presents the most interesting and EU specific insights. The first interesting insight is that various EU Institutions and Bodies are looking at DG DIGIT, responsible for digital infrastructure and services in the European Commission, to provide insights, best practices and sometimes even infrastructure. The IT capabilities and resources are not considered to be of high importance in all interviews, because of the possibility to source IT talent and resources. While some EU Institutions and Bodies might be interested in creating their own blockchain, none of the interviewees believe that the organization itself will build any infrastructure. Collaboration with blockchain vendors like IBM and Ethereum are considered to be necessary and practical. Also, some EU Institutions and Bodies consider it the task of DG CONNECT to educate other EU Institutions and Bodies on this innovation, and provide oversight on the different initiatives currently being explored throughout the EU.

"We have an entire DG dedicated to the facilitation of technology within the European Commission: DG DIGIT. Other DGs and organizations are using the services of DIGIT. They are in charge of defining the IT

strategy of the institutions and organizations. But also regarding innovation, we have DG CONNECT, whose purpose it is to promote innovation in the EU" – *Policy-maker at an EU organization in the Climate and Environment sector*

The importance of the legal framework on their ability to experiment with blockchain is valued differently by different EU organizations. Some organizations argue that the current legal framework is adaptable to the technological possibilities that are explored. They want to experiment and demonstrate with blockchain technology and believe that the legal framework will follow.

"In the end, it is a matter of trust. If we can have 1 or 2 percent extra GDP in Europe, we will twist in any design or legal corner to realize this" – *IT manager at an EU organization in the Economy and Finance sector*

Some stress the importance of the legal framework extensively, and wait for the legal framework to change before they would start looking and experimenting with blockchain technology, as displayed in the quote below.

"In the end, it will be a decision made by Council and the Parliament, and we have to implement the decision that has been made" – *Policy-maker at an EU organization in the Climate and Environment sector*

Top-management support is also explicitly mentioned in the explorative expert interviews. Whereas literature mentions managerial capabilities and management style, for blockchain experimentation in EU Institutions and Bodies, the ability of the top-management to understand the technology and its governance impact is of high importance. Blockchain cuts across many dimensions of how organizations execute their processes, and this paradigm shift needs to be supported by the top-managers in these organizations to start experimentation.

"I think, from a policy-making perspective, one important support factor is the ability of the hierarchy to well understand how blockchain could be used, how it works and how to cut through the hype. In reality, we do see many initiatives, but we don't see any concrete implementations. So the ability of top managers to understand the technology and have enough information is critical" – *Policy-maker at an EU organization in the Science and Technology sector.*

Not only financial support is of importance of the adoption of blockchain technology in EU Institutions and Bodies, the budgeting style is of importance as well. The budgets in these organizations are set per year and known sometimes years in advance. The flexibility in allocating budgets within the organization can support the experimentation with blockchain.

"Financially we are bounded by annual budgets, which are settled and known years in advance, which makes experimentation projects difficult in our organization." – *IT manager at an EU organization in the Economy and Finance sector*

Lastly, the adversity to risk taking of the organization is argued to contribute to the ability of adopting blockchain technology by an EU Institution or Body. Closely linked to the legal framework, a fast and sound risk management process can facilitate experimentation with blockchain technology.

Risk management is also an important factor. For legal purposes, the risk needs to be management in these experiments" – *IT manager at an EU organization in the Economy and Finance sector*

3.2.5.3 Concretizing the organizational factors element

Based on the literature review and explorative expert interviews, the Qualitative Data Analysis allows for the concretization of the organizational factors element. This resulted in a Thematic Network, as presented in Appendix C.2.3 Organizational factors. Not all factors for IT innovation adoption found in literature are assumed to be relevant for blockchain adoption. A total of 21 organizational factors are identified that influence the adoption of blockchain technology in governmental organizations, which can be categorized in *support factors, perceived technology factors, organizational factors, collaboration factors* and *external factors* as identified as domains by Kamal (2006), which are presented in Table 18.

Table 18. Factors influencing blockchain adoption in the EU Institutions and Bodies

Domain	Adoption factor
Support factors	*Administrative authority*
	Financial support
	Managerial capabilities
Perceived technology factors	*Interoperability*
	Blockchain complexity
Organizational factors	*Risk adversity*
	IT capabilities
	Top-management dedication
	Blockchain enthusiast
	Coordination
Collaboration factors	*Trust from collaborating parties*
	Inter-Organizational Trust
	Similar use cases in the market
External factors	*External influence*
	Legal framework
	Collaborating parties size

For the organizational factors element, the following functional requirement is presented:

The blockchain assessment tool must facilitate the assessment of ***support factors, perceived technology factors, organizational factors, collaboration factors*** *and* ***external factors*** *influencing blockchain adoption in the applicable EU Institution or Body*

3.2.6 Decision-making process

The process of how a decision on blockchain experimentation is relevant for the design of an assessment tool that facilitates EU Institutions and Bodies to enhance their decision-making regarding the experimentation with blockchain technology to support their executive processes. The literature review provided insights into the general process of IT innovation adoption in governmental organizations, and the general roles involved. The explorative expert interviews draw empirical insights in the decision-making process regarding blockchain experimentation. First, the insights from the literature are discussed, and after this empirical insights from the interviews are presented. Concluding, the decision-making element is concretized based on the explorative expert interviews, and an overview of the decision-making process in EU Institutions and Bodies regarding blockchain experimentation is provided.

3.2.6.1 Literature review insights

Literature on innovation in governmental organizations provided a high-level decision-making process for IT innovation adoption in public organizations as defined by Kamal (2005). This can be found in Figure 12 in Chapter III Theoretical Background. The literature review also stretched the various actors involved in the decision-making process (Mulgan & Albury, 2003; Schilling, 2005). The following actors are argued to be of importance in this process: 1. *knowledge engineers* (Nonaka, 1994), 2. *ministers and political leaders*, (Mulgan & Albury, 2003), 3. *directors of the organization* (Mulgan & Albury, 2003) and 4. *experts* (Schilling, 2005).

3.2.6.2 Explorative expert interview insights

The insights from the literature review served as a basis for the explorative expert interviews. What quickly became apparent is that the way decisions are made in European Institutions and Bodies are not as linear as Figure 12 would suggest. The explorative expert interviews focused on identifying the various steps and actors involved in the decision-making process.

Four stages in the decision-making process of implementing a blockchain application for an executive process of an EU Institution or Body were mentioned in the explorative expert interviews. The *motivation* stage and the *adoption decision* stage were also presented in the model of Kamal (2006). Two critical additions became apparent; the *architecture design* stage and the *directive decision stage*. As a policy-maker at an EU organization in the Climate and Environment sector was asked about the process of a previous database innovation project, he replied the following:

“It was a decision that was made in the directive, made through co-legislation. These directives are rather detailed on the implementation requirements, so we had very little room to design ourselves” - *Policy-maker at an EU organization in the Climate and Environment sector*

The architecture design stage is often subsequent to the adoption decision stage. This is mostly done because the earlier stages are more difficult as there is also a political element involved.

“At the technical level, we can redesign our systems for this technology. At the political level, it might be more difficult.” – *IT manager at an EU organization in the Economy and Finance sector*

Four actors are distinguished; the *legal/risk department*, *technology influencers, IT managers* and *top-managers*. Not every actor is involved in every stage of the decision-making process. The legal/risk department is very important in the actual adoption stage as these public organizations have strict data protection laws and regulations that they must adhere. Many potential use cases of blockchain in this domain look at cross-border applications, resulting in difficulties as many national laws prohibit data to be stored outside of the country. The IT managers are usually involved in both the motivation and the architecture design stage, yet they are not always the promotors of blockchain technology. A role that some call a technology influencer or a blockchain enthusiast are often the instigators of the organization looking at blockchain. These ‘influencers’ are members of the organization who promote blockchain in the organization, and supply the management of the organization with information on this topic. For them, it is critical to communicate efficiently with the top-manager who eventually makes the adoption decision, as can be seen in the following quote:

“Influencers are feeding the information to the management, and then gradually the management could assume this idea and try to push it down afterwards. Decision-makers are in the top, so they are generally busy people. If it takes you 2 hours to explain your idea, you are unlikely to get the time you want to explain it. In the beginning, it is about motivation to persuade the influencers. The influencers then have to persuade the decision-makers. The decision-makers then must think: okay, this is so important, I will put all my other priorities aside and dedicate resources to this blockchain implementation.” - *Technology influencer at an EU organization in the Law and Crime sector.*

Three organizations that were often mentioned and important to all blockchain applications in EU organizations, are DG DIGIT, DG CONNECT and the policy domain-specific DG. Many organizations are looking at DG DIGIT, to provide insights, best practices and sometimes even infrastructure and to DG CONNECT to promote this innovation and bring together interested parties. The policy domain-specific DG can initiate a directive adjustment, which is sometimes necessary for a blockchain application to be feasible. In an interview with a policy-domain specific DG, a policy-maker in the organization said the following:

“We, DG […][3] should take the lead. We have a coordination function, and we should be driving this paradigm shift.” – *Policy-maker at an EU organization[4].*

Various activities are part of the four decision-making stages. The creation of technology roadmaps help drive the motivation stage, but not all EU Institutions and Bodies create these. Prioritization of resources and projects is very important for top-level managers, and is currently perceived to be one of the main obstacles for blockchain adoption in these organizations. The confirmation of collaborating parties, in some cases local administrations of Member States, in other cases economic operators, is an activity that mostly takes place in the adoption decision stage. This is especially relevant for data protection within the legal framework, as a technology influencer at an EU organization in the Economy and Finance sector argues:

“We have a lot of rules on how to store and provide our data. Most of the data does not belong to us and is politically sensitive. In this area, blockchain could be useful. In this way, we could trace who accessed which data and provide access to limited parties only.” – *Technology influencer at an EU organization in the Economy and Finance sector*

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[3] Organization name anonymized
[4] Policy domain anonymized

3.2.6.3 Concretizing the decision-making process element

The Qualitative Data Analysis allows for the concretization of the fourth element: Decision-making process. The literature review and explorative expert interviews presented the insight that the decision-making process of blockchain applications in EU Institutions and Bodies are unique and complex. Different actors, activities, roles and organizations are involved in different stages of the process. The motivation and adoption decision stages are the stages where an assessment tool would provide the most benefit, as these stages are used to learn more about blockchain and where the organization assesses the fit with this technology. Also, DG DIGIT, DG CONNECT and the domain-specific DGs are organizations that are relevant for all EU institutions looking to implement this technology, in their role of providers of the infrastructure, promotor of innovation and policies in the corresponding field. Appendix C.2.4 Decision-making process codes provides an overview of a Thematic Network of the decision-making process of adopting blockchain technology in EU Institutions and Bodies. Based on this, an overview of the decision-making process of EU Institutions and Bodies deciding to experiment with blockchain technology is presented in Figure 15 .

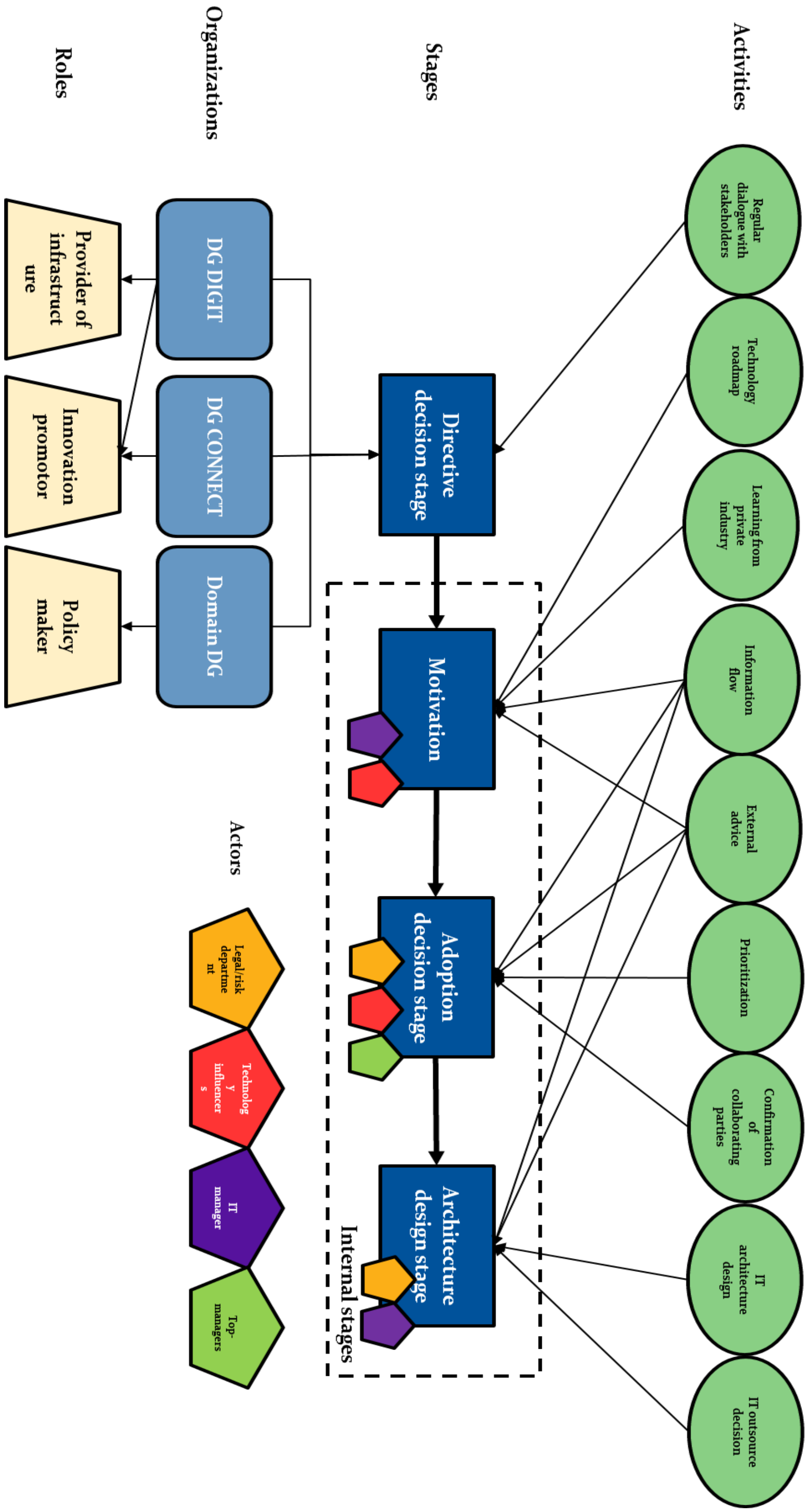

Figure 15. Decision-making process of adopting blockchain technology in EU Institutions and Bodies

For the decision-making process element, the following functional requirement is presented:

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*The blockchain assessment tool must guide decision-makers in the **motivation** and **adoption decision stages** of the decision-making process in EU Institutions and Bodies*

3.3 CONCRETIZING THE RIPPLE EFFECTS ELEMENT

As the previous section described the concretization of the first four elements, this section describes the concretization of the *ripple effects* involved in the experimentation of blockchain technology by EU Institution and Bodies. For this element interactive case study interviews and Matrix Prioritization Analysis are used. A number of ripple effects are identified in literature and interactive case study interviews are used to identify the relevant effects for the information exchange and registration process. First, the interactive case study interviews and Matrix Prioritization Analysis method is described. After that, the ripple effects are made concrete for the information exchange and registration process based on the findings.

3.3.1 INTERACTIVE CASE STUDY INTERVIEWS

Two case studies are explored to investigate the ripple effects of blockchain technology for these use cases. Decision-makers of the organization involved in the case study were asked to evaluate the ripple effects that could occur when blockchain would be implemented for that specific process, which is used as input to specify the blockchain assessment tool for the two separate processes. In order to identify relevant the ripple effects of the implementation of blockchain for a specific process, a general mapping exercise is performed. Interviewees are presented with the initial list of ripple effects as identified in blockchain literature. The effects are explained and clarified. Next, the interviewees map the effect which they deem relevant for this specific process on the applicable layers. Then, the interviewees are asked for any missing ripple effects on any of the layers. Subsequently, a Matrix Prioritization Analysis is performed, allowing the interviewees to prioritize the ripple effects of the blockchain use cases. This technique allows for the specification of the effects that are applicable to the information exchange and registration process.

3.3.1.1 Case study selection

In order to select the appropriate case studies, a number of criteria were formulated. These criteria are in place to make sure the case studies fit the intended use of the assessment tool. The following criteria are set for selecting the case studies:

- The cases should include one registration process and one information exchange process
- The organization involved in the case is an European Union-wide organization, Directorate-General or executive agency of the EU
- The case is either an existing exploration of blockchain technology or a potential exploration of blockchain technology in the organization
- The case should explore the potential for blockchain to improve the current process
- The interviewees should be either an policy-maker, IT manager or technology influencer in the organization

Based on these criteria, two cases are selected. The first case study looks at a system that monitors the movements of excise goods under duty suspension called EMCS. The second case study is a registration process: it looks at the potential of an Emissions Trading System (ETS) based on blockchain. Table 19 provides an overview of the case studies that were conducted. A more detailed description of the content of the case studies are provided in Chapter V Demonstration.

Table 19. Overview of case studies

Type of process	Case name	Case description	Date
Information exchange	The Excise Movement and Control System (EMCS)	The EMCS is a computerized, distributed, trans-European IT system aimed at monitoring the movements of excise goods under duty suspension within the territory of the EU	May 11, 2017

Registration	EU Emissions Trading System (EU ETS)	The EU ETS is a greenhouse gas emissions trading scheme for all 28 Member States, with a central registry that is run by the European Commission	May 10, 2017

3.3.2 Matrix Prioritization Analysis

The literature review used a New Institutional Economics perspective to anticipate the effects of implementing blockchain for governmental processes. Departing from the dynamic layer model of Künneke et al. (2009), three layers of impact are analyzed: on the organization, on the network and on society. Table 4 in Chapter II Theoretical Background provides the identified ripple effects of blockchain in literature. The cases are applied to the two different processes that are central in this research: information exchange and registration. These interactive case study interviews allow this study to define the ripple effects that are specific for these two different processes. Two interactive case study interviews were used to the specific cases to map and prioritize the ripple effects that are applicable to the process.

The Matrix Prioritization Analysis of the ripple effects was performed based on the input provided by the interviewees who, for confidentiality reasons, are anonymized. This technique is a semi-quantitative approach to estimate the relative prioritization of factors by a stakeholder. A form of this prioritization approach that is often applied is Wiegers Matrix Approach, which can be used to prioritize the requirements in software development projects (Bebensee, van de Weerd, & Brinkkemper, 2010). The Matrix Prioritization Analysis includes the following elements:

1. *Item Set* – The items set are the set of the items that will be evaluated by the interviewee. In this research, this set consists of the full list of possible ripple effects
2. *Criteria* – The criteria are used to evaluate the ripple effects. The criteria that the decision-makers will use to evaluate the ripple effects are the estimated impact of the effect and the importance for the EU organization to consider. For each applicable ripple effects, these criteria are used.
3. *Value Scales* – The value scale are the numeric scales that the decision-maker uses to evaluate each ripple effects. In this thesis a scale from 1 to 5 is used, 1 referring to no effect/importance to 5 referring to high impact/importance to consider this effect.
4. *Weightings* – The weightings refer to how much each criterion is weighted in the prioritization calculation. As only two criteria are used, the criteria are weighted equally.
5. *Formula* – This refers to the formula of calculating the priorities of the different ripple effects. The calculations to calculate the priority are the following: per effect, the impact of the effect was divided by the sum of all impacts. This results in the value % of the impact of the effect. The same is done for the important for the EU organization to consider. Adding the two percentages and multiplying by 100 resulted in the prioritized list of effects.

In the interviews, the interviewee was introduced to the ripple effects found in literature, and the Matrix Prioritization Analysis is used to map the ripple effects for this specific case. The insights of this exercise are translated into the specification of the blockchain assessment tool for the two process types. The value scales that were used in the Matrix Prioritization Analysis in the case interviews are found in Table 20.

Table 20. Value scales for Matrix Prioritization Analysis

Score	Impact of effect	Importance for EU organization to consider
1	There is no impact of this effect on this layer	This is not important for us to consider
2	This effect has a bit of impact on this layer	This would be only a little bit important for us to consider
3	There is a reasonable amount of impact on this layer	This would be reasonably important for us to consider
4	There is a substantial amount of impact on this layer	This would be very important for us to consider
5	This effect has a high impact on this layer	This would be extremely important for us to consider

Information exchange case (EMCS)

The first case that was investigated is a case that applies to the information exchange process. This case investigates the potential of an excise monitoring system for cross-border trade in the EU. Excise is an indirect tax on manufactured goods. Currently, the EMCS system is in place to facilitate the information exchange process. EMCS is a distributed trans-European IT system aimed at monitoring the movements of excise goods under duty suspension within the territory of the EU. The problems of the current system include errors in the data input because data is entered multiple times, and also the complexity of the data that authorities require is challenging. Also, the current system includes transaction instead of compliance-based information. The projected benefits of blockchain technology for this information exchange process include ability distribute the data accurately to the whole network, improving the quality and integrity of the data, presenting data in an interpretable format and connect various type of authorities to one overview the transactions. A full description of the case can be found in Chapter V Demonstration.

All ripple effects identified in literature were investigated whether they applied to the case study in the interactive case study interviews with a decision-maker of the EU Institution responsible for this system. For the information exchange case, a total of 18 effects were identified for this blockchain implementation which can be seen in Table 21. In this table, the prioritization of the relevant effects by the interviewees on the two criteria can be seen in the fourth and sixth column, displayed in bold. The priority in displayed in the last column of the table. The calculations to calculate the priority are the following: per effect, the impact of the effect was divided by the sum of all impacts. This results in the value % of the impact of the effect. The same is done for the important for the EU organization to consider. Adding the two percentages and multiplying by 100 resulted in the prioritized list of effects.

Table 21. Filled in Matrix Prioritization Analysis table for EMCS case

No.	Effect	Type	Impact of effect	Value %	Importance for EU organization to consider	Value %	Priority
1	Eliminate opportunism	Secondary	**4**	6.67%	**5**	7.46%	14.1293532
2	Set-up costs	Primary	**4**	6.67%	**4**	5.97%	12.6368159
3	Difficulties during transitional phases	Primary	**4**	6.67%	**4**	5.97%	12.6368159
4	More trusted inter-organizational data exchanges	Secondary	**4**	6.67%	**4**	5.97%	12.6368159
5	Increased protection against errors and forgery	Secondary	**4**	6.67%	**4**	5.97%	12.6368159
6	Robust data integrity	Secondary	**4**	6.67%	**4**	5.97%	12.6368159
7	Promoting of innovation	Tertiary	**4**	6.67%	**4**	5.97%	12.6368159
8	Stronger security of an informational database	Primary	**3**	5.00%	**5**	7.46%	12.4626866
9	Flexibility and empowered network	Secondary	**4**	6.67%	**3**	4.48%	11.1442786
10	Streamlined internal processes	Primary	**3**	5.00%	**4**	5.97%	10.9701493
11	Decentralized monitoring	Secondary	**3**	5.00%	**4**	5.97%	10.9701493
12	Permissioned data distribution	Secondary	**3**	5.00%	**4**	5.97%	10.9701493
13	Inclusion (in coordination)	Tertairy	**3**	5.00%	**4**	5.97%	10.9701493
14	Changing role of public administrators	Tertiary	**3**	5.00%	**4**	5.97%	10.9701493
15	Additional infrastructure needed	Secondary	**3**	5.00%	**3**	4.48%	9.47761194
16	Reduced effort of transacting with external parties	Primary	**3**	5.00%	**2**	2.99%	7.98507463
17	Well performing markets	Tertairy	**2**	3.33%	**3**	4.48%	7.81094527
18	Diminishing geographic boundaries	Tertairy	**2**	3.33%	**2**	2.99%	6.31840796

A number of effects were considered to be of high importance to consider. Notably, the elimination of opportunism between traders is considered to be the most important effect, as this system increases the transparency between the economic operators transacting in the system based on the distributed ledger. The increased transparency, and the increased control of data for the traders, is argued to eliminate opportunism and increasing the appetite for trade. Also, the set-up costs are considered to be very high and it will likely result in a difficult transitional phase as was the case in previous system upgrades. Also, for this use case, the public administrators involved are argued to have their role changed, from an electronic intermediary to a more supervisory role, having the ability to check and control when needed but not necessary being the intermediary in each transaction.

Registration case (ETS)
The second case that was investigated is a case that applies to a registration process. This case investigates the potential of an Emission Trading System on blockchain. Currently, there is a high-level of centralization of the registry in the EU ETS. Also, the current EU ETS is argued not to reach its goals as intended to. An ETS on blockchain would provide benefits that include the ability to connect to other systems, near real-time trading and it could improve data integrity in the system, benefiting both authorities and economic operators. A full description of the case can be found in Chapter V Demonstration.

It was found that the ETS on blockchain would not present as significant effects as was found in the information exchange case. Only 7 effects were identified in the interactive case study interview with a decision-maker of the EU Institution responsible for this system. The set-up costs for both the authorities and the economic operators are considered to be the most important, as well as the additional infrastructure needed. The set-up costs for both the traders and DG CLIMA are argued to be important. It would result in extra infrastructure that will be needed to develop. It would also create an increasing fear for reliance on network for compliance by the traders instead of relying on the registry as provided by the DG CLIMA. The integrity of the database would be improved yet it would present difficult during the phases of moving from the current system to the blockchain system. Other than promoting innovation, this use case would not have any other effects on society (tertiary effects). The interviewees indicated how important they deemed each effect and how important the effect is for the EU organization to consider. This resulted in the prioritized list of ripple effects as displayed in Table 22, using the same calculations as described in section 3.3.2 Matrix Prioritization Analysis.

Table 22. Filled in Matrix Prioritization Analysis table for ETS case

No.	Effect	Type	Impact of effect	Value %	Importance for EU organization to consider	Value %	Priority
1	Set-up costs	Primary	5	18.52%	5	17.24%	35.75989783
2	Additional infrastructure needed	Secondary	5	18.52%	5	17.24%	35.75989783
3	Difficulties during transitional phases	Primary	5	18.52%	3	10.34%	28.8633461
4	Increasing fear for reliance on network for compliance	Secondary	4	14.81%	4	13.79%	28.60791826
5	Set-up costs	Secondary	3	11.11%	5	17.24%	28.35249042
6	Stronger integrity of an informational database	Primary	3	11.11%	4	13.79%	24.90421456
7	Promoting of innovation	Tertiary	2	7.41%	3	10.34%	17.75223499

3.3.2.1 Concretizing the ripple element
The interactive case study interviews using the Matrix Prioritization Analysis allows for the concretization of the ripple effects of blockchain experimentation by EU Institutions and Bodies. The literature presented an initial overview of ripple effects of blockchain implementations, and using interactive case study interviews for an information exchange process and a registration process, the ripple effects for the two processes are identified. These effects are displayed in Table 23.

Table 23. Ripple effect identified in the interactive case study interviews

Effect level	Information exchange process	Registration process
Primary	• Set-up costs • Difficulties during transitional phases • Stronger security of an informational database • Streamlined internal processes • Reduced effort of transacting with external parties	• Set-up costs • Difficulties during transitional phases • Stronger integrity of an informational database
Secondary	• Eliminate opportunism • More trusted inter-organizational data exchanges • Increased protection against errors and forgery • Robust data integrity • Flexibility and empowered network • Decentralized monitoring • Permissioned data distribution • Additional infrastructure needed	• Additional infrastructure needed • Increasing fear for reliance on network for compliance • Set-up costs
Tertiary	• Promoting of innovation	• Promoting of innovation

- Inclusion (in coordination)
- Changing role for public administrators
- Well performing markets
- Diminishing geographic boundaries

In addition, it became clear in the evaluation of the blockchain assessment tool (Chapter VI Evaluation) that one tertiary effect was still missing: *the loss of jobs*. Automation of certain processes and the disintermediation in networks does not take place without certain jobs vanishing or being replaced. In the EU, this is a big topic of discussion, not only regarding blockchain, but also regarding robotization and artificial intelligence. This effect impacts the society and should be brought forward when thinking about potential effects caused by the blockchain implementation. Therefore, the loss of jobs effect is added to tertiary layer in the blockchain assessment tool.

For the ripple effects element, the following functional requirement is presented:

*The blockchain assessment tool must **enable a thought experiment on the potential ripple effects of the blockchain implementation**, by displaying the ripple effects for an information exchange or registration process.*

3.4 Concretizing the design features elements

As the first five elements have been concretized in the sections above, this section concretizes the design features element as identified in the theoretical background. As argued in the previous chapter, the review of literature provides all insights necessary for this element, so no empirical data is gathered form this element. The literature review investigated the design features of blockchain systems. The next section therefor only discusses the research that have focused on the way the different design features impact the systems performance. Based on this, the design features element is concretized.

3.4.1 Literature review insights

Four main types of blockchains were presented, and the design features were discussed. Also, the impact of the different blockchain design features were investigated. The different blockchain types each have their impact on process criteria, making some types more suitable to specific processes than others. The different consensus mechanisms can have a negative or positive impact on these process criteria as well, which can serve as a basis of the high-level design of a blockchain system for the executive process of an EU Institution or Body.

3.4.2 Concretizing the design features element

The literature review on the design features of blockchain technology allows for the concretization of the design features element. As identified in the problem exploration, the various design features of blockchain systems and their impact are often ignored in early stages of blockchain experimentation. A literature review presented the insight that different blockchain types each have their impact on process criteria; system reliance, control, actor transparency, external transparency, data assurance, security, scalability and energy efficiency of the system. This impacts the suitability of each blockchain type form specific processes. The overview of the impact of blockchain type and consensus mechanism on process criteria is constructed on the literature review in section 2.5 Blockchain system design, and can be seen in Table 24.

Table 24. Impact of blockchain type and consensus mechanism on process criteria

	Blockchain type				Consensus mechanism					
Process criteria	**Public permissionless blockchain**	**Public permissioned blockchain**	**Private permissioned blockchain**	**Private permissionless blockchain**	**Proof-of-work**	**Proof-of-stake**	**Proof-of-activity**	**Proof-of-capacity**	**Ripple Protocol**	**Proof-of-Elapsed Time**

System reliance	++	++	++	++	o	o	o	o	o	o
Control	--	-	+	o	o	o	o	o	o	o
Actor transparancy	o	-	++	++	o	o	o	o	o	o
External transparancy	++	++	-	-	o	o	o	o	o	o
Data assurance	-	-	++	++	+	o	o	o	+	o
Security	+	++	++	+	o	o	o	o	o	o
Scalability	o	--	-	+	-	+	o	o	-	-
Energy efficiency	--	--	o	o	-	+	+	-	o	+

For the design feature element, the following functional requirement is presented:

The blockchain assessment tool must allow for decision-makers to explicate their preference on ***process criteria****, and present a high-level design of the blockchain-system that includes the* ***blockchain type*** *and the* ***consensus mechanism.***

3.5 Overview of Requirements

This thesis aims to design a practical assessment tool design that facilitates EU Institutions and Bodies to enhance their decision-making regarding the experimentation with blockchain technology to support their executive processes. For this assessment tool, the following 6 functional requirements are defined throughout this chapter:

1) The blockchain assessment tool must take into account the **multi-actor nature, legacy systems, nature of interactions, public interest involved** and **uncertainties** involved in blockchain experimentation in EU Institutions or Bodies
2) The blockchain assessment tool must take into account the process factors that relate to the **general context**, **prioritization factors**, **process characteristics** and **data and processing power** that define the fit between the process and blockchain technology
3) The blockchain assessment tool must facilitate the assessment of **support factors, perceived technology factors, organizational factors, collaboration factors** and **external factors** influencing blockchain adoption in the applicable EU Institution or Body
4) The blockchain assessment tool must guide decision-makers in the **motivation** and **decision stages** of the decision-making process in EU Institutions and Bodies
5) The blockchain assessment tool must **enable a thought experiment on the potential ripple effects of the blockchain implementation**, by displaying the ripple effects for an information exchange or registration process.
6) The blockchain assessment tool must allow for decision-makers to explicate their preference on **process criteria**, and present a high-level design of the blockchain-system that includes the **blockchain type** and the **consensus mechanism.**

3.5.1 Non-functional requirements

The research objective of this thesis is to enhance decision-making in EU Institutions and Bodies regarding the value of experimenting with blockchain technology to improve their information exchange or registration processes. Because decision-making in this area is still unstructured, the blockchain assessment should provide structure to the decision-making process by providing an initial assessment and insights into the applicability of a blockchain implementation in the EU. Based on these objectives, the following non-functional requirements are determined:

1) The assessment tool should be used as an **initial blockchain assessment** for an information exchange or registration process of an EU Institution or Body.
2) The assessment tool should provide **insights into the applicability** of blockchain for the specific exchange or registration process.

3.6 CONCLUSION OF CHAPTER III

This chapter concretized the six elements for the blockchain assessment tool that were identified in the theoretical background using explorative interviews. Based on these interviews, requirements were presented for the blockchain assessment tool. This answers the third research question: *What are the requirements for a blockchain assessment tool that supports decision-making regarding blockchain experimentation in EU Institutions and Bodies?* First, the blockchain assessment tool should not ignore the complexities involved in blockchain implementation, as this is not just a technical innovation but an institutional innovation as well. The blockchain assessment tool must also be able to define the fit between the process, the organization and blockchain, presenting a clear image on the applicability of blockchain for a use case. The blockchain assessment should be tailored to the unique decision-making process in this area in the EU, to ensure the blockchain assessment tool can be used in the stages where decision-makers are forming an image on blockchain technology. Also, the tool should provide insights in the ripple effects of blockchain, as the larger implications of experimenting with this technology should not be ignored. Lastly, the technical perspective should be considered and the impact of the various design features on the systems performance should be included in the blockchain assessment tool. The next chapter will translate these requirements into the design of the blockchain assessment tool.

IV. DESIGN

This chapter describes how the blockchain assessment tool is designed in the Artefact Design step of this research. A Morphological Chart is used to translate the requirements into the design of the blockchain assessment tool in a structural way. The fourth research question is answered in this chapter: **How does a blockchain assessment tool for EU Institutions and Bodies look like?** First, the methodology for design is presented in paragraph 4.1. Then, the design steps that lead to the final design of the blockchain assessment tool are described in paragraph 4.2. Based on these steps, the design of the blockchain assessment tool is presented in paragraph 4.3. This chapter ends with a conclusion on the fourth research question in paragraph 4.4.

4.1 METHODOLOGY FOR DESIGN

This research uses a feedback loop between the design and requirements definition phases, to create an iterative design process. First, the initial requirements were collected based on the theoretical background and the explorative expert interviews. After this, the initial design of the tool was constructed. Two cases were used to gather feedback on the initial design and to gather empirical input on the ripple effects on the blockchain implementation. This input was in turn turned into requirements, which are used for the sequential iterations of the design. The final version of the blockchain assessment tool therefore incorporates feedback from the demonstration and evaluation steps. Figure 16 presents the iterative design process of this research.

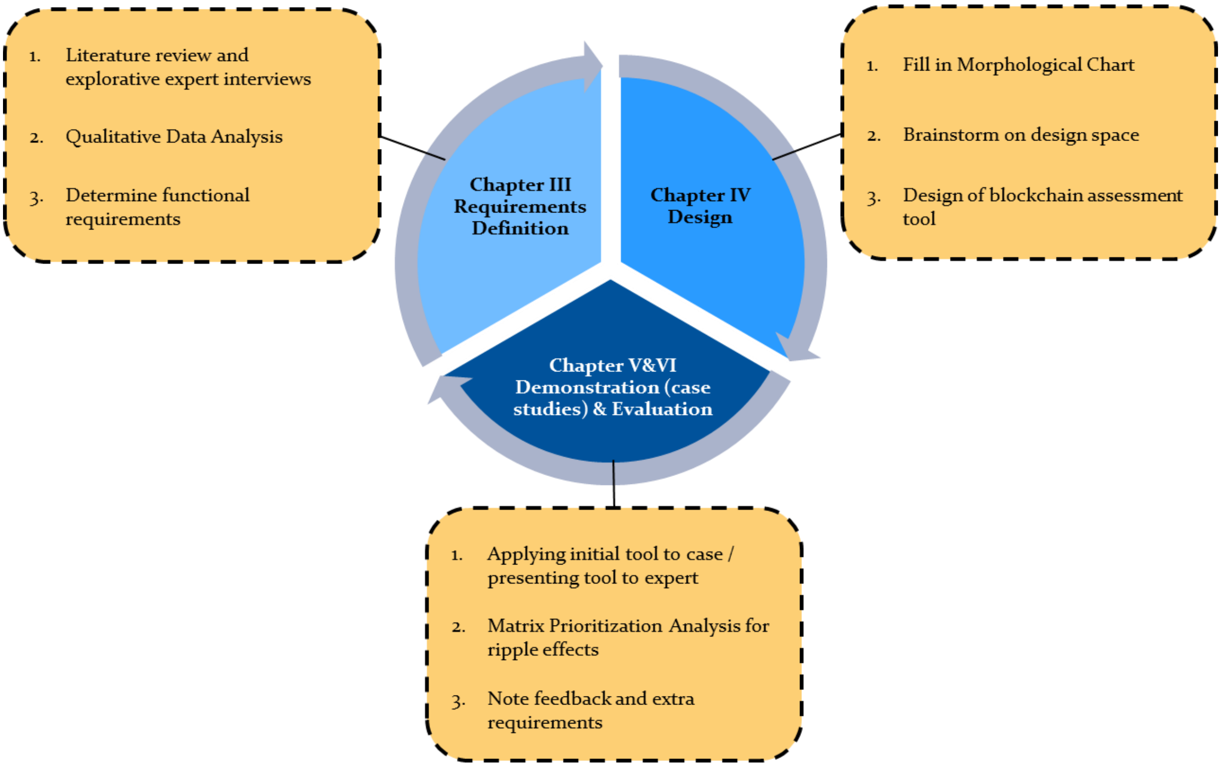

Figure 16. Feedback loop between design and requirements definition phases

4.2 DESIGN STEPS

This section describes the steps that are used to translate the defined requirements into the design of the blockchain assessment tool. A morphological chart is used to structure the process of moving from requirements to a design. This is used a basis for the multiple brainstorms that resulted in the eventual design. First, the morphological chart that is used as a foundation for the design space of the assessment tool is elaborated. Secondly, a reflection on the concretized elements is performed as a basis for brainstorming on the design options. Lastly, the multiple brainstorms on the design options are presented.

4.2.1 MORPHOLOGICAL CHART

Morphological charts are a tool to identify means that can be used to make function(s) happen (Dym & Little, 1994). These charts can be used for creating and visualizing a design space, and identifying design alternatives within that space. Zwicky (1969) argues its use for design activities, as it can be used to explore different options for subsystems, functions, attributes and other features, and creating combinations of these options (Zwicky, 1969). This thesis uses the approach used by Card, Mackinlay and Robertson (1991) in their approach of morphological design space analysis (Card, Mackinlay, & Robertson, 1991). In this Design Phase, the morphological chart is used to present the requirements on one axis, and the key design components of the assessment tool on the other axis. The combination of these two present the Design Space, the 'space' that contains or envelops all of the potential solutions.

The requirements are presented on one axis, and on the other axis the concretized elements which satisfy the requirements are presented. Before the features of the elements are chosen, critical reflection is necessary on the key question that the requirements impose, the functions they serve and perspective used in the requirement. Figure 17 displays the outline of the morphological chart for the design of the assessment tool. In the following section, this reflection is presented.

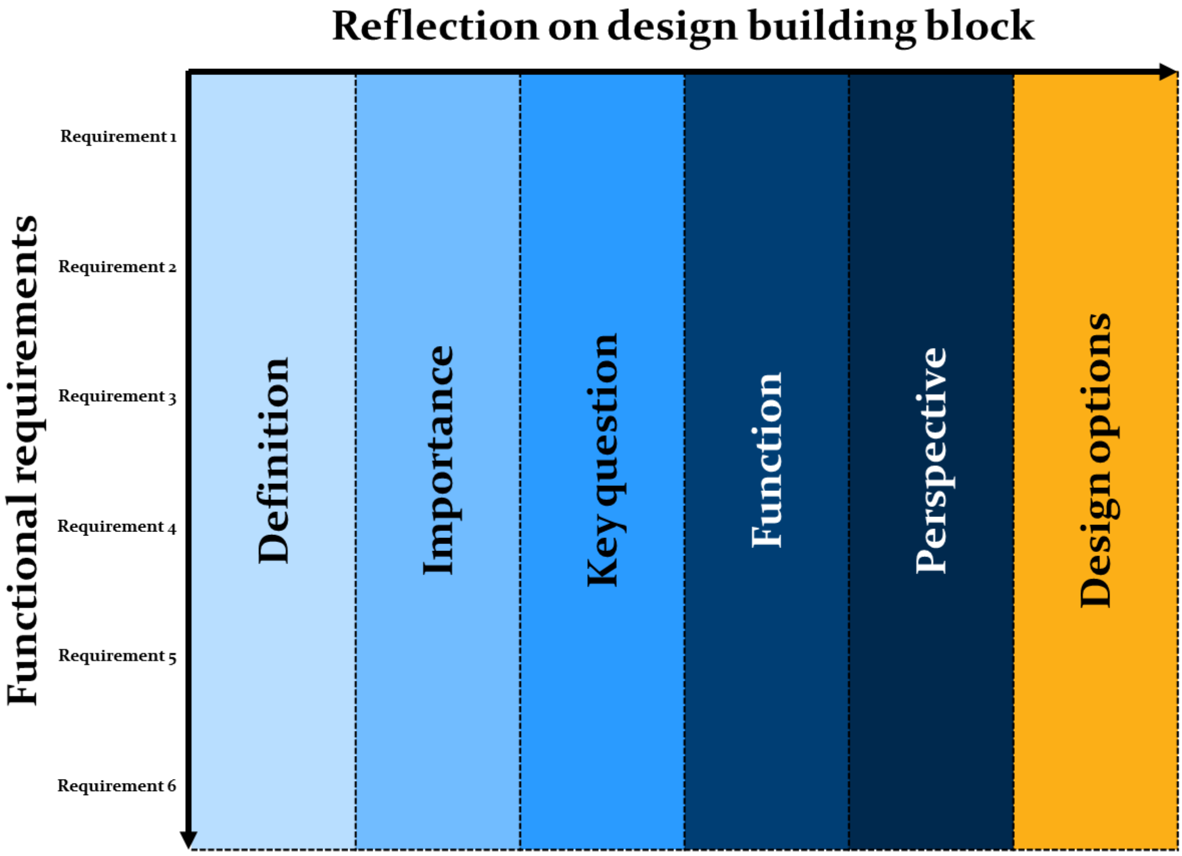

Figure 17. Outline of the morphological chart for the design of the blockchain assessment tool

4.2.2 REFLECTION ON CONCRETIZED ELEMENTS

The reflection on the design components is done by providing a definition of the design component, the importance, the key question it reflects, its function and perspective used. Table 25 presents the filled in reflection on the concretized elements.

Table 25. Reflection on concretized elements

Element	Functional requirement	Definition	Importance	Key question	Function	Perspective used
Complexities	The blockchain assessment tool must take into account the complexities involved in blockchain experimentation in EU institutions or bodies	The complex elements of the blockchain implementation that are difficult to describe, understand, predict, manage, design or change.	The complexities in the blockchain-based system need to be considered to anticipate emergent behavior and uncertainties	What are the complexities in the blockchain-system?	Explicate the complexities involved in the implementation of blockchain	Complex Systems Theory
Process factors	The blockchain assessment tool must take into account the factors that define the fit between the process and blockchain technology	Factors that refer to either the environment of the process or to the process itself, that assess the applicability of a blockchain system for the information exchange or registration process of the EU Institution or Body.	The factors that define the fit between the process and blockchain technology need to be considered	Which factors regarding the process need to be considered to assess blockchain implementation in EU institutions and bodies?	Determine the applicability of blockchain for this specific process and determine critical factors that make or break the blockchain potential	E-government
Organizational factors	The blockchain assessment tool must facilitate the assessment of factors influencing blockchain adoption in the applicable EU institution or body	Factors that refer to the support, technological compatibility, organizational, collaboration and external elements of an organization, that impact the ability to adopt an IT innovation in a governmental organization..	The factors that influence the adoption of blockchain technology in governmental organizations need to be considered to assess the fit between the organization and blockchain technology	What factors need to be considered to assess the ability of the organization to adopt blockchain-technology?	Determine the ability to adopt an IT innovation in the EU institution or body	E-government
Decision-making process	The blockchain assessment tool must guide decision-makers in the motivation and decision stages of the decision-making process	The process for making decisions and understanding innovation that are needed for IT innovation adoption in governmental organization	The process of how a decision on blockchain experimentation is reached needs to be considered	What elements of the decision-making process for IT implementation in the EU are important for blockchain projects?	Ensure the framework fits into the decision-making process in the EU institution or body	Empirical
Ripple effects	The blockchain assessment tool must enable a thought experiment on the potential ripple effects of the blockchain implementation, by displaying the ripple effects for an information exchange or registration process.	Effects on the public organization, the network involved and on society, caused by an implementation of blockchain for the information exchange or registration process of an EU Institution or Body.	Given the institutional change that blockchains might present, it is critical to take into account the ripple effects of blockchains when deciding to experiment with blockchain technology as an EU Institution or Body.	What are the potential effects on the organization, on the network and on society caused by the blockchain implementation?	To enable a thought experiment on the potential ripple effects of the blockchain implementation	New Institutional Economics
Design features	The blockchain assessment tool must allow for decision-makers to explicate their preference on process criteria, and present a high-level design of the blockchain-system	Choices that a designer can make in the technical design of a blockchain-based system that impact the process criteria.	The design features need to be considered for the high-level design of the blockchain-system	Which design features of blockchain-systems are important?	Allow decision-makers to reflect on the impact of design features of blockchain by providing a high-level design of the blockchain system based on the criteria that are relevant for the process	Technical

4.2.3 BRAINSTORM ON DESIGN OPTIONS

A number of brainstorms performed on the design options of the concretized elements. An initial brainstorm session was performed by the researcher, using the 'role-storming' technique. Role-storming is a brainstorm technique that is performed individually, where the person doing the brainstorm imagines he/she is the future user of the artefact. Reasoning from a decision-maker an EU Institution or Body, an overview of possible design options was created using post-its on multiple white-boards. The next paragraph described the design options that were considered.

For the complexities, the following option were considered: an initial step of mapping the complexities, an overview of the potential complexities and incorporating the complexities in other elements of the tool. Regarding the process factors, the following options emerged in the brainstorm: providing a blockchain-process fit score, identifying critical factors that make or break the blockchain fit and presenting the factors that indicate fit between the process and blockchain. For the organizational factors, the incorporation of organizational alignment guidelines and providing an organizational-blockchain fit were considered. To ensure the tool fits into the decision-making process in the EU Institution or Body and include the different actors, the following options were considered: presenting a guide for when to incorporate which internal actor, provide recommendations on how to motivate the network to participate and aligning the blockchain assessment tool to the stages in decision-making process in the EU. For the ripple effects, the following options were raised in the brainstorm: presenting an overview of potential effects in the beginning of the tool, enabling an automatic link between the objectives of the decision-maker and the potential effects and providing insight in the ripple effect for the specific process as a last food for thought. The options on how to incorporate the design features of blockchain systems that were considered are providing high-level design of the blockchain system based on the criteria that are relevant for the process or providing insight in the different design features of the blockchain system. For the non-functional requirements, the following options were considered: a 6-step tool that uses each element separately and a 3-step model that incorporates the complexities, process factors and organizational factors.

After this, a sequence of brainstorms were performed to choose the design options. In total, five versions of the tool were created in this research. The last three versions of the tool are described and the design choices are elaborated in the next paragraphs.

4.2.3.1 Blockchain assessment tool version 0.8

First, a number of an initial combinations of design options were explored by the researcher, drawing up a number of initial designs. Exploring assessment tools in other industries helped to get an initial idea of the structure. Many of the assessment tools included various steps and questions that need to be answered to provide the assessment. Therefore, in the first prototypes of the tool, it was chosen to separate the blockchain assessment tool in three different steps. Every step of the tool answers a question. The initial prototypes of the tool are described in Appendix D.1 Initial prototypes of the blockchain assessment tool. Next, the prototype designs were discussed with the external supervisor of this thesis. Receiving feedback on the design like not to include more than 3 steps, highlighting simplicity of complexity and the benefits of a blockchain fit score, the first iteration of the tool was designed. After gathering feedback from other supervisors of this thesis and performing the case studies, the first comprehensive version of the blockchain assessment tool was created (v0.8). Table 26 provides an overview of the design options raised in the brainstorm, with the chosen design options displayed in bold.

Table 26. Outcome of design brainstorm

Requirement	Design options
The blockchain assessment tool must take into account the multi-actor nature, legacy systems, nature of interactions, public interest involved and uncertainties involved in blockchain experimentation in EU Institutions or Bodies,	• An initial step of mapping the complexities • An overview of the potential complexities • **Incorporating the complexities in other elements of the tool**
The blockchain assessment tool must take into account the process factors that relate to the general context, prioritization factors, process characteristics and data and processing power that define the fit between the process and blockchain technology	• **Providing a blockchain-process fit score** • **Identifying critical factors that make or break the blockchain fit** • Presenting the factors that indicate fit between the process and blockchain
The blockchain assessment tool must facilitate the assessment of support factors, perceived technology factors, organizational	• Presenting organizational alignment guidelines • **Providing an organizational-blockchain fit**

factors, collaboration factors and external factors influencing blockchain adoption in the applicable EU Institution or Body	
The blockchain assessment tool must guide decision-makers in the motivation and decision stages of the decision-making process in EU Institutions and Bodies	• Presenting a guide for when to incorporate which internal actor • Provide recommendations on how to motivate the network to participate • **Aligning the blockchain assessment tool to the stages in decision-making process in the EU**
The blockchain assessment tool must enable a thought experiment on the potential ripple effects of the blockchain implementation, by displaying the ripple effects for an information exchange or registration process.	• Presenting an overview of potential effects in the beginning of the tool • Enabling an automatic link between the objectives of the decision-maker and the potential effects • **Providing insight in the ripple effect for the specific process as a last food for thought.**
The blockchain assessment tool must allow for decision-makers to explicate their preference on process criteria, and present a high-level design of the blockchain-system that includes the blockchain type and the consensus mechanism.	• **Providing high-level design of the blockchain system based on the criteria that are relevant for the process** • Providing insight in the different design features of the blockchain system
The assessment tool should be used as an initial blockchain assessment for an information exchange or registration process of an EU Institution or Body and provide insights into the applicability	• A 6-step tool that uses each element separately • **A 3 step model that incorporates the complexities, process factors and organizational factors**

The visualization of the v0.8 version of the tool is displayed in Figure 18. This is the version of the tool that is used in the case studies that are described in the next chapter. It includes a step that assesses the blockchain fit on the basis of a number of statements and a step that provides a high-level design of the blockchain system based on the input of the user on a number of process criteria. The ripple effects are still generic in this version of the tool, as this version did not make a distinction on which effects are relevant for the process.

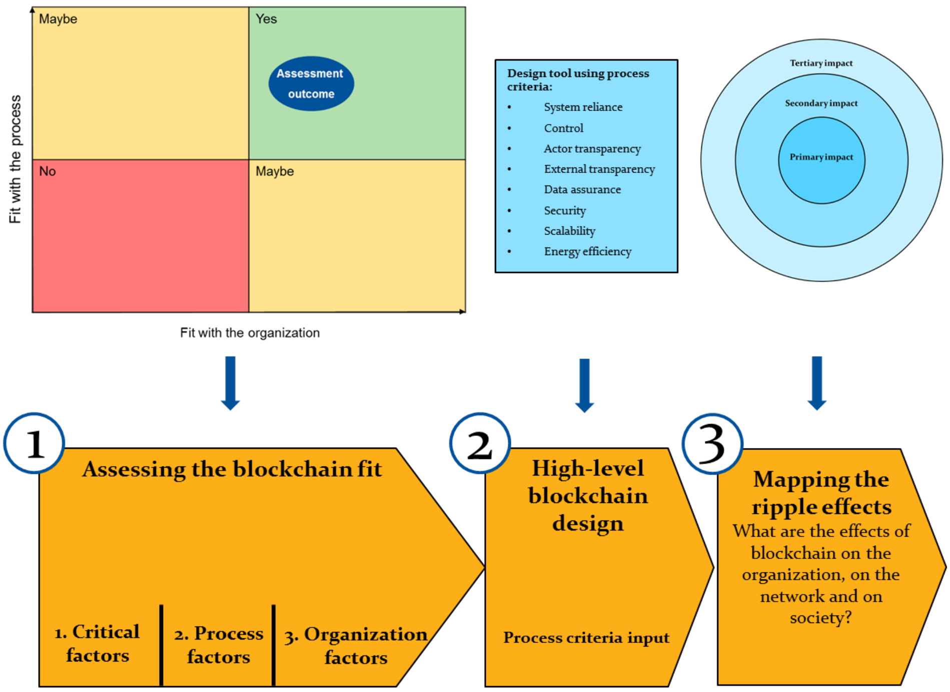

Figure 18. Blockchain assessment tool v0.8

5.2.3.2 Blockchain assessment tool version 0.9

In the case studies, it was explored which ripple effects are relevant for the two process types. The insights that the case interviews presented on the applicability of the ripple effects were incorporated in the next version of the tool (v0.9). This version of the tool segregates the effects of the blockchain implementation based on the process: whether blockchain is used for an information exchange process or for a registration process. The v0.9 version of the tool is displayed in Figure 19, and this is the version that was used in the expert evaluation that is discussed in Chapter VI Evaluation.

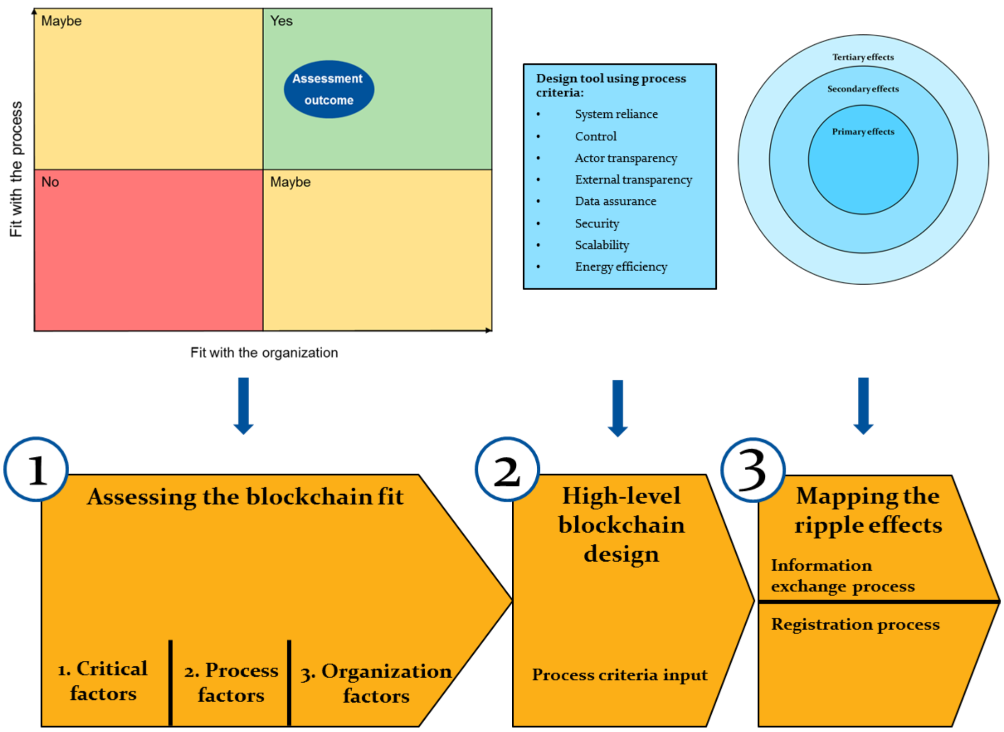

Figure 19. Blockchain assessment tool v0.9

4.2.3.3 Blockchain assessment tool version 1.0

Based on the feedback gathered in the expert evaluation interviews, the final version of the tool was created (v1.0). This feedback is presented in section 6.3 Insights translated in the blockchain assessment tool. As it was remarked that some process and organizational might overlap, the factors and the corresponding statements were reviewed to identify any potential overlap. Two potentially overlapping factor pairs where found and adjusted accordingly. Interoperability was initially mentioned in both the process and organizational factors and was merged to have it only included in the process criteria. In addition, the importance of control and the desire of the governmental organization to be the middle-man in the process were both included in the process factors. In essence, these two factors mean the same which is why they are merged and included in the process criteria. Table 27 provides an overview of the factors that were reviewed and the overlap that was removed.

Table 27. Overlap between process and organizational factors removed in final tool version (v1.0)

Factor	Factor type	Overlap with	Result
#24 Interoperability	Organizational factor	#16 Interoperability possibility	Included in process criteria
#7 High/low importance of security	Process factor	#4 Low interest of governmental organization in being the middle-man	Included in process criteria
#21 High/low importance of security	Process factor	None – contradicting findings	Removed from tool

Also, the evaluation interview presented an additional tertiary effect: the loss of jobs. As this can create a lot of discussion for policy-makers, the ripple effect was added in the tertiary effects layer. In addition, the removal of the security process factor was suggested in the evaluation interviews. This factor was removed in the final version of the tool, as it remains unclear whether blockchain truly presents advantages in terms of security with regard to other information infrastructures. Also, the initial versions of the tool were linear and included no feedback loop between the steps. As was argued in the evaluation phase, a more cyclical or stage-gate approach would allow for a user that learns from its previous steps and thereby deals with the uncertainty in the decision-making process. The final version (v1.0) of the tool therefore includes these stage-gates and the possibility to learn in the process. The next paragraph describes this final version of the tool in detail and how to apply it.

4.4 THE BLOCKCHAIN ASSESSMENT TOOL

The blockchain assessment tool consists of 3 steps that are performed can be performed in a sequence by the user or iteratively. Three main activities are distinguished: *assessing the blockchain fit*, *creating a high-level design* and *mapping the ripple effects*. The user should always start with the first step, as this is crucial in determining the applicability of blockchain for a specific process. However, insights gained in the last two steps can be used to refine the previous steps, allowing the user of the tool to learn throughout the process. The first step, assessing the blockchain fit, should be considered as a stage-gate: if there is no fit between blockchain technology, the process and the organization, then a decision should be taken to not proceed with blockchain experimentation. If there is a blockchain fit, then the next two steps of the tool should be taken.

Step 1. Assessing the blockchain fit

This step of the assessment tool assesses the fit between the process, the organization and blockchain. The design choice of including both a process-blockchain and an organization-blockchain fit allowed for the mapping of the blockchain fit based on these two axes. Another design choice was to incorporate the complexities in this fit as well. First, it was determined whether the complexity category referred to process factors or organizational factors. Then, all complexities, process factors and organization factors were translated into statements. The blockchain assessment tool uses statements that refer to the factors defined in the requirements definition. Using statements, the user of the tool can indicate whether a certain statement applies (in yes/no statements) or to what degree he/she agrees to a certain statement (using a score 0/10). This allows for the calculation of a blockchain fit score. The calculation behind this score is simple, the score is the total score of the statements divided by the highest possible score. Each statement is calculated evenly.

Another design choice was to include critical factors, to align the tool with the decision-making process, as decision-makers first look at the essentials before walking through the entire analysis. The critical factors assess whether the blockchain use case makes any sense. These critical factors are displayed in the beginning, so that if these are negatively assessed, this is known early in the process. An overview of the statements in provided in Table 28, including the element on which they are based, the part of the first step of the blockchain assessment tool it belongs to and the range on which the user of the tool can provide input on.

Table 28. Statements step 1: Assessing the blockchain fit

Element	Domain	Factor/category	Statement	Range	Part
Complexities	Multi-actor nature	Information complexity	*Are there many different uses of the data in the process? Or is there only one use of the data in the process?*	Many / Single	Process fit
Complexities	Multi-actor nature	Decentralized characteristics	*The organization would be willing to decentralize the data storage in the process*	True / False [0-10]	Organization fit
Complexities	Legacy systems	Different interfaces	*Do the stakeholders in the network each have their own custom-build interface for this process, or are the interfaces standardized?*	Multiple / Single	Process fit
Complexities	Legacy systems	Different data sources	*Does the process involve the registration of exchange of data from different sources?*	Yes/No	Critical
Complexities	Nature of interactions	Scalability issues	*Does the network involved consist of a fixed amount of participants, or is this likely to grow or reduce?*	Fixed / Growing	Process fit
Complexities	Public interest involved	Cost-effectiveness	*Would the potential of blockchain outweigh the costs of experimenting with blockchain?*	Yes/No	Critical
Complexities	Uncertainties	Technological uncertainty	*The organization would be able to handle technological uncertainty that blockchain technology currently faces*	True / False [0-10]	Organization fit
Organization-blockchain fit	Support factors	Administrative authority	*The organization has the support of the administrative authority to experiment with blockchain technology*	True / False [0-10]	Organization fit
Organization-blockchain fit	Support factors	Financial support	*The organization has the financial means to experiment with blockchain technology*	True / False [0-10]	Organization fit
Organization-blockchain fit	Support factors	Managerial capabilities	*The organization has the managerial capabilities to experiment with blockchain technology*	True / False [0-10]	Organization fit
Organization-blockchain fit	Perceived technology factors	Blockchain complexity	*The organization is able to comprehend the complexity of blockchain technology*	True / False [0-10]	Organization fit
Organization-blockchain fit	Organizational factors	Risk adversity	*The organization is risk adverse regarding IT innovations*	True / False [0-10]	Organization fit
Organization-blockchain fit	Organizational factors	IT capabilities	*The organization has (the ability to outsource) the IT capabilities needed for a blockchain pilot*	True / False [0-10]	Organization fit
Organization-blockchain fit	Organizational factors	Top-management dedication	*The organization has a top-management that is dedicated to experimenting with blockchain*	True / False [0-10]	Organization fit
Organization-blockchain fit	Organizational factors	Blockchain enthusiast	*Does the organization have a blockchain enthusiast that understands the technology and is willing to experiment with blockchain?*	Yes/No	Organization fit
Organization-blockchain fit	Organizational factors	Coordination	*The organization is willing to give up the coordinating role in the process*	True / False [0-10]	Organization fit

Organization-blockchain fit	Collaboration factors	Trust from collaborating parties	*The other stakeholders involved in the network would be willing to participate in blockchain experimentation led by the organization*	True / False [0-10]	Organization fit
Organization-blockchain fit	Collaboration factors	Inter-Organizational Trust	*The organization is trusted by collaborating parties to facilitate data exchange/registration*	True / False [0-10]	Organization fit
Organization-blockchain fit	Collaboration factors	Similar use cases in the market	*Are there similar use cases in the market already being explored?*	Yes /no	Organization fit
Organization-blockchain fit	External factors	External influence	*The organization is influenced by external forces like encouragement/pressure to recommendation, request or providing incentives or exposure to penalties*	True / False [0-10]	Organization fit
Organization-blockchain fit	External factors	Legal framework	*Does the legal framework of the organization currently allow the experimentation of blockchain for this process?*	Yes/No	Critical
Organization-blockchain fit	External factors	Collaborating parties competences	*The other stakeholders involved in the network have the competences to participate in blockchain experimentation*	True / False [0-10]	Organization fit
Process-blockchain fit	General context	Predictable actor behavior	*How predictable is the behavior and the data input of the actors in the network?*	Predictability [0-10]	Process fit
Process-blockchain fit	General context	Limited trust in current process	*Is there any lack of trust from the actors in the network that the public administration will provide this process?*	Trust [0-10]	Process fit
Process-blockchain fit	General context	Platform tendency	*Does the process have the potential to be facilitated by direct peer-to-peer interactions?*	Yes/No	Critical
Process-blockchain fit	General context	Low interest of being the middle-man	*Is there a specific need for the organization to be the middle man in this process?*	Yes/No	Critical
Process-blockchain fit	General context	No legacy systems in place	*What is the level of legacy systems currently in place?*	Brownfield / Greenfield	Process fit
Process-blockchain fit	General context	Low institutionalized environment	*What is the level of bureaucracy in place for this process?*	Bureaucracy [0-10]	Process fit
Process-blockchain fit	General context	Ability to implement standards in network	*Do the actors in the network easily adapt to new technology standards?*	Yes/No	Process fit
Process-blockchain fit	General context	High data complexity	*Are there many different data formats involved in the process?*	Many / Single	Process fit
Process-blockchain fit	General context	Desired user control over data	*Do the actors in the network want to store their data locally to keep control in this process?*	Desired control [0-10]	Process fit
Process-blockchain fit	Data and processing power	Low trust in the data storage	*Is there any information asymmetry or a lack of trust in the data in the current system?*	Yes/No	Critical
Process-blockchain fit	Data and processing power	Low data protection requirements	*Does the process involve personal data as specified in the EU Data Protection Directive*	Yes/No	Critical
Process-blockchain fit	Data and processing power	High availability of bandwidth	*Is the network able to provide enough bandwidth and computing power?*	Availability [0-10]	Process fit
Process-blockchain fit	Data and processing power	Low throughput of data	*Does the process facilitate a high frequency of transactions?*	High / low	Process fit
Process-blockchain fit	Current process characteristics	Traceability required	*Is there a need to have the ability to trace who has accessed the data in the network?*	Required traceability [0-10]	Process fit
Process-blockchain fit	Current process characteristics	Transparency required	*Is there a need for data transparency between the actors involved in the network?*	Required transparency [0-10]	Process fit
Process-blockchain fit	Current process characteristics	Currently laborious executive process	*Is there currently any human labor to facilitate the process?*	Yes/no	Process fit
Process-blockchain fit	Current process characteristics	Interoperability possibility	*Is the data that is used in the current process also involved in other processes?*	Single / Other	Process fit
Process-blockchain fit	Current process characteristics	Inter-organizational data exchange	*Does the process involve multiple organizations that exchange data?*	Yes/No	Critical
Process-blockchain fit	Prioritization factors	Privacy of high priority	*Does the process involve privacy sensitive information?*	Privacy importance [0-10]	Process fit
Process-blockchain fit	Prioritization factors	Low importance of latency	*Is it of importance to have data exchange without any delay in the process?*	Yes/No	Process fit
Process-blockchain fit	Prioritization factors	High importance of user experience	*How is the level of importance of the ease of use and user experience in the process?*	UX importance [0-10]	Process fit
Process-blockchain fit	Current process characteristics	Transaction dependency	*Is there any interaction between the transactions created by the stakeholders in the networks?*	Yes/No	Critical

Answering every statement provides insights into the applicability of blockchain for the process, and using two axes to present assessment outcome allows for easy interpretation. Figure 20 presents the assessment outcome where the fit with organization is high, and the fit with the process is high as well. Four quadrants enables structured interpretation of the results. A score higher than 50 out of 100 is assumed to be a good fit with the organization or process. A score lower than 50 out of 100 is assumed not to be a good fit with the organization or process. If there is a good fit with the process and a bad fit with the organization, the blockchain assessment tool indicates that there is 'maybe' a fit. The same goes for is there is a good fit with the organization and a bad fit with the process.

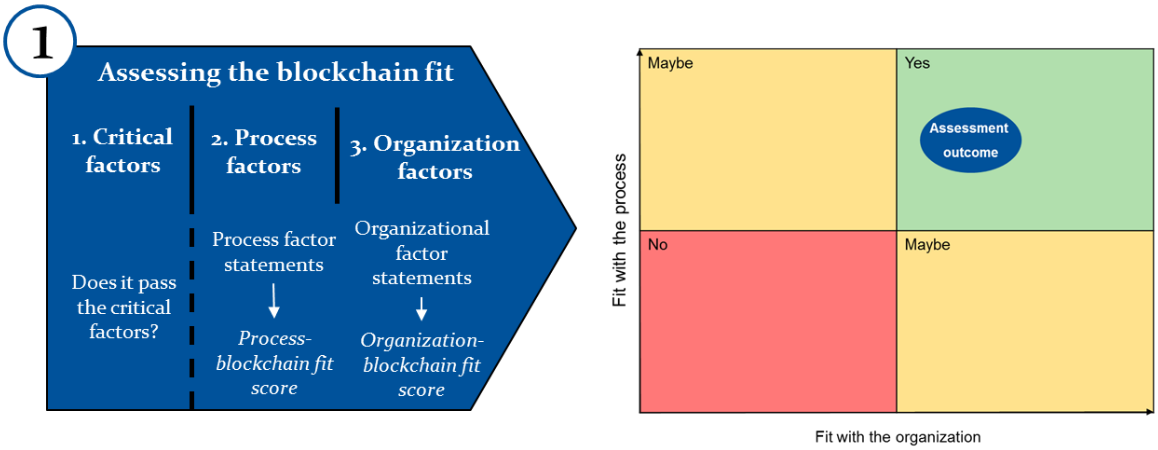

Figure 20. Step 1 of the blockchain assessment tool: Assessing the blockchain fit

Step 2. High-level blockchain design

The assessment tool allows for the high-level design of the blockchain application. Users of the tool can provide their assessment of the process criteria; *system reliance, control, actor transparency, external transparency, data assurance, security, scalability* and *energy efficiency*. This results in an advice on which blockchain type is the most appropriate for this process. Also, this results in advice on which consensus mechanism fits best with their preferences on the process criteria. Using a range from 0-100, the user can indicate the importance of each of the process criteria. Based on the impact of the design features of blockchain, a calculation is performed to indicate which blockchain type and consensus mechanism fits best. All criteria are weighted evenly and the score is calculated for all the options using *(1-answer)*(4-score)+answer*score*, presenting the most applicable blockchain design option based on the criteria. The calculations are performed based on the impact of the design features on the process criteria, as presented in Table 24 in Chapter III Requirements Definition. A visual representation of this step is provided in Figure 21.

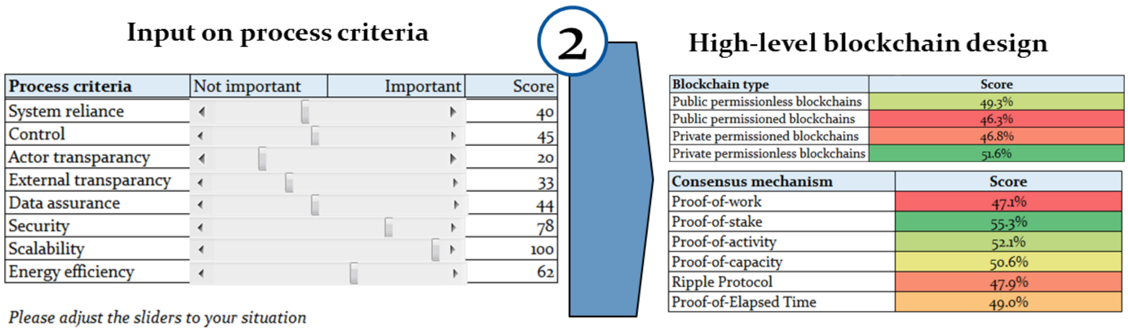

Figure 21. Step 2 of the blockchain assessment tool: High-level blockchain design

Step 3. Mapping the ripple effects

Step 3 serves as a thought experiment for the user of the tool. A separation is made for the information exchange process and the registration process in this step. By presenting the ripple effects for either the information exchange or registration process, the user can estimate the impact that this blockchain experiment will have on the organization (primary effects), on the actors in the network (secondary effects) and on society (tertiary effects). In this step, the user can map the ripple effect based on his/her own assessment.

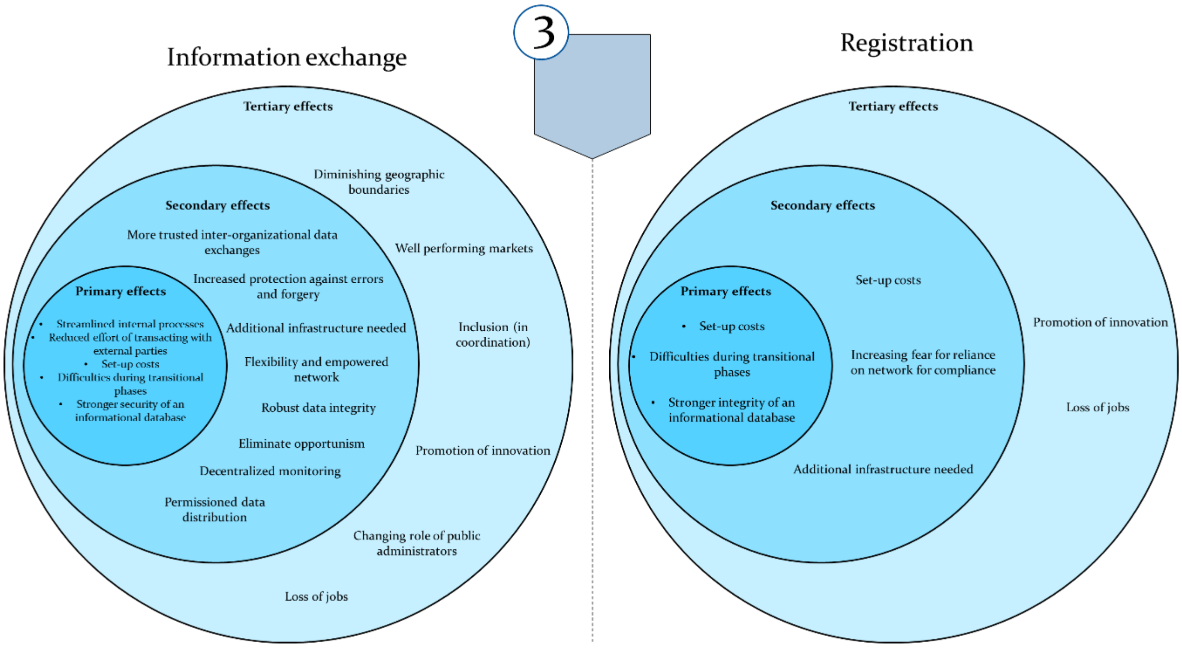

Figure 22. Step 3 of the blockchain assessment tool: Mapping the ripple effects

4.5 User guidelines

To allow for optimal use of the tool, a number of user guidelines are now presented. First of all, the user should be a decision-maker in an EU Institutions or Body that is looking to explore blockchain and aware of the information exchange or registration processes of the organization. Also, the decision-maker should be aware of the capabilities of the organizations. The blockchain assessment tool is designed to enhance decision-making in EU Institutions and Bodies regarding the value of experimenting with blockchain technology, which it can do if it is used as an initial assessment of the applicability of blockchain for a specific process. The user should start by identifying the process for which he or she is looking at the potential of blockchain. A clear image on the status quo allows for an accurate assessment of the blockchain fit, which is done in step 1 of the tool. In this step, assessing the blockchain fit, the user must also be aware of the organization he or she is part of. Reflecting critically on the capabilities of the organizations enables honest answers to the statements referring to the organizational factors, in turn enhancing the accuracy of the blockchain fit score. The statements are provided in an Excel file and automatically calculates the blockchain fit score and maps the assessment outcome. The fit can be communicated to the stakeholders in the organizations involved. For the second step, creating a high-level blockchain design, the user provides his or her preference on the eight process criteria. These preferences should be carefully chosen and preferably chosen after deliberation with all actors involved in the organization. For this step an Excel file is used as well, which allows for automatic presentation of the most appropriate high-level blockchain design. After this step, the outcome should trigger the decision-maker to think about the consequences of this design. Step 3 facilitates this thought experiment, as it provides an overview of the potential ripple effects of blockchain technology used in governmental processes. As this step is likely to fuel a number of fundamental discussions, step three should be performed in a group with relevant stakeholders in the network, to identify which effect is relevant for this process, and what the impact of this is. For example, does this implementation of blockchain cause a loss of jobs in society? If the answer is yes, what does this mean? Is this something the organization should avoid, or potentially embrace to enable economic growth? The initial overview allows for the identification of the effect before the fact and allows for the creation of appropriate policy measures to avoid negative effects and capture the benefits of blockchain technology.

4.6 Conclusion of Chapter IV

This chapter described the design of the blockchain assessment tool that was constructed based on the requirements using a Morphological Chart to structure the design process. The blockchain assessment tool is consists of three steps, that allows a user to assess the blockchain fit, create a high-level blockchain design and to map the ripple effects. This chapter answers fourth research question: *How does a blockchain assessment tool for EU Institutions and Bodies look like?*, for which a visual representation of the designed blockchain assessment tool is presented in Figure 23. The first step of the tool assesses the fit between the process, the organization and blockchain technology, based on a blockchain process fit score based on statements that the decision-maker answers. The second step of the tool allows for the high-level design of the type of blockchain application, as users of the tool can indicate their preferences on a number of process criteria. The present a thought experiment on the potential effects of either the information exchange or registration process using blockchain technology. The users of the tool, decision-makers in EU Institutions and Bodies can follow the steps in sequence or iteratively, allowing the decision-maker to learn throughout the process. The next chapter will demonstrate the blockchain assessment tool.

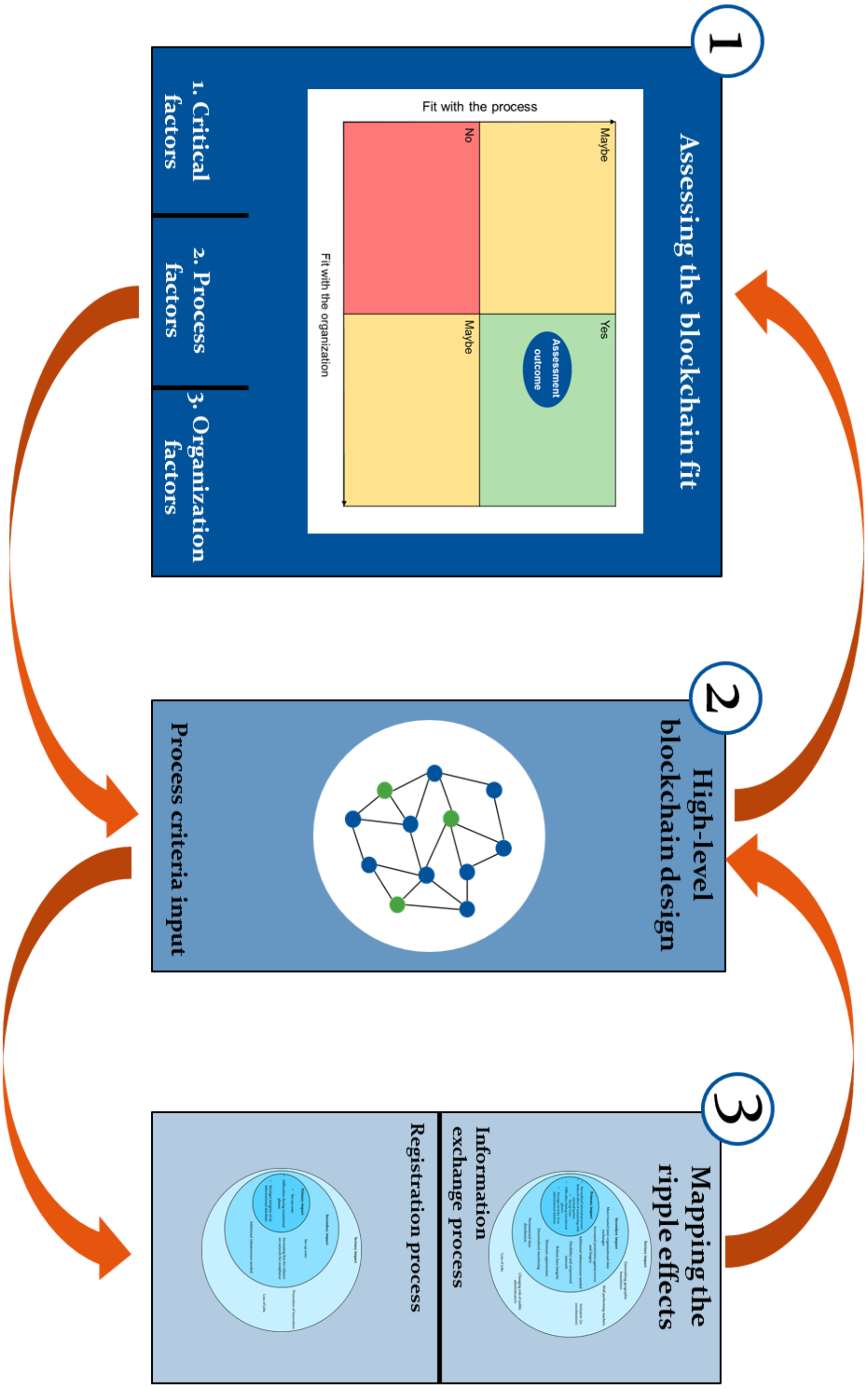

Figure 23. Blockchain Assessment Tool

V. DEMONSTRATION

This chapter demonstrates the designed blockchain assessment tool as it describes the fifth research step of this thesis: Artefact Demonstration. It answers the fifth research question: **How can the feasibility of the blockchain assessment tool be demonstrated?** Using two case studies, for both an information exchange process and a registration process of an EU Institution or Body, the feasibility and workings of the blockchain assessment tool is demonstrated. The approach to the case studies is described in paragraph 5.1. The two case studies that are used to demonstrate the tool are 1) a system that monitors the movements of excise goods under duty suspension called EMCS based on blockchain and 2) an Emissions Trading System (ETS) based on blockchain. The two case studies are described in paragraph 5.2 and 5.3. These paragraph present the different steps in applying the blockchain assessment tool on the case and describe the insights gather in the case. This chapter ends with an answer to the fifth research question in paragraph 654.

5.1 CASE STUDY APPROACH

To demonstrate how the blockchain works, two case studies are explored. The case studies will take the form of desk research and interactive case study interviews to assess the value of blockchain in the case. Using documentation on the current process and organization, the three steps of the blockchain assessment tool are used to demonstrate the blockchain assessment tool. First, an introduction to the case is provided. Secondly, the blockchain-fit is assessed using the first step of the tool. The input on all statements are provided based on desk research. Thirdly, the high-level blockchain design is created based on the process criteria that is reasoned on the desk research as well. Lastly, the ripple effects of the two case studies are explored. Based on demonstration of the blockchain assessment tool in the two case studies, the feasibility of the blockchain assessment tool is demonstrated.

5.1.1 CASE STUDY SELECTION

Section 3.3.1.1 Case study selection provided the criteria on which the two case studies were selected. The first case study looks at a system that monitors the movements of excise goods under duty suspension called EMCS. The second case study is a registration process: it looks at the potential of an Emissions Trading System (ETS) based on blockchain. Appendix E.1 Assessment tool input for EMCS case and Appendix F.1 Assessment tool input for ETS case provide an overview of the documents used in the case studies, which were either provided by the organization involved or using desk research. The interviewees of the interactive case study interviews are anonymized for confidentiality reasons and are described in section 3.3.2 Matrix Prioritization Analysis. In the next two sections, the insights of the two case studies are presented.

5.2 CASE STUDY 1: AN EMCS ON BLOCKCHAIN

The EMCS system of the European Union is a distributed trans-European IT system aimed at monitoring the movements of excise goods under duty suspension within the territory of the EU. The EMCS system is a workflow management system, management peer-to-peer transactions regarding the declaration of goods between two countries within the EU. It is used to complete a declaration form called the ‘e-AD’, that moves from a sender (consigner trader) at the country of dispatch, to a receiver (consignee trader) at the country of destination. Each country currently has their own National Excise Application (NEA), where the sender and receiver complete the dispatch data. The Excise Authority of each country has to validate the data input in the transaction, after which the e-AD is send to the other NEA. Figure 24 shows the actors involved in the transaction process.

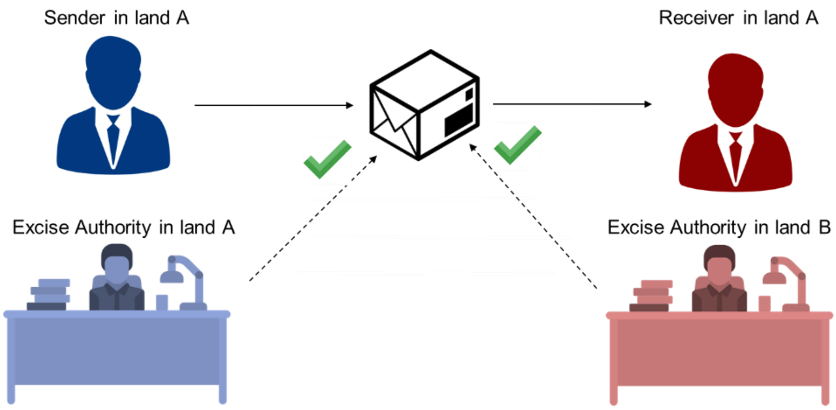

Figure 24. Actors involved in the movements of excise goods in the EU

This system involves a lot of data sharing, as there are 4 actors and 3 systems involved in one transaction. The EMCS uses the following steps in the workflow system, as is illustrated in Figure 25:

1. Sender in land A opens workflow and enters commercial transaction data.
2. EA in land A received this data, and validates this. This triggers the data to be available to the receiver and EA in land B, including validation.
3. When the goods arrive, the receiver in land B enters the receipt's data.
4. EA in land B can access the data and validates the document.
5. The full document is available to all four parties

Please note that only part of the document is exchanged in the four steps, and that the full document is only available in the last step.

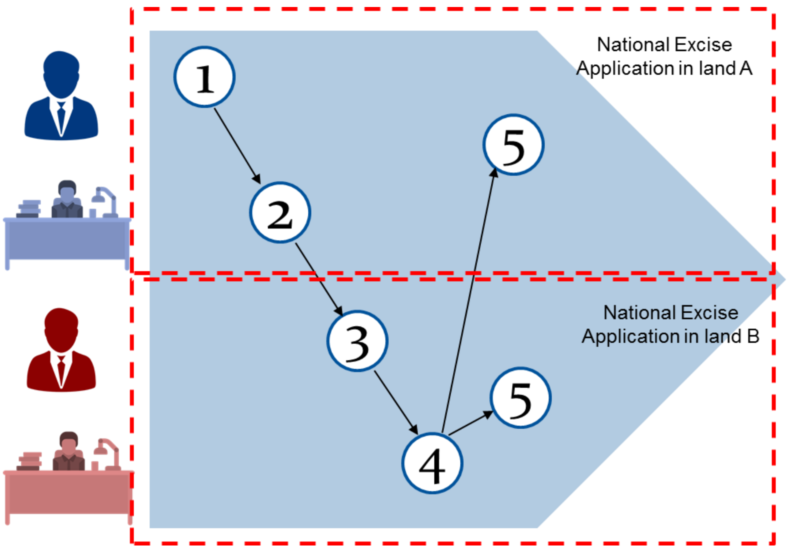

Figure 25. The workflow of the EMCS

DG TAXUD, the Directorate-General for Taxation and Customs Union is responsible for managing and developing the customs union, and is owner and creator of the pan-European EMCS system. This system is argued to be a good use case for blockchain technology, as the benefits of blockchain technology are argued to be reduced implementation and operations costs for both Member States and economic operators, higher availability of the system and better integrity in the form of that there is no need of inter-MS NEA synchronization in case of one NEA failure causing higher quality of data and lower risk of human errors as data is entered only once in a blockchain system. In addition, a distributed database could bring faster and easier searches in the movements in case of controls and investigations for authorities, and could reduce fraud caused by the improved transparency. A trader can check if its trading partner is registered or has declared the movement, which is not the case in the current EMCS.

Step 1. Assessing the blockchain fit

The potential fit of blockchain for the data exchange process and the organization is assessed using the critical factors, the process factors and the organizational factors. All nine critical factors are satisfied for this use case. An example of these factors can be seen in the interdependencies created by the transactions in the system: the receiver can only enter the receiving details when the EA of the sending country has validated the commercial transaction data as provided by the sender in country A. Investigating the process fit, the factors indicate a moderate fit for this process and blockchain, resulting in a score of 57 out of 100. This score is caused by, amongst others, relatively predictable actor behavior and the current amount of human labor in this process, but also by the multiple uses of data in the process and the already existing trust from the actors in the network towards the public administrators. The organization-blockchain fit is argued to be relatively high with a score of 72 out of 100. This is mainly caused by the IT and managerial capabilities of the organization, and the willingness to give up the coordinating role in the process. In conclusion, there is a fit between the EMCS system and blockchain technology. The full analysis for each of the 44 factors is presented in Appendix E.1 Assessment tool input for EMCS case.

Step 2. High-level blockchain design

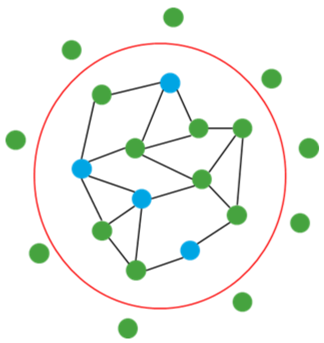

Figure 26. Visualization of the EMCS on blockchain

In this step, the importance of the process criteria are weighted and it is investigated what type of high-level design would fit for this system. The importance of systems reliance is very high in this system, as any loss of availability results in significantly less trade. The importance of control on the economic operators from the perspective of DG TAXUD is low, as their role is merely the facilitator of the data exchange process. The transparency of the identity of the actors with whom the economic operators are trading are very important given the risk of fraud. The external transparency, so the transparency of the transaction and actors in the system from an external perspective, is low, as this system includes trade details that economic operators do not wish to share. The data assurance is of high priority, as well as the security, as the identification, authentication, authorization and confidentiality of the data and IDs of the traders are a critical requirement of the EMCS system. Scalability of the system is also important, as a steady growth in transactions in the system is distinguished in recent years. The importance of an energy efficient system is moderate, as the authorities of the Member States would be willing to use more energy if this would make the system more reliant or secure. The full analysis of the process criteria is found in Appendix E.1 Assessment tool input for EMCS case.

Given these process criteria, the blockchain assessment tool provides the following recommendations regarding the design option of the EMCS system on blockchain, as can be seen in Table 29. Figure 26 presents the visualization of this network. In this system, Authorities of Member States can be validating nodes (having the original copies of the ledgers). Participating nodes are economic operators (using 'light wallets', which are digital representations of the ledger, accesses via the web). As this will be a permissioned private blockchain, NEAs of MSs can determine the requirements of the economic operators to participate. Thereby, the public administrators set the read and write rules of the data and determine permissions of different roles.

Table 29. Suggested design options for an EMCS on blockchain

Design feature	Suggested design option
Blockchain type	*Private permissionless blockchain*
Consensus mechanism	*Proof-of-stake*

Concluding, using the blockchain assessment tool, it is argued that this would be a good use case for blockchain, as it could bring a variety of benefits including improved security (no longer a single-node-of-failure), data integrity, transparency in the whole system, auditability for authorities, interoperability for other uses and reduction of fraud. However, DG TAXUD must be aware of experimentation and development costs, and the fact that legal code has its drawbacks as it is difficult to write bulletproof contracts. Also, in the EMCS on blockchain, there is still manual data input necessary, as well as an extra layer of validation necessary; the blockchain itself only validates on a technical level (not on a semantic level). Yet, this is also a weakness in the current system.

Step 3. Mapping the ripple effects

This last step answers the question of what the effects are of this blockchain application on the organization, on the network and on society. The mapping of these effects was done in an interactive case interview using a Matrix Prioritization Analysis, for which the full analysis can be found in section 3.3.2 Matrix Prioritization Analysis. This resulted in a prioritized effects list as displayed in Figure 27, based on the projected impact of the effect and the importance for EU organization to consider.

An EMCS on blockchain is considered to affect not only the authorities of the Member States (primary effects), but also society (tertiary effects). For the economic operators in the network, it promotes additional transactions as opportunism is lowered in the system by having a shared, distributed ledger and transparency in the transactions (secondary effects). This could present a changing role for the authorities of Member States, as they currently still play a central role in the information exchange process of the EMCS. Implementing a distributed ledger for this process would enable a more supervisory role for authorities, presenting a disintermediation of the public administrations involved in this process.

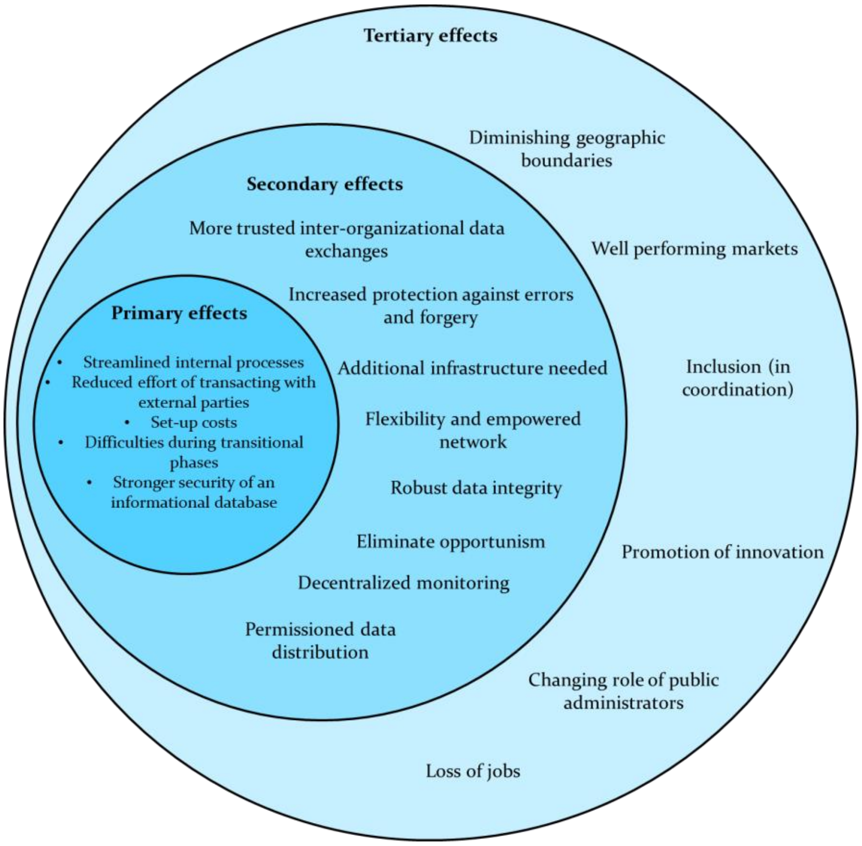

Figure 27. Mapped ripple effects of the EMCS case

5.2.1 CONCLUSIONS OF THE EMCS CASE STUDY

Based on the application of the tool to the EMCS system, a number of conclusions from the case study are derived. The blockchain assessment tool indicates a positive fit for this process to be based on blockchain, but it also highlights the potential drawbacks for DG TAXUD, including the difficulties of writing 'bulletproof' smart contracts to enforce the law. Also, a blockchain system for this process would not completely remove the need for semantic validation by the authorities in the process. Still, having an EMCS on blockchain would change the role of the public administrations, as was argued in step 3 of the tool where the ripple effect of this blockchain systems are investigated. This role would change to one were the national authorities have the ability to check and control when necessary is perceived to be an important benefit instead of facilitating the currently lengthy workflow system. Also, the shared ledger could allow for additional uses of the data for other of uses like searches in the movements in case controls and investigations.

5.3 Case study 2: An Emissions Trading System on blockchain

The European Union has taken a leading role in reducing emissions by implementing the EU Emissions Trading Scheme (ETS) in 2005, an EU-wide greenhouse gas market based on the Kyoto Protocol (Watanabe & Robinson, 2005). Greenhouse gas trading is a market-instrument that is intended to reduce greenhouse gas emissions cost-effectively. In a greenhouse gas trading system, private parties can trade allowances for greenhouse emissions. The system transforms a negative externality like pollution into a positive asset, and creates incentives to reduce the emissions of greenhouse gasses for firms. Based on transaction theory, this market-based solutions is argued to be an effective way of reducing the total amount of emissions in the EU (Tietenberg & Lewis, 2010). By providing a reducing cap of total allowances in the system, the EU ETS is supposed to steadily reduce the total amount of emissions in the market.

Currently, the registration of these allowances are centralized in the EU. Every Member State has an Emission Trading Authority, that is responsible for the issuance and updating of emission permits, the assigning and granting of emission allowances, the managing of the registers for EV and EU ETS, the issuing of emission allowances on the emission allowances auctions and the monitoring of compliance with laws and regulations. Very simply put, firms that emit CO_2 are obliged to participate in this system, and they are obliged to have enough allowances for the tons of CO_2 they emit, which they have to hand in once per year. There are generally three ways to obtain emission rights as a participant in the system: free allocation, auctioning or via trading with other participants.

In the EU there is one central system that is responsible for authorizing movement of allowances between accounts. The participants have an account to the registry which works like a web-based banking system. The verification of the transfers of allowances is automatically done in the registry. The control of granting access to the system and providing accounts is distributed to the Member States: so for example the German Emission Trading Authority is responsible for authorizing the participants to have an account in the registry in the country of Germany. This authorization should however be in accordance with commission regulation.

This system has not always been completely centralized. The registration tools were decentralized and implemented by the different Member States until 2012. In 2012, the system was completely centralized following a revision in the EU ETS Directive. Moving towards a centralized system instead of 27 different ones was done based on two drivers: cost-efficiency (not reinventing the wheel several times and fewer transaction problems) and security. The level of institutionalization is very high in this system, meaning that it is heavily regulated from the EU. The transactions are made public, yet only after three years. This is the case because of the confidentiality of the trades on the short term for the participants, causing the confidentiality rules to be strict. The Directorate-General for Climate Action (DG CLIMA) is responsible for implementing the EU's Emissions Trading System (EU ETS), as well as promoting the links with other carbon trading systems, with the ultimate aim of building a global carbon trading market. Figure 28 presents a visualization of the centralized EU ETS system.

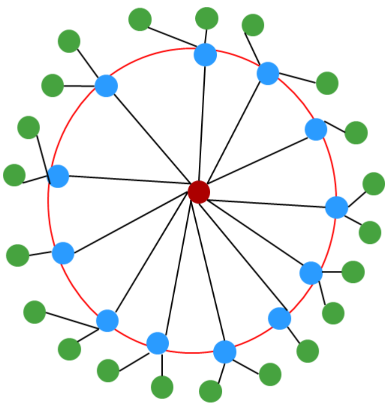

Figure 28. Current centralized EU ETS registration system

As the ultimate aim of the EU ETS is to build a global carbon trading market, the following analysis investigates the potential of a registry that is based on blockchain technology, where the participants in the market can directly trade with one another.

Step 1. Assessing the blockchain fit

Performing the first step of the technology assessment tool, the potential fit of blockchain for the data exchange process and the organization is assessed using the critical factors, the process factors and the organizational factors.

Looking at the critical factors, it is argued that there are specific needs for a central registry to be the intermediary in this process, other than to ensure compliance. The process involves multiple organizations that exchange data in the form of carbon allowances, though currently centralized. Current regulations specify very detailed how the functions of the registry would work and how the Member States should be using it, so the legal framework must be changed in order to start experimenting with this technology. Even though the benefits of a blockchain system with each firm being a node goes beyond mere registration, as it facilitates the options of additional automation like automatic auctioning based on smart contracts, connecting it to other ETS's in the world, or even attaching it to certain energy grids to real time monitor the energy emissions, it is highly doubtful whether the benefits will outweigh the costs that will be involved in setting up this system, although this is difficult to assess. There are no interdependencies between the transactions created by the stakeholders in the networks, which means that the allowances traded in the system are only used to show compliance. The allowance balance does not impose any other limitations or possibilities, so no extra interdependencies between the transactions are created other than the transaction itself. In the future, it could become possible to attach each firm's carbon allowance balance to other applications. If the energy grids will become so smart that they can monitor real-time emissions, then interdependencies between the transactions and other actions are created. Yet, this is not currently the case and firms only have to show yearly compliance.

Please note that this use case does not satisfy three of the nine critical factors, namely that the legal assessment tool does not allow for experimentation, the potential benefits are currently not outweighing the costs and there is no further independency between the actors caused by the interaction. Therefore, the blockchain assessment tool presents a negative blockchain fit for this process. The analysis is however completed to demonstrate the full working of the designed tool.

Looking at the process and organization fit, a negative assessment follows as well. The blockchain-process fit score is analyzed to be 48 out of 100, and the organization-blockchain fit is argued to be 45 out of 100. The limited process fit is caused by the fact that the current system is already highly automated, the high level of trust in the current registry by the actors in the system as the DG Climate Action and the local authorities have a vested interest in the workings of the system, the fact that transparency between the actors involved is not necessarily required or desired by the actors and the importance of data security for both traders and authorities, as compromises of the system can lead to large losses of money for firms. Blockchain is not argued to improve security in this system, because the current centralized system already has multiple parallel working system. Though it can be argued that there is still a Single-Point-Of-Failure, the blockchain system is also still only as secure as its encryption level, providing trade-off between heavily securing the data that is centrally stored in the register or trusting the encryption method of the blockchain. The blockchain is argued to increase transparency for authorities and straightforward auditability to address regulatory requirements.

The argued low fit between blockchain and the organization is caused by the lack of a blockchain enthusiast and the fact that EU ETS operates in a heavily regulated environment. In addition, the DG CLIMA is argued to be reluctant to give up the current coordinating role in the process given the recent developments to centralize the registry. However, there are already similar use cases being explored in the market, including IBM that has conducted a successful pilot for a similar system in China with Energy-Blockchain Labs (CryptoCoinsNews, 2017). This is an open source carbon allowances trading and registration platform using the Hyperledger Fabric blockchain. The full analysis for each of the 44 factors is presented in Appendix F.1 Assessment tool input for ETS case.

Step 2. High-level blockchain design

In this step, the importance of the process criteria are weighted and it is investigated what type of high-level design would fit for this system. The system should provide a high level of reliance, and the control of the authorities of the Member States on the blockchain system is also of high importance, since this created market needs to be overseen by a regulator. The importance of transparency between actors is only medium, as the actors involved only have limited benefits when this transparency increases. It is not reasoned to increase trade or effectiveness of the system. External transparency is extremely low due to the confidentiality regulations surrounding these trades of three years. Data assurance is the reason why there was heavily invested in the current system, and security was the main driver of centralizing the system, given the issues occurred in the decentralized systems. Also, scalability is of importance given the potential new entrants that will be needed to be included in the system. The energy efficiency is of somewhat importance, as the actors involved in the network will not be willing to supply unlimited resources for this system. The full analysis is found in Appendix F.1 Assessment tool input for ETS case.

Given these process criteria, the blockchain assessment tool provides the following recommendations regarding the design option of the EMCS system on blockchain, as can be seen in Table 30. Figure 29 presents the visualization of this network. In this system, a private permissioned blockchain, the traders will be able to directly transact with each other. Just as currently is done, the European regulator lays down the ground rules on how the allowances are allocated; by yearly allocation, auctioning or other mechanisms. The carbon allowances are used as a currency, these allowances are the asset that is traded in the system, similar to Bitcoin. Differences are that this system is not public and the organization(s) issuing the system are able to determine who gets to participate and the foundations of the transaction. In addition, 'mining' will not result in additional emission allowances, and it can be argued that the validating nodes in the system should be authorities.

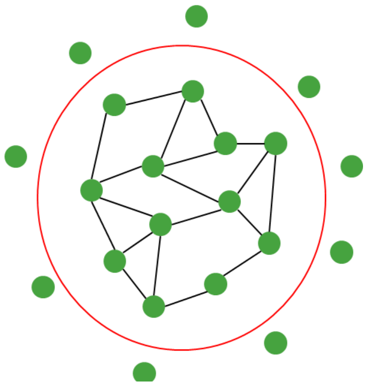

Figure 29. Visualization of an ETS on blockchain

Table 30. Suggested design options for an EMCS on blockchain

Design feature	Suggested design option
Blockchain type	*Private permissioned blockchain*
Consensus mechanism	*Proof-of-stake*

Concluding, using the blockchain assessment tool, it is argued that this would not be a good use case for blockchain. The legal framework does not allow for experimentation, the potential benefits are currently not outweighing the costs and there is not further independency between the actors caused by the interaction. Also, for the process itself, blockchain does not necessarily provide added security, and the increased transparency is not really desired by both the network and the authorities. It would allow for the ability to connect to other systems and near real-time trading, but this is not applicable yet as technologies in this area still need to mature.

Step 3. Mapping the ripple effects

Again, even though the blockchain assessment tool indicates a limited fit for this use case and blockchain, the last step is still completed. This step looks at if a system as such were to be put in place, what the ripple effects would be on the organization (primary effects), on the economic operators in the network (secondary impact) and on society (tertiary impact). The mapping of these effects was done in an interactive case interview using a Matrix Prioritization Analysis for which the full analysis can be found in section 3.3.2 Matrix Prioritization Analysis. This resulted in an overview of the ripple effects list as displayed in Figure 30.

The interactive case study interviews presented the insight that the effects of this use case would be mainly for the organization and on the network. As the current system is used to show yearly compliance, the economic operators have to trust the centralized system to accurately record the allowances transactions and provide data integrity. When using blockchain technology, an economic operator would need to rely on the network to provide help providing this compliance to the authorities. Failing to show this compliance could result in penalties or fines for the economic operator. This is an important secondary effect that needs to be considered.

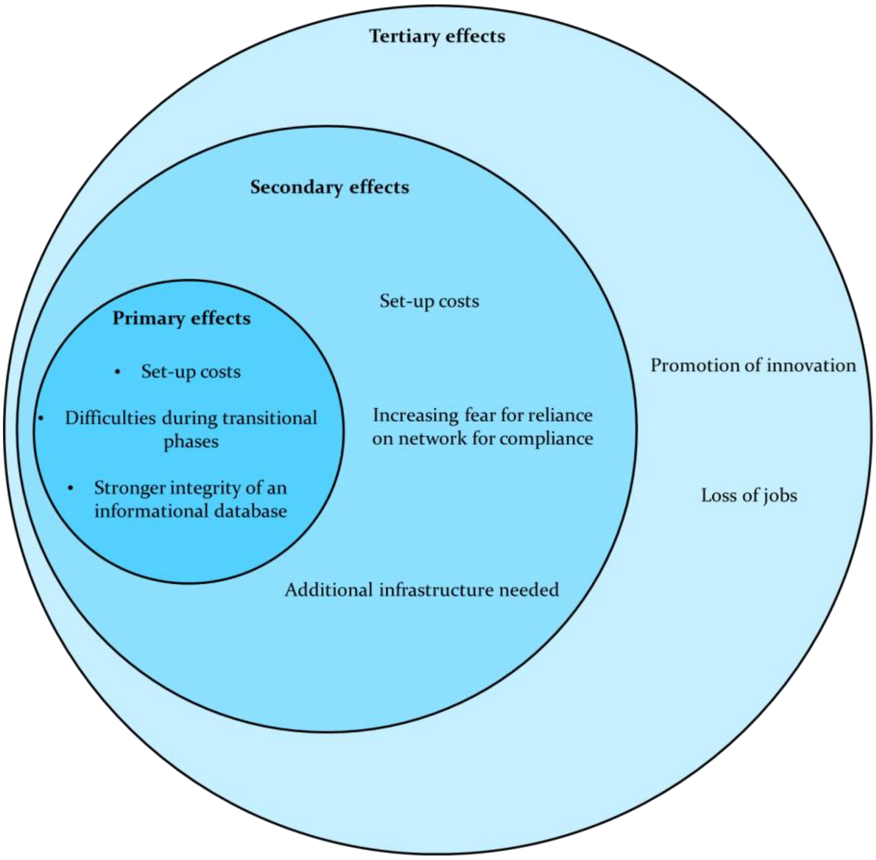

Figure 30. Mapped ripple effects of the ETS case

5.3.2 Conclusions of the ETS case study

The blockchain assessment tool indicates a negative for an Emissions Trading System for blockchain technology. This judgment is shared with the interviewee, as there are many issues that blockchain still would need to overcome to be applicable in this case. In addition, the projected benefits are not convincing in this case: currently there are few interdependencies between the actors caused by the trade besides the ability to demonstrate compliance to the authorities. Also, the current system is centralized but provides a high level of security and data integrity as the transactions are atomically verified, which allows the actors in the network to rely on this system to show yearly compliance. In this respect, the actors might want to have a public administrator guaranteeing the security and data integrity, instead of having to rely on the whole network to provide security and data integrity, endangering the potential to show compliance. The role of public administrators is not argued to change in a system as such, as the role of public administrators is now twofold: providing the ETS system and setting the rules for the trading and allocation of the emission allowances. The role of system provider and rule setter is still necessary in a private permissioned as analyzed in this case.

5.3 Conclusion of Chapter V

The two case studies presented a clear demonstration of how the blockchain assessment tool can provide insights in the applicability of blockchain for an EU Institution or Body. The first case study is the exploration the blockchain technology for a distributed trans-European IT system aimed at monitoring the movements of excise goods under duty suspension within the territory of the EU called EMCS. For this case, the blockchain assessment tool indicates a positive fit for this process to be based on blockchain. The tool also provides insights in potential disadvantages for this case, including the difficulties of writing 'bulletproof' smart contracts to enforce the law. The second case study is the exploration of blockchain for the EU Emission Trading System. For this case, the blockchain assessment tool indicates a negative fir for an Emissions Trading System for blockchain technology, mainly because the projected benefits are not outweighing the potential drawbacks. The two case studies tool provided insight in the fit with the blockchain, a high-level blockchain design and the ripple effects of the implementation. The two case studies showed the differences in estimated ripple effects as mapped by the interviewees. For the EMCS case, an information exchange process, the role of the public administration involved is argued to change: from an electronic intermediary and a key gatekeeper in each transaction, toward a more supervisory role, having the ability to check and control when needed. For the ETS case study, it became apparent that the disintermediation of the public administration can affect the network involved by creating fear of having to rely on the network when showing compliance with regulations. This allowed for the specification of the ripple effects that organizations need to consider based on the process that is involved.

Using two case studies, this chapter provides an answer to the fifth research question: *How can the feasibility of the blockchain assessment tool be demonstrated?* The two case studies demonstrated how the blockchain assessment tool can provide insights into the applicability of blockchain for an EU Institution or Body. The tool provided insight into assessing the fit with the blockchain, choosing a high-level blockchain design and assessing the ripple effects of the implementation. Therefore, the blockchain assessment tool can enrich the decision-making regarding the experimentation with blockchain technology in EU Institutions and Bodies. The next chapter describes the evaluation of the blockchain assessment tool.

VI. EVALUATION

This chapter evaluates the blockchain assessment tool, which the sixth research step of this thesis. It aims to answer the sixth research question: **How can the blockchain assessment tool be evaluated?** The evaluation is conducted using expert evaluation interviews. The expert evolution interviews are based on the plan validation method, which is outlined in paragraph 6.1. The overview of the experts that were interviewed and the feedback on the design goals, requirements, the blockchain assessment tool design and usability are presented in paragraph 6.2. The feedback gathered in the interviewed is translated into additional improvements of the blockchain assessment tool, which is presented in 6.3. This chapter ends with an answer to the sixth research question in paragraph 6.4, presenting a conclusion how the blockchain assessment tool evaluates with experts in the field.

6.1 METHOD OF EVALUATION

Verschuren & Hartog (2005) describes the three types of evaluation methodologies used in design-oriented research; plan, process and product evaluation. All methodologies have different aims and approaches, and should be used in different phases in design-oriented research. To select the appropriate evaluation methodology for this research, each of these are briefly introduced.

- *Plan evaluation* assesses the quality of the designed artefact on paper. The requirements are explicitly written down on paper, as well as the assumptions and specifications that are at the basis of these requirements. This evaluation methodology tests whether the designed artefact reaches the goal of the artefact (Verschuren & Hartog, 2005).
- *Process evaluation* is mainly done to detect errors in the process of the design. The improvement of the design process can improve the design of the artefact. This is evaluation methodology is favorable for software deployment (Verschuren & Hartog, 2005).
- *Product evaluation* aims to find the short and long term effects of the design artefact after the conception of artefact. This evaluation methodology investigates the implications of the actual deployment of the designed artefact, mostly in quantified results (Verschuren & Hartog, 2005).

As this thesis focusses on the initial design of the blockchain assessment tool that has yet to be implemented, it is essential to focus the evaluation on the *requirements*, *assumptions* and *specifications* of the designed tool, which is done in *plan evaluation*. These three elements are evaluated to test the adequacy of achieving the *design goals* (Verschuren & Hartog, 2005). The aim of plan evaluation is the "logical, ethical and empirical check of (the quality and appropriateness of) all separate design requirements, design assumptions, structural specifications, and the design goal(s)" (Verschuren & Hartog, 2005, p. 739). It evaluates the *design requirements*, the *design assumptions*, the *structural specifications* and the *design goals* on their own separate value. In addition, these elements should be evaluated on their coherence and whether they are a balanced whole, referring to their related value (Verschuren & Hartog, 2005).

6.2 EXPERT EVALUATION

To evaluate the quality and appropriateness of the design, the designed tool was discussed with various expert in the field of blockchain in governments, blockchain applications and complex systems. The overview of the expert evaluation interviews is presented in Table 31.

Table 31. Overview of expert evaluation interviews

Aspect	Expert evaluation
Interview strategy	Logical plan evaluation
Method	Expert evaluation interview
Amount of interviews	5
Objective	Evaluate the quality and appropriateness of the designed blockchain assessment tool
Input	- Designed blockchain assessment tool - Evaluation criteria
Output	- Evaluated blockchain assessment tool - Hints towards future research and improvements

Interviewees	Blockchain experts

In total five interviews were conducted in May 2017. The interviews were performed either face to face or via videoconference, and the interviews lasted around 90 minutes each. To gain feedback from multiple perspectives, the experts were chosen from different fields of expertise: complexity and uncertainty, blockchain from a technical perspective, blockchain applications and blockchain in governments. Table 32 provides an overview of the expert evaluation interviews that were conducted, and the full expert evaluation interview minutes are found in Appendix G.1 Expert evaluation minutes.

Table 32. Overview of interviewed experts for expert evaluation

No	Blockchain experts	Organization	Field of expertise
1	Lex Hoogduin	University of Groningen	Complexity and uncertainty
2	Rutger van Zuidam	DutchChain	Blockchain technology
3	Svein Ølnes	Western Norway Research Institute	Blockchain in e-government
4	Garret Bonofiglo	Gartner	Blockchain applications
5	Joachim Schwerin	European Commission (DG GROW	DLT policy in Europe

To evaluate the *design requirements*, the *design assumptions*, the *structural specifications* and the *design goals* of this thesis, four experts in the field are asked to evaluate the quality and appropriateness of these elements, based on criteria as specified by Verschuren & Hartog (2005). Regarding the design goals and assumptions, the clearness is evaluated. The design requirements are also evaluated on clearness, as well as feasibility and completeness. The structural specifications, which is the designed blockchain assessment tool, is evaluated on fit with the design goals, assumptions and requirements. Also, the design is evaluated on completeness, structure and correspondence to reality. Lastly, the experts evaluate practical criteria of feasibility of the design and usability of the blockchain assessment tool. Table 33 provides an overview of the evaluation elements used in the expert evaluation interviews.

Table 33. Overview of evaluation elements for the expert evaluation interviews

Element	Evaluation criterion	Question
Design goals	Clearness	Is the need for creating a blockchain assessment tool for public administrators clear?
Design assumptions	Clearness	Are the elements of this tool clear?
Design requirements	Clearness	Are the defined requirements clear?
	Feasibility	Are the defined requirements feasible?
	Completeness	Are there any requirements missing?
Overall blockchain assessment tool design	Fit	What is your opinion on the three steps included in the assessment tool?
	Completeness	What elements can be added to the assessment tool? Why do you feel necessary to add those elements?
	Completeness	What elements can be removed from the assessment tool? Why do you feel necessary to add those elements?
Step 1: Assessing the blockchain fit	Structure	What is your opinion on the division of critical factors, process fit and organization fit?
	Correspondence to reality	Do you recognize the critical factors that are 'showstoppers' for blockchain experimentation?
Step 2: High-level blockchain design	Fit	What is your opinion on using process criteria to determine a high-level blockchain design?
	Completeness	Are there any process criteria or design options that you are missing?
Step 3: Mapping the ripple effects	Structure	What is your opinion on the distinguishing three levels of impact for blockchain implementations by public administrations?
	Correspondence to reality	What is your opinion on the potential of blockchain to change the role of public administrators?
Usability of the blockchain assessment tool and further research	Usability	What is your opinion on the usability of the blockchain assessment tool?
	Other	In what areas should be more research performed, or which elements of the blockchain assessment tool are underdeveloped?

The expert evaluation interview began with explanation of the identified problem, and the knowledge gap this thesis intends to address. The six relevant elements involved in implementing blockchain in governmental organizations are introduced, and an explanation is provided how these were translated into requirements. The design of the blockchain assessment tool is then introduced. Based on this, questions are asked to the experts to gain feedback on the general structure of the designed blockchain assessment tool, the content of the different steps that this tool use, the usability of this blockchain assessment tool and further research directions. The following paragraphs present the general lessons of the expert evaluation interviews.

6.2.1 Feedback on design goals, assumptions and requirements

This thesis departs from the notion that blockchain technology has the potential to improve information exchange and registration processes in EU Institutions and Bodies, but an assessment tool that provides insight in the value of blockchain for these processes is lacking. Blockchain could present the next step in e-government development, yet this technology is highly complex from a multi-actor perspective and a systems perspective, causing high institutional and technological uncertainties. The interviewees were thus asked to reflect on these design goals, assumptions and requirements, and to provide feedback.

- All interviewees indicated that they follow this line of reasoning. One interviewee indicated this is in line with the discussion on this topic currently going on in the EU. One interviewee did indicate that the technological uncertainty that this research takes into account is only temporary, and will change in the future. Another interviewee compares this technology to the early days of the internet, and questions the possibility of blockchain to become successful if they are implemented in permissioned form. He stresses the importance of interoperability and therefor permissionless blockchains, as he believes that the openness of the infrastructure is critical to success.
- The need for a blockchain assessment tool for governmental organizations was also recognized by the interviewees, yet potentially ambitious. One interviewee indicated that there is a need for this in all industries, but the public sector is more interesting because of the role that the citizen has in this industry. A government cannot lose its customer, so competing with governments is difficult, but a blockchain can enable this. Another interviewee argued the importance of critically deliberating how this technology can be used, is this technology provides an economic alternative to trusted intermediaries like public administrations. But, he argued, the uncertainty surrounding an institutional change as such should be taken into account and analyzed. Another interviewee praised the setup of this research, as it presents a problem looking for a solution and not the other way around.
- The potential for blockchain in the EU was also recognized among interviewees. One interviewee argued the potential of blockchain to serve citizens directly as a supra-national government. On the other side, the interviewee with a focus on distributed ledger technology policy in the EU stretched the different layers of the EU where blockchains, and explained that in his view the EU should mainly be providing framework condition and not provide a blockchain infrastructure their selves. Yet, he also highlighted that there is an ongoing discussion in the EU whether the EU should create an EU blockchain infrastructure for governmental services.
- A lively discussion on the potential of permissioned versus permissionless blockchain systems emerged. Whereas one interviewee with a more ‘evangelical’ view on blockchain highlighted the benefits of permissioned blockchains, another interviewee presented a more critical view on this. One interviewee questions the level of decentralization of permissioned blockchains in governments, and whether you could speak of true immutability in these permissioned systems. Other interviewees recognized the perspective on this that thesis argues: that permissioned blockchains can provide benefits but that is does not completely disintermediate public administrations as there is still a manual semantic check necessary. One of the interviewees has put this in the following words: “in society, you can not only make a decision based on the legal system alone, you always need a human judgment based on ethics as well”.
- One of the interviewees raised the question what the role of open source in this area is. Open source is necessary, but not sufficient in his view, as the trust in the system is much more than just in the open source code. This discussion is both political and philosophical, and not explicitly raised in this research.
- The fact that the decision-making process is taken into account in this research is considered to be a benefit. If the tool does not match the process, it is much less valuable, was argued by one interviewee.

6.2.2 FEEDBACK ON THE DESIGNED BLOCKCHAIN ASSESSMENT TOOL

The design of the blockchain assessment tool was presented to the interviewees, and the three steps of the tool were explained. The interviewees were asked to reflect on the structure and completeness of the design, and provide feedback on the design.

- All interviewees indicated that the structure of dividing the tool into three steps is clear and logical. The interviewees recognize the steps. According to one interviewee, it is logical to first assess the fit, than think about the design and then map the impact, because this is something that is also done for other technologies in other industries.
- Using statements to determine the blockchain fit is recognized as a user-friendly way by the interviewees. One interviewee did however the fact that because a user fills in these statements, it is always up for discussion. The perspective of the person using the model is determining is this regard.
- The critical factors are widely recognized by the interviewees, and placing them in the beginning of the assessment is experienced to be beneficial. These factors highlight that blockchain cannot just be a replacement of a traditional database as one interviewee mentioned. Some reflection on the factors was done as well.
- Step 3 of the blockchain assessment tool sparked an interesting discussion on the changing role of governments by blockchains. Two interviewee mentioned that there are a lot of reasons to have governments, but it should be up to the citizen to opt-in to certain governmental services. Another interviewee raised the question whether public administrators are truly ready for the decentralized approach. It is argued by one interviewee that a permissionless blockchain enables a reducing government and one with less coercion, and a permissioned blockchain enables a changing government.

6.2.3 FEEDBACK ON THE USABILITY OF THE BLOCKCHAIN ASSESSMENT TOOL

The interviewees were asked to reflect on the overall usability of the tool.

- Interviewees indicates the overall usability to be high. The practicality of the tool to structure a discussion on blockchain applicability was mentioned by three interviewees. The overall opinion is that the scores that the user has to provide to the different factors make it user-friendly. Also, the sequence and definition of the separate steps is useful and helps to structure the discussion around this topic. The design of the blockchain assessment tool fits the line of reasoning, as one interviewee pointed out.
- The structure of the research set-up is argued to be valuable, as this allows for a structured way to look at the blockchains potential. One interviewee explicitly indicates the fit for the design science approach for this research, as it incorporates both the knowledge base and insight from the environments.
- The blockchain assessment tool steps match the steps that the EC generally consider in this area, as one interviewee points out. Therefore, the designed blockchain assessment tool is tailored for purpose. The design of the blockchain system is where the most discussion will emerge, according to this interviewee.

6.3 INSIGHTS TRANSLATED IN THE BLOCKCHAIN ASSESSMENT TOOL

The evaluation interviews provided insights into potential improvements of the blockchain assessment tool. The improvements that were suggested by the interviewees are summarized in Table 34. Some of the recommendations are used as suggestions for future research, but some of the feedback was also incorporated in the final version of the tool. The overlap between process and organizational factors was removed, the loss of jobs ripple effect was added and the security process factor was removed. The tool was also made more cyclical to enable a learning process for the user.

Table 34. Suggested improvements of the tool

Potential improvement	Explanation	Used in thesis
A governance design block	An additional block that would help to design the governance in the blockchain system, as raised by two interviewees. This is an important element in IT infrastructure design, but is dependent on the high-level	*Included in recommendations for improving the tool.* The governance design of the blockchain experiment can be added by identifying the parties needed in the

	blockchain design. One interviewee stresses the importance of consortia-forming in blockchain experimentation.	consortium, mapping each interest and objectives in the blockchain system.
Insight in trade-offs between the design features	Step 2 of the blockchain assessment tool allows the user to express their preference on certain process criteria. But, right now it is possible to indicate that all process criteria are important as two interviewees pointed out. He argues that an addition could be to provide more insights in these trade-offs, for example by investigation which process criteria present a trade-off.	*Included in recommendations for future research*. Before this insight can be provided, more research has to be performed in this area, as current literature on the impact of design features of blockchain on the systems performance do not investigate these trade-offs yet.
A citizen-centered block	Another addition, raised by one interviewee, could be the addition of a citizen-centered block. Right now, the tool is reasoned from the public organizations' perspective, but reasoning from the citizen's perspective as well could tailor it to the citizens need.	*Included in recommendations for improving the tool.* Currently, the tool reasons from the perspective of the public administration. A completely different perspective is needed to add this block, including a method of defining the exact need of citizens.
Overlap between process and organizational factors	Some concern was raised about potential overlap between process and organizational factors by one interviewee. These might strongly interact. The interviewee suggested to name them external and internal factors, which could make it clearer.	*Included in next version of tool (v1.0).* The remark raised in the evaluation interviews was taken into account by critically reviewing the factors and the corresponding statements, to create a clear distinction.
Addition of loss of jobs effect	Regarding the ripple effects, one interviewee argued that one important effect was missing: the loss of jobs. This will create a lot of discussion for policy-makers.	*Included in next version of tool (v1.0).* This ripple effect was added in the tertiary effects layer.
Making the tool more cyclical	One of the interviewees indicated that this tool might fit into a framework that his organization developed to deal with uncertainties. Yet, the blockchain assessment tool is still to linear. If you are dealing with uncertainties and complexities, a tool as such should include a more cyclical approach to learn from the steps the user has made.	*Included in next version of tool (v1.0).* The next iteration of the tool includes stage-gates that present the possibility of users to proceed to the next step or revise the previous steps based on insights gained in the current step.
Removing the security process factor	An interviewee mentioned that because the security that blockchain systems can bring is still under discussion, it might not belong in the assessment tool	*Included in next version of tool (v1.0).* This process factor was removed as this is not an undisputed factor in blockchain systems.

6.4 Conclusion of Chapter VI

Using five expert evaluation interviews, the sixth research question was answered: *How can the blockchain assessment tool be evaluated?* The interviews gathered feedback on the design goals, assumptions and requirements of this research, and on the design and usability of the blockchain assessment tool. The evaluation interviews showed that the structure and logic of the blockchain assessment tool was understood. The need for a blockchain assessment tool was clear for the public sector, and argued to provide value in other industries as well. The differences between permissionless and permissioned blockchains sparked a number of lively discussions, as well the potential of these blockchain types to change governments. The usability of the blockchain assessment tool is considered to be high by all interviewees, and the interviewees presented a number of potential improvements and additions. The potential improvements were translated into either future research suggestions or were used in the final version of the blockchain assessment tool. The next chapter presents the conclusions and of this research and suggested areas of future research.

VII. CONCLUSIONS

In this final chapter of this thesis, the conclusions of this study are presented, a reflection on the research process and outcomes is discussed and recommendations for future research and development of the tool are suggested. First, the initial research gap and objective are recapped, and the answers to the research questions are synthesized in paragraph 7.1. The main research question is answered based on this: **How can a blockchain assessment tool enhance the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology to improve their information exchange or registration processes?** In addition, paragraph 7.1 also generalizes the findings of this research and confronts them with existing literature. Second, reflections on the research process, on the choices made in this research and the outcomes of the research are presented in paragraph 7.2. Third, recommendations on how to improve the tool, how to make it commercially available and on future research directions are provided in paragraph 7.3. Finally, the link between the Systems Engineering, Policy Analysis and Management (SEPAM) Master's program and this research are explained in paragraph 7.4.

7.1 ANSWERING THE RESEARCH QUESTION

To answer the main research question of this research, six supporting research questions were formulated that are answered throughout this thesis. This section synthesizes the research questions to answer the main research question, generalizes the findings and confronts them to existing literature. After this, the scientific and societal relevance is presented. This research departs from the notion that blockchain technology is a technological and institutional innovation opening up a world of possibilities in the field of e-government. Blockchain is combination of existing technologies combined into a new information infrastructure, reshaping the way governments are able to interact with citizens, economic operators, and each other. This technology can facilitate direct interaction between citizens, provide administration without a governmental administrator and tailor the services provided by governments.

This research focused on EU Institutions and Bodies, as the EU is actively looking to implement blockchain technology to enable a more bottom-up approach to the coordination of citizens and economic administrators. Yet the multi-actor and systems complexity of blockchain is leading to institutional and technological uncertainties. The distributed nature of blockchain systems can create uncertainties regarding the control in the network and the impact of blockchain technology has the potential to alter governance structures. The changes in checks and control in the processes caused by blockchain can even enable a changing role of administrations. Blockchain technology has the potential to improve information exchange and registration processes in EU Institutions and Bodies, but the decentralized character of blockchain can also cause certain public organizations to lose power as the registration information exchange processes are distributed to the lowest level of government. An assessment tool that provides insight in the value of blockchain for these processes in EU Institutions and Bodies is lacking.

The objective of this thesis is to help EU Institutions and Bodies with decision-making regarding the experimentation of blockchain technology, by designing a blockchain assessment tool that assesses the fit between the process, the organization and blockchain technology and that provides insight in the effects of the implementation of blockchain. In order to achieve this objective, this research answers the following main research question:

> *How can a blockchain assessment tool enhance the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology to improve their information exchange or registration processes?*

To enhance the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology to improve their information exchange or registration processes, the blockchain assessment tool takes six elements into account. These six elements are critical for the structural assessment of the fit with blockchain for an information exchange or registration process to capture the benefits of this technology and avoid blockchain experiments that do not provide significant value.

The first element that is critical for this assessment are the complexities. The multi-actor nature and the systems complexity create uncertainties in blockchain implementation in governmental organizations that EU Institutions and Bodies should take into account. The complexities involved originate in the multi-actor nature, the legacy systems, the nature of interactions, the public interest involved and the uncertainties of the governmental blockchain implementation.

The second element are the process factors that determine the fit between the process and blockchain technology. Blockchain technology is well suited to be used in information exchange and registration processes traditionally provided by governments, and these factors determine for which processes blockchain can provide benefits. 23 factors were found to determine this fit, referring to four process factor domains: the general context, prioritization factors, process characteristics and data and processing power.

The third element that is critical for the structural assessment of the fit with blockchain are the organizational factors that refer to the public organization's ability to adopt this innovation successfully depends on a number of factors. Research has focused on these factors for other IT innovations, but the organizational factors have not been investigated for blockchain technology. In total, 16 organizational factors are identified that influence the adoption of blockchain technology in governmental organizations that are found in five domains: support factors, perceived technology factors, organizational factors, collaboration factors and external factors.

The fourth element that enables the blockchain assessment tool to enhance the decision-making regarding the experimentation is that it is tailored to the decision-making process in to EU Institutions and Bodies. The decision-making process of blockchain applications in EU Institutions and Bodies are unique and complex with different actors, activities, roles and organizations are involved in different stages of the process. The blockchain assessment tool can complement the motivation and adoption decision stages, as these stages are used to learn more about blockchain and where the organization assesses the fit with this technology.

The fifth element that enhances the decision-making by EU Institutions and Bodies regarding the experimentation with blockchain technology is insight in the ripple effects of blockchain technology. Governmental blockchain use cases can cause socio-technical effects on multiple layers of institutions. These effects can be divided in three layers: 1. *primary effects* (on the organization itself), 2. *secondary effects* (on the actors in the network) and 3. *tertiary effects* (on society). Insights in the effects caused by blockchain systems allow decision-makers to avoid unintended effects that might include a changing role of governments and diminishing geographic boundaries.

The sixth and last element that is essential for the assessment of blockchain in governments is the design features. Although often viewed as a one-size-fits-all technology, the various design features of blockchain systems impact the systems performance, which are often ignored. The different blockchain types and consensus mechanisms impact the following process criteria; system reliance, control, actor transparency, external transparency, data assurance, security, scalability and energy efficiency of the system. The high-level blockchain design depend on the decision-makers preference on these process criteria.

All of these elements are incorporated in the blockchain assessment tool, Morphological Chart to structure the design process. The blockchain assessment tool is consists of three steps, that allows a user to assess the blockchain fit, create a high-level blockchain design and to map the ripple effects. A visual representation is presented in Figure 23.

1) The first step allows a decision-maker to estimate the blockchain fit by answering statements that refer to the complexities, process factors and organizational factors. The tool provides a blockchain fit score based on these statements, providing insight into the applicability of blockchain for the process.

2) The second step allows decision-makers to state their preferences on the eight process criteria, which in turn provides an advice on which blockchain type and consensus mechanism is the most appropriate for this use case.
3) The third step enables a thought experiment for decision-makers, presenting the ripple effects for either the information exchange or registration process. The decision-maker can perform the steps in a sequence or iteratively tool, allowing the decision-maker to learn throughout the process.

Two case studies and five evaluation interviews demonstrated and evaluated how the blockchain assessment tool can enhance decision-making in EU Institutions and Bodies regarding the value of experimenting with blockchain technology to improve their information exchange or registration processes.

7.1.1 GENERALIZING THE FINDINGS

The blockchain assessment tool designed in this thesis is specifically tailored for EU Institutions and Bodies, but the insights this research provides are also relevant for public administrations in general. It highlights the fact that public administrations should look fundamentally different to their processes. Whereas in the past public administrations were automatically the intermediary in certain processes and governments could not lose their 'customer', blockchain technology challenges these two foundations. Investigating the potential of blockchain technology in governments goes beyond merely analyzing the fit for the process, as the ability of the organization to adopt this technology is important as well. In addition, the consequences of blockchain technology for the role of public administrations are dependent on the design of the blockchain system, as is demonstrated in the case studies. The blockchain assessment tool goes beyond just providing insight in the applicable blockchain design, but it also enables public administrations to start thinking about the effects of blockchain for their processes. The ripple effects provide insight in the socio-technical consequences of the technology, like a changing role for public administrations and the potential of diminishing geographic borders.

Public administrations might have a different role in the future if blockchain technology keeps developing like it is currently doing. Permissioned blockchains provide some means to keep control in the networks with regards to providing data quality checks by public administrations. Permissionless blockchains present a threat in networks where continuity is required to protect the common good and facilitate interaction in society, as the control is distributed to the network, with only limited ways of interfering in the process as a government. To capture the benefits of blockchain technology, public administrations might need to adjust to a new role. This new role is the role of a supervisor instead of an intermediary. Public administrations are able to function in this role, since these systems are still somewhat centralized in terms of control, as permissioned blockchains are closed systems and the architect of the system can impose participation rules. They also allow for the necessary semantic data quality checks to ensure the appropriate data quality in the system, which is not provided by the blockchain technology itself. The implementation of permissioned blockchains can allow public administrators to provide this level of trust and protect the common good while capturing the benefits of distributing the process.

The attitude towards blockchain technology by governmental actors can be dependent on the governmental actor type. The insights of this research present different contributions to the different governmental actor types. The actors that are aiming to maximize their internal control in public administrations, which are categorized as office-seeking actors by Strom (1990), can use the insights of this research not only to get a better understanding how blockchain technology can serve the public sector, but also that in permissioned blockchain systems the control is not completely distributed. The actors categorized as policy-seeking actors by Strom (1990), which are actors that look to maximize control and effect on public policy, can use the insights in this research to comprehend the policy implications and effects of blockchain technology applied in governments. The governmental actors looking to maximize their electoral support, categorized as vote-seeking actors by Strom (1990), can use the insights of this research to deepen their knowledge on the technology, its possibilities and the design of the system to identify use cases that are of value for potential voters and stakeholders. The findings of this research can therefore structure discussions and attitudes towards blockchain technology in all three actor types.

7.1.2 Confronting the findings with literature

This thesis uses a literature review to define organizational factors and process factors that define the blockchain fit. In addition, complexity domains where identified in established complex systems literature where complexities in blockchain implementation might emerge. Also, this thesis uses literature to define the ripple effects of blockchain implementations. Using explorative interviews, empirical findings were combined with the literature to identify the organizational factors, process factors, complexities and ripple effects for the blockchain assessment tool. To present the contribution to literature in this area, the empirical findings of this research are confronted with literature. The identified organizational factors, process factors, complexities and ripple effects in this research are compared with literature in the next paragraphs.

7.1.2.1 Organizational factors

Kamal (2006) presented a sound basis for identifying organizational factors that impact IT innovation adoption capabilities in government organizations, for which the explorative interviews in this thesis were used to identify which of these are relevant regarding blockchain technology. Table 35 presents an overview of the organizational factors identified by Kamal (2006), comparing it to the findings of this research.

Table 35. Comparing the organizational factors by Kamal (2006) and the findings of this research

Organizational factor found in literature	Organizational factor found in explorative expert interviews
Administrative authority	Administrative authority
Financial support	Financial support
Managerial capabilities	Managerial capabilities
Compatibility: technological	Interoperability
Compatibility: organizational	-
Complexities: technological	Blockchain complexity
Complexities: organizational	-
Organizational size	-
IT resources	-
IT skills	-
IT sophistication	IT capabilities
Championship	Blockchain enthusiast
Management style	Top-management dedication
Coordination	Coordination
Stakeholder participation in Planning & Development	Trust from collaborating parties
Inter-Organizational Trust	Inter-Organizational Trust
Critical mass	-
External influence	External influence
Policy/Legal assessment tool	Legal framework
Socio-Economic status	Similar use cases in the market
Community size	Collaborating parties size
Market knowledge	-
-	Risk adversity

What can be seen in this comparison, is that a large part of the factors are also applicable for blockchain adoption, although some are framed differently. Not all factors identified by Kamal (2006) are relevant for blockchain technology. As the organizational factors defined by Kamal (2006) are based on 'traditional' IT innovations, the institutional innovative nature of blockchain technology also challenges the ability of public organizations to be trusted by the network with which it wants to experiment with blockchain technology with. In addition, blockchain has the potential to alter the role of these organizations, stressing the importance of risk adversity as a factor that impacts the ability of the public organization to adopt blockchain technology.

7.1.2.2 Process factors

The factors that define the fit between the process and blockchain technology were more dispersed than the organizational factors. Three sources are used to define process factors that were used in the interactive case study interviews. The interviews presented a large amount of process factors that have not been explicitly mentioned in literature yet. This is not surprising, given the limited systematic research on blockchain in governments. The process factors found in this research range from the predictability of how actors will behave to the information complexity involved in the process. Table 36 compares the process factors found in literature and the process factors identified in this research using the explorative expert interviews.

Table 36. Comparing the process factors from literature and the findings of this research

Process factor found in literature	Source	Process factor found in explorative expert interviews
Low institutionalized environment	Van Zuidam (2016)	Low institutionalized environment
Low trust in current process	Van Zuidam (2016)	Limited trust in current process
Laborious processes	Van Zuidam (2016)	Currently laborious executive process
High user data control requirements	ICTU (2016)	Desired user control over data
Data silos	ICTU (2016)	-
Platform tendency	ICTU (2016)	Platform tendency
High importance of privacy	Yli-Huumo et al. (2016)	Privacy of high priority
Low throughput of data	Yli-Huumo et al. (2016)	Low throughput of data
Low importance of latency	Yli-Huumo et al. (2016)	Low importance of latency
High availability of bandwidth and computing power	Yli-Huumo et al. (2016)	High availability of bandwidth
-	-	Predictable actor behavior
-	-	Low interest of governmental organization in being the middle-man
-	-	No legacy systems in place
-	-	Ability to implement standards in network
-	-	High information complexity
-	-	Low trust in the data storage
-	-	Traceablity required
-	-	Low amount of owner changes
-	-	Transparency required
-	-	Interoperability possibility
-	-	Inter-organizational information exchange
-	-	Low data protection requirements
-	-	Importance of control over the infrastructure
-	-	High importance of user experience

7.1.2.3 Complexities

Using a complex systems perspective, literature was analyzed to identify general domains where complexities can emerge in blockchain implementations in government. Rouse (2007), Koppenjan & Groenewegen (2005) and Pierson (2000) present the following domains: *multi-actor nature*, *legacy systems*, *the nature of interactions, the public interest involved* and technological and institutional *uncertainties*. This research explicates how these complexities emerge in blockchain implementations in governments. Table 35 compares the complexity domains found in literature and the complexities identified in this research.

Table 37. Comparing the complexity domains and the findings of this research

Complexity domain found in literature	Source	Blockchain complexity found in interviews
Multi-actor nature	Rouse (2007)	*Trust in external actor data input*
		Information complexity
		Cross-organizational use-case
		Decentralized characteristics
Legacy systems	Rouse (2007) & Pierson (2000)	*Different interfaces*
		Different data sources
		Interoperability
		Legacy systems in place
Nature of interactions	Rouse (2007)	*Scalability issues*
		Low volume of transactions
Public interest involved	Koppenjan & Groenewegen (2005)	*Tax payers money*
		Cost-effectiveness
Uncertainties	Koppenjan & Groenewegen (2005)	*High institutionalized environment*
		Technological uncertainty

This research adds a complex multi-actor systems perspective to blockchain literature and presents an initial overview of the complexities that may emerge in blockchain implementations in governments. These complexities can be related to complexity domains mentioned in established complex systems literature.

7.1.2.4 Ripple effects

The ripple effects of EU Institutions and Bodies implementing blockchain technology in this thesis are based on the list presented in Table 4, and the experts in the interactive case study interviews were introduced to each of these factors and asked to map the applicable ripple effects. Almost all ripple effects were understood in the interviews, however three additions were found in this research. First, the *set-up costs* of a blockchain system as mentioned by Boucher et al. (2017) are not only for the public administration involved, but also for the network that is involved in the blockchain experiments, so for example the national authorities or the economic operator. Secondly, the *loss of jobs* are not explicitly mentioned in literature but is deemed extremely important for EU policy-makers. The evaluation interviews presented this insight.

Third, this research adds argumentation to the way blockchain can change the *role of public administrations* and what this means for society. Davidson et al. (2016a) highlight the governance capabilities and suggests the potential of blockchain technology to alter governance structures, and Atzori (2015) mentions the potential of blockchain to reduce the need for governments. Using the Public Choice and Transactions Cost Theory perspectives, this research found that blockchain technology can lead to a loss of governmental control, as blockchain technology allows a network to facilitate processes traditionally provided by public administrations. This research also argues why this shift in control might not be desirable for society, as in governmental services continuity is required to protect the common good and facilitate interaction in society, and this continuity cannot be automatically be provided by permissionless blockchains. Permissioned blockchain can provide this continuity, as these systems are still somewhat centralized in terms of control because the architect of the system can impose participation rules for the nodes in the system. In addition, in these governmental services, also the semantics of the data is of value to guarantee data quality in the process and blockchain technology alone does not provide semantic validation. Permissioned allow for semantic validation of the data input, as roles and responsibilities can be designed in the systems. This presents a new role for public administrations: from a facilitator towards a supervisor in an information exchange or registration process. Next, the scientific and societal relevance of the insights presented in this research are explained.

7.1.3 Scientific and societal relevance

The scientific relevance of the findings of this research is that it adds a systematic analysis of the value of blockchain technology for the processes of public administrations. This is done is this research in a number of ways. First, this research reflects on Public Choice theories and blockchain and argues how blockchain can change the role of public administrations. Second, this research identified process and organizational factors that determine the blockchain fit in public administrations, which have previously been established for other IT innovations from an e-government perspective, but had not been done for blockchain technology. Lastly, this research uses a complex multi-actor systems perspective to describe the complexities involved in blockchain implementations in governments.

Next to the scientific relevance, this research has societal relevance since blockchain assessment tool enhances decision-making by EU Institutions and Bodies regarding blockchain innovation. This enhanced decision-making can enable the experimentation of blockchain in areas where it can provide benefit. Also, the insights in the ripple effects of the implementation can avoid unforeseen consequences. Various experts acknowledged the usability of the blockchain assessment tool in Chapter VI Evaluation. The next section provides a reflection on the research process, the research choices and the research outcomes.

7.2 Reflection

To reflect on this research, first a reflection on the research process is provided. Next, the choices made throughout this research are reflected upon. Lastly, a reflection on the outcomes of this research is provided, to enhance the interpretation of the blockchain assessment tool and the outcomes of this research.

7.2.1 Reflection on the research process

To reflect on the research process, four scientific quality criteria as defined by Verschuren & Hartog (2005) are used: *validity, reliability, researcher-independence* and *verifiability* of the research. Each of these criteria are elaborated below.

Validity

The validity refers to question whether the findings correspond to reality. Validity in these is achieved through the collection of data through multiple sources. First, existing literature involved in the subject was explored. Next, the findings of the literature review are complemented with both explorative expert interviews and interactive case study interviews in nine different EU Institutions or Bodies. Last, the constructed blockchain assessment tool was evaluated by experts that were not involved in the research process before point. Therefore, multiple sources were used to collect the data in this research. In the evaluation step (Chapter VI Evaluation), also the design goals, assumptions and requirements were evaluated by independent external expert, demonstrating the validity of this research.

Reliability

Reliability refers to the question whether other researchers would yield the same outcomes when doing the same research. A Design Science research is oriented at designing an artefact that can solve a practical problem. In this research, the need for an assessment tool was established in the problem identification step. The perspective of the researcher determines the frame of the problem: other researchers that are for example more economic oriented could have framed the problem differently and investigated the costs and benefits of blockchain use cases in the EU. Within the research problem established by the researcher, bias and subjectivity was avoided by departing the theoretical background from the knowledge gaps. Also, systematically translating the knowledge gap to areas of literature to be explored to elements to requirements of the blockchain assessment tool enhances the replication logic of this research. In addition, the choices for analyzing certain theories in the theoretical background are all argued both in the beginning of Chapter II Theoretical Background and in 7.2.2 Reflection on the research choices. The empirical data was gather through interviews, and criteria were established to select the interviewees and the case studies. The design of the tool itself inherently reflects the perspective and creative direction of the researcher, but by describing the design process and choices made throughout the process, other researchers taking the same steps and analyzing the same research problem would design a similar blockchain assessment tool.

Researcher-independence

The research was conducted by only one person. The researcher was independent, as the study was performed using an outside view in on the experimentation of blockchain technology in EU Institutions and Bodies. The explorative expert interviews provided insight into the requirements of the blockchain assessment tool and to avoid bias and subjectivity in these interviews, the interviewees were selected to present a balance in the policy sectors of the public organizations, the roles of the interviewees and the processes that the organizations are involved in.

Verifiability

Verifiability refers to the ability of other to verify the correctness of this research. This was ensured by documenting all data used. The process factors, organizational factors and ripple effects found in literature are confronted with the findings of this research, displaying the additions to literature by this research. In Appendix C.3 Ripple effects overview, an overview of the quotes in literature on which the ripple effects in this research are established. In addition, all documents used for the case studies are presented in Appendix E.1 & F.1. Also, the criteria for selecting the interviewees and cases are made transparent. The literature review procedures are described in the thesis and the choice of theories used are presented. The evaluation expert interviews are transcribed, verified by the interviewees are included in the appendix of this thesis. However, the transcripts of the explorative expert interviews and interactive case study interviews are not included in this thesis. Including the transcripts of all of the interviews and presenting the codes on which the complexities, process factors and organizational factors are based could enhance the verifiability of this research. The confidentiality requirements of EU Institutions and Bodies are however strict and are the transcripts are therefore not included.

7.2.2 Reflection on the research choices

During the research process a number of choices were made that influence the findings of this research. This research has resulted in a blockchain assessment tool that in based on existing literature and supported by practice. However, the design of this artefact was not inevitable, as a number of research choices were made. These research choices are reflected upon.

The choice of using a design science approach

The first research choice was to use the design science approach as the research approach. As this thesis intended to create an artefact that is practical and tangible in the still unstructured research field of blockchain technology, this method was chosen as it provides a step by step framework to design an artefact. The design science approach proved to be valuable in structuring the research, however the field of blockchain research is still so dispersed that is was difficult to define a solid knowledge base that can be used to explicate the problem. This resulted in 4 different literature review sections and combining multiple lenses in the elements that were used for the design of the blockchain assessment tool. If the research topic start to move towards a more proven field of research, the theoretical background will result in a more structured overview.

The choice of designing an assessment tool

This research departs from a number of knowledge gaps that are currently causing unstructured decision-making on blockchain experimentation in EU Institutions and Bodies. Based on this assumption, the need for an assessment tool that allows for the structural assessment of the fit with blockchain. At this stage, it could also have been chosen to design a blockchain discussion format or a blockchain decision-making model, for example. While framing the research problem, the choice was made to focus this research on creating a tangible assessment tool, so that this research does not only systematically analyses blockchain in governments but also provides practical value to decision-makers in this field. Also, the non-functional requirements of the tool were determined based on the research objective, but the perspectives of other research could have resulted in different non-functional requirements and thereby in another design of the blockchain assessment tool.

The choice of using four literature sections

The limited and widely dispersed research on blockchain in governments resulted in a difficult literature exploration phase. To structure this process and focus on areas of research that are of importance to address the research problem that is formulated, a choice was made to split up the literature review into four sections of theoretical background. Four knowledge gaps were addressed in the problem identification and the theoretical background sections used these four knowledge gaps as departure points. Choosing to use four separate literature review resulted in multiple perspectives to be included in the research, but come at the expense of cohesiveness in the theoretical background. In addition, departing from these four knowledge gaps and literature sections resulted in the conclusions of this research. Choosing a different frame or focus in the research could have resulted in different conclusions, for example if a researcher would focus specifically on the legal consequences of blockchain technology as well, which were left out of scope of this research given the focus of the Master's program of which this thesis is part of.

The choice of the perspectives used in the literature review sections

The choices of the perspective used in the four different literature review sections presented with argumentation in 2.1 Theoretical background overview. The choice of these perspectives are, however, inherently dependent on the view and experience of the researcher, as well as the program of which this thesis is part of. Public Choice and Transaction Cost Theory perspective are used to explore blockchain challenging the role of governments. Another option could have been to use another Political Science perspective to analyze this, like for example Libertarian theory. The purpose of this literature review section was however to identify why we have governments and how blockchain can contribute to the disintermediation of public administrations and governmental services, for which the Public Choice and Transaction Costs Theory perspective provide the best basis. Public Choice theories allow for the analysis of why and how structures like bureaucracies are formed in governments, and Transaction Costs Theory allows for the analysis of the emergence of intermediaries. The choice for the Complex Systems perspective is motivated by the fact that blockchain technology constitutes of multi-actor complexity and systems complexity, and this is a dominant perspective in the SEPAM program of which this thesis is part of. The New Institutional Economics perspective is used to analyze the effects of blockchain technology on the institutional layers of society, and was chosen to look beyond the technological innovation that blockchain is and incorporate the view of this technology as an institutional innovation. The e-government perspective is chosen as literature with this perspective have been analyzing IT innovations in the public sector in the past, but have yet to analyze this for blockchain technology. Finally, a technical perspective is used to investigate the impact several design features on the systems performance. This perspective is chosen because it allows for a descriptive and objective analysis of the design features. Choosing other perspectives and lenses would have resulted in a different design of the blockchain assessment tool and different research outcomes, but the chosen perspectives address the research problem of this thesis.

7.2.3 Reflection on the research outcome

Throughout this research, a number of limitations of the outcomes became clear. These are discussed in the following paragraphs.

There is no consensus on the critical factors

As was mentioned in the expert evaluation interviews, the critical factors that can make or break the fit for a blockchain application in governments can be argued. As there is still debate on what blockchain technology can provide in terms of security, for example, it is arguable to present a full list of critical factors. This must be kept in mind when interpreting the results, and more research in this area is suggested in paragraph 7.3.3 Future research.

There might not be a clear distinction between the registration process and the information exchange process in blockchain systems

During the demonstration step of the research, it became clear that the two processes on blockchain might not be as distinctive as when using other data storage techniques. The two cases that are initially selected as two separate processes: *registration* and *information exchange*, are more similar once put on blockchain. The current ETS registry mainly focusses on the registration of the emission allowances, the system becomes a distributed emission allowances trading system, so the focus shifts from registration to the exchange of the allowances. This raises the question whether the distinction between the two processes is necessary.

Using the assessment of decision-makers in EU Institutions and Organizations to determine the applicability blockchain is dependent on the attitude of the decision-maker

Decision-makers in EU Institutions or Bodies using the tool can indicate how much they agree with a certain statement in the blockchain assessment tool. The attitude of the decision-maker using the tool is thereby determining the blockchain fit: if he is negative towards this technology, the assessment tool will likely indicate a negative fit as well. The model presented by Strom (1990) of a classification of three governmental actor types: vote-seeking actors, policy-seeking actors and office-seeking actors explains the attitudes towards this disruptive technology by certain governmental actors.

This thesis assumes the fact that blockchain systems cannot provide semantic checks for data input

This research highlights one shortcoming of blockchain technology to fully disintermediate public administrators in permissioned blockchain systems: the inability to semantic check the data input. Therefore, it is argued that there will still be a need to regulate these systems, but it does enable a partial disintermediation of public administrators. As this technology has yet to emerge, it might be possible that this shortcoming might not be applicable anymore. This would present lots of new research questions and potentially a complete disintermediation of public administration in certain policy areas.

The high-level blockchain design should be interpreted with care as there are not trade-offs between the process criteria included in the model

This research uses (semi-)academic literature to identify the impact of certain design features of the different blockchain types on the systems performance, using the term process criteria. The blockchain assessment tool allows a decision-maker to indicate the importance of a certain process criterion, which results in a high-level blockchain design. The trade-offs between the criteria are not incorporated in the model, so the high-level blockchain design should be interpreted with care. Next, recommendation for the improvement and commercialization of the blockchain assessment tool and future research areas are provided.

7.3 RECOMMENDATIONS

A number of recommendations can be provided based on the conclusions of the research and on the insights provided in the evaluation of the blockchain assessment tool. First, recommendations on improvements of the model are provided. After this, recommendations on making the tool commercially available and recommendations for future research is provided.

7.3.1 IMPROVING THE TOOL

In the expert evaluation, a number of potential improvement points were mentioned by the expert. An additional block that would help to design the governance in the blockchain system would increase the usability of the model. This would mean adding a way to structure the consortium that is needed for blockchain experimentation. This way, the model could also incorporate the views of the various organizations involved instead of a single organization view.

A second way to improve the blockchain assessment tool is by allowing decision-makers to think about what the citizen or economic operator wants instead of just what the organization wants. Now, the blockchain assessment tool is reasoned from the EU Institution or Body point of view. The model could be improved by incorporating the view of the citizen or economic operator as well: what are the services that the citizen or economic operator want the government to provide? A completely different perspective is needed to add this block, including a method of defining the exact need of citizens. This could be realized by incorporating a number of citizens in the decision-making process. Incorporating the citizens and economic operator's view in this process allows for the identification of the needs of the citizens and adds a multi-actor perspective in issues like whether or not centralization of data is desirable or not. Of this is included in the tool, the blockchain assessment tool would become more of a decision-making process guide than an assessment tool that supports the decision-making.

7.3.2 MAKING THE TOOL COMMERCIALLY AVAILABLE

This research uses a scientific method of drawing insights from both literature and the empery to design the blockchain assessment tool. By tailoring the tool to the decision-making process on this topic in EU in this area and interviewing decision-makers in this field, the tool was designed to also provide practical value. However, next steps in making the tool commercially interesting for public administrations in general to provide the practical value can be taken.

First, it must be explored in more detail how decision-makers in public administrations want to use assessment tools in these processes. For example, do they want to use it as an initial assessment for their own ideation on blockchain technology, or do they want to use it as an stage gate assessment tool that concretely determines whether or not a use case experimentation should take place or not.

Second, it the tool can be developed towards a tool that facilitates a group discussion. As of now, the blockchain technology assessment tool can from one perspective and does not facilitate discussion between the different decision-makers, which can improve the practical value of the tool. Decision-makers can form an attitude towards blockchain technology in numerous ways and this tool is currently one of them, and the value of the tool can be enhanced by tailoring it in a way that a group of decision-makers can use it simultaneously. This way, the blockchain assessment tool can become an indispensable part in the discussions surrounding the decision-making process.

Third, a next step should be taken to refine the calculation of the blockchain assessment fit. All the factors that are now included in the tool have an equal weight. If the tool is used for multiple blockchain exploration use cases and public organization type, the weights of the statements in the model can be determined and specified for the various public organization types. The enable this, the blockchain assessment tool should be used in a multitude of use cases, of which the feedback can be used to determine the weights of each statement.

Last, to make tool available for a larger audience than EU Institutions and Bodies alone, a next step in investigating decision-making process in public administrations in general should be taken. Currently, the tool is tailored to EU Institutions and Bodies, as it incorporates the directive decision stage and the EU Data Protection Directive in the design. Also, as EU Institutions and Bodies operate at a supra-national level, they are always collaborating with national authorities in their information registration and exchange processes. Other public administration types might not have this focus on collaboration as much, which need to be taken into account in the blockchain assessment tool. Tailoring the tool even more to the projected usage of decision-makers, allowing the tool facilitate a group discussion, determining the weights of the statements in the model dependent on the public organization type, and exploring the decision-making process in other public organization types will make the tool commercially available for public administrations in general.

7.3.3 FUTURE RESEARCH

The insights raised in this research leads to suggestions for future research in four areas. First, the factors and effects incorporated in the blockchain assessment tool can be studied in more depth. Second, research into the trade-offs between the design features is recommended. Third, more research could be done in embedding the discussion of blockchain in governments in openness of blockchain system. Last, Value Sensitive Design could be used in the design process of blockchain systems to design human values into blockchains providing governmental services.

Research into the factors and ripple effects

This model uses process factors that were drawn from literature that research blockchain in governments, combined with explorative expert interviews. Also, the organizational factors were drawn from e-government literature and are based on other IT innovations adopted by governmental organization, and were complemented by the explorative expert interviews in this research as well. These factors were translated into statements in the blockchain assessment tool, but more research could be performed in determining how much each factor contribute to the fit with blockchain technology. In addition, the ripple effects were identified in literature that research blockchain in governments, and interactive case study interviews provided insights in which ripple effects apply to the information exchange process and which apply to the registration process. Empirical research on whether these effects are complete can provide value in research in the ripple effect of blockchain implementation in governments.

Research into the trade-offs between the design features

Another improvement could be the addition of more insights in the trade-offs between the process criteria. Now, it is not clear what the trade-offs between the process criteria are, so a decision-maker can indicate the he/she deems every criterion of importance, yet there must be a trade-off of some sort. For example: is it possible to have maximal scalability and maximal security? Insights in these trade-offs can provide a better view on the possible blockchain architectures. But, before this can be included in the tool, more research has to be performed in this area. Current research has not focused on these trade-off yet and more research on the impact of the different design features of blockchain on the systems performance is suggested to focus on these trade-offs.

Research into the openness and interoperability of blockchain systems

This research investigates the potential of blockchain contribute to the disintermediation of public administration. It argues that permissionless blockchains are troublesome in this area because it does not necessarily eliminate opportunism and protects the common good as is the case in permissioned blockchains. This raises the question on the openness and interoperability of the blockchain systems and how this will contribute to their success. More research is the contribution of open source and the openness of blockchain systems into the potential of blockchain as an information technology infrastructure should be performed to create more depth in the debate of permissionless versus permissioned blockchains in governments.

Value Sensitive Design for blockchains

The multitude of effects potentially caused by blockchain implementation by governments were presented in this thesis. When designing these blockchain systems, a Value Sensitive Design approach is suggested to account for the human values that governments want to protect. Value Sensitive Design is a comprehensive method oriented at taking social values into account in the design of technical systems (Himma & Tavani, 2008). Using the Value Sensitive Design approach, blockchain systems could be designed that enable blockchain systems where authorities can be supervisors to protect public values in permissionless blockchains. This design approach could thereby provide another view in the debate of permissionless versus permissioned blockchains in governments, as it potentially can be used to design a permissionless blockchain system that is still able to protect public values.

7.4 LINK BETWEEN THE SEPAM PROGRAM AND THIS RESEARCH

Finally, the link between the Systems Engineering, Policy Analysis and Management (SEPAM) Master's program and this research explained. The SEPAM MSc program focusses on the design in complex technical environments. These complex technical environments are environment in which both multi-actor complexities and systems complexities arise. This thesis focuses on the highly complex topic of blockchain technology, and uses a Design Science approach to create a design in a highly complex technical environment. Blockchain in governments presents institutional complexities that can be analyzed using the various perspectives and theories that are thought in the SEPAM program, which are used in this thesis. In addition, the design process was structured using various Systems Engineering and design techniques that are at the forefront of the Master's degree, including Morphological Chart analysis, Matrix Prioritization Analysis and design space brainstorming. Using creativity and structure, using theoretical knowledge and empirical knowledge, using an actor's perspective and a systems perspective are at the core of designing in complex technical system, which is exactly what this thesis has done to design the blockchain assessment tool.

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Appendix

A.1 Transacting on blockchain technology

This appendix describes the way transactions on blockchain technology works. The process of transacting using blockchain technology consists of six steps. These steps are elaborated below and are displayed Figure 31.

1. *Transaction initiation.* First, the transaction is initiated by one actor in the system that wants to send a certain amount of assets to another actor in the system. A number of transaction details are recorded in this step, including time, date, the transacting parties and the assets amount.
2. *Post transaction to the network.* Next the transaction is send to the peers of the node, and these peers send it to their peers as well until all validating nodes have received the new transaction. Often, multiple transactions across the network are send to the network at the same time.
3. *Validation via consensus.* The validation of the new transactions take place using a mechanism where the validating nodes check whether the transaction satisfy the technical requirements: whether the sender has enough assets to send this amount and whether the transaction addresses of the actors are correct. If the majority agrees upon the transaction, consensus is reached.
4. *Creating blocks and rewarding.* Multiple new transactions are compiled into a 'block' that is able to connect to the previous blocks of transaction details. The compilation of the new transactions into a new block is done by the validating nodes and involve solving a mathematical puzzle. Solving this puzzle is often computational heavy and blockchains often have incentives in place to promote fast validation and the creation of new blocks. The node that solves this puzzle the fastest gets rewarded with for example a number of the digital assets. This process is called 'mining' and the validating nodes are often called 'miners'.
5. *Adding a new block to the chain.* The new block contains a link to the previous block, creating the long chain of blocks linking to each other in a chronological order. As this chain links to each other and all transactions contain timestamps, the entries in the past cannot be deleted or altered in the blockchain.
6. *Update ledger and complete transaction.* After this, the transaction log in the blockchain is updated as the majority of the network has the right chain of blocks where the transactions are stored. The transaction in completed: the other actor receive the amount of digital assets that was send.

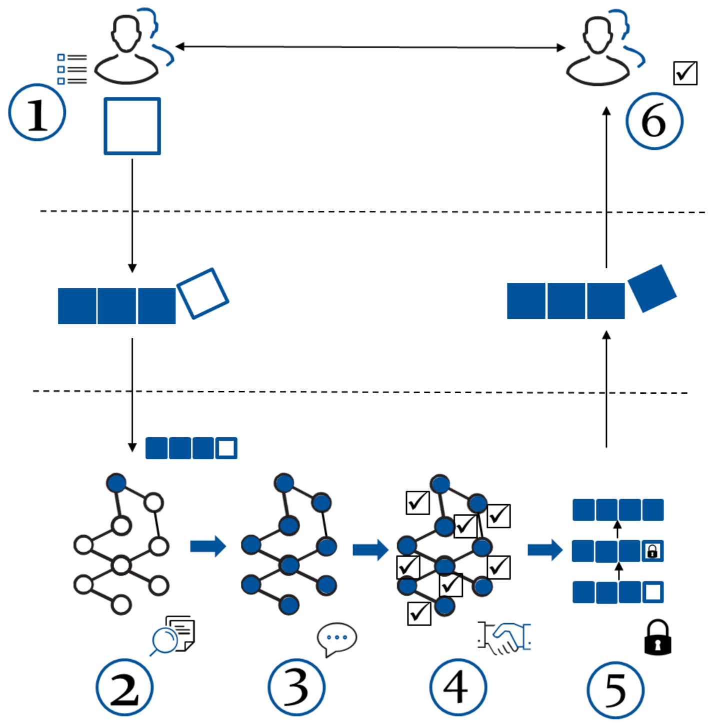

Figure 31. The transaction process on blockchain

Looking at the process from a mathematical perspective, things get a bit more complicated. Figure 32 displays an overview of three different processes in transacting with blockchain; creating an event, constructing the blockchain and browsing the blockchain, specifically Bitcoin in this case. It is not as straightforward as just voting on whether a transaction is correct and valid. There is actually a long list of things that get validated for each transaction and for the block as a whole. The mathematics come in the form of cryptographies, digital signatures, the consensus mechanism (Proof-of-Work) and the rewarding for the miners. The cryptographic foundation in Bitcoin are formed by the hashing function called the Elliptic Curve encryption algorithm, meaning that private key to a transaction is simply a random number. This private creates the public key, which is needed to decrypt the transaction (for more explanation, see Appendix A.2 The mathematics behind transacting via blockchains). Hashing is a mathematical way to decode and it makes it impossible to make two separate blocks of data with the same hash code. Still overly simplifying, a digital signature is the way for the sender to sign the transaction, which is needed for the validation of the transition. The consensus mechanism is the mechanism in which way the validating nodes (miners) validate the transactions that are published, which can be seen as a cryptographic puzzle. The node solving this puzzle gets rewarded, providing the mathematic proof of the transaction. An overview of the mathematical cryptographies involved in Bitcoin is presented in Figure 32.

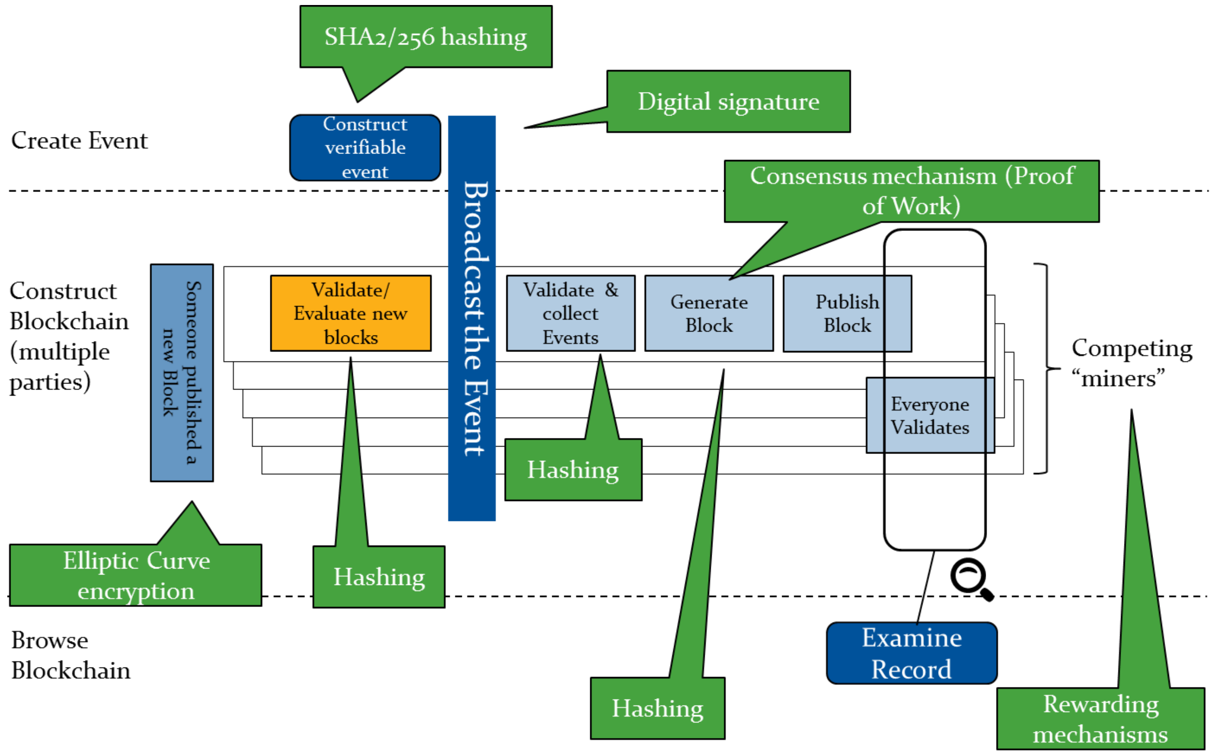

Figure 32. Encryptions in Bitcoin

A.2 THE MATHEMATICS BEHIND TRANSACTING VIA BLOCKCHAINS

This appendix describes the various algorithms that are used in a transaction via blockchain technology. It uses the Bitcoin blockchain as an example.

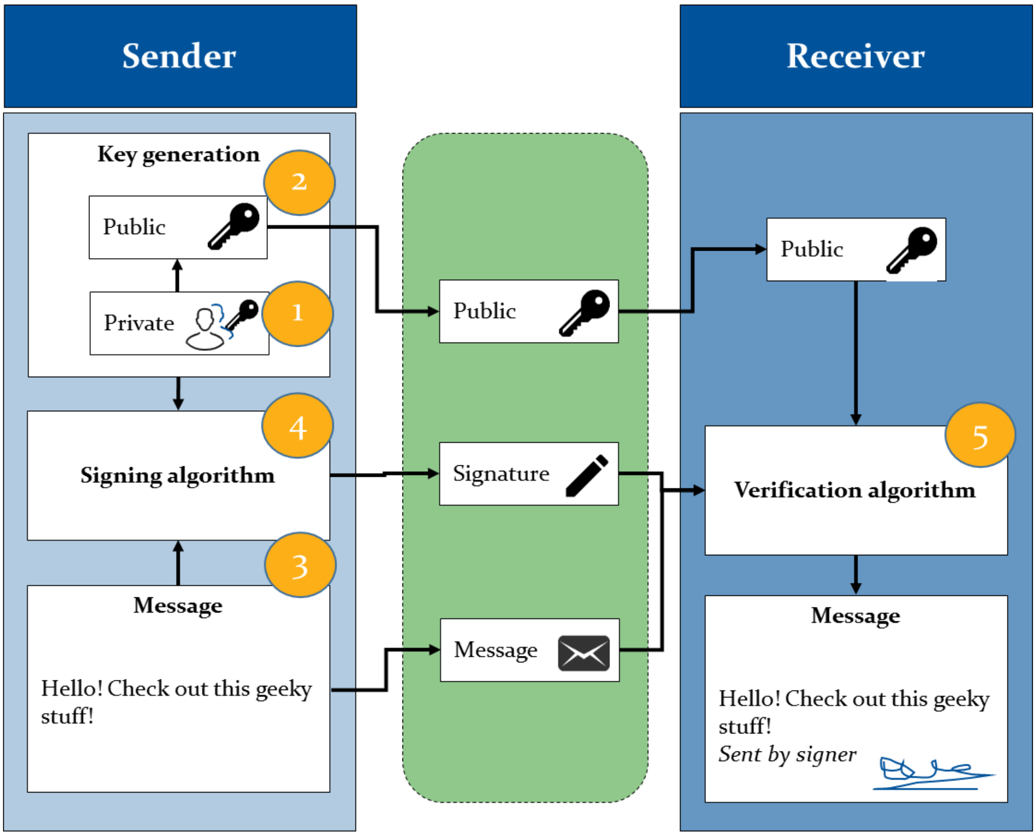

Figure 33. Transaction process [adjusted from [adjusted from CryptoCompare (2016)]

A lot of mathematics are at the base of blockchain technology. Terms like 'keys' and 'signatures' are created to make it sound like they are actual objects, but they are in fact either a number or a point in a coordinate system. Figure 33 displays the process of transacting on blockchain technology in a schematic way (CryptoCompare, 2016). The steps are elaborated below. The process that is outlined below is again overly simplified, as there is mathematics behind every step in this process.

1. The sender generates a private key using an encryption algorithm, and is essentially a random number with an extremely small chance of randomly being generated again.
2. The public key is created by using the private key number and feeding this into another algorithm. Using the private key and a string of random number, the public key is a point with an X and Y value, making it impossible to derive the private key from the public key.
3. The sender creates message (transaction details). The message is then encrypted by converting the message into numbers, again using some algorithm to create these 'hashes'.
4. The sender signs the message with a signature using a signing algorithm. This algorithm combines the private and public key and the message that is encrypted. The message, the signature and the public key is send to the network for validation.
5. The encrypted message is received by the other actor as well as the public key. The signature is needed to decrypt the message, for which the private key is necessary. The combination of the public key, the signature and the encrypted message are used in the verification algorithm and results in a decrypted message.

A.3 EU Institutions and Bodies

This thesis designs a blockchain assessment tool for EU Institutions and Bodies. This thesis provides an overview of all agencies and DGs that fall under this definition.

Executive agencies

Executive EU agencies, referred to as "Community Agencies" by the EU and also includes 'joint undertakings' and 'institutions with an executive task', are defined in this research the criteria proposed by Groenleer (2009), as an agency that;

- is a body governed by European public law;
- has its own legal personality;
- is set up by an act of secondary legislation;
- in order to accomplish a very specific technical, scientific or managerial task;
- which is specified in the relevant Community act.[5]

In this thesis, executive EU bodies are distinct from what has been referred to as 'national' agencies and other public organizations operating on the supranational level (Groenleer, 2009). The distinct features of executive EU bodies are:

1. Their legal status enables them to function autonomously, apart from Community institutions.
2. Executive EU bodies are established for an indeterminate period of time, while executive agencies only have a temporary mandate.
3. They are created on created on an intergovernmental basis, as they are part of the broader EU legal assessment tool.

Directorate-Generals

A directorate-general (DG) is the main administrative unit to be found within the European Commission. There are 33 DGs responsible for proposing and implementing policy within their designed field of expertise. Each DG is responsible for developing policies and systems in a specific policy area.

In total, 128 bodies of the European Union were indexed. 63 of them match the definition of this thesis, as they have an executive task, either by actually facilitating information exchange, registration or the distribution of assets, or by developing policies to do so. Table 38 provides an overview of the relevant organizations. The list is constructed using the 'agencies and other EU bodies page' of Europa.eu[6], desk research and Gartner's' internal resources.

Table 38. Overview of EU Institutions and Bodies relevant for executive processes

ID	EU Body	Abbreviation	EU Body type
1	Agency for the Cooperation of Energy Regulators (ACER)	ACER	Decentralized agency
2	Office of the Body of European Regulators for Electronic Communications (BEREC Office)	BEREC	Decentralized agency
3	Directorate-General for the Budget	DG BUDG	Directorate-General
4	Directorate-General for Climate Action	DG CLIMA	Directorate-General
5	Directorate-General for Communications Networks, Content and Technology	DG CNECT	Directorate-General
6	Directorate-General for Communication	DG COMM	Directorate-General
7	Directorate-General for Competition	DG COMP	Directorate-General
8	Directorate-General for International Cooperation and Development	DG DEVCO	Directorate-General
9	Directorate-General for Informatics	DG DIGIT	Directorate-General
10	Directorate-General for Economic and Financial Affairs	DG ECFIN	Directorate-General
11	Directorate-General for Employment, Social Affairs and Inclusion	DG EMPL	Directorate-General
12	Directorate-General for Energy	DG ENER	Directorate-General
13	Directorate-General for the Environment	DG ENV	Directorate-General
14	Directorate-General for Financial Stability, Financial Services and Capital Markets Union	DG FISMA	Directorate-General

[5] Via https://europa.eu/european-union/about-eu/agencies_nl

[6] https://europa.eu/european-union/about-eu/agencies_en

15	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs	DG GROW	Directorate-General
16	Directorate-General for Migration and Home Affairs	DG HOME	Directorate-General
17	Directorate-General for Human Resources and Security	DG HR	Directorate-General
18	Directorate-General for Justice and Consumers	DG JUST	Directorate-General
19	Directorate-General for Maritime Affairs and Fisheries	DG MARE	Directorate-General
20	Directorate-General for Mobility and Transport	DG MOVE	Directorate-General
21	Directorate-General for Neighborhood and Enlargement Negotiations	DG NEAR	Directorate-General
22	Directorate-General for Regional and Urban Policy	DG REGIO	Directorate-General
23	Directorate-General for Research and Innovation	DG RTD	Directorate-General
24	Directorate-General for Health and Food Safety	DG SANTE	Directorate-General
25	Directorate-General for Taxation and Customs Union	DG TAXUD	Directorate-General
26	Directorate-General for Trade	DG TRADE	Directorate-General
27	Education, Audiovisual and Culture Executive Agency (EACEA)	EACEA	Executive agency
28	European Aviation Safety Agency (EASA)	EASA	Decentralized agency
29	Executive Agency for Small and Medium-sized enterprises (EASME)	EASME	Executive agency
30	European Asylum Support Office (EASO)	EASO	Decentralized agency
31	European Banking Authority (EBA)	EBA	Decentralized agency
32	European Centre for Disease Prevention and Control (ECDC)	ECDC	Decentralized agency
33	European Chemicals Agency (ECHA)	ECHA	Decentralized agency
34	European Civil Protection and Humanitarian Aid Operations (ECHO)	ECHO	Other agency
35	European Defense Agency (EDA)	EDA	Agencies under Common Security and Defense policy
36	European Data Protection Supervisor	EDPS	Other institution
37	European Environment Agency (EEA)	EEA	Decentralized agency
38	European External Action Service	EEAS	Other institution
39	European Food Safety Authority (EFSA)	EFSA	Decentralized agency
40	European Investment Fund	EIF	Other institution
41	European Insurance and Occupational Pensions Authority (EIOPA)	EIOPA	Decentralized agency
42	European Insurance and Occupational Pensions Authority	EIOPA	Other institution
43	European Institute of Innovation and Technology (EIT)	EIT	Other agency
44	European Medicines Agency (EMA)	EMA	Decentralized agency
45	European Monitoring Centre for Drugs and Drug Addiction (EMCDDA)	EMCDDA	Decentralized agency
46	European Union Agency for Network and Information Security (ENISA)	ENISA	Decentralized agency
47	European Patent Office (EPO)	EPO	Other institution
48	European Personnel Selection Office	EPSO	Other institution
49	European Union Agency for Railways (ERA)	ERA	Decentralized agency
50	European Research Council Executive Agency (ERCEA)	ERCEA	Executive agency
51	European Securities and Markets Authority (ESMA)	ESMA	Decentralized agency
52	DG EuroStat	ESTAT	Directorate-General
53	European Union Intellectual Property Office (EUIPO)	EUIPO	Decentralized agency
54	European Organization for the Safety of Air Navigation	Eurocontrol	Other institution
55	European Police Office (Europol)	Europol	Decentralized agency
56	European Border and Coast Guard Agency (Frontex)	Frontex	Decentralized agency
57	Internal Audit Service (European Commission)	IAS	Other institution
58	Innovation & Networks Executive Agency (INEA)	INEA	Executive agency
59	Office for Infrastructure and Logistics in Brussels	OIB	Other agency
60	Office for Infrastructure and Logistics in Luxembourg	OIL	Other agency
61	European Anti-Fraud Office	OLAF	Other agency
62	Office for the Administration and Payment of Individual Entitlements	PMO	Other agency
63	Research Executive Agency (REA)	REA	Executive agency

B.1 EXPLORATIVE EXPERT INTERVIEW PROTOCOL

This appendix displays the protocol used for the semi-structured explorative expert interviews. Due to the semi-structured nature of the interviews, not all questions were answered in every interview.

I. PERSONAL

1. What is your role in this organization?
2. How many years of experience do you have in your current function?
3. Do you have experience with large-scale IT innovation projects?
4. Are you familiar with the concept of blockchain? If yes, how did you get to know about this innovation?

II. CHALLENGES

5. What are the current executive processes of this organization or the processes in a network of which this organization is part of? If more than three, please indicate the three most important. **in case of policy making organization: What are the current executive processes for which this organization develops policies?*
6. What are the major challenges that this organization is facing regarding these processes?

**Interviewer introduces IT innovation adoption process that resulted from the literature review, and introduces where the assessment tool is meant to apply.*

III. DECISION-MAKING PROCESS

7. Has your organization been involved in an IT innovation project? If yes, how did the decision-making process look like?
8. Are you currently looking at blockchain technology with your organization?

IV. PROCESS FACTORS, ORGANIZATIONAL FACTORS AND COMPLEXITIES

9. Do you currently use IT innovation criteria to assess the value of the new technology? If yes, which?
    - Or, what technology factors are important for you to investigate before you implement the new technology? If yes, which?
10. What are the supporting factors that you deem important for IT innovation in your organization?
11. What are the organizational factors that you deem important for IT innovation in your organization?
12. What are the collaboration factors that you deem important for IT innovation in your organization?
13. What are the external factors that you deem important for IT innovation in your organization?

V. EXTRA

14. Do you have any other ideas or remarks?

C.2 Qualitative Data Analysis

This appendix contains the codes used and merged in the Qualitative Data Analysis. In addition, it contains the Thematic Network created for the complexities, process factors, organizational factors and decision-making elements.

C.2.1 Complexities

First, all interviews were coded. In total, 25 complexities were coded. An overview is provided in Table 39.

Table 39. Complexities codes overview

#	Code name	#	Code name	#	Code
1	Trust in external actor data input	10	Low volume of transactions	18	Scalability issues
2	Information complexity	11	Tax payers money	19	Limited trust in system
3	Cross-organizational use-case	12	Cost-effectiveness	20	Control over the platform
4	Decentralized characteristics	13	High institutionalized environment	21	Low amount of owner changes
5	Different interfaces	14	Technological uncertainty	22	Importance of control over the infrastructure
7	Different data sources	15	Transaction dependency	23	Lacking solution in place
8	Interoperability	16	Iterative development approach	24	Low trust in current process
9	Scalability issues	17	Institutional uncertainty	25	Control over the infrastructure

Next, the codes that were overlapping or the codes that had contradicting findings were merged. In addition, the *control over the infrastructure* was also included in the process criteria, for which it was left out. Table 40 presents an overview.

Table 40. Complexities codes merging

Code	Merged with	New code	Motivation
#19 Limited trust in system	#23 Lacking solution in place	#24 Low trust in current process	Overlapping codes
#20 Control over the platform	#25 Control over the infrastructure	#25 Control over the infrastructure	Overlapping codes
#21 Low amount of owner changes	Removed	None	Contradicting findings in explorative expert interviews
#25 Control over the infrastructure	None	None	Included in process criteria

Next, a Thematic Network for the complexities element was created. The step-by-step guide by Attride-Stirling (2001) allowed for the creation of this network (Attride-Stirling, 2001). This guide allows a researcher to move from the most low-order premises in a text (Basic Themes) to categories of these themes (Organizing Themes) to the overlapping concept (Global Theme). The codes complexities were synthesized to the Basic Themes in the network. Organizing Themes were identified by referring to the abstract complexities domains found in literature. Global Theme is in this network the element *Complexities*. Figure 34 displays the Thematic Network of the complexities element.

Figure 34. Thematic Network Complexities

C.2.2 PROCESS FACTORS CODES

This appendix describes the codes used in determining the process factors and the Thematic Network that was created. First, the explorative expert interviews were coded as well as Kamal (2006). All process factors were coded, and an overview is presented in Table 41.

Table 41. Process factors codes overview

#	Code name	#	Code name	#	Code
1	Predictable actor behavior	11	High availability of bandwidth	21	High/low importance of security
2	Limited trust in current process	12	Low throughput of data	22	Inter-organizational data exchange
3	Limited trust in system	13	Traceability required	23	Ability to implement standards in network
4	Low interest of governmental organization in being the middle-man	14	Transparency required	24	Currently laborious process
5	No legacy systems in place	15	Control over the platform	25	Platform tendency
6	Low institutionalized environment	16	Interoperability possibility	26	Control of the infrastructure
7	Importance of control over the infrastructure	17	Low amount of owner changes		
8	Desired user control over data	18	Privacy of high priority		
9	Low trust in the data storage	19	Low importance of latency		
10	Low data protection requirements	20	High importance of user experience		

Next, overlapping codes were removed. Also the *low amount of owner changes* process factor was removed because the explorative expert interviews presented contracting findings. One expert argued that if data often changes from owner, that then blockchain can be valuable. Another expert argued the contrary. Also, in the evaluation interviews, it became apparent that because there is no consensus on whether blockchain technology presents additional security compared to traditional information infrastructures. An overview of the merging of the codes is provided in Table 42.

Table 42. Process factors codes merging

Code	Merged with	New code	Motivation
#15 Control over the platform	#26 Control over the infrastructure	#7 Importance of control over the infrastructure	Overlapping codes
#17 Low amount of owner changes	Removed	None	Contradicting findings in explorative expert interviews
#7 Importance of control over the infrastructure	#4 Low interest of governmental organization in being the middle-man	#4 Low interest of governmental organization in being the middle-man	Overlapping codes
#21 High/low importance of security	Removed	None	Contradicting findings in evaluation interviews

Lastly, a Thematic Network was created for the process factors element. Using the same steps described in Appendix C.2.2 Process factors codes, the Basic Themes, Organizing Themes and Global Theme for this element was created. The Organizing Themes were identified to be *prioritization factors, general context, data and processing power* and *current process characteristics.* Figure 35 presents the Thematic Network.

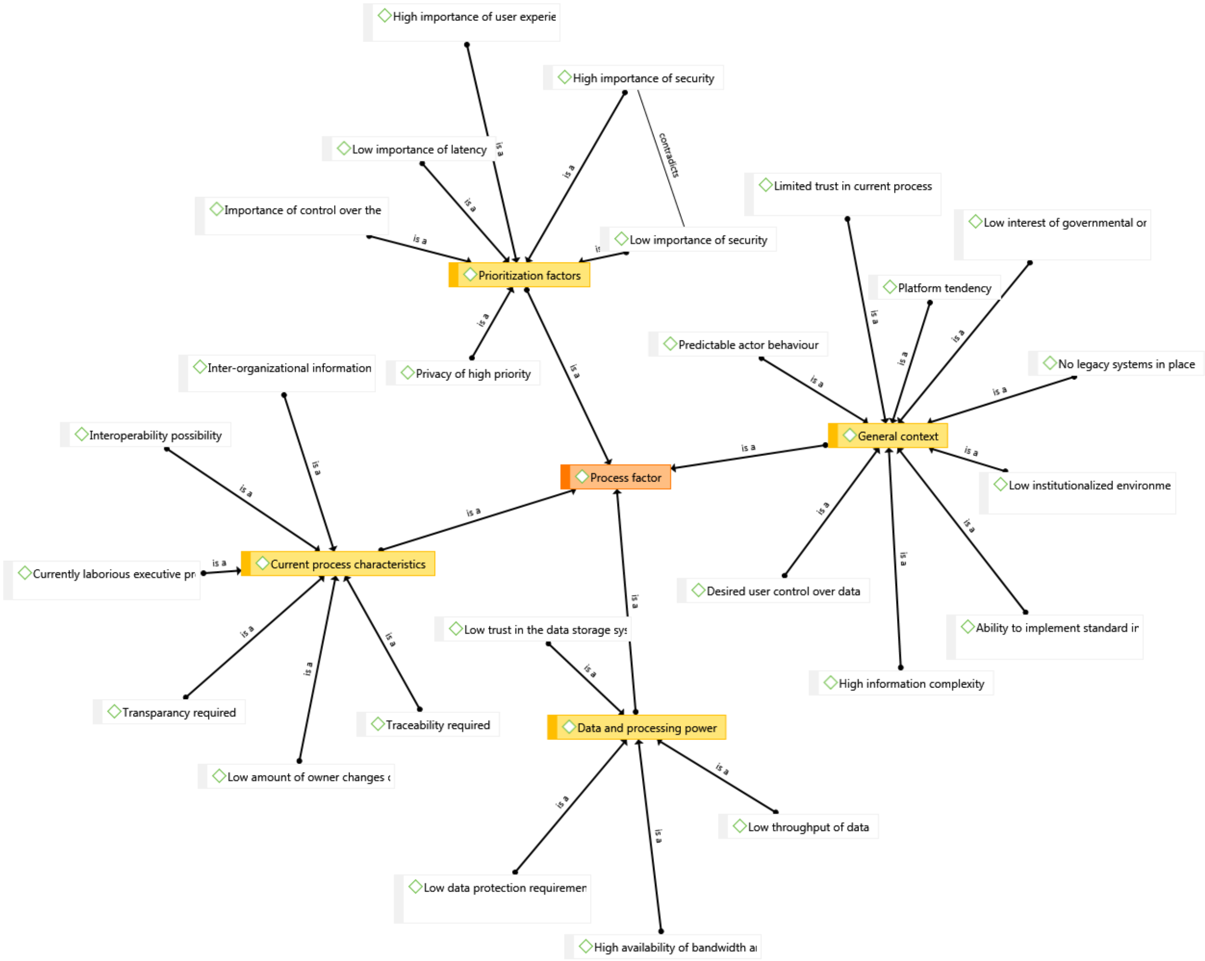

Figure 35. Thematic Network Process Factors

C.2.3 ORGANIZATIONAL FACTORS

This appendix presents the codes used and merged for the organizational factors element and the Thematic Network based on this. In total 41 organizational factors were coded using the transcriptions of the explorative expert interviews and Kamal (2006). Table 43 presents the overview of the codes.

Table 43. Organizational factors codes overview

#	Code name	#	Code name	#	Code
1	Administrative authority	16	Top-management dedication	31	Management style
2	Blockchain complexity	17	Risk adversity	32	Stakeholder participation in Planning & Development
3	Blockchain enthusiast	18	External influence	33	Inter-Organizational Trust
4	Budgetting style	19	Legal framework will adapt	34	External influence
5	Critical mass	20	Legal framework	35	Socio-Economic status
6	Coordination	21	Inter-organizational trust	36	Market knowledge
7	Decision-making process	22	Similar use cases in the market	37	Collaborating parties size
8	Design features	23	Trust from collaborating parties	38	Financial support
9	External influence	24	Interoperability	39	Blockchain complexities
10	IT resources	25	Competability: technological	40	Community size
11	IT sophistication	26	Competability: organisational	41	Collaborating party size
12	IT capabilities	27	Complexities: technological		
13	IT skills	28	Complexities: organizational		
14	Managerial capability	29	Organizational size		
15	Policy/Legal framework	30	Championship		

Next, the codes were merged that were overlapping. Also, the *organizational size* was removed because there was no consensus on whether a large organizational size positively or negatively impacts the ability to adopt blockchain technology. The same is the case for the *budgeting style*, as there were contradicting findings in how this contributes to the organizations ability to adopt blockchain technology. The *interoperability* organizational factor was removed, as this is also included in the process factors. Table 44 presents an overview.

Table 44. Organizational factors codes merging

Code	Merged with	New code	Motivation
#27 Complexities: organizational	#27 Complexities: technology	#39 Blockchain complexities	Overlapping codes
#25 Competabiltity: organizational	#27 Competabiltity: technological	#24 Interoperability	Overlapping codes
#5 Critical mass	#22 Similar use cases in the market	#22 Similar use cases in the market	Overlapping codes
#36 Market knowledge	#22 Similar use cases in the market	#22 Similar use cases in the market	Overlapping codes
#32 Stakeholder participation	#23 Trust from collaborating parties	#23 Trust from collaborating parties	Overlapping codes
#33 Inter-organizational trust	#23 Trust from collaborating parties	#23 Trust from collaborating parties	Overlapping codes
#9 External influence	#20 Legal framework	#20 Legal framework	Overlapping codes
#15 Policy/Legal framework	#20 Legal framework	#20 Legal framework	Overlapping codes
#35 Socio-economic status	#40 Community size	#41 Collaborating parties size	Overlapping codes

#29 Organizational size	Removed	None	Contradicting findings in explorative expert interviews
#30 Championship	#3 Blockchain enthusiast	#3 Blockchain enthusiast	Overlapping codes
#31 Management style	#16 Top-management dedication	#16 Top-management dedication	Overlapping codes
#6 Coordination	#14 Managerial capabilities	#14 Managerial capabilities	Overlapping codes
None	Additional code	#12 IT capabilities	Overarching code
#4 Budgeting style	Removed	None	Contradicting findings in explorative expert interviews
#24 Interoperability	Removed	None	Overlap with process factors

After this, a Thematic Network was constructed using the steps described in Attride-Stirling (2001). The organizational factors are used as the Basic Themes, and are connected to the overlapping Organizing Themes. The Organizing Themes are determined based on the domains by Kamal (2006). The Global Theme in this network is the *organizational factors* element. The Thematic Network is presented in Figure 36.

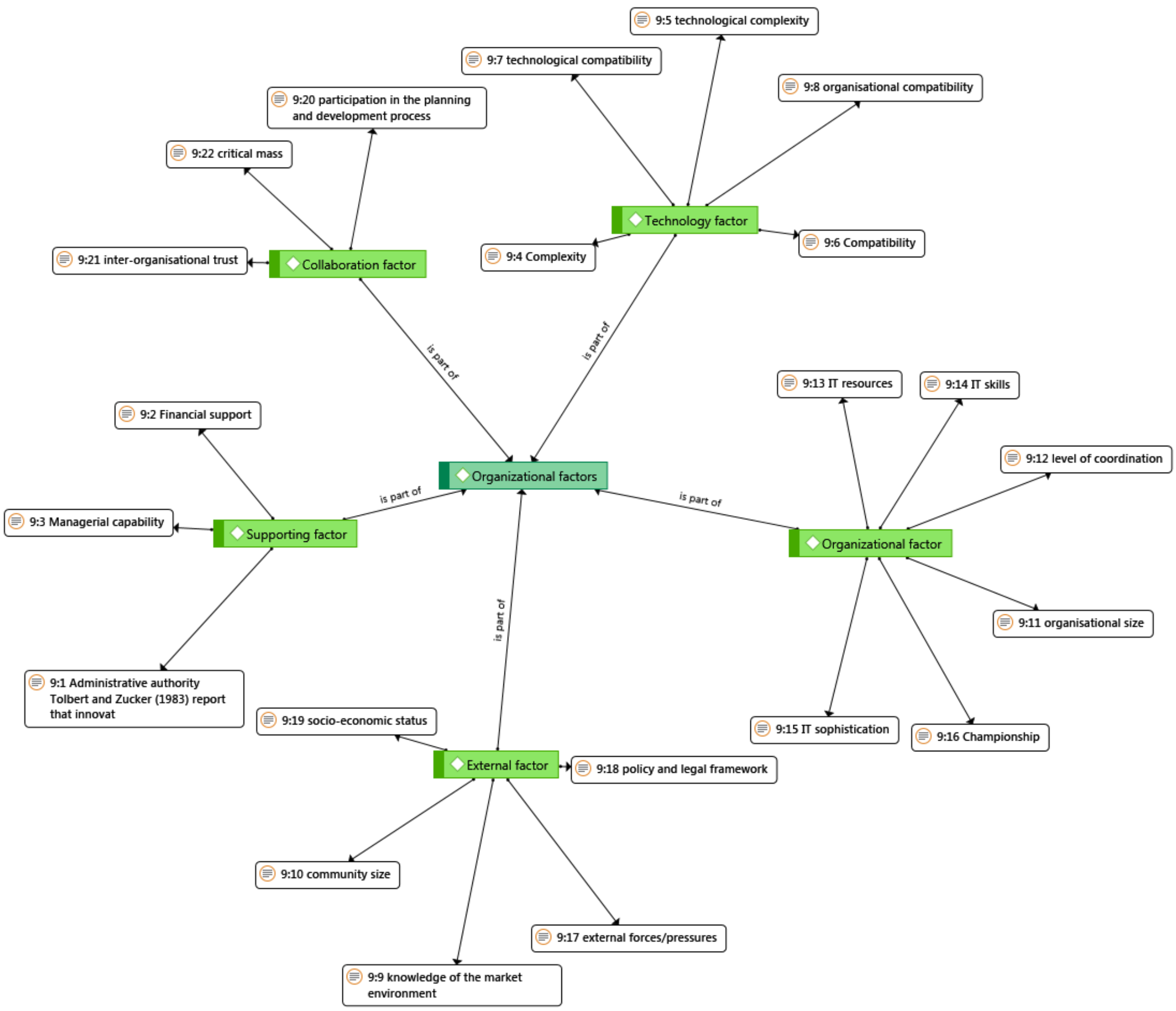

Figure 36. Thematic Network Organizational Factors

C.2.4 DECISION-MAKING PROCESS CODES

This appendix describes the codes that were used in the Qualitative Data Analysis for the decision-making process element. Also, it described how codes were merged for this element and the resulting Thematic Network. In total 26 codes were identified in the transcripts of the explorative expert interviews. Table 45 presents the overview.

Table 45. Decision-making process codes overview

#	Code name	#	Code name	#	Code
1	Allocation of resources	11	IT architecture design	21	Regular dialogue with stakeholders
2	Architecture design stage	12	IT manager	22	Technology influencer
3	Budget boundaries	13	IT outsource decision	23	Technology roadmap
4	Confirmation of collaborating parties	14	Learning from private industry	24	Top-managers
5	Decision stage	15	Legal framework	25	Prioritization process
6	Directive decision	16	Legal/risk department	26	Prioritization
7	Directive decision-making stage	17	Motivation stage		
8	EC innovation promotion	18	Policy-maker		
9	External advice	19	Prioritization		
10	Information flow	20	Providence of infrastructure		

The *prioritization code* was merged with the *prioritization* code as they mean the same thing.

Table 46. Decision-making codes merging

Code	Merged with	New code	Motivation
#25 Prioritization process	#26 Prioritization	#26 Prioritization	Overlapping codes

Based on the codes, it was attempted to create a structured Thematic Network for the decision-making process element (Attride-Stirling, 2001). The codes were used Basic Themes, and the Organizing Themes were identified to be different *activities, actors, stages* and *roles.* The Organizing Theme is the decision-making process for this network. The Thematic Network for this element as presented in Figure 37, and especially the Organizing Themes and their related Basic Themes, were used to create an overview of the current decision-making process for IT innovation adoption in EU Institutions and Bodies in Figure 15.

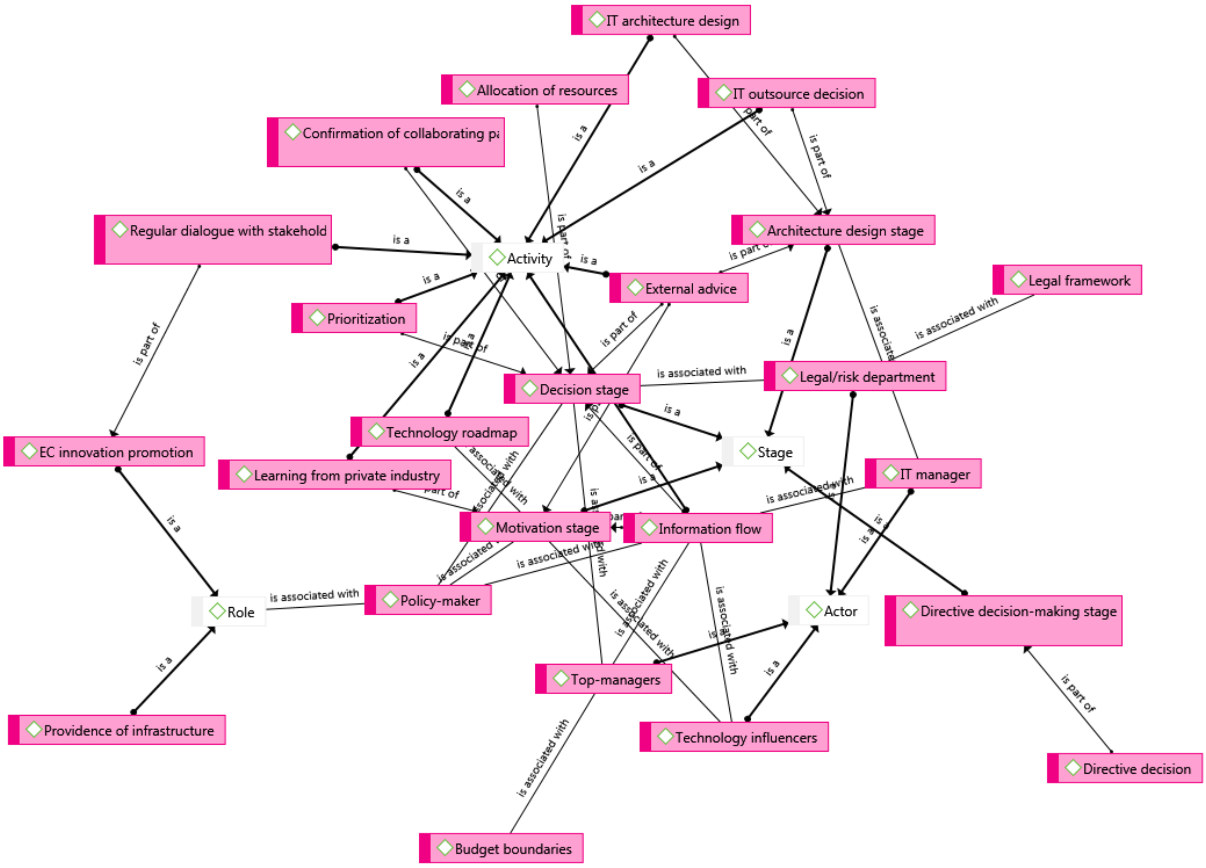

Figure 37. Thematic Network Decision-Making Process

C.3 Ripple effects overview

This appendix describes the identified ripple effects of blockchain in governmental implementations, including the sources and related quotes. Table 47. Ripple effect descriptions overview provides an overview.

Table 47. Ripple effect descriptions overview

Effect	Type	Description	Sources	Quote
Streamlined internal processes	Primary	Blockchain would enable a more streamlined process, making the steps more transparent to the users, the external data sources and the internal actors.	Boucher, Nascimento, & Kritikos (2017)	*"Blockchain-based proof of existence services could be offered as the first step in the process of applying for a patent. From here, the process could be streamlined and secured, making the steps more transparent to the applicant, while simultaneously reducing the potential for corruption." (Boucher et al., 2017, p. 11)*
Set-up costs	Primary	There will be high set-up costs when implementing a blockchain system for this process for the issuing organization	Boucher, Nascimento, & Kritikos (2017)	*"First, in moving to a new system for digital records, there will be set-up costs and potential technical and procedural difficulties in running back-up and parallel systems during transitional phases." (Boucher et al., 2017, p. 19)* *"Blockchain innovations increase total factor productivity by their effect on marginal factor productivity. They do so by reducing the production costs associated with any endeavour to produce a particular output. A prime example is private or permissioned blockchains that reduce the cost of doing a particular thing (such as reconciliation, or international money transfers). " (Davidson et al., 2016a, p. 12)*
Difficulties during transitional phases	Primary	There will be technical and procedural difficulties in running back-up and parallel systems during transitional phases when implementing a blockchain system for this process.	Boucher, Nascimento, & Kritikos (2017)	*"First, in moving to a new system for digital records, there will be set-up costs and potential technical and procedural difficulties in running back-up and parallel systems during transitional phases. (Boucher et al., 2017, p. 19)*
Disintermediation of control by network	Primary	The network will gain more control over the network, as democratic mining and validation are in place instead of penalties or hierarchical validation.	Meijer (2017)	*"Due to the decentralized nature of blockchain environments, we suspect that blockchain technology decreases control from a systems-perspective" (Meijer, 2017, p. 74)*
Stronger security of an informational database	Primary	The application of blockchain for this process enables a stronger security of an informational database than in the current system.	Davidson, De Filippi, & Potts (2016a)	*"Blockchains enable better end-to-end performance of a value transfer system, faster reconciliation and clearing of a transaction ledger, stronger security of an informational database, cheaper discrimination of access, and so on." (Davidson et al., 2016a, p. 14)*
Set-up costs	Secondary	There will be high set-up costs when implementing a blockchain system for this process for the participating organizations	Mentioned in evaluation interviews	*None*
Reduced effort of transacting with external parties	Secondary	For participants in the network, the effort of transacting with counterparties is reduced, for example by stripping out layers of activity that are no longer needed.	Davidson, De Filippi, & Potts (2016a)	*"Rather the source of the productivity gain often traces to an organizational efficiency gain. Blockchains economize on production costs by changing the organizational form by which value I created, often stripping out layers of activity that are no longer needed because trusted third-parties are no longer required, or can be achieved more efficiently using, say, multisig protocols (Tapscott 2016)." (Davidson et al., 2016a, p. 14)*
More trusted inter-organizational data exchanges	Secondary	The information exchange between the actors in the actors will gain in trust, meaning that since the blockchain avoids the chances of opportunistic data usage, that the trust in how the provided data will be used and weather the received data is integer is enhanced.	Boucher, Nascimento, & Kritikos (2017)	*"Introducing blockchain technology to public administrations could lead to streamlined internal processes, reduced transaction costs, more trusted interactions and data exchanges with other organisations and governmental silos, and increased protection against errors and forgery." (Boucher et al., 2017, p. 19)*
Increased protection against errors and forgery	Secondary	The introduction of blockchain for this process would lead to an enhanced protection against the forgery of data in the system.	Boucher, Nascimento, & Kritikos (2017)	*"Introducing blockchain technology to public administrations could lead to streamlined internal processes, reduced transaction costs, more trusted interactions and data exchanges with other organisations and governmental silos, and increased protection against errors and forgery." (Boucher et al., 2017, p. 19)*
Additional infrastructure needed	Secondary	The actors in the network would need to purchase or develop additional infrastructure to implement a blockchain system for this process.	Boucher, Nascimento, & Kritikos (2017)	*"Private individuals and organisations will need to invest further resources to preserve their documents in the long term because of hashes" (Boucher et al., 2017, p. 19)*
Flexibility and empowered network	Secondary	Actors in the network will feel more empowered in this process, and will have more flexibility in the process.	Buterin (2015)	*"Blockchains are not about bringing to the world any one particular ruleset, they're about creating the freedom to create a new mechanism with a new ruleset extremely quickly and pushing it out. They're*

				Lego Mindstorms for building economic and social institutions." (Buterin, 2015, p. 1)
Decentralized control on transactions	Secondary	Participants are able to transact without an intermediary, causing participant to have an increase in control over counterparties in a transaction between users in the system.	Davidson, De Filippi, & Potts (2016a) & Meijer (2017)	*"As a class of technology, what distributed ledger technologies do is decentralize." (Davidson et al., 2016a, p. 15)* *"Thus, blockchain technology increases control between counterparties in a transaction." (Meijer, 2017, p. 8)*
Increased in data integrity	Secondary	The application of a blockchain system for this process eliminates the need for centralization that was previously needed for reconciliation or consensus in the record-keeping or data storage. As the whole network has a shared ledger, the data integrity is increased.	Davidson, De Filippi, & Potts (2016a) & Yli-Huumo, Ko, Choi, Park, & Smolander (2016)	*"Blockchains create distributed systems by eliminating centralization that was previously needed for reconciliation or consensus in record-keeping on a ledger by providing an alternative distributed technology for that purpose" (Davidson et al., 2016a, p. 15)* *"High integrity of transactions and security, as well as privacy of nodes are needed to prevent attacks and attempts to disturb transactions in Blockchain" (Yli-Huumo et al., 2016, p. 2)*
Elimination of opportunism	Secondary	Blockchain technology will reduce opportunism in this process by imposing radical transparency in the whole network coupled with crypto-consensus mechanisms (and executed automatically with smart contracts).	Davidson, De Filippi, & Potts (2016b)	*"To the extent that blockchains can eliminate opportunism, they will be at a competitive advantage to traditional organizational hierarchies and relational contracts. So how do blockchains eliminate opportunism? In essence, by radical public transparency coupled with crypto-consensus mechanisms, executed automatically with smart contracts (Swanson 2014)" (Davidson et al., 2016b, p. 16)*
Decentralized monitoring	Secondary	Monitoring of the behavior and input of the actors in the network will become distributed or decentralized (not tacit) and the need for hierarchical monitoring is reduced.	Davidson, De Filippi, & Potts (2016b)	*"However, what blockchains introduce is a new prospect of distributed or decentralized monitoring. (To the extent that this monitoring is not tacit.) In this instance, blockchains undermine the main argument for the comparative efficiency of the firm (in the context of the generalized efficiency of production with shared inputs)." (Davidson et al., 2016b, p. 18)*
Self-sovereign identity and data	Secondary	Actors in the system will be in control of their own data, including their own identities.	ICTU (2016)	*"Burgers en organisaties kunnen structureel als eigenaar in controle zijn over hun eigen data, inclusief een eigen identiteit. Dit heet selfsovereign identity. Data hoeft niet eens structureel gekopieerd of overgedragen te worden, maar mag op transparante manier gebruikt worden als de eigenaar dit toestaat" (ICTU, 2016, p. 5)*
Permissioned data distribution	Secondary	Data does not need to be copied or transferred structurally, but will be used transparently if the owner permits.	ICTU (2016)	*"Gedistribueerde private data sources: elke burger is eigenaar van zijn eigen data en geeft toestemming aan derden om deze te gebruiken." (ICTU, 2016)*
Exacerbate the existing digital divide	Tertiary	Citizens who are unable to use internet services for whatever reason may not be able to take full and direct advantage of the blockchain developments that would give them more control over their data and transactions, exacerbating the digital divide in society	Boucher, Nascimento, & Kritikos (2017)	*"Citizens who are unable to use internet services for whatever reason may not be able to take full and direct advantage of the blockchain developments that would give them more control over their data and transactions." (Boucher et al., 2017, p. 19)*
Diminishing geographic boundaries	Tertiary	The application of blockchain in this process can contribute to an economy unconstrained by geography and political and legal institutions in which blockchains rather than trusted third parties constrain behavior all transactions recorded on a decentralized public ledger.	Davidson, De Filippi, & Potts (2016a)	*"This is the foundation of the emergence of a so-called cryptoeconomy (Evans 2014, Babbitt and Dietz 2015) as an economy unconstrained by geography and political and legal institutions in which blockchains rather than trusted third parties constrain behavior all transactions recorded on a decentralized public ledger, and in which DAOs are a common organizational feature of the economic order." (Davidson et al., 2016a, p. 11)*
Well performing markets	Tertiary	This application of blockchain improves the performance of the market(s).	Davidson, De Filippi, & Potts (2016a)	*"When coupled with token systems, blockchains make possible new institutional orders that operate at a micro scale, yet with the full coordination properties of what we would otherwise attribute to a self-organizing macroeconomy. Distributed ledgers are a technology for making entire economies where previously agents were technologically constrained to the types of economic order that could be generated only by firms, organizations, markets and governments." (Davidson et al., 2016a, p. 15)*
Inclusion (in coordination)	Tertiary	The application of blockchain for this process improves economic coordination, also serving citizens or economic operators that are currently either poorly served or not served at all by extant coordination mechanisms of markets, hierarchies and governments.	Davidson, De Filippi, & Potts (2016a)	*"But Backfeed also shows that this may bring economic coordination and governance institutions, with the tools for collective decision-making, allocation of resources, coordination, money, constitutions, and other instruments of governance, to spaces that currently are either poorly served or not served at all by extant coordination*

				mechanisms of markets, hierarchies and governments." (Davidson et al., 2016a, p. 23)
Protection against the tyranny of the majority	Tertiary	The application of blockchain for this process enables self-organization of the network, avoiding the tyranny of the majority and the exploitation by organized minorities.	Davidson, De Filippi, & Potts (2016b)	*"The tyranny of the majority (Buchanan and Tullock 1962), exploitation by organized minorities (Olson 1965) and rational voter ignorance are all significantly mitigated when self-organizing communities can adapt to optimal size based on governance not resource conditions." (Davidson et al., 2016b, p. 2)*
Promoting of innovation	Tertiary	Innovation will be promoted by the application of blockchain for this process.	Ølnes (2015)	*"They differentiate between a centralised and decentralised governance regime and argue that the strategic interplay of governance regimes and platform layers is deterministic of whether disruptive derivatives are permitted to flourish. They use the PayPal service (centralised governance) and Coinkite (decentralised governance) in their comparative use cases study. CoinKite is a Bitcoin wallet." (Ølnes, 2015, p. 5)*
Level playing field	Tertiary	The application of a blockchain system for this process creates a level playing field for citizens/economic operators to participate in the market or society.	Boucher, Nascimento, & Kritikos (2017), Swan (2015) & Tapscott & Tapscott (2016)	*"Some argue that peer-to-peer and commons models would manage resource use better, and others are already developing platform cooperatives that are collectively owned and democratically governed by their users or workers. Blockchain can support such organisations by allowing for the direct and instantaneous exchange of data or property, execution of budgets, automatic enforcement of contracts or decision-making inside an organisation, all in a transparent and encrypted form."(Boucher et al., 2017, p. 20)* *"In addition to Blockchain 2.0 protocol projects, there are several developer platform companies and projects offering tools to facilitate application development. Blockchain.info has a number of APIs for working with its ewallet software (it's one of the largest ewallet providers) to make and receive payments and engage in other operations." (Swan, 2015b, p. 19)* *"With blockchain, data and rights holders could store metadata about any substance, from human cells to powered aluminum, on the blockchain, in turn opening up the limits of corporate manufacturing while also protecting intellectual property. New markets could enable buyers and sellers to contract more easily in an open market."(Tapscott & Tapscott, 2016b, p. 3)*
Changing for public administrators	Tertiary	The application of blockchain technology for this process enables disintermediation of institutions and decentralization of services, changing the role of public administrators.	Atzori (2015)	*"All the processes described so far have one major common thread: they have explored new forms of coordination and interaction between State and society, with a significant shift of power from central institutions to individuals and/or markets. The blockchain-based governance can be considered as the final stage of this process of decentralization and disempowerment of institutions." (Atzori, 2015, p. 14)*
Loss of jobs	Tertiary	As there is automation of processes by smart contracts, it is inevitable that jobs will be lost in legacy systems when blockchain systems will be used	Mentioned in evaluation interviews	*None*

C.4 MATRIX PRIORITIZATION ANALYSIS FOR RIPPLE EFFECTS

This appendix describes the Matrix Prioritization Analysis for the ripple effect of blockchain implementations. This analysis is described in detail in section 3.3.2 Matrix Prioritization Analysis. In this appendix, the item set tables of the two Matrix Prioritization exercises in the interactive case study interviews are presented.

C.4.1 MATRIX PRIORITIZATION ANALYSIS FOR EMCS CASE

The prioritization of the relevant effects as shown in Table 48 were provided in the interactive case study interview by the interviewee for the EMCS case.

Table 48. Item set table for EMCS case

Effect	Type	Impact of effect	Importance for EU organization to consider
Streamlined internal processes	Primary	3	4
Reduced effort of transacting with external parties	Primary	3	2
Set-up costs	Primary	4	4
Difficulties during transitional phases	Primary	4	4
Stronger security of an informational database	Primary	3	5
More trusted inter-organizational data exchanges	Secondary	4	4
Increased protection against errors and forgery	Secondary	4	4
Additional infrastructure needed	Secondary	3	3
Flexibility and empowered network	Secondary	4	3
Robust data integrity	Secondary	4	4
Eliminate opportunism	Secondary	4	5
Decentralized monitoring	Secondary	3	4
Permissioned data distribution	Secondary	3	4
Diminishing geographic boundaries	Tertairy	2	2
Well performing markets	Tertairy	2	3
Inclusion (in coordination)	Tertairy	3	4
Promoting of innovation	Tertiary	4	4
Reducing need for public administrators	Tertiary	3	4

An overview of the prioritized ripple effects on all layers for the information exchange case are presented in Table 49.

Table 49. Prioritized ripple effects of the EMCS on blockchain

No.	Impact	Type
1	Eliminate opportunism	Secondary
2	Set-up costs	Primary
3	Difficulties during transitional phases	Primary
4	More trusted inter-organizational data exchanges	Secondary
5	Increased protection against errors and forgery	Secondary
6	Robust data integrity	Secondary
7	Promoting of innovation	Tertiary
8	Stronger security of an informational database	Primary
9	Flexibility and empowered network	Secondary
10	Streamlined internal processes	Primary
11	Decentralized monitoring	Secondary
12	Permissioned data distribution	Secondary
13	Inclusion (in coordination)	Tertairy
14	Changing role for public administrators	Tertiary
15	Additional infrastructure needed	Secondary
16	Reduced effort of transacting with external parties	Primary
17	Well performing markets	Tertiary
18	Diminishing geographic boundaries	Tertiary

C.4.2 MATRIX PRIORITIZATION ANALYSIS FOR ETS CASE

In Table 50, the item set table for the ETS is presented as prioritized in the interactive case study interview by the interviewee.

Table 50. Item set table for EMCS case

Impact	Type	Impact of effect	Importance for EU organization to consider
Set-up costs	Primary	5	5
Difficulties during transitional phases	Primary	5	3
Stronger integrity of an informational database	Primary	3	4
Set-up costs	Secondary	3	5
Increasing fear for reliance on network for compliance	Secondary	4	4
Additional infrastructure needed	Secondary	5	5
Promoting of innovation	Tertiary	2	3

This results in a list of prioritized ripple effects for the ETS case if it would use blockchain for the registration process, as displayed in Table 51.

Table 51. Prioritized ripple effects of the ETS on blockchain

No.	Effect	Type
1	Set-up costs	Primary
2	Additional infrastructure needed	Secondary
3	Difficulties during transitional phases	Primary
4	Increasing fear for reliance on network for compliance	Secondary
5	Set-up costs	Secondary
6	Stronger integrity of an informational database	Primary
7	Promoting of innovation	Tertiary

D.1 Initial prototypes of the blockchain assessment tool

This appendix presents the initial prototypes of the blockchain assessment tool. The first version of the tool is presented is Figure 38.

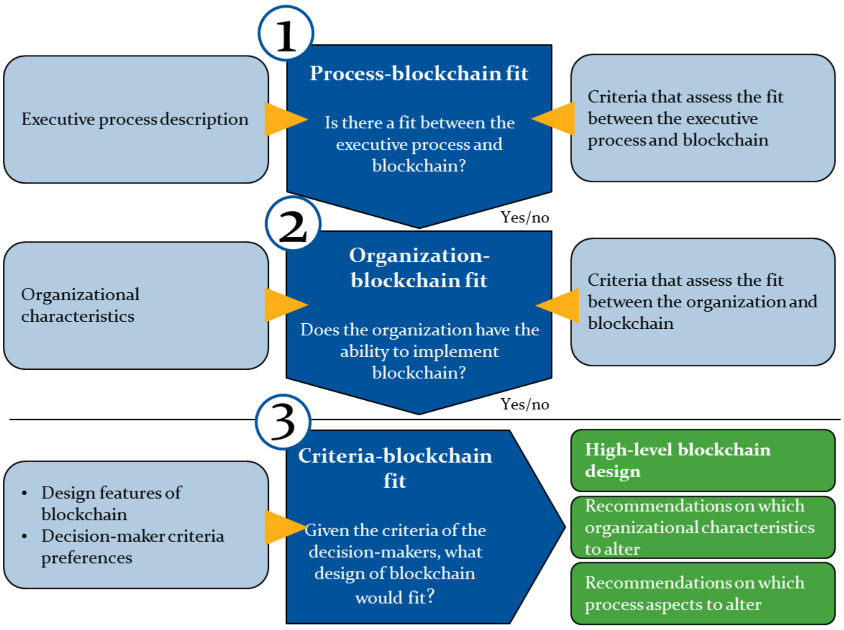

Figure 38. Initial prototype of the blockchain assessment tool (v0.1)

Figure 39 presents the second prototype of the blockchain assessment tool.

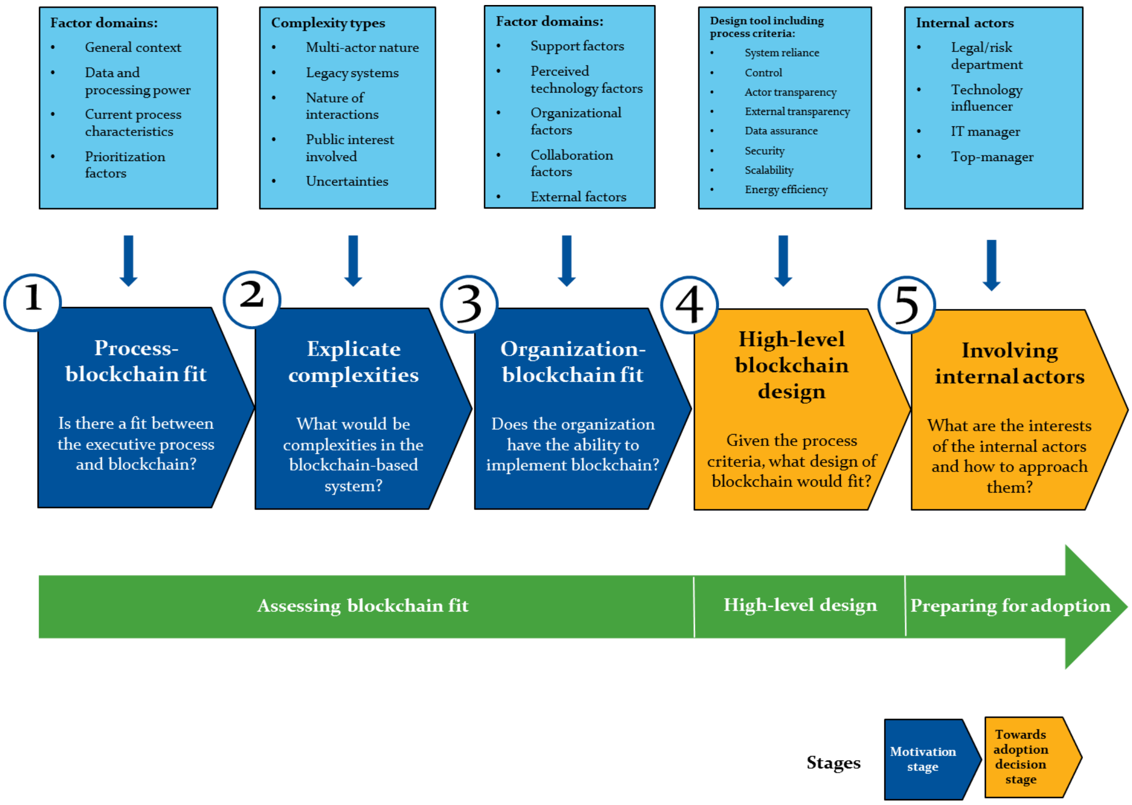

Figure 39. Second prototype of the blockchain assessment tool (v0.2)

E.1 Assessment tool input for EMCS case

This appendix describes the input that is used for the EMCS case study. In Table 52, the documents that were used as input for the case study.

Table 52. Documents used for EMCS case study

Title	Author	Year	Retrieved	URL
Case description	Anonymized	2017	From organization	None
Blockchain (Distributed Ledger Technology) solves VAT fraud	Ainsworth & Shact	2016	Desk research	https://www.bu.edu/law/files/2016/10/BLOCKCHAIN-3.pdf
Blockchain and tax administration	Tax Journal	2017	Desk research	https://www.taxjournal.com/articles/blockchain-and-tax-administration-29032017
"Blockchain: Taxation and Regulatory Challenges and Opportunities"	WU / NET Team	2017	Desk research	https://www.wu.ac.at/fileadmin/wu/d/i/taxlaw/institute/WU_Global_Tax_Policy_Center/Tax___Technology/Backgrd_note_Blockchain_Technology_and_Taxation_03032017.pdf
Blockchain: A Better Possible Solution to Tax Leaks	Wipro LTD	2016	Desk research	http://www.wipro.com/documents/Blockchain-A-Better-Possible-Solution-to-Tax-Leaks.pdf
How blockchain could shape tax automation	Misso, Kid	2016	Desk research	http://www.vatlive.com/vat-news/how-blockchain-could-shape-tax-automation/
Two Banks Make First Cross Border Trade Using Blockchain Technology	Cointelegraph	2016	Desk research	http://www.altcointoday.com/first-cross-border-trade-using-blockchain/
Proof-of-Concept for application of Blockchain Technology to Cross-border Trading Operations	Sumitomo Mitsui Banking Corporation	2017	Desk research	http://www.smbc.co.jp/news_e/pdf/e20170224_02.pdf
Blockchain – speeding up and simplifying cross-border payments	Deloitte	2016	Desk research	https://www2.deloitte.com/nl/nl/pages/financial-services/articles/1-blockchain-speeding-up-and-simplifying-cross-border-payments.html
7 Major European Banks Form Blockchain Platform 'Digital Trade Chain'	Cryptocoin news	2017	Desk research	https://www.cryptocoinsnews.com/7-major-european-banks-form-blockchain-platform-digital-trade-chain/

Table 53 displays the input that was used in the critical factors assessment in the EMCS case, including explanation.

Table 53. Critical factors input for EMCS case

Critical factors			
Question	**Statement**	**True?**	**Explanation**
1.1	Does the process have the potential to be facilitated by direct peer-to-peer interactions?	Yes	EMCS' core business manages a workflow of peer-to-peer transactions (e.g. declaration, aka

			"e-AD", from a consignor trader at dispatch to its National Administration; report of receipt from the consignee trader at destination to its National Administration)
1.2	Is there a specific need for the organization to be the middle man in this process?	*No*	Validation needs to occur, but not necessarily as a middle man. Currently, the system also does not encompass a middle-man as such, but more of a workflow system for different actors to work on the same administrative document
1.3	Is there any information asymmetry or a lack of trust in the data in the current system?	Yes	Data is currently entered multiple times in the system, so there is a chance of human error. Also, the National Excise Applications can fail, and it is difficult to check if the trading partner is registered or has declared the movement, since multiple NEAs are used.
1.4	Does the process involve personal data as specified in the EU Data Protection Directive	No	Though privacy sensitive, it does not involve personal data as specified in the EU Data Protection Directive, and the privacy sensitive data could be encrypted in the scheme. The blockchain system could specify the rules who can read and write the data
1.5	Does the process involve multiple organizations that exchange data?	Yes	Yes, 4 actors, 2 administrative systems and 1 distributed workflow system are involved in a single transaction. Each actor enters their own data in the workflow. Both NEAs store the document in their system.
1.6	Does the legal framework tool of the organization currently allow the experimentation of blockchain for this process?	Yes	Legal assessment tool does not prohibit it to experiment this beside the ordinary system.
1.7	Does the process involve the registration or exchange of data from different sources?	Yes	It involves a lot of information sharing between the stakeholders involved in a given movement.
1.8	Would the potential of blockchain outweigh the costs of experimenting with blockchain?	Yes	Expected benefits include reduced implementation and operations costs, both IT and business services, higher availability and faster and easier searches in the movements in case of controls, investigations, etc.
1.9	Is there any interdependencies in the transactions created by the stakeholders in the networks?	*Yes*	Yes, for example, the receiver can only enter the receiving details when the EA of the sending country has validated the commercial transaction data as provided by the sender in country A.

Table 54 displays the input that was used in the assessment of the process factors in the EMCS case, including explanation.

Table 54. Process factors input for EMCS case

Process factors			
Question	**Statement**	**Answer**	**Explanation**
2.1	Is there currently any human labor to facilitate the process?	Yes	Each actor provides manual data input, for example the CN code, the quantity dispatched, the quantity arrived and the validation of the dispatch.
2.2	What is the level of legacy systems currently in place?	Brownfield	Each country has their own NEA, and the EMCS currently in place has been around in multiple forms since 2004.
2.3	Are there many different data formats involved in the process?	Single data format	The electronic Administrative Document is specified and uses one data format.
2.4	Does the process facilitate a high frequency of transactions?	Low frequency	3M messages/year means less than 1 transaction per second. This is less than the bitcoin network and is considered to be of low frequency.
2.5	Is the data that is used in the current process also involved in other processes?	Involved in other processes as well	The data can be involved in other processes like book keeping and registration of inventory by economic operators.
2.6	Are there many different uses of the data in the process? Or is there only one use of the data in the process?	Different uses of data	This data is also involved in other uses like searches in the movements in case of controls, investigations, for own record keeping and potentially ERP systems.

2.7	Do the stakeholders in the network each have their own custom-build interface for this process, or are the interfaces standardized?	Multiple interfaces	The system has multiple interfaces, as each MS has their own NEA. The actors involved in the system include both authorities and economic operators, which each need their own options, roles and interfaces.
2.8	Does the network involved consist of a fixed amount of participants and transactions, or is this likely to grow or reduce?	Growing	Scalability is necessary given the growth of transactions in the recent year. There could be a possibility to share information with Guarantee management, Customs, VAT and/or other business domains. Consequently, scalability is a strong requirement.
2.9	Do the actors in the network easily adapt to new technology standards?	No	Likely this will cause resistance, but it can create efficiencies as well. It needs to be showed first though
2.10	Is it of importance to have data exchange without any delay in the process?	No	Currently, the system is based on asynchronous exchanges (15 MN delay, 2h response). Delay is not too important.
2.11	How predictable is the behavior and the data input of the actors in the network?	8	The data input is predictable, as imposed by standards in the system, and yet the behavior of some actors can be unpredictable (resulting in a less than 100% conversion rate in the current EMCS).
2.12	Is there any lack of trust from the actors in the network that the public administrations will provide this process?	8	The trust is there, yet the availability of the system is 97%.
2.13	What is the level of bureaucracy in place for this process?	3	The system is already distributed (in a workflow). The only bureaucratic aspect is the manual validation of the EAs of the two countries.
2.14	Do the actors in the network want to store their data locally to keep control in this process?	5	If possible yes, but it is not critical as there are no problems with the storage of the current systems
2.15	Is the network able to provide enough bandwidth and computing power?	10	In a system where the Excise Authorities are the validating nodes, this should be sufficient. Standards can be imposed for this.
2.16	Is there a need to have the ability to trace who has accessed the data in the network?	5	Not specifically who accessed the data. Specification of who can read the data is preferred, especially for immediate and automatic availability of data to enforcement authorities if legislation allows
2.17	Is there a need for data transparency between the actors involved in the network?	10	Yes, this can lead to a reduction of fraud, as a trader can easily check if its trading partner is registered or has declared the movement.
2.18	Does the process involve privacy sensitive information?	8	As the economic will have the control of granting or denying access to their data, unless the legislation makes access mandatorily granted, the privacy measures are of important in this system.
2.19	How is the level of importance of the ease of use and user experience in the process?	6	Given the frequency of usage (for each time you send a 'package' abroad'), the ease of use needs to be taken into account.
2.20	How is the level of importance of data security in the process?	10	Security (identification, authentication, authorization, confidentiality) is a critical requirement given the various roles and uses of the system.

Table 55 displays the input that was used in the assessment of the organizational factors in the EMCS case, including explanation.

Table 55. Organizational factors input for EMCS case

Organizational factors			
Question	**Statement**	**Answer**	**Explanation**
3.1	Does the organization have a blockchain enthusiast that understands the technology and is willing to experiment with blockchain?	Yes	Multiple people in the organization understand the technology and are investigating blockchain applications.
3.2	Are there similar use cases in the market already being explored?	Yes	Multiple tax collection use cases are currently explored, especially regarding cross-border trade.

3.3	The organization has the support of the administrative authority to experiment with blockchain technology	3	Member States might not wish to participate. Legally these systems are more difficult, and the success of such a system depends on whether it is possible to get two champion Member States to start experimenting. Most authorities of Member States only develop short term goals and are mostly bounded by limited resources.
3.4	The organization has the financial means to experiment with blockchain technology	5	If the benefits are expected to be high, budget would be made available, but case would have to be made strong and rigid.
3.5	The organization has the managerial capabilities to experiment with blockchain technology	9	DG TAXUD has experience with distributed systems (not blockchain) and possesses knowledge and IT and business processes.
3.5	The organization is able to comprehend the complexity of blockchain technology	8	The initial idea of an EMCS on blockchain originated from DG TAXUD, showing the capabilities of DG TAXUD to comprehend this technology.
3.6	The organization is risk adverse regarding IT innovations	4	If this technology can create efficiencies and enhance the GDP of Europe by just a little bit, the DG TAXUD is willing to explore the possibilities.
3.7	The organization has (the ability to outsource) the IT capabilities needed for a blockchain pilot	9	DG TAXUD has experience with large IT projects and has significant IT capabilities in-house.
3.8	The organization has a top-management that is dedicated to experimenting with blockchain	6	An increasing positive attitude towards blockchain experimentation and its potential benefit can be seen by a number of studies issued by the European Commission and the assignment of a task force focused on blockchain in collaboration with various DGs.
3.9	The organization is willing to give up the coordinating role in the process	10	Currently, the system already works distributed, so no coordinating role is given up. It is a trans-European system.
3.10	The other stakeholders involved in the network would be willing to participate in blockchain experimentation led by the organization	5	Perhaps, if sponsored and benefits are clearly shown.
3.11	The organization is trusted by collaborating parties to facilitate data exchange/registration	10	The coordinating role of the EU is accepted in this field and DG TAXUD considers it to be their role to facilitate developments in this field.
3.12	The organization is influenced by external forces like encouragement/pressure to recommendation, request or providing incentives or exposure to penalties	4	Other than the legal assessment tool no external influences in this respect are found
3.13	The other stakeholders involved in the network have the competences to participate in blockchain experimentation	3	This might pose a problem, unless you are looking at a system where the economic operators use light wallets (which are easier to use) and the validating nodes are the EAs of the Member States.
3.14	The organization would be able to handle technological uncertainty that blockchain technology currently faces	3	It will be difficult to imagine experimentation with this technology on a trans-European system without it being fully mature.
3.15	The organization would be willing to decentralize the data storage in the process	7	Yes, as this is already in place.

Table 56 displays the process criteria input that was used in the step 2 of the tool in the EMCS case, including the explanation of the chosen importance value.

Table 56. Process criteria input for EMCS case

Process criteria			
Criterion	**Criterion explanation**	**Importance value [0-100]**	**Importance explanation**
System reliance	Refers to the level of reliance in the system of actors, where even if there is no explicit external governance as part of the operating model, the system should continue providing the intended level of assurance	100	The importance of systems reliance is very high in this system, as any loss of availability results in significantly less trade

Control	Refers to the control on the counterparties in the system from perspective of the organization that is issuing the system	10	The importance of control on the economic operators from the perspective of DG TAXUD is low, as their role is merely the facilitator of the data exchange process. It is not reasoned to increase trade or effectivity of the system
Actor transparency	Refers to the transparency of the identity actors that are transacting in the system to the other actors in the system	100	The transparency of the identity of the actors with which the economic operators are traders are very important given the risk of fraud.
External transparency	Refers to the transparency of the transaction and actors in the system from an external perspective	10	The external transparency is low, as this system includes trade details that economic operators do not wish to enclose
Data assurance	Refers to the recording and protection of the origin and history of all identity, attributes and certification hash records.	100	The data assurance is of high priority, as well as the security, as the identification, authentication, authorization and confidentiality of the data and IDs of the traders are a critical requirement of the EMCS system.
Security	Refers to the confidentiality, integrity and availability of the ID of the participant	100	The data assurance is of high priority, as well as the security, as the identification, authentication, authorization and confidentiality of the data and IDs of the traders are a critical requirement of the EMCS system.
Scalability	Refers to how the system performs under a large volume of read-and-write operations workload	100	Scalability of the system is also important, as a steady growth in transactions in the system is distinguished in recent years
Energy efficiency	Refers to whether the system operates economically, thus serving a large population of user entities with minimal cost and waste.	30	The importance of an energy efficient system is moderate, as the authorities of the Member States would be willing to use more energy is this would make the system more reliant or secure.

F.1 Assessment tool input for ETS case

This appendix describes the input that is used for the ETS case study. In Table 57, the documents that were used as input for the case study.

Table 57. Documents used for EMCS case study

Title	Author	Year	Retrieved	URL
EU carbon credit system still 'at risk of VAT fraud'	Teffer, Peter	2015	Desk research	https://euobserver.com/economic/129433
EU ETS Registry Regulation - more than just technicalities	Emissions-EUETS	2015	Desk research	http://www.emissions-euets.com/registry-regulation
IBM Develops Blockchain Platform to Fight Carbon Emissions in China	CryptoCoinsNews	2017	Desk research	https://www.cryptocoinsnews.com/ibm-develops-blockchain-platform-to-fight-carbon-emissions-in-china/
Energy-Blockchain Labs and IBM Create Carbon Credit Management Platform Using Hyperledger Fabric on the IBM Cloud	IBM	2017	Desk research	http://www-03.ibm.com/press/us/en/pressrelease/51839.wss
Blockchain – A New Era for the Energy Market?	atham & Watkins LLP	2017	Desk research	http://www.lathamlondon/2017/03/blockchain-a-new-era-for-the-energy-market/
IBM partners with blockchain venture to target Chinese carbon market	CarbunPulse	2017	Desk research	https://carbon-pulse.com/32112/
European Commission Proposes Blockchain RegTech Pilot	Higgins, Stan	2017	Desk research	http://www.coindesk.com/european-commission-proposes-blockchain-regtech-pilot/
IBM delivers blockchain carbon management	Murphy, Ian	2017	Desk research	https://www.enterprisetimes.co.uk/2017/03/20/ibm-delivers-blockchain-carbon-management/
Global Carbon Trading	Casaloti, Andrea	2016	Desk research	http://bblf.info/blockchain-bugle/global-carbon-trading
A New Model for Carbon Pricing Using Blockchain Technology	Dodge, Edward	2015	Desk research	http://www.edwardtdodge.com/2015/09/22/a-new-model-for-carbon-pricing-using-blockchain-technology/

Table 58 displays the input that was used in the critical factors assessment in the ETS case, including explanation.

Table 58. Critical factors for ETS case

Critical factors			
Question	**Statement**	**True?**	**Explanation**
1.1	Does the process have the potential to be facilitated by direct peer-to-peer interactions?	Yes	Currently, all allowances are held in the accounts managed by the Member States, and the national registry administrators in all 31 countries participating in the EU ETS are the point of contact for the economic operators in located in that Member State. Emissions trading have the potential to be traded directly instead of via a centralized platform. The EU ETS is much more centralized than the UNFCCC ITL, which is a system that connects registries and secretariat systems that are involved in the

			emissions trading mechanism defined under the Kyoto Protocol.
1.2	Is there a specific need for the organization to be the middle man in this process?	*No*	Not specifically, other than to ensure compliance. The DG CA does have interest in preventing violations and reducing the overall cap to reach the goal of the system: to combat climate change and reducing greenhouse gas emissions cost-effectively
1.3	Is there any information asymmetry or a lack of trust in the data in the current system?	Yes	In the past, the EU ETS was involved in a fraud called 'carousel fraud', where companies where able to disappear without having to pay taxes. In the EU ETS, in 2008 and 2009 this resulted in a large loss of national tax incomes, with estimates of the total fraud ranging from 2 to 5 billion euros.[7] The fraud occurs when a company sends its carbon allowances to a company in another country, without paying the VAT tax. These allowances are then traded within the country for a price that includes this tax, without it being paid to the national authority. This displays the information asymmetry in the system and the ability of actors to exploit it. In a report by the European Court of Auditors titled *The integrity and implementation of the EU ETS* published in 2015 it is argued that this loophole is not yet closed (ECA, 2015). Each Member State is responsible for implementing mechanisms to avoid this fraud, but not all Members States are argued to have implemented sufficient measures. As there is an EU-wide market, with the Member States each having their own authority to check compliance, they are dependent on each other that the supplied data is correct, without having the ability to check this their selves, displaying the information asymmetry in the system.
1.4	Does the process involve personal data as specified in the EU Data Protection Directive	No	Though privacy sensitive, it does not involve personal data as specified in the EU Data Protection Directive, and the privacy sensitive data could be encrypted in the scheme.
1.5	Does the process involve multiple organizations that exchange data?	Yes	Yes, in the form of carbon allowances. Polluters that want to increase their emissions must buy permits from others willing to sell them. Right now, this is centralized, as the Member States provide access to the system for economic operators that want to participate.
1.6	Does the legal assessment tool of the organization currently allow the experimentation of blockchain for this process?	*No*	No, current regulations specify very detailed how the functions of the registry would work and how the Member States should be using it.
1.7	Does the process involve the registration or exchange of data from different sources?	Yes	It would involve the registration of carbon allowances from different Member States and the exchange of these allowances by the economic operators, but
1.8	Would the potential of blockchain outweigh the costs of experimenting with blockchain?	No	Even though the benefit of a blockchain system with each firm being a node goes beyond mere registration, as it facilitates the options of additional automation like automatic auctioning based on smart contracts, connecting it to other ETS's in the world, or even attaching it to certain energy grids to real time monitor the energy emissions, it is highly doubtful whether the benefits will outweigh the enormous costs that will be involved in setting up this system.
1.9	Is there any interdependencies in the transactions created by the stakeholders in the networks?	*No*	In this system, it could become possible to attach each firm's carbon allowance balance to other applications. If the energy grids will become so smart that they can monitor real-

[7] Via Reuters Business News*: FACTBOX - How carousel fraud works*. Published on August 20, 2009, via http://uk.reuters.com/article/uk-carousel-fraud-britain-factbox-sb-idUKTRE57J43U20090820

			time emissions, then interdependencies between the transactions and other actions are created. Yet, this is not currently the case and firms only have to show yearly compliance.

Table 59 displays the input that was used in the assessment of the process factors in the ETS case, including explanation.

Table 59. Process factors for ETS case

Process factors			
Question	**Statement**	**Answer**	**Explanation**
2.1	Is there currently any human labor to facilitate the process?	No	Currently, the registry is completely automated
2.2	What is the level of legacy systems currently in place?	Greenfield	The IT provision part is completely centralized, meaning that the Member States are using a system issued by the Commission.
2.3	Are there many different data formats involved in the process?	Different data formats	The system covers different type of emissions and the EU aims to link the EU ETS with other compatible system, as it is already linked to the ITL
2.4	Does the process facilitate a high frequency of transactions?	Low frequency	Trading does not take place more than 7 transactions per second.
2.5	Is the data that is used in the current process also involved in other processes?	Involved in other processes as well	Blockchain technology could enable an extension to smart monitoring devices, real time checking the emissions and verifying whether the economic operator has sufficient allowances on their account.
2.6	Are there many different uses of the data in the process? Or is there only one use of the data in the process?	Multiple uses of data	The firms will be able to attach this ledger to their own accounting systems, automatic trading or connect this to their energy grids
2.7	Do the stakeholders in the network each have their own custom-build interface for this process, or are the interfaces standardized?	Multiple interfaces	Given the potential of blockchain to expand to real-time monitoring, multiple interfaces should be considered.
2.8	Does the network involved consist of a fixed amount of participants and transactions, or is this likely to grow or reduce?	Growing	The EU ETS applies to the whole markets, so new entrants also have to be included in the registry
2.9	Do the actors in the network easily adapt to new technology standards?	Yes	No local systems are currently required for the registry, which is currently centralized per Member State, and overall in the EU. The actors also adapted to new standards in 2012.
2.10	Is it of importance to have data exchange without any delay in the process?	Yes	If expanded towards more real time monitoring and interoperability with other applications, a delay in the consolidation of transactions is critical
2.11	How predictable is the behavior and the data input of the actors in the network?	3	The data input is predictable, as imposed by standards in the system, yet the actor behavior and intentions are unpredictable, as can be seen in the VAT carrousel fraud in the earlier days of the registry.
2.12	Is there any lack of trust from the actors in the network that the public administrations will provide this process?	10	There is currently high trust, as the DG Climate Action and the local authorities have a vested interest in the workings of the system.
2.13	What is the level of bureaucracy in place for this process?	6	The system is hierarchically designed, with a distribution of access control and monitoring towards the Member States. Checks of the input of the data do not take place in real time, but Member States perform the know-your-customer check, to make sure they provide all the documents and certificates that are required by the legislation. This will not change in this process.
2.14	Do the actors in the network want to store their data locally to keep control in this process?	9	Local data storage and a full copy of the ledger in the system allows firms to efficiently trade allowances and enhances decision-making regarding their emissions.
2.15	Is the network able to provide enough bandwidth and computing power?	10	Standards can be imposed on this, and the firms involved all have the resources to supply this

			computing power to fuel the blockchain network.
2.16	Is there a need to have the ability to trace who has accessed the data in the network?	10	As security is of high priority for this system, it is essential to have data traceability. From a firm's perspective, this is also true.
2.17	Is there a need for data transparency between the actors involved in the network?	3	Though this provides transparency, the firm is able to input the data their selves, still creating the need the need for heavy annual reporting and audit procedures.
2.18	Does the process involve privacy sensitive information?	10	Privacy is of high importance in this process. All transactions are public, except for the last 3 years of transactions. The EU ETS has very strict regulatory rules. So real-time transparency is not desirable for this process.
2.19	How is the level of importance of the ease of use and user experience in the process?	7	Currently, firms can use the system like a web-based banking system. So ease of use is of important but not of the highest priority.
2.20	How is the level of importance of data security in the process?	10	One of the main drivers of the system is the security, which is one of the reasons the Commission decided to centralize the system. Compromises of the system can lead to large losses of money for firms, or worse. This is also true for the firm's perspective.

Table 60 displays the input that was used in the assessment of the organizational factors in the ETS case, including explanation.

Table 60. Organizational factors for ETS case

Organizational factors			
Question	**Statement**	**Answer**	**Explanation**
3.1	Does the organization have a blockchain enthusiast that understands the technology and is willing to experiment with blockchain?	No	The organization is not aware of any employee with an expertise on this
3.2	Are there similar use cases in the market already being explored?	Yes	IBM has conducted successful pilot for a similar system in China with Energy-Blockchain Labs. This use case uses the Hyperledger blockchain to provide a platform to store and trade allowances for emissions for emitting companies in China.
3.3	The organization has the support of the administrative authority to experiment with blockchain technology	2	The EU ETS operates in a heavily regulated environment, and any experimentation with blockchain technology would have to be approved by the European Parliament in a long procedure
3.4	The organization has the financial means to experiment with blockchain technology	5	If the benefits are expected to be high, budget would be made available, but case would have to be made strong and rigid.
3.5	The organization has the managerial capabilities to experiment with blockchain technology	9	Earlier big IT transformation projects (from a decentralized to centralized registry) were also managed successfully.
3.5	The organization is able to comprehend the complexity of blockchain technology	5	Only little is currently explored on the potential of blockchain for this system
3.6	The organization is risk adverse regarding IT innovations	10	The organization is very cautious to experiment with this technology, as anything that could compromise the security and privacy of the data is cautiously deliberated to avoid scandals.
3.7	The organization has (the ability to outsource) the IT capabilities needed for a blockchain pilot	9	Earlier big IT transformation projects (from a decentralized to centralized registry) were also managed successfully.
3.8	The organization has a top-management that is dedicated to experimenting with blockchain	6	An increasing positive attitude towards blockchain experimentation and its potential benefit can be seen by a number of studies issued by the European Commission and the assignment of a task force focused on blockchain in collaboration with various DGs.
3.9	The organization is willing to give up the coordinating role in the process	1	The way this system is set-up, completely distributes the registry, which the organization

			will not be willing to do given the recent developments to centralize the registry.
3.10	The other stakeholders involved in the network would be willing to participate in blockchain experimentation led by the organization	2	This will require investments or at least new knowledge at each of the firms in the network, which they will not be easily willing to invest in.
3.11	The organization is trusted by collaborating parties to facilitate data exchange/registration	10	The coordinating role of the EU is accepted in this field and no forces to create another entity to register the allowances are distinguished
3.12	The organization is influenced by external forces like encouragement/pressure to recommendation, request or providing incentives or exposure to penalties	1	No external influences in this respect are found.
3.13	The other stakeholders involved in the network have the competences to participate in blockchain experimentation	3	This will be difficult but can be mitigated with the concept of a Light Wallet
3.14	The organization would be able to handle technological uncertainty that blockchain technology currently faces	3	Though difficult to assess, as security is of high priority for this organization, it is difficult to imagine a registry based on a not fully proven technology.
3.15	The organization would be willing to decentralize the data storage in the process	7	In principle there would be willingness for this decentralization, yet security aspects and cost effectiveness were the main reason for a centralized system. But blockchain can be secure and cost-effectiveness can also be matched in a blockchain system, as long as the standards are made clear.

Table 61 displays the process criteria input that was used in the step 2 of the tool in the ETS case, including the explanation of the chosen importance value.

Table 61. Process criteria for ETS case

Process criteria			
Criterion	**Criterion explanation**	**Importance value [0-100]**	**Importance explanation**
System reliance	Refers to the level of reliance in the system of actors, where even if there is no explicit external governance as part of the operating model, the system should continue providing the intended level of assurance	100	The system should provide a high level of reliance, given the criticality of the system towards the mission of the DG
Control	Refers to the control on the counterparties in the system from perspective of the organization that is issuing the system	100	The control of the authorities of the Member States on the blockchain system is also of high importance, since this created market needs to be overseen by a regulator
Actor transparency	Refers to the transparency of the identity actors that are transacting in the system to the other actors in the system	50	The importance of transparency between actors is only medium, as the actors involved only have limited benefits when this transparency increases. It is not reasoned to increase trade or effectivity of the system.
External transparency	Refers to the transparency of the transaction and actors in the system from an external perspective	0	External transparency is extremely low due to the confidentiality regulations surrounding these trades of three years
Data assurance	Refers to the recording and protection of the origin and history of all identity, attributes and certification hash records.	100	Data assurance is the reason why there was heavily invested in the current system
Security	Refers to the confidentiality, integrity and availability of the ID of the participant	100	Security was the main driver of centralizing the system, given the issues occurred in the decentralized systems
Scalability	Refers to how the system performs under a large volume of read-and-write operations workload	100	Scalability is of importance given the potential new entrants to will be needed to be included in the system
Energy efficiency	Refers to whether the system operates economically, thus serving a large population of user entities with minimal cost and waste.	50	The energy efficiency is of somewhat importance, as the actors involved in the network will not be willing to supply unlimited resources for this system.

G.1 EXPERT EVALUATION MINUTES

This appendix contains the minutes of the expert evaluation interviews. The interviews were conducted in May 2017, either face-to-face or via telephone. Table 62 presents an overview of the interviewed experts for expert evaluation.

Table 62. Overview of interviewed experts for expert evaluation

No	Interviewee	Organization	Field of expertise	Date	Method
1	Lex Hoogduin	University of Groningen	Complexity and uncertainty	22/05/2017	Face-to-face
2	Rutger van Zuidam	DutchChain	Blockchain technology	18/05/2017	Face-to-face
3	Svein Ølnes	Western Norway Research Institute	Blockchain in e-government	19/05/2017	Telephone
4	Garret Bonofiglo	Gartner	Blockchain applications	19/05/2017	Telephone
5	Joachim Schwerin	European Commission (DG GROW	DLT policy in Europe	23/05/2017	Telephone

The minutes were send to the interviewees to check for correctness, and consent was given to include the minutes in this thesis. In the following sections, the minutes of the expert evaluation interviews can be found.

G1.1 Rutger van Zuidam, DutchChain

18/05/0217

Achtergrond

Rutger van Zuidam is sinds 2010 betrokken met Bitcoin. Hij is de oprichter van intoblockchain.com, waarbij hij keek naar hoe Bitcoin in contact kwam met mensen die van invloed zijn binnen de mainstream media. In 2013 is hij begonnen met product ontwikkling met Bitcoin applicaties, en in 2015 organiseerde hij het eerste Blockchain Congres in Nederland. Rutger van Zuidam heeft in 2016 een whitepaper geschreven over hoe de Nederlandse overheid blockchain technologie kan gebruiken om een ander verdienmodel op te zetten genaamd 'Blockchain-as-a-service'. In 2017 organiseerde hij de Dutch Blockchain Hackathon, waar meer dan 400 mensen aan mee deden om binnen 48 uur 50 blockchain applicaties the bouwen.

Toelichting onderzoek en design doelen, assumpties en requirements

- David ligt toe dat het onderzoek zich focust op blockchain voor de overheidsprocesses, specifiek voor de EU. De gesprekspartner geeft aan dat hij de mogelijkheden voor blockchain binnen de overheid goed ziet, en dat de overheid een speciale markt is. De overheid kan in principe zijn klant niet verliezen, dus concureren met de overheid is heel moeilijk. Ook zegt de gesprekspartner dat de EU door middel van blockchain direct de burger kan gaan dienen.
- David ligt toe dat dit onderzoek uitgaat van limieten in schaalbaarheid en security van de technology. De gesprekspartner vergelijkt de technologie met het begin van het internet en stelt dat hij uitgaat van een exponentiele groei, dus dat niet een enorme belemmering is.
- De gesprekspartner herkent de vraag naar een blockchain assessment tool om verschillende use cases te evalueren binnen de overheid.
- David introduceerd de waarde van controle binnen overheids processen. De gespreksparter geeft aan dat vertouwen is goed is, maar controle beter is. Hij verteld over een applicatie die zijn bedrijf gebouwd heeft op de Bitcoin blockchain voor een stadspas systeem dat gemeenschappelijk geld verdeeld naar behoevigen binnen Groningen in de vorm van vouchers, die de ontvangers alleen bij specifieke bedrijven kunnen inwisselen. Op deze manier vergroot de blockchain de controle van de overheid.

Toelichting Blockchain Assessment Tool

- David legt de drie stappen waar de blockchain assessment tool uit. De gesprekspartner vind het fijn dat de tool gestructureerd is en dat er op een gestructureerde manier gekeken kan worden naar de experimentatie met blockchain.
- De gesprekspartner geeft aan dat het model nu nog uitgaat vanuit de organisatie zelf, en dat er wellicht een stap ervoor toegevoegd kan worden, waarbij er vanuit de burger geredeneerd kan worden. Dus in plaats van vragen of de organisatie zelf de middle-man in een proces wilt zijn, kijken in welke welke processen de burger wilt en waar zij graag een overheidspartij willen als vetrouwende partij. Dan voeg je een element toe aangezien de organisatie-burger fit ook van belang is.
- David legt uit dat er in de blockchain tool ook gekeken wordt naar of het netwerk mee kan doen in de experimentatie. De gesprekspartner geeft aan dat dit erg belangrijk is, omdat consortium vorming erg belangrijk is in blockchain applicaties. Er zijn altijd meerdere organizaties betrokken, en het vormen van een consortium is echt een kunstvorm. Je moet lego'en met organizaties en dat is erg moeilijk. De APIs zijn de sleutels tot de organisaties, dus zijn ook heel erg van belang, en die ziet de gesprekpartner nu nog niet erg terug in het model.
- De gesprekpartner geeft aan dat het wellicht een idee is om de blockchain experimentatie als startup te definieren in plaats van project vanuit de organisatie. Hierdoor kan je zonder legacy werken, en het project kan zijn eigen leven gaan leiden, en dan wordt de organisatie echt gedecentraliseerd. Dan geef je een extra laag aan je model: hoe ga je bestuurlijk om met het project. David geeft aan dat dit ook naar voren kwam in de exploratieve interviews en dat dit interessant is om nader te onderzoeken.

Step 1: Determining the blockchain fit

- David legt de de critical factors uit, en legt uit hoe dit werkt in de tool. De gesprekspartner geeft aan dat dit ingewikkeld is, omdat de antwoorden op de vragen discutabel zijn. Sommige van de vragen slaan echt op de fantasie van de gene die de tool gebruikt: kan het process ook op een andere manier opgezet worden. De antwoorden van de vragen hangen dus of van het perspectief. Ook heeft hij aan dat hij meer iemand is die zegt: Why not blockchain?

- De gesprekspartern geeft aan dat de kritische factor wat betreft vertrouwen ook anders geinterpreteerd kan worden, omdat het vetrouwen niet niet alleen in de data zit maar ook in het process. Ook wat betreft persoonlijke data geeft de gesprekspartner aan dat de dit afhangt van hoe je het experiment opzet. Het hangt ook af van het netwerk dat meedoet aan het experiment of je toch wat nuttigs met de persoonlijke data kan doen. Gesprekspartner legt een use case uit waarbij levens gered kunnen worden als ook persoonlijke data gebruikt kan worden.
- David legt uit wat de verschillende process factoren. De gesprekspartner geeft aan dat hij de factoren herkent en de scheiding proces en organisatie factoren herkent. Wat betreft privacy sensitive informatie geeft de gesprekspartner aan dat hij juist de waarde van security bij blockchains als een manier om je data gedistribueerd op te slaan ziet, omdat we dan afstappen van een single-point-of-failure systeem waar de data centraal opgeslagen staat. In een ideaale wereld, heeft de burger daarin volledig controle over de eigen data.
- Bij het uitleggen van de organizatorische factoren, geeft de gesprekspartner aan dan hij het belang herkent van een blockchain enthousiast. Een potentieel verbeterd punt zou zijn het meer expliciet maken van het innovatie proces: erken je dat er meer kennis buiten de organisatie dan binnen zit, en hoe haal je die binnen?
- David legt de veranderde rol van overheden uit bij blockchain. Gesprekspartner geeft aan dit te herkennen, en voegt toe dat wij als burgers de overheid zijn. Bij blockchain kan je dit vanaf de grond af opbouwen op een nieuwe infastructuur. Er zijn volgens de gesprekpartner veel redenen om overheden te hebben, maar dat moeten we als burgers wel zelf kunnen bepalen.

Algemene bruikbaarheid

- Veel dingen die in het model komen vindt de gespreksparter erg handig om te hebben in dit veld. Hij geeft aan dat de mindset van deze organisaties de grootste challenge is, dat de ziel van de organisatie hierbij van belang is. In hoever de organisatie bewust van is, is niet alleen kritiek voor een succesvolle blockchain implementatie, maar ook voor het overleven van overheids organisatie. Het veranderingsvermogen is erg belangrijk, en dat element is voor overheids organisaties is kritiek.
- De gesprekspartner geeft aan het overzicht van de trends richting de decentralisatie van overheidsprocessen en dat blockchain mogelijk de volgende stap is, interessant te vinden.

G1.2 Svein Ølnes, Western Norway Research Institute

19/05/2017

Background

Svein wrote a literature review on blockchain technology in e-government research in 2015. He has been involved in the e-government field for more than 20 years. His focus has been on services and e-services. Svein has written a number of papers on the concepts of e-services and interoperability, and lately he has been writing a number of papers on blockchain technology for governments. He discovered Bitcoin in 2011, and has become more and more interested in the application of blockchain in governmental services after this.

Explanation of design goals, assumptions and requirements

- David introduces the research problem and the theories that are used in the research. The interviewee indicates that he follows the line of reasoning. He compares blockchain technology with the internet. He indicates the similarities of extranet in the early days of the internet and private blockchains as of now. A critical question that he thinks is essential is: What makes this technology so innovative? He says it is decentralized computing, and gaining trust. David indicates that this thesis does addresses this, it the form of intermediation.
- David explains how blockchain can contribute to the changing role of public administrations, and the difference between permissionless and permissioned blockchain. The interviewee indicates that this is an interesting topic, and that he focusses also on the interoperability. He indicates that he questions the potential to have interoperability if we have multiple permissioned blockchains throughout the EU. He draws a parallel to the internet, and questions the potential of blockchain if you don't make it an open system like permissionless blockchains. David introduces the potential for an EU-wide blockchain infrastructure for these services to be provided on. The interviewee recognizes the fact that the thesis cannot focus on all aspects, but indicates that he thinks that if this technology is going to evolve into a truly adopted infrastructure, it should be open. This could be added to the research.
- The interviewee questions the possibility of permissioned blockchains to really be considered to be decentralized. Also, he questions the true immutability of permissioned blockchain, as these systems can more easily rewrite history than on a permissionless blockchain. He presents an example of a permissioned blockchain experiment within hospitals, where it was easy to rewrite a specific data input. In permissionless blockchain, there are more stakeholders so this is more difficult, yet still possible.
- David introduces the view of this thesis on permissioned and permissionless blockchains. The interviewee expresses the concern on the difference between open systems and open source. Open source is necessary, but not sufficient in his view. The trust in the system is much more than just in the open source code. The interviewee indicates that this discussion is very interesting to raise, as it is both political and philosophical.
- David introduces the view of this research on technical and institutional uncertainties, and the knowledge gap that this blockchain assessment tool intends to address. The interviewee indicates that the research objective is good, especially for a thesis. He also indicates that there is a need for these assessment tools, as we need to know more about public sector bodies and what they need, in order to benefit from this technology.
- The interviewee argues that an important aspect in this area is the question of future development. Many open source project die a lonely death because of no interest from volunteers. This is an important part of the public/private blockchain debate. How will future development be secured for a private blockchain? He states that it is not impossible to secure future development, but he argues that it is more challenging than for open blockchains. There are already hundreds of open blockchains (altcoins) out there, and they are competing for scarce developer resources. This will be an issue also public sector needs to consider, and he indicates that this could be added in the research as well.
- The interviewee indicates that he shares the concerns of transferring power to a techno-elite like today's leading developers of blockchain technology. He points to the failing of the DAO, were this power transfer went wrong.

Explanation of the six elements that are used in the assessment tool

- David introduces the six elements, and the interviewee indicates that he is not really familiar with this. He advises that this should maybe be a little bit simpler. He indicates simplicity above all, as this is not immediately clear and looks complex.

Explanation of the Blockchain Assessment Tool

- David provides a walkthrough of the blockchain assessment tool and the three steps. The interviewee indicates that he agrees with having a number of critical factors. He indicates that it cannot just be a replacement of a traditional database.
- David elaborates on the critical perspective that thesis takes on the blockchain potential and these critical factors. The interviewee shares this critical perspective, and indicates that blockchain technology is extremely inefficient, because of the enormous redundancy. It has to be emphasized, to not confuse it with a normal database.
- David asks for the perspective of the interviewee of the projection of growth, as he compares blockchain technology with the internet. The interviewee says that it is likely to grow. He urges to ask public organizations: are you ready for the decentralized approach? Because blockchain technology means giving away a lot of your control. Highlight the trade-offs. David indicates that the research touches upon this.
- David introduces the second step. Interviewee indicates that this seems logical, also as these indicators provide insight in the systems performance. The interviewee suggest more insights in these trade-offs could be beneficial.
- The interviewee indicates that he sees how this design makes sense in the light of this thesis. The overall feedback of the interviewee is to include more of the open versus closed infrastructure discussion, as this is essential for blockchains in governments. The interviewee indicates his interest in seeing how Blockchain can present the next step in e-government development.

G1.3 GARRETT BONOFIGLO, GARTNER

19/05/0217

Background

Garrett Bonofiglo is a consultant for Gartner in Chicago. His focus in on Data & Analytics, and he mostly operates in the manufacturing industry. In addition, he is investigating how blockchain can be used in manufacturing and supply chains, and is one the leads in looking for blockchain applications across industry for Gartner. His academic background is an Analytics Master at the University of Chicago and an undergrad degree in Economics, Finance and Information Systems at Loyola University Chicago.

Explanation of design goals, assumptions and requirements

- David introduces the concept of e-government. The interviewee states that he was not familiar with the concept of e-government as a separate concept, but recognizes the three actor groups involved from his economics background.
- David explains a number of challenges of the EU, and which functions of blockchain technology can potentially solve these. The interviewee likes this structure, as this presents a problem looking for a solution and not the other way around. He indicates that he is not familiar with these challenges, as he focusses on other industries.
- David presents the multi-actor and systems complexity that is leading to institutional and technological uncertainties. The interviewee states that this structure is presented clearly. He indicates that a potential addition would be also uncertainties about the ownership of the network, instead of only uncertainties of control in the network.
- After the knowledge gap and the research objective is introduces, the interviewee states that the gap and objective are clear. He recognizes the need for an assessment tool that indicates the fit for a blockchain use case, and argues that this could be valuable for multiple industries. Also, he argues that it might be good to include the analysis on whether these public organizations are able to understand the 'futuristic' technology that is the blockchain. David indicates that one of the factors that is addressed in the tool is the ability to understand the technology itself, and the complexity around it.
- Regarding the clearness of the requirements of the tool, the interviewee indicates that these are in his eyes complete.

Explanation of the six elements that are used in the assessment tool

- David presents the six elements that are incorporated in the assessment tool. The interviewee indicates that this is not immediately clear. He states that if this is made more generic, than it can be more understandable. He also states that he recognizes the aspect that he deems relevant for considering when deciding to experiment with blockchain. He states that when he thinks about architecture, that he sees the relevance of making it more hierarchical. This is currently only sort of reflected, and could be improved to make it clearer. Perhaps by clearly indicating what the layers are and what they mean.

Explanation of the Blockchain Assessment Tool

- David provides a walkthrough of the blockchain assessment tool and the three steps. The interviewee indicates that it is clear why there are three steps, and it is logical to first assess the fit, than think about the design and then map the impact. There are no elements missing according to interviewee, and he recognizes this approach in the way he assesses the fit of other types of technologies for companies.
- The interviewee indicates that a potential element that good be added to the tool is around the governance side. He indicates that this an important element of the design of the system, and could be made more explicit.

Step 1: Mapping the blockchain fit

- As David explains the various critical factors that are identified, the interviewee expresses his concern about having the privacy sensitive information critical factor included in the critical factors, as there is no consensus in whether blockchain systems really provide additional security over centralized systems. As long as it is debated, maybe this should not be included as a critical factor.

- Regarding assessing the blockchain fit and a certain use case falling into one on the quadrants, the interviewee states that he likes this approach as it is not black and white, and provides nice overview into the potential.
- The interviewee indicates that he sees how this design makes sense in the light of this thesis. The overall feedback of the interviewee is to include more of the open versus closed infrastructure discussion, as this is essential for blockchains in governments. The interviewee indicates his interest in seeing how Blockchain can present the next step in e-government development.
- Also, the interviewee raises the question of when a public administrator falls into the maybe quadrant, then it is interesting to see what the main drivers are that would push them to a yes vs. no; is it cost, ease of implementation/ exploration.
- Overall, the structure of mapping the blockchain fit makes complete sense according to the interviewee. He recognizes the need to look at the critical factors first, and the three steps are also clear. He generally uses a similar approach when looking at the information infrastructure of companies, where people, process and technology are central. All these elements are found in this step.

Step 2: High level blockchain design

- David introduces the workings of step 2. The interviewee indicates that he likes the practicality of this step. A potential addition could be the incorporation of the trade-offs between the criteria. So if you want to have full scalability, you can't have a maximum systems reliance, for example. Insights in these trade-offs can be valuable, as you highlight the different dependencies.
- The structure of this step is in line how systems should be designed, indicates the interviewee. This is clear and makes it easy for the user.

Step 3: Mapping the impact

- David explains the three layers, and the interviewee indicates that he recognizes the three layers and that they make sense.

Usability of the tool

- The scores that the user has to provide to the different factors make it user-friendly. A potential addition that would enhance the usability is the addition of business rules in the second step, and this allows users to understand the trade-offs in the blockchain design.
- The interviewee states that he likes the way the tool is structured and he deems this to be very usable. He argues that this tool can be generalized to other industries as well, like broadened to manufacturing
- The third step is more of a thought exercise than a practical tool, and the interviewee indicates that more development could be done for this step.

G1.4 Lex Hoogduin, University of Groningen

22/05/2017

Achtergrond

Lex Hoogduin is Professor Economics of Complexity and Uncertainty in Financial Markets and Financial Institutions aan de Universiteit van Groningen. Ook is hij Non-excutive bestuurslid van de London Stock Exchange groep, Voorzitter van het bestuur van LCH, en oprichter van GloComNet, the Global Complexity Network. Hij is macro-econoom en heeft verschillende rollen vervuld bij de Nederlandse Bank en de EcB. Als oprichter van GloComNet ontwikkelt hij een framework die ervoor zorgt dat organisaties en individuen met complexiteit en onzekerheden kunnen omgaan, genaamd FAUC. Hij is in blockchain geintresseerd geraakt in 2014, toen hij sprak op het eerste Bitcoin Congres (nu Blockchain Congres). De onzekerheid en complexiteit van deze innovatie is waar zijn intresse ligt.

Uitleg van het onderzoeks doel en redenering

- David introduceert de verschillende onderdelen waar het onderzoek zich op focust, waaronder complexiteit en onzekerheid. De gesprekspartner ligt toe wat hij verstaat onder complexiteit en onzekerheid. Onzekerheid is een situate waar niet de gehele set met variabelen bij een beslissing van anderen bekend zijn, dus dat er per definitie nieuwe aspecten na de beslissing kunnen gebeuren. Complexiteit is een groot aantal interacterende agenten of elementen, die adaptive zijn. Deze grotere heterogenteit heeft de consequentie dat je niet alle informatie kan centralizeren. Dit presenteert een structureel kennis probleem. Per definitie moet een mens dus beslissingen nemen in onzekerheid.
- David vraagt zich af hoe de gesprekspartner de complexiteit zich ziet uiten in een blockchain system. De gesprekspartner geeft aan dat blockchain een onderdeel is van het maatschappelijk netwerk, en een vehicle in transacties kan zijn. Traditioneel gebruiken we contracten om ruil te faciliteren. Omdat we onzekerheid hebben, stellen we contracten op. We hebben vier verschillende basale instituties gecreerd om toch interactie in onzekerheid mogelijk te maken: wetgeving (contracten), geld, taal en boekhoudsystemen. Daar overheen ligt vertrouwen: je kan wel contracten sluiten, maar je moet vertrouwen dat de andere partij zich aan het contract houdt. Daarbij leven we ook per definitie in een situatie van schaarste. Schaarste betekent concurrentie en dat is de reden waarom we altijd moeten handelen en transacties plaatsvinden. Blockchain verandert de manier van transacten door het vertrouwen te verzekeren in technologie, juist daar waar afgelopen decenia een kink in de vertrouwenskabel is gekomen. Het is een economisch alternatief to trusted intermediaries gevormd zijn in onze samenleving, aangezien het een alternatief mechanisme is om transacties te valideren. De gesprekspartner geeft aan dat hij de DAO niet kent.
- David geeft aan wat dit onderzoek verstaat onder onzekerheid, en introduceert de lens waarmee het onderzoek kijkt naar de transacties. David roept de vraag op of contracten waterdicht kunnen zijn, en of blockchain dit kan garanderen. De gesprekspartner geeft aan dat dit een fundamentele reden is dat we daarom intermediaries hebben gevormd in economische systemen. Waterdichte contracten bestaan niet, en er zijn altijd nieuwe toekomstige situaties die kunnen ontstaan ondanks een contract. Een rechter moet altijd een judgement maken als er zich een nieuw geval voordoet. Je kunt nooit een volkomen waterdicht expert systeem maken, en je hebt altijd menselijke judgement als aanvulling nodig. Dit betekent misschien ook dat je in je oordeel ook moet meenemen dat het blockchain systeem niet volledig mens vervangend is. Het kan nog steeds een heel nuttige tool zijn vanuit technisch oogpunt en economisch oogpunt.
- David introduceert het perspectief van blockchain voor overheden. De gesprekspartner geeft aan dat hier veel verschillende opvattingen over zijn, vooral over de vraag hoeveel overheid je ndoig hebt. David vertelt over de DAO, en de implicaties van de hack ervan. De gesprekspartner geeft aan dat hij ziet hoe dit relateert aan ethiek die nodig is voor sommige judgments. Het juridische rechtsysteem is een primaire functie voor de overheid, dit definieert de formele regels. Maar in menselijke systemen heb je ook altijd te maken met ethiek: je kunt niet alleen een beslissing nemen op basis van het rechtssysteem alleen. Smaken en voorkeuren kan je niet perfect modelleren, wat ook te zien is in de moeilijkheden in kabinetsvorming.
- David presenteert de vraag of een blockchain altijd permissionless moet zijn binnen overheden of dat het ook permissioned kan zijn. De gesprekspartner geeft aan dat het de vraag is wat je open gooit binnen het systeem. Het zou kunnen dat als je verschillende open opt-in communities

krijgt, dat het het begrip overheid helemaal verandert. Het is een enorm disruptieve technologie voor overheden, omdat het de core functies van de overheid raakt als het technisch heel goed werkt. Het ligt voor de hand dat overheden om deze reden de infrastructuur willen gaan reguleren, omdat het een bedreigend systeem is.

Introductie institutionele en technische onzekerheid

- David introduceert de institutionele en technische onzekerheden bij blockchain implementatie in overheden. De gesprekspartner geeft aan dat deze onzekerheden in zekere zin nog overwinbare omstandigheden kunnen zijn. Er is nog een overkoepelende onzekerheid: het blijft een non-computational marktspel en het zal atlijd door de gebruikers ervan geopereerd moeten worden. Het feit dat het mensen blijven die opereren zorgt nog steeds voor de inherente onzekerheid, want de samenleving is per definitie complex. De gesprekspartner beargumenteert dat er een minimale core nodig in om een systeem te laten functioneren: regels en regels die regels laten veranderen. Dit laatste is erg lastig in zowel overheden en blockchains: het aggregeren van voorkeuren is moeilijk en per definitie een imperfect process. Dit wordt normaal gesproken opgevangen door een constitutional government waarvan de vorm van de regels niet 'gehacked' kan worden. De gesprekspartner geeft aan dat je daarom nooit helemaal de overheid kan automatiseren.
- David vraagt zich af op de gesprekspartner ook de machtsverschuiving naar een techno-elite ziet bij open blockchain system. De gesprekspartner stelt dat dezelfde type vragen bij blockchains als bij overheden worden opgeroepen: wie moet er de macht hebben? Collectieve processes zijn er altijd elites die aan de macht komen, bij zowel blockchains als overheden. Daarom moet je eisen aan de vorm van de regels stellen, dan bouw je check & balances in het systeem. Een open blockchain system dringt de rol van de overheid terug volgens de gesprekspartner. Ook haalt het de dwang weg in sommige processen.

Introductie ontwerp Blockchain Assessment Tool

- David presenteert het ontwerp van de blockchain assessment tool. De gesprekspartner vraagt zich af wie de gebruiker is van de tool. De user maakt veel verschil in het ontwerp van de tool. David geeft aan dat het voor EU Instituties en organizaties is om de tool te gebruiken. De gesprekspartner geeft aan dat de libertaire manier van kijken naar de potentie van blockchain dan moeilijk te verwerken in het ontwerp is.
- De gesprekspartner geeft aan dat hij de structuur begrijpt en drie stappen herkent. Hij ziet ook overeenkomsten met het FAUC model wat hij met zijn eigen bedrijf heeft ontworpen. Hij geeft ook aan dat wellicht het model iets meer cyclisch dan linear moet zijn, aangezien je hier een complex probleem aanpakt. Door feedback loops te creeren, zorg je voor een leerprocess, wat essentieel is in het begin van een innovatie project. Er zijn meerdere effecten die op elkaar inwerken in dergelijke problemen, en die kan je nooit alleen proces analytisch op papier oplossen, maar daar moet je van leren. De gesprekspartner ziet mogelijkheden om deze feedback loops in te passen.

Algemene bruikbaarheid

- De gesprekspartner vindt het model zeker bruikbaar. Hij geeft aan dat doordat hij er met een complexiteitsbril naar kijkt, je er met dit model alleen nog niet bent. Zodra deze tool embedded wordt in een groter, meer cyclisch process zoals Design Thinking, dan verhoogt het nog de bruikbare waarde voor dit complexe probleem.

G1.5 Joachim Schwerin, European Commission, DG GROW

23/05/2017

Background

Dr. Joachim Schwerin is Principal Economist in the unit responsible for SME access to finance within the Directorate-General Internal Market, Industry, Entrepreneurship and SMEs ("DG GROW") of the European Commission. He is in charge of designing policy measures to improve SME access to capital markets as well as alternative forms of finance, including crowdfunding. Moreover, he is developing the policy approach of DG GROW towards FinTech and its applications for SMEs. He has been part of the EC for 16 years now, and is part of the FinTech taskforce of the EC.

Explanation of research goals and assumptions

- David asks about the view and experience with blockchain of the interviewee, and whether he also looks at other applications then finance. The interviewee indicates that the EC is one of the leading actors in this field, as it is their task to set framework conditions. He indication that blockchain is an enabler to foster real economic activity. It presents a completely new way of doing business, as enables the democrazation of the economy. It puts the power in the hands of the economic agents, bring supply and demand directly to each other. The transition from what we now have to what we get is critical in this respect. It has enormous potential, but is also a big threat to the traditional intermediaries in these markets. The problems are often related to the legacy systems that include banks, politics and other intermediaries.
- David presents the line of reasoning, and the research goal and objective. The interviewee indicates that this is an ambitious goal, as it is difficult to create a tool that applies to every policy field. Every policy field (in the EC) looks at blockchain from a different perspective. For example, looking at the virtual currency aspect of blockchain, the large impact is often stretched. To make this tool very practical, it should be specified to each policy field, as it is questionable whether one tool can be unified for all sort of blockchain applications.
- The interviewee indicates that the need for an assessment tool is reasonable and also reflected in a line of discussion within the EU. There are currently two lines of discussions on this topic: 1) the discussion that reflects the EU as enabler of market solutions, that does not develop the solutions itself but create framework conditions, and 2) the discussion on whether to create the blockchain infrastructure ourselves. This research is in line with this second line of discussion

Introduction of research approach and elements of the tool

- David introduces the design science approach used in this research. The interviewee indicates that he likes this approach, as it incorporates both the knowledge base and insight from the environments. Assessing blockchain technology includes market learning, which is reflected in this approach.
- David introduces the six elements for the design of the blockchain assessment tool. The interviewee indicates that he likes the hierarchy in the blocks, which helps to structure the discussion. He indicates the importance of the technical perspective, as interoperability is an important topic in this field. Also the decision-making process is an important element, because if the tool does not match the process, it is much less valuable
- The interviewee raises the fact that he questions some of the relationships between the elements. He indicates that complexities will always exist and that is currently sounds negative, but these are more environmental characteristics than anything else, so he questions the relevance of making this very explicit in the research.
- The interviewee indicates his concern on the potential overlap between process and organizational factors. These might strongly interact. David explains these factors in more detail. The interviewee argues that these factors can also be considered external and internal factors, which could make it less confusing.

Introduction of the blockchain assessment tool

- David introduces the 3 steps of the blockchain assessment tool. The interviewee indicates that the three steps make sense. The separation of the steps and the structures also clearly make sense.
- The interviewee indicates that the European Commission generally do step 1 and step 3, and that step 2 is often done by market parties. David questions whether only the very high level design of

the blockchain (blockchain type & consensus mechanism), is not also done by the commission. This because the blockchain architecture impacts the way the blockchain system can effect society, the network and the organization. The interviewee indicates that he agrees with this, as is also done other IT innovation decisions in the EC, so potentially the wording is somewhat confusing,

- The interviewee argues that it as an interesting question on who is doing the issue, also at what level. As there are different layers of where blockchains can be implemented (local, regional, country-level or European), the issue of subsidiarity comes into play. Some countries are already very far in the development of some blockchain system, and there more centrally issues European solutions might not be accepted. The process criteria in step 2 is an area where in practice a lot of discussion emerges, and the input of these criteria is always relative. Potentially this can be mitigated by creating some feedback loop and tailoring the tool to the specific area of policy.

Introduction to effects of blockchain implementation

- David introduces the effects of blockchain implementation for governmental processes. According to the interviewee, this overview raises a lot of important aspects. He indicates that he is missing one important effect: the loss of jobs. As there is automation of processes by smart contracts, it is inevitable that jobs will be lost in legacy systems. This is very important to politicians and policy makers. If you have a decision-making process as such in an EU Institution or Body, you always have two agendas: 1) the enterprise efficiency agenda and 2) the keep control agenda. Policy-makers and politicians will to some extend keep control and highlight the problems in security in these systems.

General usability

- The interviewee indicates that the general usability is high. The sequence and definition of the separate steps is useful and helps to structure the discussion. In these decision-making processes, generally less than 10% of the participants understand the blockchain. Structuring the process as is done in this tool, helps to provide guidance.
- Additional research could focus on case studies, especially for cases that already have started experimenting with blockchain. This provides insights in how these decision-making processes currently are structured, and can help to tailor this blockchain assessment tool.

F.1 WORK BREAKDOWN STRUCTURE OF THIS RESEARCH

This appendix contains the Work Breakdown Structure of this research, as displayed in Figure 40.

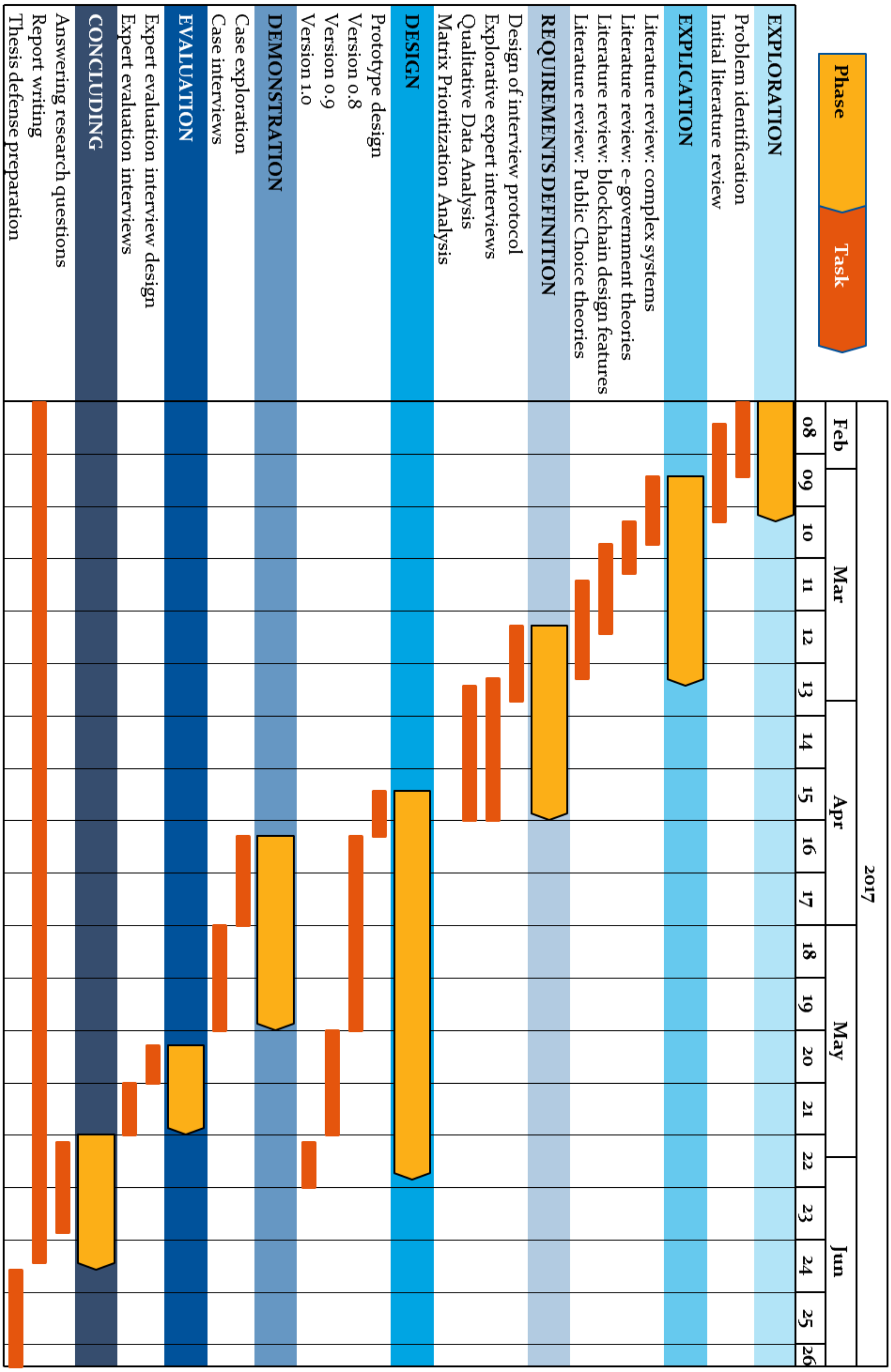

Figure 40. WBS