Blockchain Technology:

A Policy Instrument

by

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My concern is that decision makers are too
often caught in traditional, linear and
nondisruptive thinking, or too absorbed by
immediate concerns to think strategically
about the forces of disruption and
innovation shaping our future.

— ***Klaus Schwab***

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 1 March, 2020

Abstract

As we continue to progress into the Fourth Industrial Revolution the need for technologically advanced government administration tools has become more evident as governments are struggling to remain influential and effective in implementing public policy. In addition to the challenges of technological advancement, governments also continue to face internal issues of corruption, inefficiency, and distrust, which influences its ability to produce value for citizens and further national development. This research identifies the innovative technology *blockchain* as a tool to achieve goals and address various existing problems within the processes of public policy implementation. A literature review identified a research gap indicating that *no research* has been undertaken by policy scholars to explore this technology as a policy instrument, despite various blockchain scholars recognizing it as an 'instrument of government'. To address this lacuna, a qualitative exploratory research approach was used to explore whether blockchain can fulfil the functions of policy instruments. This study applied a newly constructed analytical framework called the *Īnstrūmentum framework.* It was used to analyse data on the applications of blockchain technology within government to determine if it can fulfil the functions of a policy instrument. This study proceeded from the premise that if blockchain can fulfil the functions associated with policy instruments, then those who study policy instruments should devote attention to it.

The data examined was drawn from publicly available sources which focus on the application of blockchain technology for 1) national land registries, 2) national elections (voting) and 3) citizen identity management. The findings produced by this research concluded that blockchain technology can fulfil the functions of policy instruments in a way that has both theoretical and practical implications. Firstly, considering blockchain can fulfil the functions associated with policy instruments, it is necessary for policy scholars to study this technology in depth. Furthermore, from a practical understanding, as a policy instrument, blockchain has the potential to address various real-world issues (corruption, inefficiency, lack of accountability and transparency) within existing techniques of policy implementation. This technology could be highly beneficial to governments for policy administration. This thesis recommends that governments, especially in developing nations, rethink traditional governance mechanisms and policy instruments, and embrace this new age technology for future policy implementation and digital public administration in the Fourth Industrial Revolution.

Uitvoerende Opsomming

Namate ons voortgaan met die Vierde Nywerheid revolusie, het die behoefte aan tegnologiese gevorderde regerings administrasie hulpmiddels duideliker geword namate regerings sukkel om invloedryk en effektief te bly in die uitvoering van openbare beleid. Benewens die uitdagings van tegnologiese vooruitgang, het regerings steeds probleme met korrupsie, ondoeltreffendheid en wantroue in die gesig, wat 'n invloed het op die vermoë om waarde vir die burgers te produseer en nasionale ontwikkeling verder te bevorder. Hierdie navorsing identifiseer die innoverende tegnologie *blockchain* as 'n instrument om doelwitte te bereik en verskeie bestaande probleme binne die prosesse van die implementering van openbare beleidsrigtings aan te spreek. In 'n literatuuroorsig is 'n navorsing gaping geïdentifiseer wat aandui dat beleidstudente *geen navorsing* onderneem het om hierdie tegnologie as 'n beleidsinstrument te ondersoek nie, ondanks verskeie blockchain-wetenskaplikes wat dit as 'n 'instrument van die regering' erken. Om hierdie leemte aan te spreek, is 'n kwalitatiewe ondersoekende benadering gebruik om te ondersoek of blockchain die funksies van beleidsinstrumente kan vervul. Hierdie studie het 'n nuutgeboude analitiese raamwerk, genaamd die Īnstrūmentum raamwerk, toegepas. Dit is gebruik om data oor die toepassings van blockchain-tegnologie binne die regering te ontleed om te bepaal of dit die funksies van 'n beleidsinstrument kan vervul. Met hierdie studie is uitgegaan van die veronderstelling dat indien blockchain die funksies verbonde aan beleidsinstrumente kan vervul, diegene wat beleidsinstrumente bestudeer, daaraan aandag moet gee.

Die data wat ondersoek is, is verkry uit bronne wat in die openbaar beskikbaar is, wat fokus op die toepassing van blockchain-tegnologie vir 1) nasionale grond registrasie, 2) nasionale verkiesing (stem) en 3) bestuur van burger identiteit. Die bevindings wat deur hierdie navorsing gelewer is, het tot die gevolgtrekking gekom dat blockchain-tegnologie die funksies van beleidsinstrumente kan vervul op 'n manier wat beide teoretiese en praktiese implikasies het. In die eerste plek, as die oorweging van blockchain die funksies verbonde aan beleidsinstrumente kan vervul, is dit nodig dat beleid studente hierdie tegnologie in diepte bestudeer. Verder, uit praktiese begrip, as beleidsinstrument, het blockchain die potensiaal om verskillende probleme in die wêreld aan te spreek (korrupsie, ondoeltreffendheid, gebrek aan verantwoordbaarheid en deursigtigheid) binne bestaande tegnieke vir die implementering van beleid. Hierdie tegnologie kan voordelig wees vir regerings vir beleid administrasie. In hierdie tesis word dit aanbeveel dat regerings, veral in ontwikkelende lande, die tradisionele bestuur

meganismes en beleidsinstrumente moet heroorweeg en hierdie nuwe tegnologie omhels vir toekomstige implementering van beleid en digitale openbare administrasie tydens die vierde industriële rewolusie.

Preface and Acknowledgements

This research journey truly was an exploratory one even before I put pen to paper, or in this case, fingers to keys. I had originally started this research project with very little knowledge about either blockchain technology or policy studies. My love for blockchain bloomed after participating in the Bitcoin boom of 2017. I remember not really understanding what it was or how it works, but my cryptocurrency investments were growing along with the hype, which made me happy. By the end of 2017, however, the cryptocurrency market saw a significant decrease in value which many considered the crypto-bubble bursting. This put my interest in digital currencies on the side-lines and allowed me to start my journey to better understanding the underlying technology, which was being compared to the Internet 2.0 as a disruptive technology for the Fourth Industrial Revolution. I became fixated on understanding the technology which many spoke of as a tool to redesign the fabric of economic and political interactions. The other side of this journey began in my third year at university. My "Introduction to policy studies" class was in fact presented by the supervisor of this thesis, Dr Ubanesia Adams-Jack. This introduced me to the world of policy implementation, the multiple factors involved in the implementation process and, most importantly, how complex public administration and governance can become in confronting all sorts of challenges. This idea of public policy and what I understood of blockchain technology sparked an idea to explore blockchain within the policy implementation process, and the potential it could have as an instrument to assist government (especially in developing nations) during a time when corruption, mismanagement and distrust in public administration are alive and well.

To my wife, Hannah de Jongh, you are my node which allows for functionality. You helped me get through this and I am so grateful to have you in my life. You carried me in times when I had no hope and pushed me to be the best I can be. Thank you, I love you.

To my parents (Ian and Elmaré), sister (Tiané) and grandparents (Hennie; Margot Louw and Minnaar; Annette Pieters) this would never have been possible without you. You are the miners I needed to get the job done and brought me to where I am today. You inspire me more every day and I look up to you more than you could ever understand. Lief vir julle.

To Dr Adams-Jack, my consensus mechanism. You did this with me knowing nothing about blockchain, yet your desire to learn inspired me to break barriers. Your level of professionalism and dedication to understanding new topics goes beyond the call of duty. Thank you for everything you have done for me. This was a tough journey, but one I will remember for the rest of my life.

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Blockchain Glossary and Abbreviations

51% Attack – A form of cyber-attack on a blockchain network that results in a group of people (miners) controlling over 50% of the network's mining hashrate. These miners therefore take control of the blockchain and can manipulate information on the network.

Blockchain Application (Use-case) - An example where blockchain technology can be implemented or used.

Bitcoin - The first cryptocurrency to run on a blockchain network

Block - Blocks are immutable packages of data stored on a blockchain network.

Consensus mechanism - The computational process responsible for reaching consensus on the blockchain ledger's contents.

Cryptocurrency - A digital currency based on mathematical code. Encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds.

Cryptography - A method for securing communication using digital code.

Cryptographic Primitive - A cryptographic primitive is a low-level algorithm used to build cryptographic protocols for a security system. It's used by cryptographic designers as their most basic building blocks. These building blocks are a part of a cryptosystem, which is a suite of cryptographic algorithms needed to implement a particular security service, such as encryption functions or one-way hash functions.

DApp - An application that is open source, operates autonomously and stores its data on a blockchain decentralized network.

Decentralization - The transfer of authority and responsibility from a centralized organization, government, or party to a distributed network.

Digital signature - Generated by public key encryption, a digital signature is a code attached to an electronically transmitted document to verify its contents on a blockchain.

E-governance - E-governance refers to governmental services that are accessible through the internet. It encompasses any government process or function in digital form. E-governance is the involvement of digital democracy, online service delivery and any form of online citizen participation.

Hash - A function that takes an input and then outputs an alphanumeric string known as the hash value or digital fingerprint. The hash is used to confirm transactions on the blockchain.

Immutable - An inability to be altered or changed over time. All data once written onto a blockchain can never be altered.

Mining – This is the process by which transactions are verified and added to a blockchain network. This process solves cryptographic problems using a significant amount of computing resources.

Node (Full Node) - A computer connected to the blockchain network. A full node is a program that can fully validate transactions and blocks on a blockchain peer-to-peer network.

P2P - Peer-to-peer (P2P) refers to the decentralized interactions that happen between at least two parties in a highly interconnected network. In this network participants deal directly with each other through a single mediation point without the need for a third party.

Proof of stake - Proof of stake is a type of consensus algorithm by which a cryptocurrency blockchain network aims to achieve distributed consensus. A person can mine or validate block transactions according to how many coins he or she holds.

Proof of work – Algorithm used to confirm transactions and produce new blocks to a blockchain. With PoW, miners compete against each other to complete transactions on the network and get rewarded.

Protocol - A set of rules that dictates how datum is exchanged and transmitted.

Wallet – A file that links to a blockchain network and stores private keys needed to access information. A wallet is made up of software to view and create transactions on the blockchain it was designed for.

Chapter One: Introduction

1.1 Background and rationale

As we continue to progress into the Fourth Industrial Revolution, the technology most likely to have the greatest impact has already arrived, and it is not automated robotics, big data or artificial intelligence, as many might think (Tapscott & Tapscott, 2016). It is called *blockchain* and came into existence as the underlying technical system of Bitcoin, a digital currency that became one of the most talked about topics of 2017 because of its ever-increasing value as a virtual asset. What started as "a solution to the double-spending problem" (Nakamoto, 2008:4) grew to become a global phenomenon as scholars, mainstream media and critical thinkers began raising awareness of what digital cryptocurrencies are and, most importantly, what blockchain could mean for political, business and social life.

The idea and configuration of blockchain technology came into existence after the financial crisis of 2008. During this difficult time, there were concerns about a global financial failure of government-controlled currencies and many affected citizens sought an alternative free of the institutions that had caused this financial catastrophe (Penrose, 2014:529). Some advocated returning to the gold standard, while others wanted to return to silver as legal tender. Although possible, these suggestions were not viable in our technologically advanced systems. This gave rise to a new idea to issue "digital gold" that could function in our digital age while maintaining its value in a way that regular currencies could (Penrose, 2014:530). Soon after, the idea of digitizing currency was introduced by an unknown individual or group called "Satoshi Nakamoto" who, perhaps propitiously, released a document titled *Bitcoin: A Peer-to-Peer Electronic Cash System* on the 31st of October 2008 (Tapscott & Tapscott, 2016:4).

The document contained the explanation and configuration for a digital cash system that could "act as a new financial system" according to its creator(s) (Nakamoto, 2008:2). This system would "*allow any two willing parties to transact any form of digital value* (in this case Bitcoins) *directly with each other without the need for a trusted third party*" (Nakamoto, 2008:3). Nakamoto's (2008:3) vision was to shift away from the need to trust third-party financial institutions who arguably caused the crash of 2008, and instead to utilize a "trustless" system powered by computational power. This new system would be governed by rigid protocols to ensure efficiency, security and transparency free of human error (Tapscott & Tapscott, 2016:13). Blockchain had initially been created as a 'digital ledger system' to securely store and distribute financial information. As it gained popularity in more recent years, however, research produced multiple other potential applications in all "trusted-service" industries who depend on third parties or bureaucracy. This gave rise to a new outlook on the potential of this disruptive technology as a "*general-purpose technology*" (Kane, 2017).

As research has progressed, it became evident that blockchain can act as an immutable proof of public records capable of storing and transferring not only any digital currencies, but also proof of assets, audio, contracts or other digital documents on a decentralized distributed network similar to that of the internet (Sultan, Ruhi & Lakhani, 2018:48). It showed the possibility of sharing digital assets and information between different agents with unquestionable transparency and trust – all the while without a controlling central authority. (Sultan *et al.*, 2018:49). Based on this understanding, blockchain can potentially be applied to circumvent any services where third-party intermediaries are needed to coordinate valuable information (Wright & De Filippi, 2015:24). Moura and Gomes (2017:13) also found that with blockchains design that, apart from its utility, the way information and value is stored would become more controlled by the individual and any deviation from the truth would be detected by the blockchain security protocol. It was this understanding of a *decentralized democracy* that sparked interest from all over the world in exploring its applications in government. Blockchain became known as a potential "trust machine" in a sector notorious for its tendencies towards corruption (Jun, 2018:2).

1.1.1 The Fourth Industrial Revolution

Schwab, who coined the term in 2015 states that "*the fourth industrial revolution is characterised by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries*" (Levin, 2017:5).

The Fourth Industrial Revolution marks an era where the development of advanced social technologies such as the internet of things (IoT), robotics, artificial intelligence (AI) virtual reality (VR) and blockchain are changing the way all industries, societies and governments function. It is a time characterized by innovation and societal changes which have left governments and bureaucratic organisations in an increasingly difficult situation as they are unable to adapt quickly enough with their existing outdated methods. This has created a range of new uncertainties and challenges with regards to public policy, governance and the future of bureaucratic institutions (Levin, 2017:6).

In contemporary times there has been a rise of new information communication technologies (ICT) and social technologies allowing citizens to engage more effectively with governments, contribute to decision-making processes and voice their opinions. Similarly, governments have simultaneously incorporated and progressively made use of new technological powers to increase their control over populations and these processes of citizen engagement through elaborate surveillance networks and administrative abilities in digital networks (Schwab, 2015:6). The reality, however, is that the Fourth Industrial Revolution is progressing at a rapid pace that is generating social impacts and technological changes that are challenging legislators and regulators (Prisecaru, 2016:59; Xu, David & Kim, 2018:92).

Governments, especially in developing nations, are slowly falling behind as a result of issues of centralised government, slow technological innovation, industry concentration and low trust in bureaucracy (Schwab, 2015:6) This is pressuring them to reconfigure their existing approach to policymaking and public engagement (Schwab, 2015:7). The failure of the developing country governments to embrace the digital-driven Fourth Industrial Revolution may result in their being left behind (Manda & Dhaou, 2019:244). Government systems and public authorities' ability to adapt will ultimately determine whether they will "survive", while uncertainties pertaining to governance continue to increase. If government agencies are able to embrace this technological change and the necessary levels of transparency and efficiency, they will maintain an essential role and survive this new era of technological advancement (Manda & Dhaou, 2019:245)

Existing government systems of decision making and public policy evolved from the Second Industrial Revolution, which marked an era when policy makers had enough time to inspect a particular issue and develop an appropriate response or regulatory framework (Schwab, 2015:7). This approach to policy, however, is less feasible in contemporary times as the Second Industrial Revolution was linear and mechanistic with a "top down" approach to decision making, regulation and implementation (Schwab, 2015:6). There is a need for governance to be more flexible, agile and adaptive, which means existing policy implementation processes must be re-evaluated (Schwab, 2015:6). Government will need to embrace the use of new techniques and seek to understand the political nature of new age technologies and their impact on governance and society. If embraced successfully, "this revolution could create new opportunities and help developing countries leapfrog stages of development and align with developed markets by implementing emerging technologies such as blockchain and other advanced technologies" (Manda & Dhaou, 2019:244).

1.1.2 What is a blockchain and how does it work?

This section explains the composition and utility of blockchain before clarifying the aims of this research project. A consideration of the detailed technical underpinnings of blockchain is beyond the scope of this paper and it is therefore only necessary to review the basic functionality and features of this technology to foster an understanding of its technical attributes and how they work in the real world.

At its core, blockchain technology uses cryptographic primitives to derive its capabilities, and gained its reputation as a secure way of documenting and transferring data through its mathematical and technological configuration (Atzori, 2015:3). A blockchain is a decentralized distributed network that consists of a digital chain of virtual blocks governed by interlinked computers called *nodes*. Each generated block on the network contains an aggregated set of data which can represent any value, depending on the purpose of that specific blockchain (Nofer, Gomber, Hinz & Schiereck, 2017:183).

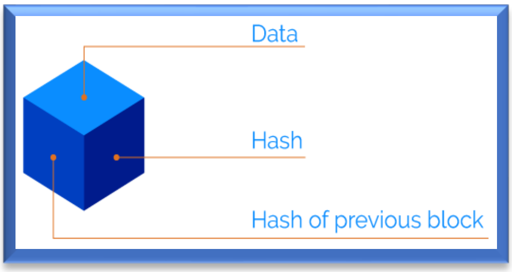

Figure 1: A block in the chain (Deloitte, 2018)

A block can store digital money and transaction details, or it can be designed to store digital certificates of land ownership, capture votes during an election or secure something as simple as birth certificates (Nofer *et al.*, 2017:183). The first factor which makes blockchain different from existing networks is how data are stored. In addition to the data stored within each block, encrypted details about the parties involved in each transaction is recorded and protected by the *Merkle Tree hash function*. Each block contains a *hash key* and this hash is a unique value generated by *miners*. Miners are computer owners who contribute computing power and energy to the network to validate new blocks for a blockchain. To generate a valid hash key, participating miners compete to solve complex math problems from a string of text to prove their legitimacy, while processing ongoing transactions (Ankalkoti & Santhosh, 2017:1757)

This process is enforced by the blockchain's *consensus mechanism*, which makes sure all nodes and miners are synchronised with each other and agree on which transactions are legitimate and added to the network. Once generated, a hash key (64-digit hexadecimal number) can be compared to a fingerprint: they are all unique and essential to identifying, creating and validating new blocks on a blockchain network (Khudnev, 2017:11). What makes this hash key so significant is the fundamental role it plays in maintaining the validity of transactions on a blockchain network. Hash keys act as time stamps to maintain the chronological order of blockchain transactions. What this means is that each block on a blockchain network contains the hash key of the previous block all the way back to the "genesis block" which refers to the first data block created and validated by miners on a network (Maxwell, Speed & Pschetz, 2017:4). If a corrupt entity attempts to alter data within a block or process invalid transactions the hash key of that block would change immediately thus rendering the entire blockchain invalid as it would no longer match the existing agreed upon chronological order.

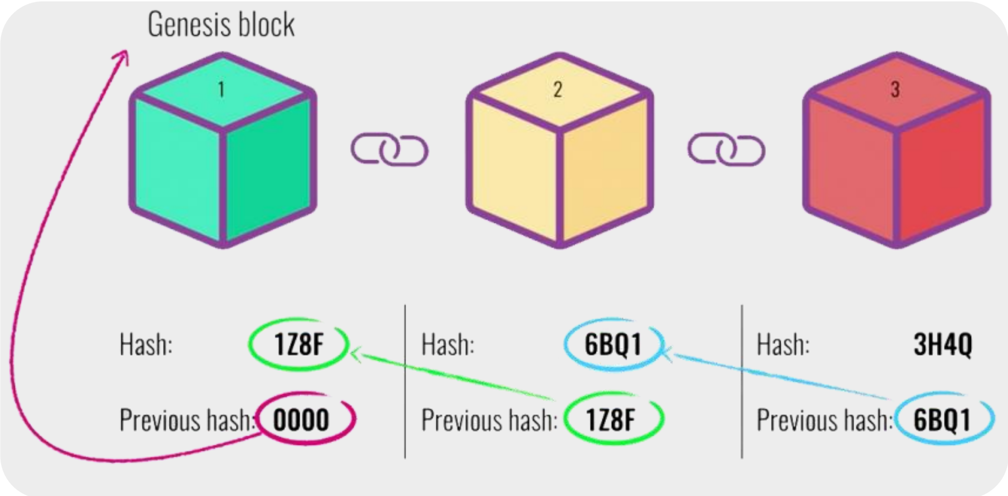

Figure 2: The Merkle Tree Hash Function (Medium, 2017).

The best way to explain this is as follows (Figure 2): if a blockchain contained only three blocks, block three will contain the hash of block two, and block two will contain the hash of block one (genesis), and this pattern continues as new blocks are added to the blockchain network, regardless of the actual data being stored within each block (Khudnev, 2017:10). To ensure the chain remains in chronological order and to regulate the legitimacy of new blocks and their hash keys, *nodes* are used to govern the network in its entirety. A node is an electronic hardware device (computer) on the network; it serves as the foundation allowing this technology to function in partnership with miners. Nodes work in a joint effort to create the server which stores the entire blockchain and runs the applicable software to process and regulate all transaction data conforming to the network protocol (Ankalkoti & Santhosh, 2017:1758).

Nodes store and validate all transactions of a blockchain network and may be compared to a traffic control officer controlling and directing traffic. Every node governs a blockchain network by containing an immutable and verifiable record of every transaction ever made on the network. Each transaction in the ledger is verified by the majority of nodes in the system through the consensus mechanism, which allows for a distributed network built on the pillars of accountability, transparency and security (Ankalkoti & Santhosh, 2017:1759).

Information can therefore *never* be erased or altered from its original state unless all nodes agree to these changes. The network is constantly monitored by the nodes to ensure the transaction chain is valid and all nodes participate in broadcasting what is occurring on the network to other nodes in real time to confirm whether the hash keys being produced are valid. A basic example will explain the notion of a node. It is easy to steal money from a piggy bank when you are home alone, but if that piggy bank was placed in the middle of a table being observed by thousands of people at once, it would be impossible to steal that money without somebody noticing and preventing it from happening (Crosby, Nachiappan, Pattanayak, Verma & Kalyanaraman, 2016:12).

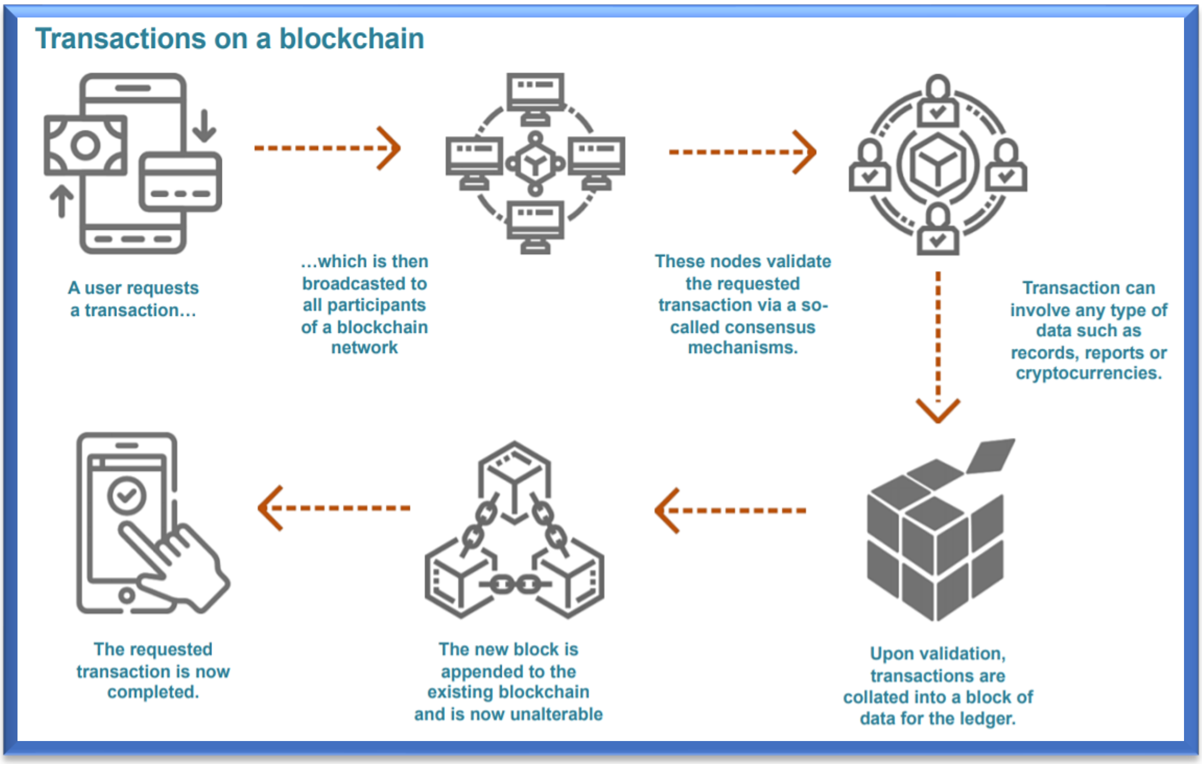

Figure 3: How does a blockchain work? (PricewaterhouseCooper, 2018)

Full nodes, miners and the consensus mechanism therefore work together to remove the need for human intervention or a controlling authority as they automatically govern all transactions and deter potential hackers and other forms of service abuse (Atzori, 2015:4). These agents work together in real time to ensure a blockchain remains both secure and fully functional to allow credible transactions to continue uninterrupted (Figure 3), even if attempts are made to hack the system (Khudnev, 2017:11). Blockchain technology is therefore significant because all data blocks are interlinked, and to gain access, a hacker would need to control more than 50% of the networks' computational power, while simultaneously altering every hash key of every block, and the entire history of commerce while bypassing the highest level of encryption. At the present time no computers exist with the capacity to hack a blockchain which is why Tapscott & Tapscott (2016) identifies it as the most secure existing network.

1.1.3 Types of Blockchain technology

In addition to the technical functions of blockchain technology, there are also different types of blockchain networks namely, private, consortium and public. It is important to understand this typology when exploring how the technology can function within different contexts.

Private blockchain: Private blockchains, also known as "permissioned blockchains" (Sultan *et al.*, 2018:53), use privileges to control who participates. In this instance consensus algorithms, e.g. proof of stake (PoS) or proof of work (PoW), and miners are usually not required, as a single entity controls block creation and validation on the network. The "permissions are kept centralized to one organization and may be public or restricted to an arbitrary extent". Here the controlling entity decides who participates in the network. Internal database management and auditing are proposed applications for this type of blockchain, e.g. the Hyperledger blockchain (Casino, Dasaklis & Patsakis, 2018:57).

Consortium blockchain: A consortium blockchain is partly private. The consensus process is controlled by a pre-selected set of nodes to ensure the network is decentralized and distributed. Here, for example, the network would have a consortium of multiple entities who each operate a node. For a new block to be added and validated, the majority of participating nodes would need to validate transactions. The right to read the blockchain (view transactions) may be public or restricted to the participants. A consortium platform provides many of the same benefits associated with private blockchain without being controlled by only one entity e.g. Corda blockchain (Sultan *et al.*, 2018:53).

Public blockchain: This type of blockchain can essentially be accessed by any individual worldwide, similarly to the internet and world wide web. This blockchain is 'permissionless' (Sultan *et al.*, 2018:53) and allows all participants the ability to read and write data on to the public blockchain. Public blockchains are open-source systems which are secured by a system of economic incentives (e.g. mining Bitcoins) and cryptographic verification backed up by consensus algorithms such as proof of work and proof of stake (Kikitamara, 2017:13). Public blockchains are open and therefore likely to be utilized by multiple entities to benefit from cutting costs, increased efficiency, improved security or automate services that would usually require intermediaries e.g. the Bitcoin or Ethereum blockchain (Kikitamara, 2017:14).

1.2 Introduction to the study

This research project explores the potential for blockchain technology to be understood as a policy instrument for e-governance. As previously stated, the “Fourth Industrial Revolution continues to merge our physical, digital, and biological worlds” (Schwab, 2015:6), and this creates a need for technologically advanced governance techniques. If governments and policymakers are to remain effective in implementing public policy, there is a need for policy administrators to provide the tools necessary to stay ahead of the inevitable societal change which will affect all aspects of governance and public service delivery (Schwab, 2015:7).

This study identifies blockchain technology as a tool to assist governments in both developed and developing countries at a state and local level to stay ahead of these inevitable societal changes as the world continues to advance technologically. The idea stemmed from an observation made early in the course of determining the direction of this project. When exploring the capabilities of blockchain, it was noted that the social and technical functions of this technology indicate that it has the potential to be understood as an “instrument” for policy implementation and regulation (Casino *et al.*, 2019:64).

This research was based on the hypothesis that there are similarities between how the core functions of policy instruments have been defined by policy scholars and the proposed functions that blockchain technology can facilitate in government when applied within the context of public service delivery. This observation, paired with the need for government to be more flexible, agile and technologically adaptive in the Fourth Industrial Revolution led the researcher to investigate whether blockchain has been explored as a policy instrument at “a time where government needs to embrace the use of new regulatory techniques” (Manda & Dhaou, 2019:244). The main purpose of this study is to assess if blockchain technology can fulfil the functions of a policy instrument.

In addition, this study aims to serve as a foundation for understanding blockchain technology within the context of its application as a policy instrument for government in an era of e-governance and inevitable digitization. Finally, this study also aims to contribute to future research exploring blockchain technology within the context of government, policy implementation and public service delivery.

1.3 Problem statement

The preliminary literature review for this project indicated that attempts were made to explore the application and benefits of adopting blockchain technology in government, but no research was found specifically exploring the use of blockchain as a policy instrument. This is problematic, as existing blockchain research indicates that it has the potential to function as an interface (Allessie, Sobolewsk & Vaccari, 2019:21) to solve problems and achieve goals (Tapscott & Tapscott, 2016:13), which are among the key traits that have been used to conceptualize existing policy instruments (Hoogerwerf, 1987:57; Bovens, Hart, van Twist & van Twist, 1996:80; Bekkers, 2007:25; Hellström & Jacob, 2017:609). The potential therefore exists for blockchain to be understood by government as a "tool" or "instrument" (Oseni & Ali, 2019; Jun, 2018; Swan, 2015; Hou, Wang & Lui, 2017) but, policy scholars have not explored this technology as a policy instrument for policy administration.

This gap is problematic as exploring blockchain as a policy instrument can help create a better understanding to how this technology can be utilized within policy implementation processes and improve public service delivery for citizens and state. This gap is also problematic as it occurs at a time when there is "a need for evidence-based policy" (Williamson, 2008:344) and governance to be more flexible, agile (Schwab, 2015:7) and politically decentralized (Nzimakwe & Pillay, 2014:17). These are all attributes associated with the application of blockchain in government (Oseni & Ali, 2019; Jun, 2018; Swan, 2015; Hou *et al.*, 2017), yet no policy scholars have explored this potentially constructive technology as a policy instrument. In order to demonstrate why those who study policy instruments should devote more attention to blockchain technology in terms of its current use and potential applications within government, it is necessary to explore the main research question of this study: **Can blockchain technology fulfil the functions of a policy instrument?**

1.4 Research methodology

This research makes use of *exploratory approach* as it is initial research into a hypothetical idea. "Exploratory studies are a valuable means of understanding what is happening, to seek new insights, to ask questions and to assess phenomena in a new light" (Yin, 1994:13). This approach was selected as it enables the researcher to "address a subject with high levels of uncertainty and lack of awareness, where there is little to no research on the subject matter" (Van Wyk, 2012:8). This exploratory approach therefore aims to generate initial ideas and a foundation for future research pertaining to blockchain as a policy instrument.

Furthermore, this research makes use of *desktop research* to collect data and is *qualitative* in nature. Desktop research, according to Peffers, Tuunanen, Rothenberger and Chatterjee (2008:8), refers to the exploration of secondary data which can be collected without fieldwork. Only publicly available sources were used to conduct this research and assess whether blockchain technology can fulfil the functions of a policy instrument. The data sources for this research will include academic journal articles, government reports and grey literature pertaining to three applications of blockchain in government. The data focus on both existing and future projects in both developed and developing countries where blockchain is utilized by government for 1) land registration, 2) national elections (voting), and 3) citizen identity management.

1.4.1 The īnstrūmentum analytical framework

Given the fact that neither policy scholars nor blockchain researchers have attempted to investigate this technology as a policy instrument, this research makes use of a newly constructed analytical framework called *the īnstrūmentum framework* to examine blockchain technology as a policy instrument. Īnstrūmentum means "instrument" or "tool" in Latin (World of Dictionary, 2020). The īnstrūmentum framework was constructed in three phases. The first was to review multiple definitions of policy instruments as described by policy scholars. The second phase identified the most prominent recurring concepts in these definitions. An integrated definition was then created by compiling the most prominent recurring concepts. This project's integrated definition of a policy instrument is:

Policy instruments are social and technical government-citizen interfaces utilized to organize social relations and create structures of opportunity for actions, achieving goals and desirable outcomes and problem-solving.

This integrated definition was used to generate the four main questions and various sub-questions to facilitate the systematic process of answering the main research question of this study. These questions were applied to data on various potential and ongoing government projects in which blockchain technology is utilized in the context of national land registries, national elections (voting) and citizen identity management. This allowed the researcher to assess whether blockchain can fulfil the functions policy scholars have attributed to policy instruments in three different public policy contexts. The īnstrūmentum framework therefore allowed the researcher to assess whether this technology can fulfil the functions of a 1) government-citizens interface that 2) organizes social relations and 3) creates structures of opportunity for actions, achieving policy goals; desirable outcomes and 4) problem solving.

1.5 Ethical considerations

This research project is limited to a desktop study. The researcher will ensure that information collected for this research is referenced in the appropriate manner and that all illustrations used will credit the original creator, website, article or book. This research will be conducted in an ethical manner and only seeks to ensure a positive contribution is made to the existing literature on blockchain technology and policy studies.

1.6 Outline of the study

Chapter One provided background to the study as well as clarified the concepts associated with blockchain technology and the political context we find ourselves in during the phenomenon known as the Fourth Industrial Revolution. This chapter also introduced the aims of this research, its relevance and how it contributes to closing the gap in existing literature. This chapter identified the research problem and stated the main research question which needs to be answered. The chapter gave an outline of the methodology and analytical framework that will be employed to analyse the data collected. Finally, ethical considerations were addressed.

Chapter Two offers a contextualisation of the study by reviewing the literature on a variety of topics pertinent to the questions and aims of the research. Prominent themes and current applications of blockchain being researched are reviewed, and what have been identified by researchers as the gaps in existing blockchain literature are addressed. This section examines existing blockchain research in computer sciences, the financial sector, private healthcare and supply chain industries. This is followed by an in-depth look at how this technology has been researched in the context of government and contextualizes the various applications it can offer with regards to data storage, financial activities and public service delivery as a whole.

The second section of Chapter Two outlines how policy instruments are defined and briefly discusses the connection between public administration, policy instruments and the implementation process. The focus here is to introduce definitions of existing policy instruments as described by policy scholars. These conceptualizations are then utilized to construct the analytical framework of this thesis. This section elaborates on the analytical framework that will be used to answer the main research question. This constructed analytical framework is called the īnstrūmentum framework. It outlines how the research problem will be explored and provides an understanding of the particular concepts within the analytical framework; it describes how these concepts will be utilized to form an analytical tool, which in turn positions this project within the larger field of policy implementation.

Chapter Three is the methodology chapter. Here a detailed discussion of the research methodology is provided to describe the research design and data-collection methods. This chapter explains why an exploratory approach was selected; it outlines the data-selection processes of this study and explains why certain sources of data were selected. Finally, this chapter provides an in-depth explanation of how the analytical framework will be applied to the three selected blockchain government applications.

Chapter Four is the results chapter. This chapter serves to produce the evidence needed to answer the main research question of this study. It provides an outline of the analytical process and presents the results that emerged when the īnstrūmentum framework was applied to three blockchain government applications. The data focused on existing and future projects in various countries where blockchain is utilized by government for 1) land registration, 2) national elections (voting), and 3) citizen identity management. To organize this chapter, the findings for the three selected blockchain applications were presented in three sperate sections. Each section consists of an introduction, responses to the four questions from the analytical framework and a conclusion. For each question, a discussion of the findings is presented after they have been answered to substantiate how the data were interpreted to produce results. This is followed by a chapter conclusion to compare the findings produced for all three applications examined. This chapter highlights the most important findings of the analytical process.

Chapter Five concludes this study. This chapter outlines the purpose of this research and addressed the question of whether blockchain technology can fulfil the functions of a policy instrument within the three selected government applications. It provides the meaning, implications and value of the results and contextualises the findings within the contemporary political climate, policy studies and blockchain research. This chapter concludes by making recommendations for future research.

Chapter Two: Literature Review

2.1 Introduction

The aim of this study is to explore whether blockchain can fulfil the functions of a policy instrument for government; so, this chapter starts by reviewing the literature on the main concepts of this study, namely *blockchain technology* and *policy instruments*. The chapter starts by discussing the rise of blockchain research and how this technology has been examined by scholars from various sectors in the last decade. It identifies the most prominent emerging themes within current blockchain research. This is followed by a conceptualization of blockchain and how scholars have defined this new type of technology.

Furthermore, the aim of this chapter was to determine 1) the current state of blockchain research; 2) the applications that have been proposed for this technology and 3) the potential benefits and limitations of this technology. These three themes are discussed within the field of computer sciences, the financial sector, private healthcare and the supply chain industry. These sectors were selected because various scholars (Jun, 2018; Atzori, 2015; Hou, 2017; Ubacht, 2018) have identified them as being the most prominent in emerging blockchain research. This sector-specific exploration of blockchain research is followed by an in-depth review of how blockchain has been researched in the context of government. The literature review of blockchain in government focused on identifying recurring themes and current gaps within this strain of blockchain research.

The second section of this chapter introduces the concept of *public policy* and provides a clear understanding of the term as it is used and applied throughout this study. The second section looks at *policy implementation* and introduces the connection between policy implementation and policy instruments. This section also highlights the importance of policy instruments in the implementation of public policy. It examines how *policy instruments* have been defined by policy scholars. Based on the most prominent recurring characteristics, this research constructed an integrated definition of what constitutes a 'policy instrument'. Finally, this section introduces an in-depth explanation of how the analytical framework was constructed and explains its purpose and design in this research project. Here the concepts within the analytical framework are explained, as well as the way it was constructed to facilitate the analytical process and how it will be applied to answer the main research question of this thesis.

2.2 The evolution of research on blockchain technology

What few people know is that the idea of "blockchain" (or how such a technology would function) was first outlined by Haber and Stornetta (1991:2). They had a vision of implementing a system where digital document timestamps could not be tampered with. Their research had initially predicted the prospect of a world in which all text, audio, picture, and video documents are in digital format on modifiable media platforms. This, they argued, would raise the issue of how to certify the point at which a file was created or last changed in an authentic manner. To address this issue, their research proposed that computational protocols be used for timestamping digital files so that it would not be possible for a user to commit fraud by back-dating or forward-dating files. These procedures would also maintain complete privacy of the files themselves and require no record-keeping by the time-stamping service, which is how blockchain functions at present (Holotescu, 2018:2).

It wasn't until nearly two decades later, however, with the launch of the digital cryptocurrency Bitcoin in January 2009, that blockchain, a technology that could provide the functions discussed by Haber and Stornetta (1991), had its first real-world application. This sparked interest and began to fuel international research in both academia and industry-related applications (Jun, 2018:2). This initial spark of interest is considered to be the Blockchain 1.0 period which predominantly focused on researching blockchain and the application of cryptocurrencies (2009 - 2014). This was followed by the Blockchain 2.0 period (2015 - present) which focused on applications extending beyond the use of cryptocurrencies to make blockchains programmable. The 2.0 period included the rise of smart contracts, namely automatized, "self-executing actions in the agreements between two or multiple parties on a blockchain" (Atzori, 2017:46) and artificial intelligence (AI). This period was quickly intertwined with the Blockchain 3.0 period (2016 – present) when blockchain gained recognition as "*a general-purpose technology"* (Kane, 2017:19).

The start of the Blockchain 3.0 period changed how researchers understood this technology which in turn enhanced the proposed software and applications across all existing sectors (Casino *et al.*, 2019:57). A study conducted by Hileman and Rauchs (2017) estimates that between 35% of blockchain research remains related to the banking industry and other financial services. This is an overwhelming majority compared to other sectors such as government which makes up roughly 13%, healthcare at 8% and supply chain management which is roughly 10% (Hileman & Rauchs, 2017:35). The remaining areas of research are divided amongst several other sub-industries such as the education sector, entertainment industry, and real estate, while a large percentage also focuses on the study of blockchain technology itself within computer sciences. (Hileman & Rauchs, 2017:35).

That being said, Zīle and Strazdiņa (2018:15) argue that due to blockchain still being in its infancy the percentages outlined by Hileman and Rauchs (2017) could still change drastically as "current expectations and adaptation cycles are highly inflated estimations". Regardless of percentages, however, Jutila (2017:15) makes a compelling argument in saying that all industries relying on intermediaries to establish trust are compatible with blockchain technology, as it is a "trust machine that functions according to mathematical code and not human subjectivity". Furthermore, the fact that this technology is being explored within multiple domains across various academic disciplines signifies the impact it has had in both a theoretical and practical sense in just a decade since it was officially introduced to mainstream audiences by Satoshi Nakamoto in 2009 (Zīle & Strazdiņa, 2018:14).

2.3 Defining blockchain technology

In recent years the concept of blockchain has become increasingly prevalent in mainstream media and is compared to the likes of the World Wide Web and the internet (Hernandez, 2017:2). The generic mainstream understanding of blockchain as "an immutable digital ledger of records linked and hence secured using cryptography" (The Economist, 2015:4) is, however, a very basic explanation and for the purpose of this study it is necessary to examine how this technology has been defined by notable blockchain scholars. The explanation of blockchains' functionality in Chapter One was to provide a technical understanding of how this technology operates in real time. The definitions outlined below look at the general concept of blockchain and how it is understood from a scientific perspective.

Among the most simplified and clear definitions of blockchain technology was one by Yaga, Mell, Roby and Scarfone (2018:4). They state that "the basic function of blockchain is to act as a tamper-resistant and tamper-evident digital ledger, which is implemented in a decentralized and distributed manner through computer nodes". Blockchain, they continue, "enables a trustless community of users to record transactions in a shared ledger which cannot be changed once published, without the need for a controlling central authority". "Trustless", in this case meaning participating users do not need to blindly trust those they are interacting with as the blockchain ensures the legitimacy of transactions. Another conceptualization for blockchain technology that is commonly used is, that it is "distributed ledger technology" or

DLT (Johnson, 2018:2). This understanding by Johnson (2018) touches upon the main characteristics of blockchain: "a technology that is decentralized, distributed, and mostly a public ledger" (Davidson, 2016:22).

Sultan *et al.* (2018:49) build on Yaga *et al.* (2018) by arguing that while at its core blockchain is just a method of securely storing and distributing information, it is the multifaceted application of blockchain technology that make it so empowering. They define blockchain as "a distributed public ledger of all transactions (e.g. currency) or digital events (e.g. uploading ID documents) that have been executed and shared among participating parties in an immutable manner" (Sultan *et al.*, 2018:50). A more elaborate explanation of blockchain technology was discussed by Atzori (2015:3). She defines blockchain as "an immutable distributed digital ledger that uses nodes to collectively regulate and govern a digital system with cryptography and consensus protocols to ensure the authentication of data transactions." Atzori (2015:4) continues by saying that what defines the true innovation introduced by this technology is that it is "a network that functions similarly to that of the internet, but it is different in that participants do not need to know or trust each other to interact." It is a system where "transactions can automatically be verified and recorded by nodes of the network through cryptographic algorithms, without the need for human intervention or a third-party authenticator" (Atzori, 2015:5).

In addition to the practical definitions of blockchain, it is important to also explore a more psychological approach to this technology. Jun (2018:2) introduces blockchain as a "social technology" and argues that if we are to fully understand blockchain within social sciences we must understand that "it goes beyond simply defining the utility of this technology". His idea of "social technology" is drawn from an analysis by Nelson and Nelson (2002). They argue that we must distinguish between social and physical technology, while acknowledging that the two concepts are also interwoven. Social technology can be described as a form of technology used to cooperate, communicate and compromise (Nelson & Nelson, 2002:265). It is a way of using human, intellectual and technological resources to influence the social structures of society, social relations and interactions (e.g. the Internet and social media). Physical technology, in contrast refers to the actual hardware that needs to be constructed to allow functionality. These technologies are interwoven because of the physical technology necessary to enable the construction and expansion of new social technology (Jun, 2018:2).

In contemporary times, when there is an increased fusing of the physical, digital and biological worlds (Schwab, 2015:6), the nature and characteristics of social technologies that weave the interaction and social fabric between individuals, groups and society as a whole become a very important subject to understand (Jun, 2018:2). Satoshi Nakamoto's blockchain technology can certainly be considered a "social technology" (Davidson, De Filippi & Potts, 2016:1) and a clear example of efforts to change how individuals interact (Jun, 2018:2).

When examining the various understandings of blockchain technology it can, therefore, be said that the recurring concepts are "decentralized" and "distributed". 'Decentralized' refers to the levels of control, which in this sense means that the system is not controlled by a central authority, but instead governed in a decentralized manner by nodes (Atzori, 2017:46). 'Distributed' refers to how the information is stored and how the network operates from separate locations (Songara & Chouhan, 2017:2). The concept of "immutable" was also a recurring notion which means that data cannot be altered once it has been submitted. The blockchain contains a certain and verifiable record of every transaction ever made. Information can never be erased or altered from its original state and is constantly monitored (Crosby *et al.*, 2016:12). Based on these observations, this research project's integrated definition of blockchain can therefore be understood as follows:

Blockchain is a social technology which is an immutable decentralized and distributed digital ledger governed by nodes, cryptography and a consensus mechanism to ensure authenticity of information without the need for a central authority.

As a "social technology" (Jun, 2018:2), blockchain has the potential to restructure government-citizen relations, interactions between companies and their consumers and social interactions between people. This is significant, as Schwab (2015:6) discusses the importance of social technologies in the Fourth Industrial Revolution and the urgent need for government to embrace the use of such technologies within processes of public administration.

2.4 A review of blockchain technology research

The following section provides an overview of existing blockchain research based on the various industries and sectors that have explored and adopted this technology. *This review of the research is not exhaustive,* but instead focuses on the most prominent research. An article by Hileman and Rauchs (2017:35) acted as a guideline for what should be focused on. This review examines the general state of blockchain research to provide context for how it is used and understood in different sectors, and finally to ascertain whether blockchain has been researched as a policy instrument for government.

2.4.1 Blockchain research in computer sciences

In computer sciences the majority of research focuses on how the computer code and physical technology can be improved to ensure better functionality of blockchain systems for future applications. The primary focus, especially in the early stages (Blockchain period 1.0), was on how improvements could be made to address technical challenges and limitations (Yli-Huumo, Ko, Choi, Park & Smolander, 2016:12). The research concentrates on the performance, scalability, security and privacy issues of blockchain, which was primarily concerned with the functionality of cryptocurrencies as Bitcoin was the first popular application on a blockchain network during these early stages. The security and performance vulnerabilities of a blockchain network were among the first factors to be questioned as the growing interest in Bitcoin as a digital asset increased the potential of economic losses for both miners and end-users (Yli-Huumo *et al.*, 2016:11).

Initial security vulnerabilities examined include computation power-based attacks, such as the 51% attack (Beikverdi, 2015), selfish mine attack (Eyal & Sirer, 2013), transaction data malleability problems (Decker & Wattenhoffer, 2014), deanonymization of participants and cryptography issues (Bos, Halderman, Heninger, Moore, Naehrig & Wustrow, 2014). As the demand for implementing blockchain in larger systems increased, issues of scalability and latency also became focus points for researchers. Batubara, Ubacht and Janssen (2018:4) state that the immaturity of the technology itself is at the basis of all existing technological challenges. They argue, however, that the vulnerabilities and limitations can be understood as something that is common in all new technologies and that the issues of security, scalability and latency will only be resolved as research produces increasing amounts of reliable empirical evidence.

Several research projects that offer solutions for these issues were also found. Some scholars (Gilad, Hemo, Micali, Vlachos & Zeldovich, 2017; McConaghy, McMullen, Parry, McConaghy & Holtzman, 2017; Sharples & Domingue, 2016) present notable breakthroughs relating to issues of performance, scalability, security and privacy, while others are criticised (Valenta & Rowan, 2015; Decker & Wattenhofer, 2014) as simply being suggestions that lack concrete empirical evaluation of their effectiveness (Yli-Huumo *et al.*, 2016:15). Despite this research, an overview of more recent efforts (Sayadi, Rejeb & Choukair, 2018; Li, Wang, Liu,

Liu, He & Huang, 2018; Zheng, Xie, Dai, Chen & Wang, 2018; Atzori, 2017:51), reveals that the challenges mentioned before, and related issues remain prevalent.

As research progressed into the "Blockchain 2.0 era" (2015 –) a new strain of blockchain-related research emerged which attracted a significant amount of attention within the field of computer sciences. *Smart contracts*, originally proposed by Nick Szabo in 1994, were researched extensively by various scholars for their ability to self-execute contracts between participating parties (Casino *et al.*, 2019:56; Mourouzis & Tandon, 2019; Sadiku, Eze & Musa, 2018). The two separate programs, namely blockchain and smart contracts, can work together to trigger payments or services when a preprogramed condition of a contractual agreement is met" (Crosby *et al.*, 2016:13). Smart contracts are proposed to be applicable to nearly all sectors that require contractual agreements (Tapscott & Tapscott, 2016; Cong & He, 2019), and research has looked at how this application combined with blockchain technology can improve these processes (Kosba, Miller, Shi, Wen & Papamanthou, 2015; Peters & Panayi, 2015; Cong & He, 2019).

Within the context of smart contracts in general, there are some unique studies (Christidis & Devetsikiotis, 2016; Bistarelli et al., 2020) that discuss blockchain smart contracts and the internet of things (IoT) (Bahga & Madisetti, 2016; Ferrag, Derdour, Mukherjee & Derhab, 2018), but mostly the focus is on explaining what smart contracts are (Clack, 2018; Levy, 2017), how they work (Christidis & Devetsikiotis, 2016; Cardeira, 2015), what potential they have for future application in various industries (Bartoletti & Pompianu, 2017; Mohanta, Panda & Jena, 2018) and the security issues they raise (Atzei, Bartoletti & Cimoli, 2017). Additional research relating to applications that can function in partnership with blockchain technology is artificial intelligence (Sgantzos & Grigg, 2019; Salah, Rehman, Nizamuddin & Al-fuqaha, 2018). Artificial intelligence (AI) research relating to blockchain technology has become a major focus point as both are understood as 'disruptive technologies' that benefit more by working together than apart (Panarello, Tapas, Merlino, Longo & Puliafito, 2018:8).

Salah *et al.* (2018:10129) present findings which show that many shortcomings of AI and blockchain are addressed effectively when these two technologies are combined. AI algorithms rely on data to learn, infer and make final decisions, which works more efficiently when the data being collected are sourced from a platform or repository that is secure, trusted, reliable and credible (Salah *et al.*, 2018:10130). Data scientists spend eighty percent of their efforts collecting, preparing and organizing data for artificial intelligence purposes, which can be very time consuming. With blockchain however, Dillenberger, Novotny, Zhang, Jayachandran, Gupta, Hans, Verma, Chakraborty, Thomas, Walli, Vaculin, Sarpatwar and Verma (2019:1) argue, the data have already been identified, collected and organized in a usable format, which significantly simplifies the process. Research within this field will therefore continue to expand as researchers explore the technological advancements that will occur by successfully partnering these systems.

This review was also able to identify gaps in this strain of research. The first is that research on topics such as latency, throughput, block sizes and bandwidth is limited (Yli-Huumo *et al.*, 2016:14). This is problematic, as these issues need to be resolved if scalable real-world applications are to be realized effectively. These topics are not the most interesting for researchers at the moment and they require the attention of highly skilled computer scientists and electronic engineers, which could explain why they have not developed alongside more prominent 'mainstream' themes. If blockchain solutions are to be used by millions of people for their day to day activities, however, more research needs to be conducted to explore solutions for these issues.

2.4.2 Blockchain research focussed on the financial sector

Financial institutions currently perform the necessary functions of keeping money safe and secure for their clients. These processes, however, require multiple third parties to authenticate transactions and these mediators charge fees, which can be expensive. Moreover, with the involvement of too many agents and manual processes, the chance of security breaches, errors and fraud also increases (Tapscott & Tapscott, 2016:1).Tapscott and Tapscott (2016) argue that although our global financial system moves trillions of dollars a day and is trusted by the billions of people it serves, the system remains rife with problems, unnecessarily high fees, payment delays, redundant paperwork, and is open to opportunities for fraud and crime.

These are but some of the issues faced, which is why the researchers Lewis¸ Mcpartland & Ranjan (2017:13) argue that interest in blockchain technology has grown and will continue to grow in the financial industry as "it is likely to be a key source of future financial market innovation." According to Swan (2017:8), a sector in which blockchain research has seen the most attention in recent years is the financial market and commercial banking. The reason for this that "blockchain [is] simply an improvement over the way that traditional databases have been designed and will therefore eventually outperform existing systems" (Crosby *et al.*, 2016:15).

Initial research efforts within this industry focused on the capabilities blockchain displayed through the trading of digital currencies (Kelly, 2014; De Vries, 2016; Hileman, 2016). This gave rise to the idea of how its implementation within the 'real' financial system could remove the need for third-party authenticators through its peer-to-peer protocol (Crosby *et al.*, 2016:14). In the research examined, some articles suggest this technology to be so disruptive that it could completely replace third party payment facilitators in its entirety (Shah & Jani, 2018; Tapscott & Tapscott, 2016). This view that blockchain has the potential to replace financial service providers entirely was found to be a reoccurring theme in the literature (Swan, 2018; Miller, Mockel, Myers, Niforos, Ramachandran, Rehermann & Salmon, 2019; Jutila, 2017). It should be noted, however, that multiple studies (Holotiuk, Pisani & Moormann, J, 2019; Fanning & Centers, 2016; Fanti & Viswanath, 2019; Shah & Jani, 2018; Shah & Chatterjee, 2017) adopt a more moderate approach that identifies blockchain as an *additional tool* to simplify and speed up existing processes, rather than something that would replace financial service providers. The most prominent arguments in the research reviewed focused on the potential applications of blockchain by financial service providers, the improvements that its successful implementation could provide within this sector, and finally, the challenges, issues and limitations around the implementation of blockchain. See Casino *et al.* (2019:60) for a more in-depth review of blockchain applications in the financial sector.

The sub-themes identified within this broad scope of research includes what potential blockchain technology holds for instant payments (Fanti & Viswanath, 2019), administrative costs (Shah & Jani, 2018), issuing loans (Shah & Chatterjee, 2017), security measures (Cocco, Concas & Marchesi, 2017) and combating corruption and fraud (Casino *et al*., 2019:63). This research included banks such as Bank of China, China Merchants Bank, JP Morgan Chase and Bank of America, among others, who have collectively invested large sums of money in blockchain-related projects focused on how financial service providers could benefit from this technology (Lewis et al., 2017:12).

In addition to looking at the various positive attributes, the literature also examines security and scalability concerns that would arise in utilizing blockchain in the financial industry (Dobrovnik, Herold, Fürst & Kummer, 2018). A recurring concern found is that, although on a small scale blockchain seems to be a solution to many problems, it still lacks appropriate and feasible uses for large-scale implementation in modern society (Shah & Jani, 2018; Tsai, Blower, Zhu & Yu, 2016; Peter & Moser, 2017). As a result of this, the proposed idea that blockchain is able to replace financial providers in their entirety beco highly unlikely at this stage because of the large amount of resources it would require to power and regulate such a system. Jonéus (2017) discusses the issue of limited resources at greater length. At a micro level, however, it certainly is plausible according to these studies (Casino *et al*., 2019; Varma, 2019; Lewis *et al.*, 2017). A limited number of journal articles were found addressing issues of scalability in the finance industry (Herrera-Joancomartí & Pérez-Solà, 2016; Koteska, Mishev & Karafiloski, 2017; Polyviou, Velanas & Soldatos, 2019). They propose an increase in the size of each block or reducing the number of submitted transactions at a time, but according Koteska *et al.* (2017:32), these suggestions do not yet solve these problems in their entirety and new issues are likely to arise if either of the proposed techniques were implemented.

In summary, a review of existing research on blockchain technology in the financial industry found that researchers, banking experts and financial service providers have certainly taken notice of blockchain technology's potential advantages. The potential applications of blockchain have been the most prominent theme within this industry. These applications are discussed for the potential benefits they can provide the financial sector to simplify and expedite existing processes. Current research lacks empirical evidence at such an early stage of development. The research also does not provide evidence to support blockchain being used on a larger scale and some articles specifically discuss the issues of scalability, performance and security (Casino *et al*., 2019; Varma, 2019; Lewis *et al.*, 2017). More research would be necessary to prove that blockchain can in fact improve efficiency and security beyond micro systems, as discussed by some researchers (Swan, 2018; Miller, Mockel, Myers, Niforos, Ramachandran, Rehermann & Salmon, 2019; Jutila, 2017). According to Lewis *et al.* (2017:9), given how rapidly financial institutions are investing in blockchain solutions, this will certainly change as increased real-time testing methods will provide the information needed to quantify the proposed outcomes that have been researched to date.

2.4.3 Blockchain research focused on the private healthcare industry

Blockchain research in the private healthcare industry was among the first *non-financial* avenues which pushed researchers to identify it as a general-purpose technology (Casino *et al.*, 2019:65). Here research has focused predominantly on applications of blockchain such as identity management (Santos, 2018), patient dispute resolution (Leeming, Cunningham & Ainsworth, 2019), medical contract management (Katuwal, Pandey, Hennessey & Lamichhane, 2018) and health insurance (Siyal, Junejo, Zawish, Ahmed, Khalil & Soursou, 2019). Additional themes were identified in an in-depth mapping study by Agbo, Mahmoud and Eklund (2019). Their research examines blockchain research in the healthcare industry and similarly found that a great deal of research focused on the applications in healthcare. These applications include the management and storage of digital medical records, facilitating pharmaceutical supply chains, storing biomedical research, enabling remote patient monitoring, streamlining health insurance claims and facilitating the processing of health data analytics (Agbo *et al.*, 2019:22).

The research examines what existing blockchain-based healthcare applications have been developed, what the challenges and limitations are of these blockchain-based healthcare applications, how these challenges are currently being addressed and what the potential areas for improvement are (Angraal, Krumholz & Schulz, 2017; Mettler, 2016; Roman-Belmonte, De la Corte-Rodriguez & Rodriguez-Merchanet, 2018). Additional noteworthy research on the applications of blockchain was conducted by Engelhardt (2017) who outlines various blockchain development companies in the healthcare sector. In his study he groups different companies under different blockchain healthcare applications, namely patient-centred medical records, the dental industry and prescription drug fraud detection, and examines what the benefits and effects of blockchain were in various case studies (Engelhardt, 2017:2).

A report by Mettler (2016) also examines various examples of blockchain applications and companies exploring the potential of blockchain technology in public healthcare services. Ku, Kim and Ohno-Machado (2017) have produced an interesting study in which they discuss the main benefits of blockchain technology when compared to traditional databases for healthcare applications. They explain how these benefits can be harnessed to expedite insurance claim processes, better secure healthcare data ledgers and improve medical record management (Ku *et al.*, 2017:1215). An area of concern, however, is noted by Agbo *et al.* (2019:2). They argue that because blockchain is still a relatively new and exciting technology, its medical utility may be exaggerated in the press as well as in grey publications. This has resulted in an abundance of inaccurate information and speculations about blockchain in the healthcare industry which needs to be countered by empirical evidence for the sake of future success.

In summary, existing blockchain research focuses on various private healthcare applications, which include drug and pharmaceutical supply chain management, the managing of electronic medical records, remote patient monitoring, tracking of health data analytics and advancing biomedical research, among others. Articles were found exploring what blockchain-based healthcare applications have been developed to test emerging blockchain paradigms and the benefits they could bring to the healthcare sector. That being said, more research is required to better understand, characterize and evaluate the utility of blockchain technology in healthcare. Finally, factors that tie back into the technical aspects of blockchain itself are also present in the healthcare sector and needs to be researched further to supplement ongoing efforts to address the challenges of scalability, security and patient privacy (Agbo *et al.*, 2019).

2.4.4 Blockchain research focused on the supply chain industry

Supply chain management is another notable industry where blockchain has been researched as a tool to improve transparency (Ahram, Sargolzaei, Sargolzaei, Daniels & Amaba, 2017), regulatory compliance (Kshetri, 2017), reduce paperwork (Kshetri, 2018) and provide a real-time audit trail of events (O'Leary, 2017). In contrast to the financial and health care industry, research on blockchain in supply chain management is still in its infancy (Babich & Hilary, 2018:4). The main reason for this, according to Chang, Katehakis, Melamed and Shi (2018) is because of the difference between the way that blockchain would be used in supply chain management and the core value it brings to each industry. The core value for financial applications, for instance, would be information security, whereas the value for supply chain management is system transparency and traceability (Chang *et al.*, 2018:2).

Similar to Chang *et al.* (2018) this review found that transparency and traceability are the most prominent themes in blockchain research relating to the supply chain industry. Some articles provide an outline of how a blockchain-powered supply chain would function (Helo & Hao, 2019; Litke, Anagnostopoulos & Varvarigou, 2019; Chang *et al.*, 2018) Much research proposes blockchain solutions in a theoretical sense, however, without significant evidence to indicate if their claims have been successfully tested in the real-world (Chang *et al.*, 2018:4). Regardless of the 'real-world' particularities, however, blockchain can in theory offer a wide set of advantages according to a study by Litke *et al.* (2019).

Blockchain-based applications are proposed as having the potential to generate breakthroughs in three areas in the supply chain industry: visibility, optimisation and demand. Research was found exploring the registration and documentation of a product's lifecycle on a blockchain to increase the transparency and the trust of the participating actors, as well as allowing buyers and sellers to transact directly without manipulation by intermediaries (Subramanian, 2017:2). According to Litke *et al.* (2019:2), this eliminates the need for a trusted third party, which in turn allows for greater scalability as any number of participants can virtually participate in the chain with the appropriate level of trust. Additionally, a research project by Verhoeven, Sinn and Herden (2018) identifies “characteristic applications” and “mindful use of blockchain” for logistics and supply chain management. Here the focal points are the traceability and transparency aspects of blockchain and how it can be a more secure infrastructure for business because of its decentralized network structure.

Furthermore, Dorri, Kanhere and Jurdak (2017:173) demonstrate how the utilization of blockchain-based applications in supply chain networks can improve overall security measures and lead to more robust contract management mechanisms for participating agents. Blockchain is also discussed as a tool to enhance tracking mechanisms, while traceability assurance also received a notable amount of attention as a potential benefit (Düdder and Ross, 2017; Lu and Xu, 2017; Apte and Petrovsky, 2016; Heber and Groll, 2017). The same was observed when blockchain was examined as a “tool” to provide better information management across complex supply chains (O’Leary, O'Reilly, Feller, Gleasure, Li & Cristoforo, 2017; Turk & Klinc, 2017), improving intellectual property protection (Holland, Nigischer & Stjepandic, 2017; Herbert and Litchfield, 2015), offering better customer service through advanced data analytics (i.e. encrypted customer data) and finally, looking at ways it could contribute to smart transportation systems (Lei, Cruickshank, Cao, Asuquo, Ogah & Sun, 2017).

Additionally, research was found exploring the *societal effects* this technology can produce. Abeyratne and Monfared (2016) examined the benefits of blockchain traceability and transparency based on the Nike child labour scandal in 1996. The focus is placed on what blockchain could mean for transparency issues to avoid a repeat and the continuation of such events. Blockchain is also discussed in this article as a “tool to enhance trust through traceability and transparency in supply chain applications” (Abeyratne & Monfared, 2016:3). Another ongoing discussion taking place is the articulation between supply chains and ethics. Litke *et al.* (2018:4) examine "modern-day slavery in supply chains” and how blockchain can “make the invisible, visible” through enabling the traceability of products and means manufacturing.

In summary, the literature shows traceability and transparency as key themes in blockchain research relating to the supply chain industry. Research in this sector remains a general-level overview of what the implementation of blockchain technology could mean for supply chain management in both a practical and social sense, but with limited empirical evidence. This will, however, change according to Litke *et al.* (2019:15), as the technology becomes more readily available and understood within supply chain infrastructures.

2.4.5 Blockchain research focused on the government sector

At the time this study was initiated to investigate the subject of "blockchain technology in government", it was unexpected to find the vast number of blockchain research projects already underway in various countries (Figure 4). Likewise, the speed of expansion of government-led blockchain projects worldwide is also something to take note of. A survey by IBM (2018) reported that nine out of ten governments will invest in some sort of blockchain project in the near future. More than one hundred blockchain projects have been piloted since 2018, and as it becomes better understood in a theoretical sense these numbers have continued to rise (Jun, 2018:4). Existing research shows an overwhelmingly positive narrative among nations around the world regarding the use of blockchain technology within the governmental sector (Oseni & Ali, 2019; Jun, 2018; Swan, 2015; Tapscott & Tapscott, 2016, Hou, Wang & Lui, 2017).

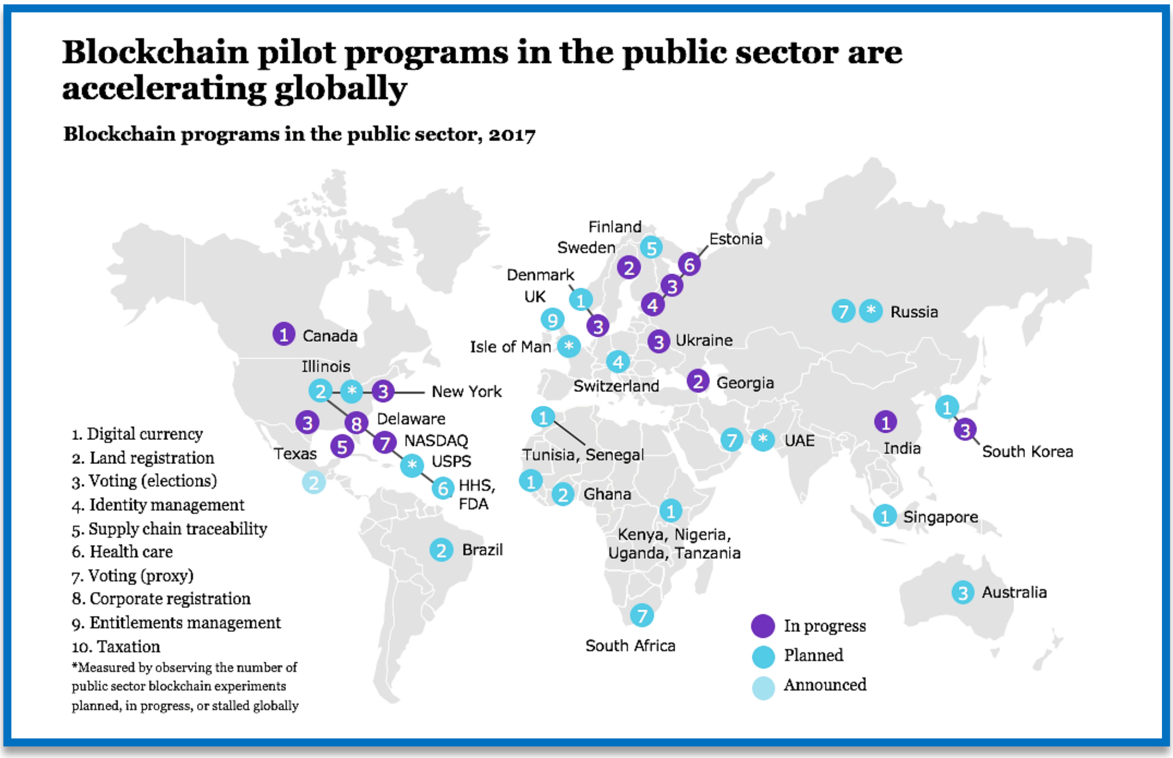

Figure 4: Government Blockchain Initiatives (National Journal, 2017)

Although many governments had adopted a strict stance regarding the trading and regulation of cryptocurrencies (Oseni & Ali, 2019), the same cannot be said about blockchain, as various countries have identified the potential this technology holds for service delivery by state institutions. According to IBM (2018) the United States of America, Estonia, Netherland, Switzerland and China are but some of the pioneering countries that have publicly recognized the potential benefits inherent in the successful implementation of blockchain technology for governmental applications and service delivery. These governments are currently either studying potential blockchain-based applications for service delivery or are already in the process of testing and funding such applications on a small scale (Jun, 2018:6). The map above (Figure 4) provides a representation of the vast number of blockchain projects underway as of 2017. The list of numbers to the left of the map show the type of blockchain project and on the map itself the numbers indicate which countries are participating in those respective projects.

As the prevalence of blockchain technology has continued to grow in government, enthusiasts and academic scholars have also advocated for and continued to research the impact that blockchain could have on government and public service delivery (Swan, 2015; Jun, 2018; Tapscott, 2018; Hou *et al.*, 2017). Governments throughout the years have been entrusted with managing and holding official records of both citizens and/or enterprises, and a popular narrative among pioneering researchers is how blockchain can be a promising addition as a "*trust machine*" in a sector known for its corrupt tendencies (Jun, 2018:2). Academic research on the subject of "blockchain in government", however, remains in a ambiguous stage and attempts at utilizing this technology also remains a topic that needs to be explored beyond the general discussions (Ølnes, 2016:13). As it is a new phenomenon, with little established theory and a small number of recognized experts, it is understandable that blockchain research in this industry has remained generalized to some extent. This is sure to change, however, as the process of testing and funding blockchain projects has continued to expand (Atzori, 2015:5).

To examine what has been discussed within blockchain research relating to government, this literature review started by examining systemic reviews by Batubara *et al.* (2018), Casino *et al.* (2019) and Lin and Liao (2017) to gain a general understanding of existing research on "blockchain in government". Their research papers are titled respectively: "Where Is Current Research on Blockchain Technology in Government?", "A review of government research on blockchain" and "A systematic literature review of blockchain-based applications: current status, classification and open issues". The review of their articles led to the conclusion that a large portion of existing blockchain research that is focused on the governmental sector discusses the potential government applications, the benefits of these applications and the challenges of implementation and evaluates the prospects of blockchain adoption.

The articles reviewed by Batubara *et al.* (2018), Casino *et al.* (2019) and Lin and Liao (2017) focus on themes of how the utilisation of blockchain can improve transparency, traceability, accountability, address corruption, increase efficiency and improve overall costs. A wealth of research also focuses on the infrastructural benefits of blockchain itself for government in that it is “a more secure, transparent and inexpensive database technology when compared to existing centralized networks” (Ølnes, 2016; Chiang, Betanzos & Savage, 2018; Nordrum, 2017; Ølnes and Jansen, 2017; Ølnes, Ubacht & Janssen, 2017). An article by Allessie, Sobolewsk and Vaccari (2019:21) explores how blockchain-based services can be combined with digital user interfaces (UI) and other information communication technologies (ICT) to improve existing government-citizen interfaces for interactions between public authorities and citizens of any country.

Interestingly, three articles touch on the idea of blockchain within the context of policy studies and policy administration. Deloitte (2017:4) states that “to understand the transformative effects blockchain can achieve in government processes, policymakers should first learn the basics of this new architecture”. The second article focuses on viewing state monopoly as a Single Point of Failure (SPOF) and calls for academics to explore less “top-down” state-centric instruments such as blockchain to increase interaction among public, private and non-governmental subjects (Atzori, 2017:50). Atzori (2017:45) also argues that blockchain and decentralized platforms can be considered as “hyper-political tools” capable of managing social interactions on a large scale. Lastly, Allessie *et al*. (2019:10) argues that “blockchain is one of the most innovative digital technologies to be considered under the new paradigm of governmental policy making and service delivery”. These arguments are important as they relate to the aims of this project but differ in that they do not specifically explore whether blockchain can fulfil the functions of a policy instrument.

In addition to the notable research by Batubara *et al.* (2018), Casino *et al.* (2019) and Lin and Liao (2017), it was necessary to conduct a more refined examination of existing research pertaining to blockchain in government. This aided attempts to determine the various areas of public service delivery and policy themes that blockchain researchers have identified and explored within government. This also allowed for a deeper understanding of existing research themes within the government domain, which directly relates to the research question and contextualization of this project.

2.4.5.1 Blockchain for government data storage

The majority of blockchain research within the context of government clearly focuses on the applications of this technology and what existing problems can be solved by implementing a blockchain network. Blockchain is discussed in various studies as an alternative to existing centralized infrastructures (Atzori, 2017:50; Ølnes, 2016; Nordrum, 2017; Ølnes & Jansen, 2017; Ølnes, Ubacht & Janssen, 2017). Data storage on the blockchain is one such application which has continued to present itself as a prominent theme within this strain of research. The reason for this according to Cheng, Daub, Domeyer and Lundqvist (2017) is that “a key function of government is to process and secure trusted information about individuals, organizations, activities and assets”. Managing and making use of this data can, however, become complex for even the most advanced governments in the international community. This understanding of government responsibilities and its known flaws in data management, combined with the favourable attributes of blockchain is what brought it to the attention of researchers and subsequently formed part of the proposed “non-financial applications” of blockchain (Casino *et al.*, 2019:60).

Ahram *et al.* (2017) and Liu (2016) propose the integration of blockchain into the system of public medical records to better control patient data and solve the problem of data theft and inconsistent patient records in public healthcare. Ølnes (2016) also explores blockchain as an information infrastructure relating to how citizen and government data is stored and accessed on a daily basis. Research by Jabbar and Bjørn (2017), Ojo and Adebayo (2017) and Shrier, Wu and Pentland (2016) discusses blockchain as an information infrastructure that relates directly to the way government stores the identity authentication data of citizens, ownership rights and other related personal data. Similar to what was discussed in the supply chain industry, Shrier *et al.* (2016) also locate the value of blockchain in the transparency, security and traceability it would bring to data management in government.

Another focus point in this theme is the use of blockchain technology in the education sector to overcome the lack of data integration and integrity (Bore, Karumba, Mutahi, Darnell, Wayua & Weldemariam, 2017; Raju, Rajesh & Deogun 2017; Sharples & Domingue, 2016). According to Alammary, Alhazmi, Almasri and Gillani (2019:11) “blockchain technology could bring significant benefits to education, including improved security, lower costs, enhanced student experiences, better accountability, identity authentication, improved records management and improved overall trust”. Despite blockchain showing great potential in the context of public education, Alammary *et al.* (2019) state in their study, *Blockchain-Based Applications in Education* that “there are multiple challenges that need to be considered when implementing this technology in the public education sector”. Here the issue of maintaining efficiency, security and privacy simultaneously has been a focal point as observed in the industries mentioned above. Implementation costs have also been researched as a potential problem (Han, Li, He, Wu, Xie & Baba, 2018:178).

Blockchain adoption is also proposed in the context of smart cities (Gaetani, Aniello, Baldoni, Lombardi, Margheri & Sassone, 2017; Marsal-Llacuna, 2017; Biswas & Muthukkumarasamy, 2017) and digital identity (Borrows, Harwich & Heselwood, 2017; Sullivan & Burger, 2017; Cheng, Zeng & Huang, 2017). With regards to smart cities, Casino *et al*. (2019:63) undertook a study which examines the safety, accountability and automation blockchain offers for processing public records and the impact it could have on corruption while improving the efficiency of government services. Their research, among others (Jaffe, Mata & Kamvar., 2017; Biswas and Muthukkumarasamy, 2016; Sharma, Moon & Park, 2017), explores how blockchain could serve as a secure digital interface for integrating physical, social and business infrastructures in a smart city context (Casino *et al.*, 2019:63).

With regards to storing citizens' identities, a case is made that the integration of digital technologies in everyday life requires mechanisms able to accurately determine who the users are and certify their basic information such as name, address, credit record, as well as other personal characteristics (Buchmann, Rathgeb, Baier, Busch & Margraf, 2017; Leiding and Norta, 2017; Lemieux, 2016). Borrows, Harwich & Heselwood (2017) presents a study which argues that a more efficient identification system can be implemented using blockchain to ensure identity information is documented securely in a way that gives the individual full control of their identity. In contemporary times digital identity has become a crucial security measure and with one sixth of the world lacking the necessary documentation to confirm their existence officially, blockchain is discussed as a tool to reinforce opportunities and equality among global citizens (Rivera, Robledo, Larios & Avalos, 2017).

Additional research relating to government data storage has been conducted on how land titles can be registered on a blockchain in an immutable and transparent manner (Van den Berg, 2018:3). Blockchain advocate and scholar de Soto (2017:7), among others (Osborne, 2017; Jun, 2018; Van den Berg, 2018) states that by recording land registrations onto a blockchain, multiple societal and policy issues related to land disputes can be addressed directly. Osborne (2017) agrees with this in his research and states that this would especially be useful in developing nations where corrupt officials often claim land for personal gain. Osborne (2017) further argues that blockchain can be very useful to countries lacking infrastructure where land registrations are recorded poorly or non-existent. Blockchain is discussed as a tool to improve the security, traceability and transparency of government systems and furthermore assist financial institutions when issuing home loans to citizens (Osborne, 2017).

Research by Pichel (2016) a year prior to Osborne (2017) also examines blockchain as a tool to "manage land" and "regulate ownership" (Casino *et al.*, 2019:64). Similarly, Kshetri (2017) and Bates (2016) assess the potential for *Bitland* in Ghana, a company that aims to protect and secure land titles by anchoring them on a public blockchain. Allessie *et al.* (2019:19) similarly examine blockchain for the use of land registration in the Republic of Georgia, where blockchain was implemented to "fight corruption, resolve disputes over property claims, lower existing operational costs and increase public confidence in property-related record-keeping". Bates (2016:12) emphasizes how blockchain could vastly improve service delivery in registering land assets. Van den Berg (2018), however, counters this positive outlook on the problems blockchain can solve, and instead argues that control over land can remain a conflict driver, even when official ownership is documented in a secure and immutable manner. This, he further explains, is a problem that cannot be addressed by blockchain because of its political hence 'emotional' nature. He states that "disputed ownership goes beyond simply being a problem of record-keeping and incompetent administration; it is an emotionally driven political problem." (Van den Berg, 2018:5).

E-voting (Electronic Voting) is identified by scholars such as Boucher, Nascimento and Kritikos (2017) and Tapscott (2017) as a promising development in the governmental voting process. At first this was not plausible as central databases were needed to capture votes. But this changed with the introduction of blockchain technology and became both plausible and attractive to explore as a potential application for government (Noizat, 2015; Kubjas, 2017; Meter, 2015; Hsiao, Tso, Chen & Wu, 2018). This application was one of the first to be recognized as a possible utility in government, as the combination of e-voting and blockchain technology creates favourable circumstances to redesign the way in which democratic electoral systems function (Boucher, Nascimento & Kritikos, 2017:12).

That being said, research was found that is also increasingly sceptical about the use of blockchain for e-voting and suggests that various technical issues such as latency and scalability can create serious issues (Gupta, Patel, Gupta & Gupta, 2017). These issues would first need to be solved before it could truly be an improvement to current voting systems (Zhang, White, Schmidt, Lenz & Rosenbloom, 2018:352). Ayed (2017) similarly explores the security issues that need to be taken into consideration for blockchain in the context of e-voting. His research confirms that although it seems plausible and desirable to improve this ancient democratic process, multiple security and scalability issues need to be addressed if blockchain e-voting is to be implemented successfully and reliably.

2.4.5.2 Blockchain for financial activities of government

As blockchain has been researched for its utility within the financial industry, so too has it been explored within the context of financial activities by governments. Wijaya, Liu, Suwarsono and Zhang (2017:2) explore methods to transfer tax credits between taxpayers and to create tax invoices through blockchain technology. O'Loughlin (2018:10) proposes blockchain as a tool for intergovernmental payments and suggests that if governments were to allow for the digitization of their national currency on government-owned blockchains, it would create greater efficiency and cost-effectiveness. O'Loughlin (2018:12) argues that a significant sum of money can be saved if payments of social grants were regulated by a blockchain in a digital format. A study by Williams-Elegbe (2018) agrees with O'Loughlin (2018) and examines how smart contracts can be incorporated into social grants and public procurement "which is the process by which a government buys goods and services needed to fulfil its functions to maximise public welfare" (Williams-Elegbe, 2018:5). In her research she addresses the issue of corruption in South Africa and how "an estimated 50% of the R800 billion annual procurement and public funding is lost to illegal activities". O'Loughlin's (2018:11) research reveals the complexity of controlling and monitoring social welfare systems and how current systems are extremely vulnerable to corruption and internal fraud. O'Loughlin (2018:11) also speaks to the issues highlighted by Williams-Elegbe (2018) and argues that blockchain can prevent potential fraud, theft or corrupt dealings within government welfare systems because of its transparent configuration (O'Loughlin, 2018:14).

The topic of corruption evident in the financial activities of government was further found to be a prominent theme in the research (Casino *et al.*, 2019: 63). In a review of blockchain applications by Casino *et al.* (2019), they identify corruption to be a recurring theme in research findings and argue that addressing corruption with blockchain applies to all sectors. The impact blockchain could have and currently has on combating corruption was identified as one of the most prominent themes in the research relating to government operations. Here scholars were found to be particularly interested in the influence this technology could have in "a sector known for its corrupt tendencies" (Jun, 2018:2). Kossow and Dykes (2018:10) discuss how blockchain shows great potential for more "transparent, accountable and efficient ways of storing government data and administering transactions" to minimize corruption at the state level. They, like other scholars, explore, how blockchain can have positive effects for anti-corruption drives if safeguards against corruption are taken into account in the design and implementation process for future programmes and reforms by government (Ibba, Pinna, Seu, & Pani, 2017; Jaffe *et al.*, 2017; Biswas & Muthukkumarasamy, 2016; Sharma *et al.*, 2017).

2.4.5.3 The technical challenges and regulatory issues in implementing blockchain

A strain of research which developed alongside the positive narrative about blockchain in government is on the challenges that would arise with implementing this technology in the "real-world" (Swan, 2015:63). These challenges include the technical aspects of 1.) security, 2.) latency (speed) and 3.) scalability which have proven to be a focal point across all sectors researching blockchain. The research indicates that there is a 'trade-off' as to what level of efficiency a blockchain can offer while maintaining its security (Hou, 2017:13). This trade-off also has a third factor, where researchers (Gilad *et al.*, 2017; McConaghy et al., 2017; Sharples & Domingue, 2016) are questioning the scalability of blockchain as both security and latency need to be maintained while scaling this technology. These concerns of maintaining efficiency, security and scalability simultaneously is called the *blockchain trilemma* (Swan, 2015:63).

In addition to the technical challenges faced in the governmental context, research on regulatory issues is also a recurring theme. Research looks at the challenges blockchain could face during implementation from both lawmakers and government officials. According to Hou (2017:4), regulatory uncertainty is an important issue to consider when deciding whether to use blockchain, as governments will have virtually no control over how a public, permission-less system is governed. Pisa and Juden (2017:11) argue that the issue of appropriate governance of blockchains – in terms of rule design and responsibility – remains to be worked out before large-scale implementation. This would also create a need for new governance models, and as with all new systems, issues of acceptability are identified as the most important challenges from an organizational point of view (Hou, 2017; Konashevych, 2017; Ølnes *et al.*, 2017).

Furthermore, an argument is made by Reijers and Coeckelbergh (2018:105) that acceptance challenges could also come from users who will utilize the blockchain applications. Their research highlights the social, cultural and political ramifications that could arise with utilizing blockchain technology. According to Ølnes *et al.* (2017) this is mainly because of the uncertainty around the technology itself, since blockchain is relatively new and its reliability and impact have not yet been proven convincingly (Sharples & Domingue, 2016; Sullivan & Burger, 2017). Although limited, research on the regulation of blockchain has steadily increased over the past five years and will certainly become a focal point once it is utilized more regularly in the real world (Batubara *et al.*, 2018:7). This was the case for cryptocurrencies, which saw a significant spike in regulatory research once governments recognized the regular use and influence this technology has on financial policy and e-commerce (Batubara *et al.*, 2018:8). Similar articles on the regulation of blockchain (Gabison, 2016; Kakavand, de Sèvres & Chilton, 2017; Peters, Panayi & Chapelle, 2015) also mention the regulatory issues involved in implementing blockchain technology, but they mainly focus on regulations relating to cryptocurrencies (Casino *et al.*, 2019).

In summary, the literature review found that the research addresses the potential applications of this technology, the benefits of these applications, challenges of implementation and the evaluation of blockchain adoption in government. Based on an overview of current research, the majority of articles relating to *blockchain in government* present promising initial ideas on the potential of blockchain in public administration. It was observed, however, that blockchain research in government and public service delivery has yet to move beyond discussing the potential of blockchain in a broad sense (Ølnes, 2016:11). Jun (2018:7) states that the current avenues of research will most certainly expand further as the technology becomes better understood. These are the defining stages of blockchain in government, and we have only scratched the surface of what we understand about this technology (Jun, 2018:8).

2.5 Public administration and policy instruments

This second section of Chapter Two focuses on *policy implementation, policy instruments* and the *analytical framework* of this thesis. It starts by discussing the relationship between policy instruments and policy implementation. This is followed by a review of how policy instruments have been understood and conceptualized in the literature. These definitions were then used to construct the integrated definition of a policy instrument applicable to this thesis. Finally, this section introduces the analytical framework of this thesis. It outlines how the analytical framework has been constructed and provides an understanding of the particular concepts within the analytical framework.

2.5.1 Public administration

To understand public policy and policy implementation, it is first necessary to understand public administration. Public administration is the actions by government to pursue a purpose or goal (Marume, 2016:15). It is the systematic ordering of affairs and calculated use of resources, aimed at "making those things happen which government agencies want to happen" (Marume, 2016:16), while simultaneously preventing issues that could limit or cause agencies failing to achieve what they want to happen. "It is the organizing of available materials and labour needed to gain that which is desired by both government and its citizens at the lowest cost in money, time and energy" (Marume, 2016:15). Public administration can be understood as "all government operations" for the purpose of fulfilling or enforcing public policy (Simon, Smithburg, & Thompson, 1952:615).

In public administration, *public policy* acts as a framework for governmental intervention and covers a variety of activities for future ideas, goals and plans of action (Kateb, 2015:1). According to Khan (2016:3), "public policy is the guide to action and connotes a broader framework to operationalise a vision or mandate". Public policy is "a purposive course of action followed by an actor or set of tools in dealing with a problem or matter of concern" (Anderson, 1975:3). Stewart, Hedge and Lester (2008:14) discuss public policy as "an outline of government activities designed to remedy economic or social problems by implementing policy". *Policy* is therefore understood as the system of principles to guide decisions and achieve desired outcomes. A policy is a statement of intent and is implemented as a procedure or protocol (Shakil, Sharna, Al Noman & Hridi, 2016:1). An important factor in any policy is that it must be implemented to become operative in public administration. Every policy, regardless of the political context has the same basic guidelines that outline its cycle (Figure 5) (Lasswell, Schachter & Tinbergen, 1971:322). The study of public policy therefore involves the various policy measures, policy instruments and policy processes that provide insights into how a government exercises public administration (Hassel, 2015:2).

2.5.2 Policy implementation

To put policy into effect, governments require implementation, which "encompasses the actions by government that are directed at achieving objectives set forth in prior policy decisions." (Van Meter & Van Horn, 1974:447). In the context of *policy implementation*, policy instruments are utilized by government to put policy into effect and provide insights into how a given policy is to be implemented (Hellström & Jacob, 2017:607). Selecting the appropriate policy instrument is essential to the implementation process as "it contributes to the success of public policy" (Howlett, 1991:2). It can therefore be argued that even the very best policy on

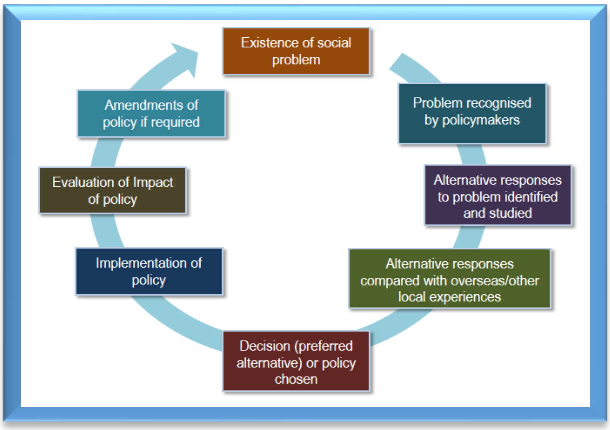

Figure 5: The Policy Cycle (Wu et al., 2010)

paper is of little worth if it cannot be implemented successfully. Considering this, it is understandable why scholars (Woodside, 1986:775; Khan, 2016:3; Perrels, 2001) emphasize the importance of policy instrument selection as this contributes directly to governments' ability to accomplish public policy goals.

2.5.3 Defining policy instruments

When assessing how policy instruments have been defined, the following points were noted. *Policy instruments* are understood as the means by which government intentions are turned into action (King & Mori, 2007:27). Policy instruments are described as the tools used by governments to pursue desired outcomes (Cairney, 2015:22), and they encompass techniques at the disposal of governments to create structures of opportunity for achieving policy goals (Bekkers, 2007:21). Capano, Pritoni and Vicentini (2019:13) elaborate on this and define policy instruments as the various actors, organizations, procedures and mechanisms that are utilized collectively or individually to put public policy into effect.

Policy instruments are defined as "the multitude of techniques at the disposal of governments to implement policy objectives (Howlett, 1991:2). They are the "fluid tools, techniques or mechanisms" used to achieve key policy goals (Bressers, Bressers & Larrue, 2016:23). Bekkers (2007:21) argues that policy instruments are tools to achieve intended goals conforming to the objectives of public policy: "Policy instruments are used to implement intentions, choices and actions of one or more governmental agency aimed at steering certain developments in society". These various explanations suggest that policy instruments are the multiple techniques and actors at the disposal of government to implement policy for achieving its goals and desired outcomes.

Moreover, various definitions identify the social impact of policy instruments. Halpern, Jacquot and Le Galès (2011:1) discuss policy instruments as both social and technical tools: "Policy instruments are a means to organize social relations among government and citizens within a country, which is then sustained through regulation". Bevir (2010:21) similarly defines policy instruments as the technical means of organizing social relations. Hellström and Jacob (2017) identify policy instruments as a means to organize social relations and refer to it as an interface between government and citizens. They state that "policy instruments are technical and social government-citizen interfaces which organize social relations and create structures of opportunity for action" (2017:609). Hood and Margetts (2007:15) similarly refer to policy instruments as interfaces between government and society. More specifically, they argue that policy instruments represent an interface between policymaker and policy targets (Hellström & Jacob, 2017:608; Vabo & Røiseland, 2012:936). These various definitions would suggest that policy scholars identify policy instruments as an interface between government and citizens. Policy instruments are defined as government-citizen interfaces used to intervene in society to create structures of opportunity for action and solving problems (Ajulor, 2018:1500).

Problem solving is a key function of policy instruments. Van Nispen (2011:1928) argues that policy instruments are not only used to achieve goals, but also to solve problems: "A policy instrument refers to the means of government intervention in markets and society to accomplish goals and solve problems". Various other scholars (Hellström & Jacob, 2017:609; Hassel, 2015; Peters, 2005:355) similarly define policy instruments as a means to solve social and economic problems. Research by Capano and Lippi (2016:272) argues that policy instruments are by nature meant to solve problems for government within the national and international community. These definitions show that policy scholars identify problem solving as a core function of policy instruments. How these various definitions are used to construct the integrated definition of what constitutes a 'policy instrument' is discussed in the following section (2.6).

2.6 The īnstrūmentum analytical framework

An analytical framework is used by researchers to create and implement an applicable structure of analysis for a study. It provides the basic vocabulary of concepts and helps explain how the analysis of a project will be conducted (Coral & Bokelmann, 2017:1). As there have been no attempts to explore blockchain technology as a policy instrument, this study was unable to find an analytical framework that could help to answer the main research question of this thesis: *Can blockchain fulfil the functions of a policy instrument*? It was therefore necessary to construct a new analytical framework. This project's analytical tool – *the īnstrūmentum framework* – was constructed in three phases.

2.6.1 Phase one: An integrated definition of policy instruments

The first phase was to conduct a review of how policy scholars have defined existing policy instruments**.** This provided a clear understanding of how policy instruments are defined by policy scholars and most importantly allowed the researcher to identify the recurring concepts on the way that policy instruments function. The literature review showed that policy instruments are understood as a social and technical interface between governments and citizens (Hellström & Jacob, 2017; Vabo & Røiseland, 2012; Khan, 2016:2).

Policy instruments are further defined as a means to organize social relations (Jacquot & Le Galès, 2011; Bevir, 2010; Hellström & Jacob, 2017) and create structures of opportunity for achieving policy goals (Bekkers, 2007:21; Woodside, 1986:775; Khan, 2016:3; Perrels, 2001; Howlett, 1991:2; Bressers *et al.*, 2016:23; Van Meter & Van Horn, 1974:447; Ajulor, 2018:1500; Hellström & Jacob, 2017:609) and desired outcomes (Cairney, 2015: 1). Finally, policy instruments are defined by multiple scholars as a tool to solve problems (Van Nispen, 2011:1928; Hellström & Jacob, 2017:609; Hassel, 2015; Peters, 2006:355). In light of this consensus regarding the various functions of a policy instrument, the researcher extracted the recurring functions to form an integrated definition of what constitutes a ‘policy instrument’. The integrated definition is:

Policy instruments are social and technical government-citizen interfaces utilized to organize social relations and create structures of opportunity for actions, achieving goals; desirable outcomes and problem-solving.

This integrated definition serves as the definition of a policy instrument for the purpose of this research project. Any reference made to ‘policy instrument(s)’ beyond this section should be understood accordingly.

2.6.2 Phase two: Conceptualizing the īnstrūmentum framework

Pacheco-Vega (2018: 81) states that it is important to “dissect” the analytical framework of a research project to ensure that the specific concepts involved are clearly understood. For the second phase of constructing the analytical framework, it was therefore necessary to unpack each concept within the īnstrūmentum framework. This provides a clear understanding of the integrated definition. The key functions of a policy instrument can be understood as outlined:

- **Government-citizen interface:** Vivier, Seabe, Wentzel and Sanchez (2015) argue *a government-citizen interface constitutes how government interacts with the public and vice versa*. An effective interface can strengthen government responsiveness and deepen citizen engagement, which in turn contributes to the success of policy implementation (Benton, 2014:1). Such communication methods and information exchange take many formats, especially in contemporary times, when numerous platforms and technologies are available specifically for this purpose. Policy instruments are understood as government-citizen interfaces in that they create a social or technical window for communication and intervention by government (Hellström & Jacobs, 2017:605).

- **Organize social relations:** Social relations is a blanket term for interactions between two or more people, groups or organizations (Hall & Lamont, 2013:5). Social relationships are composed of several social, physical and verbal interactions that facilitate a climate for the exchange of feelings and ideas. *Organizing social relations refers to the environment intentionally created by government to facilitate and influence social interactions or perception.* Rules implemented by government can influence how social relationships are composed. Policy instruments have the potential to influence both government-citizen relations and the social relations among citizens (Hall & Lamont, 2013:6).

- **Create structures of opportunity:** Opportunity structure is a concept developed by Cloward and Lloyd (1960) who argue that the term "opportunity structure" refers to the opportunities available in any given society or institution. These structures shape the social relations and economic structure of a country. *Opportunity structure refers to the notion that the opportunity to gain certain goals or outcomes is shaped by how a society or institution is organized or structured through guidelines, rules and regulation.* According to Gildenhuys (1997:6), policy instruments can be implemented to shape societal opportunity structures for the purpose of producing value for citizens and desired outcomes for government.

- **Achieve goals:** *In policy implementation, to achieve policy goals means to accomplish the declared objectives that a government has set for itself.* By achieving goals, government preserves the interests of the state and national community (Evans & Cvitanovic, 2018:2). Howlett (2014:281) and Cairney (2015:1) argue to achieve a policy goal is to succeed in attaining desired outcomes or objectives outlined before implementation.

- **Solve problems:** The process of problem-solving involves working through details of a problematic situation to reach a solution. *Problem solving involves systematic operations and critical thinking to address an identified problem.* Problem solving plays a significant role in policy processes as the very nature of policy implementation is to either achieve goals or solve problems (Dostál, 2015:2798). Policymakers are tasked with defining the problem at hand, generating potential solutions in the form of policy, and then implementing a policy instrument to achieve an intended outcome (Hanberger, 2001:46).

Problem solving also includes evaluating the effectiveness of the systematic operations after implementation (Dostál, 2015:2799; Hanberger, 2001:48).

2.6.3 Phase three: Constructing the īnstrūmentum framework

The third and final phase of constructing the analytical framework was to create a set of questions based on the above-mentioned conceptualizations of the key concepts within the integrated definition. The analytical framework consists of the following questions and sub-questions (See 2.7 The īnstrūmentum framework), which will be applied to analyse data pertaining to the selected government applications. These government applications include using blockchain for 1) land registration, 2) national elections (voting), and 3) citizen identity management. This framework will answer the main research question of this thesis: *Can blockchain fulfil the functions of a policy instrument*?

The sub-questions were constructed directly from the definitions discussed in phase two: *Conceptualizing the īnstrūmentum framework*. The sub-questions will act as guidelines during the analytical process to produce results related to each of the four main questions within the analytical framework. This allows for a robust assessment of the source data and contributes to answering the main research question in greater depth. How the analytical framework was applied will be discussed in the methodology section, Chapter Three.

2.7 The īnstrūmentum framework

1)	***Can blockchain act as a government-citizen interface?***
-	Can blockchain enable government to communicate and respond to citizens?
-	Can blockchain facilitate citizen engagement?
-	Can blockchain facilitate government intervention?
2)	***Can blockchain organize social relations?***
-	Can blockchain influence social relations between citizens?
-	Can blockchain influence government-citizen relations?
-	Can blockchain configure social behaviour among citizens?
3)	***Can blockchain create structures of opportunity for actions and achieving goals?***
-	Can blockchain provide rules and regulations to influence opportunity structures?
-	Can blockchain provide opportunity for action and achieve policy goals?
-	Can blockchain assist government in achieving desired outcomes?
4)	***Can blockchain solve problems?***
-	Can blockchain assist government to solve identified policy problems?
-	Can blockchain help prevent future problems?
-	Can blockchain allow policymakers to assess whether an identified policy problem has been solved successfully?

2.8 Chapter Two conclusion

Chapter Two showed that research on blockchain is still at a definitional stage but has continued to expand to various sectors in recent years. Exploratory research to create the initial ideas of blockchain's potential is apparent in a number of research projects and has contributed greatly to the proposed applications, understanding and influence blockchain can have for all levels of society and business. This review found that blockchain research has progressed through three periods. During the blockchain 1.0 period (2008 – 2014), blockchain research focused predominantly on Bitcoin, cryptocurrencies and their regulation. Here blockchain was understood as a peer-to-peer decentralized system to make digital transactions and additional financial services such as fast transactions and cross-border transactions. Given that cryptocurrencies had showcased the financial capabilities of this technology at such an early stage of its development, it is understandable that the majority of blockchain research focused on the financial industry in the initial stages.

The blockchain 2.0 period (2015- present), stemmed from rapid growth in the number of Bitcoin studies and financial applications as cryptocurrencies became increasingly mainstream. This period experienced a significant increase in studies that specifically pay attention to the programmability of blockchain. Here smart contracts, Artificial Intelligence (AI) and the internet of things (IoT) were among the software applications discussed. The surge in research after 2015 focused on blockchain as a 'general-purpose technology' and can be understood as the blockchain 3.0 era. Here scholars explored the potential applications for blockchain across multiple sectors as a disruptive technology. The research was found to be abundant in industries that have historically relied on third parties to ensure efficiency, security and trust. As research on blockchain continues to mature in an empirical sense, these applications and related research efforts are likely to penetrate more industries in addition to those explored by this review.

This review further demonstrated that within the various industries explored, blockchain scholars have largely focused on the main characteristics of blockchain, that it is a peer-to-peer, immutable, decentralised, distributed and independently verifiable network, as well as examining which industries could benefit from such functions. The research themes focus on the applications of this technology, technical issues/solutions, acceptance, regulation and adoption challenges. Keywords such as transparency, traceability, accountability, efficiency, privacy and cost effectiveness were among the most prominent focal points and are in many cases the exact terms used to characterize this technology.

Important fields of research which have reportedly been "neglected" by mainstream studies according to some scholars (Swan, 2018; Casino *et al.*, 2019; Yli-Huumo *et al.*, 2016) is the technical issues of efficiency, security and scalability around blockchain. These issues will need to be solved if scalable *real-world* applications are to be realized effectively. Furthermore, while the potential for blockchain has been well covered in various sectors and industries, there remains research gaps to be filled. Exploratory directions need to be expanded upon to break away from what already seem like repetitive research programmes. This review identified a large amount of research that was predictive in nature and focused on the potential application benefits of the technology, but discussions on how blockchain has already contributed value in ongoing projects do not provide empirical results.

With regards to 'blockchain in government', this literature review found that data relating to 'blockchain as a tool of government', 'governance technology' and 'a general-purpose technology' lack concrete evidence in the form of case studies that have produced results on ongoing blockchain projects in government. A wealth of information was found focusing on hypotheses of "what could happen if" or "potential benefits and risks of" blockchain implementation by government, but there has been limited research with concrete results based on the real outcome and value-creating processes of implementing this technology (Nofer *et al.*, 2017:186). This is understandable as blockchain is only a decade old which means research on the topic is still in its infancy and has yet to move beyond theory.

Finally, this review found no research specifically focusing on exploring blockchain as a policy instrument or the role it can have within in the policy implementation process. This gap in the research is problematic as various articles were identified discussing blockchain as a 'tool of government' (Batubara *et al.*, 2018; Lewis *et al.*, 2017; Casino *et al.*, 2019; Osborne, 2017) Furthermore, in various studies the applications of blockchain show at least in theory that it could be used by government as a tool to achieve goals and solve problems (Tapscott & Tapscott, 2016; Swan, 2018; O'Loughlin, 2018:14; Casino *et al.*, 2019; Jun, 2018; Atzori, 2017). This provides the basis for this research to ask, why policy scholars have not studied this technology as a policy instrument, when it shows the potential to be understood accordingly.

Chapter Three: Research Methodology

Chapter Three outlines the research methodology of this thesis. This chapter elaborates on the implementation of the īnstrūmentum analytical framework and explains how it will be applied to analyse the collected data to provide insights on whether blockchain technology can fulfil the functions of a policy instrument for government. This chapter also outlines the data selection criteria and limitations of the methodology.

3.1 Introduction

According to Bless and Higson-Smith (2000:11), the purpose of research is to contribute to knowledge creation through the collection, interpretation and evaluation of data in ways that have not yet been examined. This, they continue, is how scholars fuel the expansion of knowledge. To conduct scientific research, certain guidelines need to be followed to maintain the credibility of what is presented and to ensure that the contribution enriches the related field(s) of study (Bhattacherjee, 2012:14). This chapter outlines the procedures followed during the analytical process undertaken in this thesis.

3.2 Research design

Durrheim (2004:29) defines the research design of a study as "a strategic framework for action that serves as a bridge between the research questions and execution of the research strategy". The research design of this project follows an *exploratory approach*. Exploratory research is the initial research into a hypothetical idea; this is an appropriate method of research for projects that are addressing a subject where very little to no research has been undertaken. It serves to understand, describe or discover new findings through methods that have not been explored to create new perspectives on a phenomenon (Reiter, 2017:144). An explanatory approach is most appropriate for researching new areas of inquiry, where the goal of the research is to examine a particular phenomenon and to then generate initial ideas within a certain field of study (Reiter, 2017:145).

An exploratory research approach was selected because of the freshness of blockchain technology as a topic of research and because, to the researcher's knowledge, no attempts have yet been made within the sphere of policy studies to explore blockchain technology as a policy instrument. This research seeks to generate the initial ideas to expand the scope of the nature and extent of the research gap and to assess blockchain from this new perspective. Furthermore, an exploratory approach served as the best method to provide new explanations that have been overlooked (Golafshani, 2003:600) and allowed the researcher to shed new light on a phenomenon within the context of its use (Yin, 1984). An exploratory method was therefore most appropriate to analyse blockchain technology within its "natural environment" and formulate hypotheses for future investigation (Zainal, 2007:4). An explanatory research approach was also a useful method to test the possibility for more extensive future research regarding the phenomenon known as blockchain technology and the potential it can have as a policy instrument for government and public service delivery.

3.3 Research methodology

Schwandt (2007:195) defines the research methodology of a thesis as an explanation of how an inquiry should proceed. It involves an outline of the assumptions, principles and procedures in a particular study. This project made use of MacMillan and Schumacher's (2001:166) "methodological guidelines" to organize its research methodology. They define it as a plan for 1) selecting data, 2) explaining how data were collected and 3) outlining how the collected data were analysed to answer the research question underlying the project.

3.3.1 Data selection: criteria and procedure

Given the nature of exploratory research, the methodology adopted for this study is a qualitative multiple-case study which was approached by collecting secondary sources focused on the three blockchain government applications mentioned above. A multiple-case study "allows researchers to study a complex phenomenon within different contexts while using a variety of data sources" (Baxter & Jack, 2008:544). This design was selected as it allowed for an in-depth understanding of blockchain technology both within each application examined and the researcher could then compare how this technology could fulfil the functions of a policy instrument in different policy contexts by comparing the results produced. According to Gustafsson (2017:9), the evidence that is generated from a multiple case study is more reliable as it allows for "a wider analytical evaluation of the data" and is "useful for research where authenticity and a depth of understanding is the goal" (Budd, 2016: 25).

To collect data on the three selected applications namely, 1) land registration, 2) national elections (voting), and 3) citizen identity management, and the multiple existing and potential government projects within these applications, this study made use of the internet to collect secondary data online from the public domain. The source data were selected based on the following criteria:

- *The data focused on both existing and potential government projects where blockchain applications for 1) land registration, 2) national election voting and 3.) citizen identity management are explored, or the potential for these applications is explored;*
- *The data were sourced from academic literature such as books, journal articles, dissertations, conference papers, working papers or government publications;*
- *The data on both existing and potential government projects must have been published in the past seven years (2014 – 2020) to ensure they are not outdated and applicable to the most recent research on blockchain technology;*
- *Data from both developed and developing countries must be included in all three blockchain applications.*

When gathering these data, a qualitative approach allowed the researcher to embrace his involvement within the research. It "allowed the researcher to determine the importance of the data collected and how it will be interpreted through his understanding of existing literature" (Hancock, Ockleford & Windridge, 2009:6) as reviewed in Chapter Two. Furthermore, the researcher assessed the value, interest and originality of the material collected during the analytical process to ensure that only the most relevant material was selected to answer the questions in the analytical framework.

3.3.2 Reasons for selecting these data sources

While conducting the literature review, it was noted that researchers have focussed on certain key functions blockchain can provide government. Blockchain's ability to securely store data was identified as the most prominent theme, while facilitating financial transactions was a close second. The majority of blockchain applications are categorized within these two themes and it was therefore necessary to assess examples where blockchain demonstrates these functions within government. To answer the research question, this project therefore selected three current government blockchain applications where this technology has either been utilized or shows the potential to be used by government. *These government applications include 1) land registration, 2) national elections (voting), and 3) citizen identity management.*

Furthermore, the literature review, also indicated how blockchain technology is used for different reasons in developed nations than it is in developing nations. The researcher therefore decided that it is necessary to analyse the applications of blockchain within these three policy contexts in both developed and developing countries. This ensured a holistic understanding of the existing and potential functions of this technology as a policy instrument within different political, economic and social settings.

3.4 Applying the īnstrūmentum framework

Maree (2016:154) states it is important to provide a brief explanation of the analytical process before presenting the results. It is therefore necessary to outline the following: This research's analytical framework utilized the integrated definition: *Policy instruments are social and technical government-citizen interfaces utilized to organize social relations and create structures of opportunity for actions, achieving goals; desirable outcomes and problem-solving*, to create questions and analyse data focused on the before mentioned applications of blockchain in government. The goal was to assess whether blockchain technology can fulfil the functions policy scholars have attributed to policy instruments. By constructing questions from the integrated definition, the researcher was able to analyse the data and determine if blockchain technology can fulfil the functions of a policy instrument. In doing so this study was able to demonstrate why policy scholars should consider studying this technology as a policy instrument.

The īnstrūmentum framework was applied to assess the data collected and answer the main and sub-questions within the analytical framework. Based on the observations made during the analytical process, this research answered either 'Yes', 'Partially' or 'No' to each question within the analytical framework to determine whether blockchain fulfilled the functions of a policy instrument when used within the context of 1) land registration, 2) national elections (voting) and 3) citizen identity management. To produce results for these main questions within the īnstrūmentum analytical framework, the analysis was done as outlined below.

If the majority of sub-questions below a main question were answered with 'yes', it meant that enough data were identified to suggest that in the blockchain application examined, the technology was able to fulfil the functions associated with existing policy instruments. Therefore, if most sub-questions were answered 'yes' by the researcher it confirmed that blockchain did fulfil the functions associated with policy instruments. If, however, the majority of sub-questions were answered either 'no' or 'partially' it would mean that insufficient or partial evidence was found to suggest that blockchain was able to fulfil the policy instrument functions in question. Through this systematic application of the īnstrūmentum analytical framework, the researcher produced answers to the four main questions.

3.5 Limitations of the research

The limitations of a study are defined as the characteristics of the design or methodology that impacted the findings from the research. They are the limits on the generalizability and utility of the findings that result from the way you initially designed the study, or the method used to establish validity (Price & Murnan, 2004:66).

The lack of available data on blockchain projects within government was a limitation for this research project and for the process of producing results. As discussed in the concluding remarks of the literature review, a wealth of information was found focusing on 'what could happen' if blockchain were utilized by government, but few examples were found where empirical results have been provided on the outcome of blockchains application in government. Furthermore, the lack of available quantitative data was a limitation as statistics would have generated more robust responses to the questions within the analytical framework. This would have enabled this research project to test to what degree blockchain can fulfil the functions of a policy instrument, especially for the functions of influencing social relations, achieving goals and solving problems.

3.6 Ethical considerations

This research process was limited to a desktop study and did not involve human participants or any form of primary data. The researcher ensured that information collecting for this research was referenced appropriately and all illustrations used were credited to the original creator. All collected data are freely accessible in the public domain and on the internet. This research was conducted ethically and seeks to ensure a positive contribution to knowledge on blockchain technology within the sphere policy studies.

3.7 Conclusion

Chapter Three explained the purpose of the analytical framework (īnstrūmentum framework) and how it was applied to find answers to the framework questions, which in turn offered a means to answer the main research question. This chapter further outlined the criteria for data collection, why certain data sources were selected, and the limitations of these methods and their ability to produce results. An exploratory qualitative design was selected because of the freshness of blockchain technology as a topic of research and it "allows the researcher to shed new light on a phenomenon within the context of its use" (Yin, 1984:13). Furthermore, this approach allowed the researcher to create the initial ideas to describe or discover new findings through methods that have not yet been explored. These initial steps were necessary as we have only scratched the surface of what we understand about this technology within the context of government and policy studies (Jun, 2018:8).

Chapter Four: Blockchain Technology as a Policy Instrument

4.1 Introduction

The analytical process began by identifying various articles, dissertations, working and government papers relating to either ongoing projects or potential projects of blockchain usage in government. This included blockchain applications relating to public administration for the *1) national land registry, 2) national election (voting) and 3) citizen identity management.* The īnstrūmentum framework was applied to assess these applications in both developed and developing nations. The analytical framework was applied to answer the main research question of this project: ***Can blockchain fulfil the functions of a policy instrument?*** This chapter concluded that blockchain technology can fulfil the functions of policy instruments in all three government applications examined.

To organize this chapter, the results for the three selected government blockchain applications were presented in three separate sections. Each section consists of an introduction, the four questions from the analytical framework, and a conclusion. Below *each* main question the key finding is presented. This is followed by a discussion of the overall findings and observations made to substantiate how the data were interpreted to answer the question. The discussion section also provides the sources used to produce answers. The discussion is followed by a conclusion which outlines the findings and a table summary is provided of the key findings. This format was selected to ensure an organized presentation of the results related to blockchain's functions. This further ensured the results for each respective government application is understood independently. This was the preferred approach as multiple findings of equal significance are presented. This helped create a clear understanding of each finding before proceeding to this chapter's conclusion where the findings for all three government applications are discussed and compared.

4.2 Blockchain Technology for National Land Registry

A national land registry refers to the government system whereby ownership of property and other land-related rights are recorded by government agencies (Benbunan-Fich & Castellanos, 2018:1). The key purpose of land registration records is to provide evidence that an individual or group of people legally own the title registered to a specific piece of land. As legal documents, land titles determine who can use sections of land, for how long and under what conditions. Land registration records contain and verify the transactions which took place to either buy or sell land titles and aims to prevent fraud, internal corruption by government agents and land disputes between citizens (Shang & Price, 2018:72).

For citizens, land rights have an impact on their access to economic opportunities. For governments, records of land ownerships are essential for collecting taxes and providing services, and they establish its territorial authority (Benbunan-Fich & Castellanos, 2018:1). The security of a legitimate land registry system is essential for the development of countries, as “it incentivizes title holders to further invest in their land, harbours trust in government agencies and generates broader social and economic development” (Shang & Price, 2018:72). An efficient land registry system “should promote economic growth, addresses economic inequalities, alleviate disputes and support local governance processes” (Benbunan-Fich & Castellanos, 2018: 1). Regardless of a country’s political or legal context, the goal of a land registry remains “to provide a system for recording titles of ownership and facilitating the legal transfer of land property rights in a secure manner” (Benbunan-Fich & Castellanos, 2018: 2).

4.2.1 Can blockchain act as a government-citizen interface?

Answer: *Blockchain technology can fulfil the function of a government-citizen interface for buyers, sellers, notaries and government land registry authorities when integrated with a website or decentralized mobile application (dApp).*

Blockchain is considered a next-generation “information and communications technology” (ICT) (Oyelere, Tomczyk, Bouali, & Joseph, 2019:85; Suikkanen, 2017:28).

> *Blockchain technology, which supports low-cost decentralized distributed data management featuring tamper resistance, high availability, and transparency is a breakthrough technology that will lead to the next generation of information and communications technology* (Kogure, Kamakura, Shima & Kubo, 2018:56).

“Information and communications technology” (ICT) describe the unified communication and integration of wireless signals (internet) and computers, as well as software and storage that enables users to access, store, transmit and edit digital information (Tamilselvan, Sivakumar & Sevukan, 2012:15). Governments have increasingly made use of ICTs for communicating and interacting with citizens; Bemile (2015) describes their role as follows:

> *Information and Communication Technology is a diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information. ICT’s enable Government-to-Citizen Information flow via the internet and*

> *vice versa. ICT can also facilitate Citizen-to-Citizen interaction by creating a virtual community to exchanges words, ideas and thoughts* (Bemile, 2015:115).

Considering that blockchain is understood as "a next generation information and communications technology" (Kogure et al., 2018:56), it requires a graphical user interface (GUI) for participants to access, store, transmit and manipulate information. A graphical user interface is the most common type of user interface in contemporary times and a 'friendly' way for users to interact with a computer network and other participants (Müller & Seifert, 2019:4). To support this understanding of blockchain as an ICT, existing pilot projects and potential future projects were analysed in which governments utilize blockchain as a government-citizen interface for national land registration and related administrative processes.

The Republic of Georgia is one of the few countries where blockchain has successfully been implemented and tested for the purpose of land registration. The National Agency of Public Registry (NAPR) has made use of blockchain since April of 2016 (Allessie *et al.*, 2019:19). In the case of Georgia, it was found that blockchain provided the function of a government-citizen interface for the NAPR land registry in various ways. By combining blockchain with the existing NAPR website, the Georgian government was able to "communicate and interact with citizens in the process of registering, selling and buying land titles" (Allessie *et al.*, 2019:20). Blockchain allowed citizens of Georgia to "access their property information and related public records at any time via the blockchain-based NAPR website" (Allessie *et al.*, 2019:21). This evidence is significant for two reasons: firstly, via the blockchain, government can communicate with citizen, and secondly, because of the additional transparency provided by blockchain, citizens are able to monitor the administrative processes of the national land registry, which can deepen citizen engagement.

Moreover, blockchain displayed its ability to function as an interface for the Georgian government as it could intervene in land registration processes. The NAPR could "mediate the buying and selling of land titles between citizens" (Shang & Price, 2018:77). This is achieved through their involvement in the process of approving transactions. How citizens interact with NAPR and each other on the national land registry is characterized as "programmable" (Berryhill, Bourgery, & Hanson, 2018:42). This programmability is enabled by the blockchain protocol and administrative privileges granted to the NAPR as the ruling authority. The NAPR therefore has the potential to govern how the land title system functions and ensures the integrity of data being processed between citizens and government agencies. This suggests that blockchains programmability and administrative privileges could help government agencies intervene in land administration processes to ensure policy goals are achieved.

Regarding blockchain's ability to provide government responsiveness the following articles look at blockchains application in Georgia (Allessie *et al.*, 2019; Berryhill *et al.*, 2018; World Bank, 2016) and they found that blockchain improved response time significantly. "Whereas the previous systems took up to 3 days to register, verify and approve land title registration, transactions on the blockchain took a few minutes to be processed and approved" (Allessie *et al.*, 2019:20). This is supported by Berryhill *et al.* (2018): "time required for a land transaction moved from days to an average of ten minutes" (2018:42). The "Doing business report" (World Bank, 2016:211) states it "took a maximum of one day to register property in Georgia" whereas "developed nations such as Germany and the United States took between 39 and 15.2 days respectively to register properties" (Shang & Price, 2018:75).

Considering the data presented by Allessie *et al.* (2019), Berryhill *et al.* (2018), the World Bank (2016) and Shang and Price (2018), it can be argued that blockchain is able to improve government responsiveness in land administration. It was therefore concluded that blockchain can fulfil the function of a government-citizen interface in the case of Georgia. In partnership with the government website, this technology allows the National Agency of Public Registry to communicate, interact and intervene in the processes of registering, buying and selling land titles via the graphical user interface (GUI) and applicable information communication technologies (ICT).

The case of Lantmäteriet (Swedish land registry) was also identified as a notable example of blockchain's ability to fulfil the function of a government-citizen interface. In 2016 actors from the Lantmäteriet strategy consultancy Kairos Future, along with the telecom Telia Company and the blockchain start-up ChromaWay, began to explore potential blockchain applications for real estate in Sweden. In a case study of Lantmäteriet, McMurren, Young and Verhulst (2018) explained how blockchain can function as an interface for the various parties involved in land registration:

> *Users navigate the blockchain through the app, with differing interfaces for different classes of user. End users such as buyers and sellers use a dedicated mobile app, with guidance from their realtor if necessary. End users see the state of the contract and are prompted when action on their part is needed. Professional users, such as banks, realtors, and Lantmäteriet, access the contract in a professional interface, which can*

be integrated with their own systems and processes. Administrators at the Lantmäteriet and its technical partners administer the contract through a third interface, with changes overseen by all partners running the blockchain (McMurren *et al*, 2018:5).

This evidence demonstrates two notable findings. The first is that blockchain shows the potential to function as an interface between not just two, but *multiple actors* (Figure 6). This included citizens (buyers and sellers), professional users such as banks and realtors (the facilitators) and the government agency Lantmäteriet (the authenticator). The second finding is that blockchain again displayed its ability to facilitate government intervention in the implementation of land policy, as the government agency Lantmäteriet and its technical partners have the ability to “administer the contract through a third interface, with changes overseen by all partners running the blockchain” (McMurren *et al.*, 2018:5). This also answers the question of whether blockchain can facilitate citizen engagement. The statement that “end users can see the state of the contract and are prompted when action on their part is needed” (McMurren *et al.*, 2018:5) indicates that blockchain allows for greater citizen engagement and transparency in the administrative processes of Sweden’s land registry.

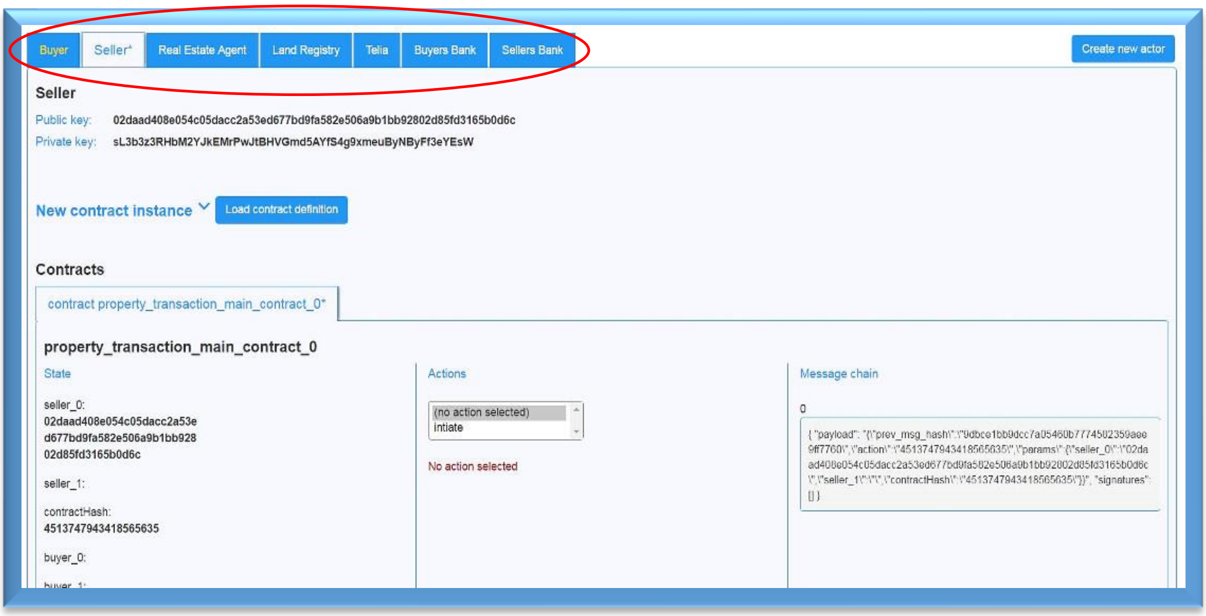

Figure 6: Sweden Lantmäteriet Website User Interface (Allessie et al, 2019).

In Brazil, a blockchain company called Ubitquity partnered with Brazil's real estate registry office in April of 2017, called Cartório de Registro de Imóveis, to potentially improve its land and property ownership recording process (Graglia & Mellon, 2018:56). A case study by Lemieux, Flores and Lacombe (2018) discuss the “front end web interface” (Figure 7) of the blockchain land registration system and how information communications technology can work together to process and display land recordings:

> *The solution comprises a web front end that captures information taken from the real estate registry's and general real estate registry, as well as a web server and back-end storage. These components communicate with the Application Programming Interface (API), translating what is entered using the front-end web user interface into a format that permits assets (i.e., land) and transactions involving those assets (i.e., land transfers) to be recorded on a blockchain* (Lemieux *et al.*, 2017:11)

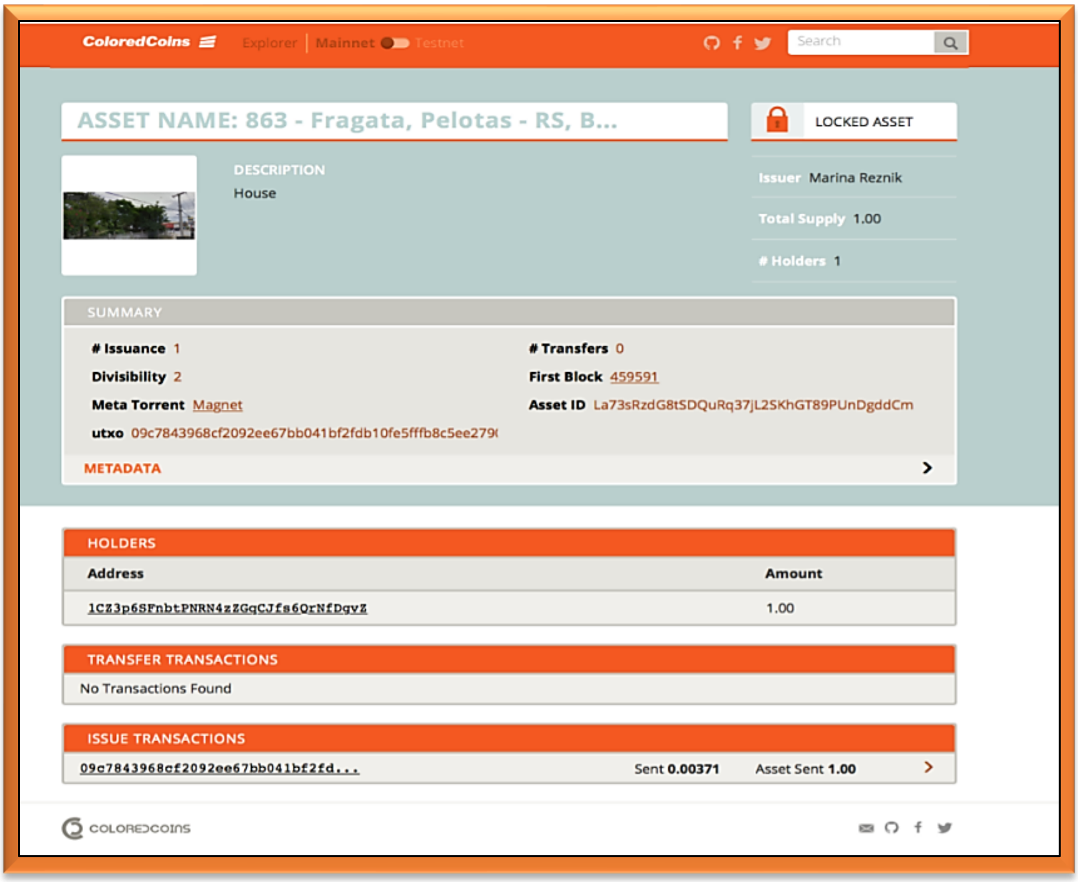

Figure 7: Cartório de Registro de Imóveis (Brazil) Website Interface (Lemieux, 2016).

Furthermore, in line with what was observed in articles discussing the use of blockchain in Georgia, Sweden and Brazil, instances were found where the *potential* of using blockchain as a government-citizen interface for land registration is discussed. Two studies (Atzori, 2017; Kombe, Manyilizu & Mvuma, 2017) discuss the ease of communication for end-users (citizens) when integrating blockchain with a graphical user interface (GUI).

> *Through simply downloading an app on your smartphone, you can choose your code of law, your preferred arbitration method, title your land, notarize a will and much more, in just a few minutes for a couple of dollars* (Atzori, 2017:48).

Similarly, Kombe *et al.* (2017) discuss how in Tanzania a blockchain-based land registry could facilitate the necessary security, while allowing for greater transparency and citizen engagement in land registration processes. They state that “all user interfaces are in web-based format and can be accessed easily with standard web browsers and normal mobile devices like smartphones and tablets” (2017:10). Müller and Seifert (2019:4) discuss India and the prospects for blockchain to facilitate interaction between the government and citizens. Here, “the blockchain backend will be combined with a web app as a frontend to provide citizens with more data transparency and accessibility.”

An important factor to consider is that blockchain cannot provide the function of a government-citizen interface in countries where land registry data are not in digital format. Governments who do want to implement blockchain for the purpose of land registration would first need to digitize non-digital documents to integrate existing systems. Four articles (Flores *et al.*, 2017:27; Benbunan-Fich, 2018:1; Tembo, Nkwae, Kampamba, 2014:4; Graglia & Mellon, 2018:95) discuss the issue of implementing blockchain in a country with a paper-based land registry and the problems associated with centralized paper-based systems.

In summary, when looking at blockchain’s ability to function as a government-citizen interface for land registration, there is a clear understanding that this technology must be partnered with some form of information communication technology (ICT) to facilitate interactions between governments, third parties and citizens. The terms “website”, “smartphone application” (app) and “decentralized application” (dApp) recur throughout the data examined. Blockchain cannot function as an interface by itself, but when integrated with any form of graphical user interface it becomes a means for government actors, banks and citizens to communicate in a transparent manner while administrating the buying, selling and registering of land titles. In instances (Georgia, Sweden and Brazil) where land titles had been successfully recorded in digital format, blockchain showed that it can fulfil the function of a government-citizen interface for land registration processes. Where the potentialities for blockchain to function as an interface for land registries have been discussed (Atzori, 2017; Kombe *et al.*, 2017) the data further indicate that blockchain can allow for communication, intervention and engagement by government actors and citizens.

4.2.2 Can blockchain organize social relations?

Answer: *Blockchain acts as a social technology in the context of national land registries and demonstrates the potential to partially influence the social structures of society, social relations, and interactions.*

Currently the process of land registration remains strictly manual and highly paper-intensive, which involves numerous government agencies for authentication and verification of data (Deloitte, 2018:12). Land, being a highly appreciating asset, is a matter of great value to people. Hence, citizens do not trust each other for title transfer and government bodies are needed to authenticate and verify the buying, selling and registration of land titles (Deloitte, 2018:11). This has left land registries open to fraud and land disputes which creates a social environment of distrust and doubt. This is especially present within the context of developing nations, where centralised government, inefficiency, corruption and lack of technological innovation have created high levels of distrust towards land administration (Levin, 2017:8).

As outlined in Chapter Two, Satoshi Nakamoto's blockchain technology is considered a ‘social technology’ (Davidson, De Filippi & Potts, 2016:1) and a clear example of an attempt to change how individuals interact (Jun, 2018:2). This is discussed by various scholars (Davidson *et al.*, 2016; Jun, 2018; Ulieru, 2016; Graglia & Mellon, 2018) who examine the societal effects blockchain can have in developed and developing nations.

> *Blockchain is unusual in that it is a social technology, designed to govern the behaviour of groups of people through social and financial incentives. It is inherently political in a way that few other technologies are* (Graglia & Mellon, 2018:90).

As a social technology, blockchain is proposed as a tool to increase citizens’ confidence in the government and make the overall experience of land registration less cumbersome.

> *A blockchain is a way of creating a robust, secure, transparent distributed ledger. This revolutionary technology is an unusual technology in that while manifestly understood as an information and computation technology (an ICT)—a software protocol based on cryptography and a new technology for public databases (of digital information)—it is actually better understood as an institutional or social technology for coordinating people* (Davidson *et al.*, 2016:1).

Blockchain’s “ability to govern the behaviour of groups of people through social and financial incentives” (Graglia & Mellon, 2018:90) and “coordinate people” (Davidson *et al.*, 2016:1) is based on the technical composition of this technology and its fundamental purpose as a "trustless network" (Al-Saqaf & Seidler, 2017:13) to ensure transparent and immutable land registry records. The assurance that registry information recorded by notaries is both secure and monitored by the blockchain protocol creates a social environment where relations between government agencies and citizens can be built upon "good faith" (Thomson Reuters, 2018:2) instead of scepticism. Galen, Brand, Boucherle, Davis, Do, El-Baz, Kimura, Wharton and Lee (2018:57) state that blockchain's ultimate goal is to empower citizens to interact directly with the government agents that facilitate societal interactions. This empowerment, they continue, could be measured in terms of decreased numbers of court disputes over land, or increased trust between citizens and land authorities.

The key blockchain features identified as having the potential to effect social relations are *transparency, immutability, improved security and data decentralization*. These are considered the main qualities that blockchain can offer governments for land administration which has the potential to influence social relations amongst citizens and between citizens and government agencies (Atzori, 2017:46; Benbunan-Fich, 2018:3; Herian, 2018:28; Davidson *et al.*, 2016; Graglia & Mellon, 2018:32) Considering that transparency is a feature of accountability and fighting corruption, the fact that "blockchain can provide transparency of the citizen and government relationships" (Lazuashvili, 2019:30) suggests that this technology has the ability to influence the relationship citizens have with government agencies in the process of land registration. One scholar writes: "Blockchain has the potential to make government operations more efficient by increasing trust in public sectors" (Carter & Ubacht, 2018:1).

Furthermore, various articles (Benbunan-Fich & Castellanos, 2018:3; Thomson Reuters, 2018; Galen *et al.*, 2018:53) discuss blockchain's ability to establish trust and how this can potentially influence social behaviour amongst citizens. Lazuashvili (2019) points out that

> *blockchain can be a useful tool to protect the land transaction parties, provide trust among the owner of the land and a seller and this way lead to increased validity of the land title records* (Lazuashvili, 2019:16).

This argument suggests that blockchain has the potential also to influence *citizen-citizen relations* when buying and selling land. To provide further evidence of blockchains potential to organize social relations, an analysis was done of reports where the existing and potential social effects of blockchain for land registries have been discussed. An article on the Republic of Georgia, where blockchain has already been tested, explains that relationships amongst citizens, and between government and citizens, were "influenced by the assurance of trust embedded in the cryptographically secured blockchain database architecture" (Shang & Price, 2018:74). This was similar to what was observed for Sweden's Lantmäteriet (Land Registry) by McMurren *et al.* (2018), who wrote:

> *The intended major outcome for this project was the creation of a secure, efficient, and trusted process of land transfer through the blockchain. The project designers intended that the blockchain solution would increase trust in the transfer of land titling, since all necessary information is visible to all parties before signing. The Lantmäteriet saw blockchain as a potential solution that could improve trust by increasing the security, transparency, and accuracy of the land transfer process, allowing all parties to track a transaction digitally from beginning to end* (McMurren *et al.*, 2018:6).

In developing nations, the issue of distrust of government agencies is especially high (Roelofs, 2019:567). In South Africa the 2019 Edelman Trust Barometer report found that only 14% of those surveyed trust the government institutions responsible for land registration. The same was observed in Nigeria and Ghana, where trust in government is considered to be low relative to developed nations (Godefroidt, Langer & Meuleman, 2017). Godefroidt *et al.* (2017) argue:

> *In numerous African countries facing relatively high levels of fractionalization, corruption, and inequality scepticism and distrust in legal-political institutions and actors are thought to be widespread* (Godefroidt *et al.*, 201:917).

To address this, Angel Gurría, secretary-general of the Organisation for Economic Co-operation and Development (OECD), argues that "governments must focus on investing in good public governance and move towards a more inclusive society." Interestingly, this request for good governance is indirectly answered by Atzori (2015:20), who argues that "blockchain can be instrumental in promoting development and good governance". This argument is supported by various other scholars (Vos, 2016; Joshi & Rajeswari, 2019:424; Chandra & Rangaraju, 2017:25), who describe blockchain's ability to promote good governance and greater inclusivity in administrative processes of land titling. Vos (2016: 25), for instance, specifically argues that "in the case of blockchain technology, many of the principles of good governance in land administration can or will be met in the future".

To substantiate that blockchain can in fact provide the function of organizing social relations, this study had to establish whether there is a correlation between transparency and trust, and whether increased transparency can influence the degree of trust citizens have towards government. To do this an article by Mabillard and Pasquier (2015) was examined. The main goal of their research was to examine if a higher level of transparency directly leads to higher levels of trust in government. Unexpectedly, their results show that "there is no direct correlation between the reinforcement of transparency measures and the level of trust in government" (Mabillard & Pasquier, 2015:30). This, they argue, is because greater transparency could in fact expose existing corruption which could in fact decrease trust in government. This could therefore have a negative outcome on social relations.

These data are presented not to invalidate blockchain's potential ability to influence trust, but it is necessary to show that there are conflicting arguments on the topic. It can therefore not be guaranteed that blockchain's ability to provide complete transparency of land registries will be positive in all respects. In some cases where there is already a desirable level of trust it could strengthen the existing social relations between the state and citizens, but it can also have a negative influence on social relations if the greater transparency exposes existing unwanted corruption or fraud. That being said, additional sources demonstrate that the results found by Mabillar and Pasquier (2015) are not necessarily true in all cases. An extensive analysis by Grigorescu (2003) found that there is in fact a correlation between these variables and affirms that "the higher the level of transparency, the higher the level of trust in government". Regardless of these contesting arguments blockchain does have the potential to organize social relations to some extent.

It should be noted that it is not only transparency that blockchain brings to the table. Improved security, immutability and decentralization of land title data are all variables which have the potential to organize social relations amongst citizens when buying and selling land titles. These variables can also influence the relationship citizens have with government agencies in charge of registering these transactions and the interactions they have with one another. In summary, the data indicate that blockchain technology can partially fulfil the function of organizing social relations in the context of national land registries. These social relations relate to the level of trust amongst citizens and the interactions that citizens have with government agencies. To what extent this can be achieved will be subject to future investigation, as the current evidence could not provide enough data to draw conclusions at such an early stage of this technology's development.

4.2.3 Can blockchain create opportunity structures for action and achieving goals?

Answer: *A function of blockchain technology which continuously presented itself is the potential to provide sets of rules, achieve goals and create desirable policy outcomes in the context of national land registries.*

Before substantiating this finding, it is necessary to note that the key purpose of a land registry is to provide evidence that an individual or group legally owns the title registered to a specific piece of land. As legal documents, land titles determine who can use sections of land, for how long and under what conditions. According to Shelkovnikov (2016:13), regardless of political context, the goal of a land registry remains the same: "to provide a system for recording titles of ownership and facilitating the legal transference of land property rights in a secure manner".

A core motivation for integrating blockchain with a national land registry is to capitalize on how this technology can improve the existing administrative processes for all parties involved. Blockchain, like any new technological innovation, has been, -and will be implemented in the future with the purpose of improving existing processes. Various scholars (Osborne, 2017; Jun, 2018; Van den Berg, 2018:3; Casino *et al.*, 2019:64; Allessie *et al.*, 2019:19; Bates, 2016:12) discuss how blockchain can create opportunity structures to facilitate the essential policy goals of a national land registry. These policy goals are to 1) provide a system for recording titles of ownership, 2) facilitate the legal transference of land property rights, and 3) provide evidence that an individual or group of people legally own the title to a specific piece of land they claim to be theirs. (Shelkovnikov 2016:13).

In addition to performing the essential functions, blockchain creates a new opportunity structure for government in that it can enforce sets of rules through programmable protocols. *Smart contracts* can potentially have a major impact on how land titles are processed, how citizens buy and sell land, and the regulation of such transactions. As outlined in the literature review (Chapter Two), "a smart contract is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation of a contract" (Sadiku *et al.*, 2018:538). A computer protocol is described by Encyclopaedia Britannica (2018) as follows:

> *a set of rules for transmitting data between electronic devices. In order for computers (users) to exchange information, there must be a pre-existing agreement as to how the information will be structured and how each side will send and receive it.*

A smart contract protocol therefore defines the rules and regulations around an agreement on a blockchain and automatically enforces those obligations (Martyn, 2018:68; Miller, Bennett & Kara, 2019:1; Méndez, 2018). This is significant in the context of land registries for two reasons. The first is that it demonstrates how smart contracts allow government the ability to ensure the validity of land title transactions through codes rather than human subjectivity, while predetermined contractual agreements need to be met before any land title is transferred or validated to the network. For example, a buyer would need a sufficient sum of money to purchase a land title, and the land title to be sold would need to be 1) up for sale, 2) owned by the person selling the title, and 3) validated by a government authority.

If any of these conditions are not met, the blockchain would automatically deny the transaction as it would be considered incomplete. This could prevent fraudulent transactions from taking place between citizens as well as assist government agencies in regulating the validity of ongoing land transactions in near real time (Sadiku *et al.*, 2018:539). The second point of significance is that from an administrative perspective this demonstrates that substantial gains are to be had from utilizing a blockchain-based land registry. Governments are given the potential to stipulate rules and monitor the state of the property and sale deed in near real time, as well as have instant access to a complete and permanent transactional history for each property deed. Smart contracts can therefore assist blockchain technology in fulfilling the function of providing sets of rules and guidelines to shape an opportunity structure for the purpose of producing value for citizens and state.

Furthermore, in existing registries the registration of title deeds is performed manually, which can lead to error, excessively long processing times and high costs. Land registration also involves multiple government bodies for authentication, which creates bottle necks for implementation. Land title transfer, similarly, involves repetition and duplication of processes, which result in long processing times and costs. To rectify these undesirable issues blockchain is proposed as having the potential to assist government in achieving policy goals and creating desirable conditions. Deloitte (2018) states:

> *In a blockchain-based land registration and title transfer process, all the players are on a single platform with distributed ownership rights. This provides transparency, automated verification and irreversible trail of title transfer; thus, blockchain enables faster, secure and cheaper mode of asset registry maintenance* (Deloitte, 2018:13).

Implementing a decentralized, single-platform blockchain system for land registration records could reduce the number of intermediaries required for authentication, increase process efficiencies, and decrease the time and cost to process. Many scholars (Méndez, 2018:21; Deloitte, 2018:6; Krigsholm, Ridanpää & Riekkinen, 2019:6; McMurren *et al.*, 2018:4) make the argument that recording property rights via blockchain could enable annual cost savings for title insurers through a tamper-proof ledger, reduce lead times and expedite the registration process.

The table below further outlines blockchain's ability to achieve policy goals and create desirable conditions for land administration. The left column stipulates the policy goal(s) and desirable outcome(s) that blockchain technology can offer, the middle column summarises the functions that blockchain provides which have the potential to create the opportunity structures needed to achieve these beneficial outcomes, and the right column lists the sources used to support the argument being made.

Policy goals and Desirable Outcomes	**Blockchain Function**	**Sources**
Lower administrative costs	Blockchain can lower the costs of land title transactions; this is beneficial to buyers, sellers and government fiscal budgets. This could result in cheaper registration fees for citizens and allow more funds to be available for other policy implementation drives by government.	Allessie *et al.* (2019:66) Deloitte (2018:12) Catalini & Gans(2019:13) Müller & Seifert (2019:7)
Improved Processing Time	Blockchain can reduce the time to validate and verify land transactions at every level which is beneficial for all participants. This can improve end-customer experience because of shorter waiting times and government effectiveness in achieving land administration goals. This can also increase overall efficiency for all participants involved in the buying, selling and registration of land titles (Figure 8).	Allessie *et al.* (2019:27) Deloitte (2018:11) Kairos Future (2017:16) Stefanović *et al.* (2018:5)

Immutable and reliable land transaction details	Blockchain can enhance data integrity, immutability and data consistency between organisations, which is beneficial to land administration and future economic growth. This eliminates the possibility of selling a property more than once and increases the credibility of land titles. Reliable land registries can influence the economic growth of a country.	Barbieri & Gassen (2017:2) Sanders & Steeves (2018:20) Saull & Baum (2019:7)

To support these observations, cases were examined where efforts have moved beyond the potentialities and produced actual results. In the Republic of Georgia, Sweden (McMurren *et al.*, 2018) and Ghana (Eder, 2019) blockchain has demonstrated its ability to achieve policy goals and create desirable outcomes. A report by Allessie *et al.* (2019) highlights the following:

> *Blockchain increased efficiency in the land registry system as a whole by reducing processing times from days to a matter of seconds* (Allessie *et al.*, 2019:20). *The registration of property extracts became 400 times faster than the previous system and government operational costs were reduced up to 90% for the land title registering service* (Allessie *et al.*, 2019:18).

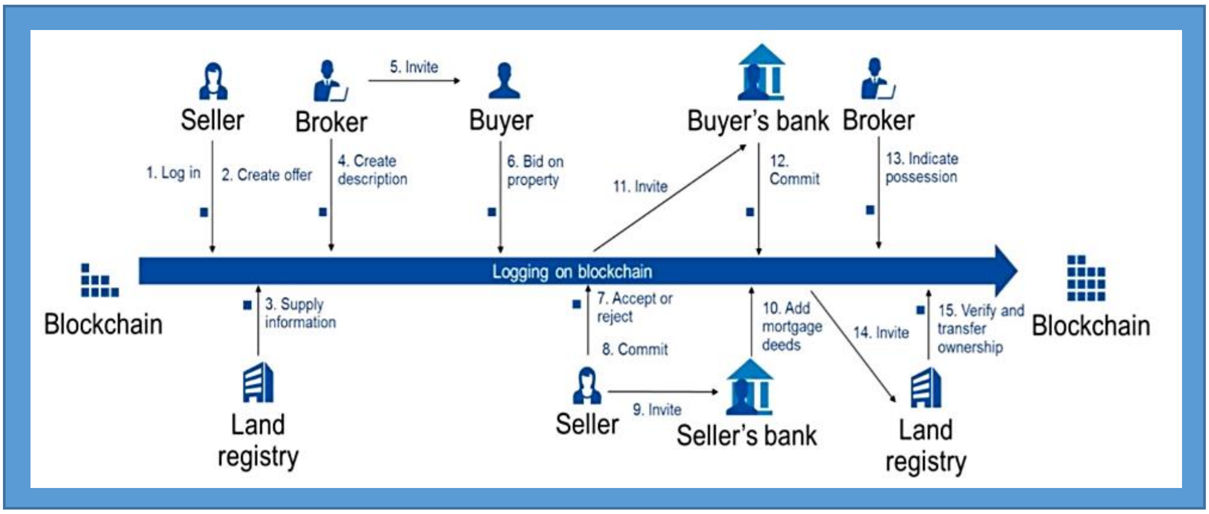

Figure 8: Chromaway land transfer workflow, Sweden (Allessie et al, 2019).

Furthermore, blockchain's ability to provide secure, efficient and immutable land title transactions has the potential to establish a reliable land registry. Interviews conducted with blockchain experts by Krigsholm *et al.* (2019) found that:

> *Interviewees identified blockchains ability to maintain integrity, reliability, and originality of data in situations where trust is missing between parties as the most important reformation of the blockchain technology* (Krigsholm *et al.*, 2019:8).

This was an important observation as, according to Mburu (2017:33), a reliable land registry creates an economic environment where citizens, investors and government agencies could all benefit. Governments along with financial institutions use registered property as collateral (Osborne, 2017). Knowing that the information recorded on the blockchain is immutable can therefore serve as a reliable basis for investment and issuing loans. This indicates that the integrity and security of a land registry has the potential to directly influence economic growth. Saull and Baum (2019) argue that:

> *Land titles provide financial protection. If a secure title is guaranteed by a reliable land registration system, land can be used to create wealth for the broader benefit of society and contribute to the eradication of poverty. Insecure title to land prevents people from taking full advantage of its productive capacity and limits economic growth* (Saull & Baum, 2019:7).

Research by Holden and Ghebru (2016) similarly support this claim in the context of Nigeria. Their work found a direct correlation between the security and reliability of land tenure and government's ability to stimulate investment in land. This indicates that blockchain's ability to ensure a secure and reliable land registry has the potential to influence opportunity structures for economic growth in both developed and developing nations, and can assist government in achieving both financial and operational policy goals within the context of land administration.

In summary, the evidence shows that a prominent function of blockchain is its ability to create opportunities for action and achieve goals for administrative processes related to a national land registry. Smart contracts were identified as a key component in blockchains ability to create opportunity structures for regulation of policy implementation and attaining desirable outcomes. Smart contracts (self-executing protocols) allow for preprogramed sets of rules and regulations which citizens must abide by to participate and interact on a blockchain based land registry. Blockchain's potential to provide sets of rules can directly influence how citizens and government agencies interact during land registration processes and any related land title transactions between citizens. Finally, with regards to achieving desirable outcomes, the key improvements blockchain can offer a national land registry are 1) lower administrative costs, 2.) faster processing times, 3) increased reliability, and 4) data security, which can create opportunity structures to better facilitate the implementation of policy goals.

4.2.4 Can blockchain solve problems?

Answer: *Blockchain has the potential to solve multiple problems related to land registries and allow government agencies to prevent future problems of land disputes; it can also assess how effectively problems are solved through data tracking.*

There is a consensus (Ziolkowski, Miscione & Schwabe, 2018:14; Kairos Future, 2017:15; Sanders & Steeves, 2018:24) that a key function of blockchain is addressing problems which hamper government's ability to provide an inclusive, secure and reliable land registry. Key problem areas identified in the context of national land registries are issues of corruption, cyber-attacks, data loss and unequal accessibility to registration processes. In some cases there is a complete lack of infrastructure, which has resulted in more than 70 percent of the world's population lacking a legally registered title to their land (World Bank, 2017).

Although to different degrees, these issues are faced in both developed and developing nations, according to Tembo *et al.* (2014). To address these pressing issues, a blockchain-based land registry is proposed (Sekhari, Chatterjee, Dwivedi, Negi & Shukla, 2019; Müller & Seifert, 2019; Kogure *et al.*, 2018; Shang & Prince, 2018). From the data examined, it is clear that features such as *transparency, immutability, and decentralization* offered by blockchain indicate that this technology has the potential to address or solve many problems faced within the context of national land registries.

The issues of corruption and fraud are among the most prominent. Anand, McKibbin and Pichel (2015) rank land administration to be "amongst the topmost corrupted sectors in the world". Blockchain technology shows the potential to reduce government corruption by enhancing the existing processes of government. Various articles (Shang & Prince, 2018; Vos, 2016; Aggarwal & Floridi, 2018; Allessie *et al.*, 2019) discuss both why and how blockchain can address the problems of corruption and fraud. The key features identified are immutability and transparency and these factors show its potential to help curb corruption and fraud. A statement by Shang and Prince (2018) supports this argument:

> *Governments can harness blockchain technology to address multiple issues. More specifically, the immutable and transparent nature of this technology could curb*

> *forgery of land title and create an incorruptible history of land transactions* (Shang & Prince, 2018:73).

The reasoning behind their arguments suggest that blockchain's immutability, auditability and increased transparency has the ability to expose corruption or restrict corrupt officials in their ability to manipulate data for their own benefit without being noticed. On a blockchain, the land registration process would potentially be less vulnerable to error and fraud, and all parties participating in transactions will have a digital copy, creating data redundancy and lessen the probability of corruption. To support this argument, cases were found which move beyond the potentialities and look at practical examples of where blockchain has been implemented.

In the Republic of Georgia, the reasoning for implementing blockchain technology, from a public policy perspective, was specifically a part of a broader initiative to attract international investors by curbing corruption (Eder, 2019:5). "Blockchain was integrated with Georgia's land registry network as an independent and incorruptible layer to cease land title disputes and combat internal fraud" (Allessie *et al.*, 2019:21). To prevent corruption, Georgia's verification of land certificates is now made on a public blockchain, which is beyond the control of any government official, participant or a group of participants. The technology's independent and incorruptible layer helps to combat fraud and prevent land title disputes. Brazil, as a developing nation, similarly implemented blockchain specifically for its anti-corruption potentialities after citizens began to question the credibility of existing land records (Aggarwal & Floridi, 2018:2). Weizsäcker, Eggler and Atarim (2019) states:

> *Blockchain-based recording of land titles is particularly relevant in contexts where existing land licensing and registration processes are facing fraudulent and corrupt practices, particularly related to document fraud, double selling, or risk of malicious actors within governmental institutions confiscating land. The auditability and transparency introduced by blockchain would significantly increase trust in land registries and management* (Weizsäcker *et al*., 2019:4).

This indicates that both the transparency and technical configuration provided by using blockchain as an implementation tool can influence future policy outcomes and points towards the way that governments can address internal challenges of fraud and corruption successfully.

Contesting arguments, however, point out that blockchain is not necessarily a perfect solution to eradicate corruption. Ziolkowski *et al.* (2018:14) found that the initial data input point to blockchain-based systems remains a crucial vulnerability and can be subject to fraud if not monitored. Ziolkowski *et al.* (2018) agree with the positive narrative that as soon as a land title is registered, it will be immutable and irreversible, but they add that in the initial phases of blockchain implementation what data are actually recorded will remain in the hands of authorities. This observation encouraged further investigation into opposing arguments, which found that some scholars (Aggarwal & Floridi, 2018; Aliyev & Safarov, 2019:10) have questioned blockchain's ability to truly act as a solution for corruption, especially in developing countries, where corruption and mistrust in the political order are widespread.

Irrespective of this, immutability and transparency remain good deterrents of fraud. Once entered, fraudulent data will remain visible to the public and can be brought to court if necessary, which could steer both citizens and government officials' behaviour towards acting honestly as the risk of being caught rises exponentially. This indicates that blockchain can still at the very least address the issue of corruption and has the potential to solve fraud cases as a result of its immutable and transparent configuration. Krigsholm *et al.* (2019) support this argument and similarly highlight blockchain's transparency and immutability as a potential solution to unlawful administrative behaviour:

> *Blockchain it is more difficult to falsify or eradicate information, or at the very least it is possible to trace down at which point the chain of information had been fudged* (Krigsholm *et al.*, 2019:8).

Cyber-attacks were also identified as a problem that blockchain can address. The increased use of information and communication technologies (ICT) by both citizens and state has left government administrations increasingly vulnerable to cyber-attacks (Sekhari *et al.*, 2019:1). Coats (2019:5) found that in 2019 76% of organisations in the United states alone experienced some form of cyber-attack. Many of these are traced back to China, Russia and Iran. A blockchain-based framework is proposed by various scholars as a potential solution to this policy problem (Allessie *et al.*, 2019:14; Mathew, 2019:3823; Sari, 2018:62) Three articles (Alladi, Chamola, Rodrigues & Kozlov, 2019:20; Dong, Luo & Liang, 2018:2; Taylor, Dargahi, Dehghantanha, Parizi & Choo, 2019) identify blockchain's decentralized structure, immutability and cryptographic configuration (See page 14) as qualities which can address the issue of cyber-attacks. Krigsholm *et al.* (2019) highlight that

> *The decentralized structure of a blockchain land-based system has a high tolerance for faults since the maintained database locates at several servers simultaneously. This*

> *means that a single server is not alone in a critical position in case of possible attacks or other faults* (Krigsholm *et al.*, 2019:9).

These features would make it significantly more difficult for hackers to infiltrate a government network (Allessie *et al.*, 2019:14). This indicates that blockchain's decentralization of land registries can bring two main strengths: security and removing a single point of failure. Atzori (2015:47) supports this by arguing that since multiple participants share an immutable copy of the information on a blockchain based land registry, it has *no single point of failure* and is significantly more resilient to attacks than existing centralized land registry databases. A hacker would need to simultaneously compromise over fifty percent (51% attack) of the network nodes before the data would be permanently insecure (Mathew, 2019:3822). This suggests that if a national land registry database was distributed and copies of each land transaction are also decentralized and protected through cryptography on a public network, a blockchain could maintain the integrity of land records and be useful for detecting, exposing and deterring cyber-attacks. Blockchain therefore has the potential to address the problem of cyber-attacks, or at least provide improved security measures for national land registries in comparison to existing centralized network servers.

The problem of *natural disasters* destroying land registry records is also a problem which can affect land registry regulation for both developed and developing nations. The data suggest that developing countries seem to be more vulnerable to this problem (Wirtz, Kron, Löw & Steuer 2014:135) as land records are typically kept on paper in a centralized location. This again raises the issue of a single point of failure (SPOF) as described by Atzori (2015:47). A paper-based land registry is therefore significantly more vulnerable to natural or man-made disasters which can cause data loss. As witnessed in the case of Haiti's devastating 2010 earthquake, large amounts of land documents and transaction details were ruined, which resulted in an increase in land disputes and fraud (World Bank, 2010:39). To address this issue, blockchain is proposed as a solution (Benbunan-Fich & Castellanos, 2018:3; Maupin, Kahlert, Weizsäcker, Eggler, Honsel, Peter, Hess & Fischle, 2019:41; Sravani & Murali, 2019:21) to reduce the vulnerability of data loss and increase the reliability of land registration systems through decentralization and essential data redundancy. Goonathilaake, Deshapriya, Jayakody & Dharanidu, 2018) support this argument:

> *Data loss is addressed because even if the database crashed and become unavailable, the Blockchain transactions will be there. Since every node in land registry has a copy*

> *of Blockchain, even if 99% of nodes are down, the system can still be recovered with the use of the single node which was not down* (Goonathilaake *et al.*, 2018:44).

Finally, inequality in accessibility to land registration was also found to be a recurring problem within the context of national land registries. In developing nations especially, the issue of unequal access to land registration processes has been hampering economic equality and growth (Cotula, Toulmin & Quan, 2006:36). Ghana, which piloted blockchain in 2016, is among the countries that have been crippled by this issue. Nwuba and Nuhu (2018:148) found that the land registration processes is inaccessible to "most Ghanaian citizens and appears not to provide tenure security." The latter was identified after the authors conducted multiple interviews with local Ghanaian land users on how they feel about the existing land registry system. In Mozambique, Nwuba and Nuhu's (2018:148) research similarly found that registration is not easily accessible to low-income groups because of a lack of information and high costs, many of which are illegal payments to officials to process applications unlawfully.

As previously demonstrated, blockchain-based land registries can fulfil the function of a government-citizen interface and create a more accessible environment for land administration via a website or smartphone application. This was proven in the case of both the Republic of Georgia and Sweden (Allessie *et al.*, 2019:21; McMurren *et al.*, 2018:5) If the claims of blockchain improving accessibility hold true as outlined by these scholars, a blockchain-based land registry does have the potential to address the problem of providing equality in land registration processes to all citizens in a country, regardless of their economic position. A limitation of this, however, is that blockchains ability to improve accessibility would be "dependent upon whether citizens have access to internet and some form of computer device" (Kairos Future, 2017:14).

Finally, whether it be the issue of corruption, fraud or inequality in accessibility, the fact that blockchain technology networks are transparent, immutable and digital in nature allows policy makers the ability to assess whether systematic operations to solve an identified policy problem has been successful or to what extent it is being addressed. Allessie *et al.* (2019:10) state that a key benefit of blockchain technology is that "it's distributed configuration shares content across multiple parties. This shared nature makes transactions easily trackable and full disclosable even in large and complex ecosystems." A blockchain based land registry has the ability to enable real-time tracking and transparency for policy makers and make data analysis significantly more user-friendly than paper-based records (Davidson *et al.*, 2016:18).

In summary, when assessing whether blockchain technology can fulfil the function of solving problems for government in the context of national land registries, the data examined were predominantly positive, but scepticism remains about its ability to completely resolve the issue of corruption. Blockchain's features of immutability, transparency and decentralization of data were identified as the key qualities which can influence a government's ability to solve problems for their national land registry. Blockchain's ability to track data in near real time can also be a key feature in helping policy makers analyse the effectiveness of implementing and regulating land administration. This can incorporate better evidence-based policy making and in turn improve public service delivery. Finally, inequality in accessibility to land registration processes can be addressed by implementing a blockchain-based land registry. Having access to land registries via a website or smartphone application shows the potential to make land registration processes more accessible to low-income groups. This was found to be a policy problem blockchain can address particularly in developing nations.

4.2.5 Conclusion

Blockchain technology demonstrates both the ability and potential to fulfil three of the four functions of a policy instrument when implemented within the context of a national land registry. The evidence suggests that blockchain can fulfil the function of a government-citizen interface. In some cases (Georgia, Sweden, Ghana and Brazil) the application of this technology for land administration has already been tested, while in future projects (South Africa, Botswana, Mozambique and India) the data indicate the potential benefits this technology can offer governments and citizens as an implementation and regulation tool. It was concluded that blockchain could only fulfil three of the four functions as no evidence was found to conclude that blockchain can directly configure social behaviour at such an early stage. This was mostly due to the limited data available. Blockchain therefore only partially fulfilled the analytical framework's criteria of organizing social relations

That being said, it was concluded that blockchain can influence social interactions among citizens and influence government-citizen relations. Furthermore, blockchains features of *transparency*, *immutability*, *decentralization* and *programmability* were identified as the qualities that give it the potential to provide the functions of creating opportunity structures for achieving goals, implementing sets of rules and solving problems. It should be noted that the *blockchain trilemma* of maintaining efficiency, security and scalability simultaneously is a factor which will directly influence the success of a blockchain-based land registry. These issues have a direct influence on blockchain’s ability to provide the core functions of a policy instrument in the context of national land registries.

4.2.6 Summary of findings

Blockchain Technology for National Land Registries	Yes	Partially	No
1.) Can blockchain act as a government-citizen interface?	✓		
- Can blockchain enable government to communicate and respond to citizens?	✓		
- Can blockchain facilitate citizen engagement?	✓		
- Can blockchain facilitate government intervention?	✓		
Sources: (Allessie *et al.*, 2019); (Berryhill *et al.*, 2018); (Benbunan-Fich & Castellanos, 2018); (Eder, 2019); (Lazuashvili, 2019); (Sekhari *et al.*, 2019); (Müller & Seifert, 2019); (Kogure et al., 2018); (Tamilselvan *et al.*, 2012); (Terzi et al., 2019); (World Bank, 2016); (McMurren *et al.*, 2018); (Graglia & Mellon, 2018); (Flores *et al.*, 2017); (Atzori, 2017); (Kombe *et al.*, 2017); (Flores *et al.*, 2017); (Benbunan-Fich, 2018); (Tembo *et al.*, 2014).			
2.) Can blockchain organize social relations?		✓	
- Can blockchain influence social relations among citizens?	✓		
- Can blockchain influence government-citizen relations?	✓		
- Can blockchain configure social behaviour among citizens?			✗
Sources: (Deloitte, 2018); (Levin, 2017); (Davidson *et al.*, 2016); (Jun, 2018); (Ulieru, 2016); (Graglia & Mellon, 2018); (Al-Saqaf & Seidler, 2017); (Thomson Reuters, 2018); (Galen *et al.*, 2018); (Atzori, 2017); (Benbunan-Fich, 2018); (Herian, 2018); (Lazuashvili, 2019); (Carter & Ubacht, 2018); (Shang & Price, 2018); (McMurren *et al.*, 2018); (Godefroidt *et al.*, 2017); (Vos, 2016); (Joshi & Rajeswari, 2019); (Chandra & Rangaraju, 2017); (Mabillard & Pasquier, 2015); (Grigorescu, 2003).			
3.) Can blockchain create structures of opportunity for actions and achieving goals?	✓		
- Can blockchain provide rules and regulations to influence opportunity structures?	✓		
- Can blockchain provide opportunity for action and achieve policy goals?	✓		
- Can blockchain assist government in attaining desired outcomes?	✓		
Sources:(Shelkovnikov 2016); (Osborne, 2017); (Jun, 2018); (Van den Berg, 2018); (Casino *et al.*, 2019); (Bates, 2016); (Sadiku *et al.*, 2018); (Encyclopaedia Britannica, 2018); (Martyn, 2018); (Miller *et al.*, 2019); (Méndez, 2018) (Deloitte, 2018); (Méndez, 2018:21); (Krigsholm *et al.*, 2019); (McMurren *et al.*, 2018); (Allessie *et al.*, 2019); (Shah & Chatterjee, 2017); (Müller & Seifert, 2019); (Kairos Future, 2017); (Stefanović *et al.*, 2018); (Barbieri & Gassen, 2017); (Sanders & Steeves, 2018); (Saull & Baum, 2019); (McMurren *et al.*, 2018); (Eder, 2019); (Krigsholm *et al.*, 2019); (Mburu, 2017); (Osborne, 2017);(Holden & Ghebru, 2016); (Martyn, 2018); (Miller *et al.*, 2019); (Méndez, 2018); (Catalini & Gans, 2019).			
4.) Can blockchain solve problems?	✓		
- Can blockchain assist government to solve identified policy problems?	✓		
- Can blockchain help prevent future problems?	✓		
- Can blockchain allow policymakers to assess whether the systematic operations to solve an identified problem was successful?	✓		
Sources: (Benbunan-Fich & Castellanos, 2018);(Ziolkowski *et al.*, 2018); (Kairos Future, 2017); (Sanders & Steeves, 2018); (World Bank, 2018); (Tembo *et al.*, 2014); (Sekhari *et al.*, 2019); (Müller & Seifert, 2019); (Kogure *et al.*, 2018); (Shang & Prince, 2018); (Transparency International, 2019); (Anand *et al.*, 2015); (Vos 2016); (Aggarwal & Floridi, 2018); (Allessie *et al.*, 2019) (Eder, 2019); (Weizsäcker et al., 2019); (Aliyev & Safarov, 2019); (Krigsholm *et al.*, 2019); (Sekhari *et al.*, 2019); (Alon, 2019); (Mathew, 2019); (Liang *et al.*, 2019); (Alladi *et al.*, 2019); (Dong *et al.*, 2018); (Taylor *et al.*, 2019); (Wirtz *et al.*, 2014); (World Bank, 2010); (Dobhal & Regan 2016); (Maupin, 2019); (Sravani & Murali, 2019); (Goonathilaake *et al.*, 2018); (Cotula *et al.*, 2006); (Nwuba & Nuhu, 2018); (Davidson *et al.*, 2016).			

4.3 Blockchain Technology for National Elections (Voting)

There is agreement (Wojtasik, 2013; Lindberg, 2004; Norris, Frank & Coma, 2013) that elections are central to the development of a good democracy in any country. Elections are considered to be of central importance for good democratic governance, and, in every democracy, the security and integrity of an election is a matter of national security (Dill, 2016). A national election is an instrument through which all groups of citizens are granted an opportunity to elect rulers of their choice. Elections are therefore a mechanism through which citizens can truly participate in how a country is governed and its legitimacy can either make or break a nation's potential for continued democratic consolidation.

4.3.1 Can blockchain act as a government-citizen interface?

Answer: *Blockchain technology can function as a government-citizen interface for national elections (voting) when integrated with a website or decentralized mobile voting application.*

Blockchain can fulfil the functions of a government-citizen interface for national elections when integrated with a graphical user interface (GUI). As witnessed in the context of national land registries, blockchain functions as a "next generation information and communications technology" (Oyelere *et al.*, 2019:85; Suikkanen, 2017:28) which allows users to access, store, transmit and edit digital information (Tamilselvan *et al.*, 2012:15). Within the context of voting, the way that government and citizens interface -meaning the process of casting a vote- is "a very private matter" and should be treated accordingly (Sturgis, 2005:18). Although ordinary ICTs cannot ensure this, blockchain has the ability to provide the necessary privacy through "peer-to-peer" functionality (Yi, 2019:2).

Some (Osgood, 2016; Zheng *et al.*, 2018:337) argue that blockchain can offer the personal experience that voters expect, similar to the way paper ballots are used as a government-citizen interface to cast votes. The difference, however, is that paper based systems require a 'trusted' intermediary to count votes, whereas a blockchain based e-voting system could partially "eliminate the need for a trusted third party altogether" and instead allow citizens to "directly interface through an online portal" (Hjálmarsson & Hreiðarsson, 2018:8). This indicates that citizens would have the ability to interact with government during election time, be in control of and monitor their vote, but also "remain completely anonymous amongst other voters to preserve privacy" (Wei & Chuah, 2018:337). Curran (2018) states:

> *One of the most valid domains for a blockchain is for e-voting. Platforms like this allow citizens to cast their votes anonymously on smartphone apps, rather than having to queue up at inconvenient polling stations* (Curran, 2018:2).

In addition to its *peer-to-peer* communicative abilities, this technology can offer other functions as a government-citizen interface which can be utilized for the benefit of voters, policy makers and electoral commissions. Four articles (Ayed, 2017:2; Young & Verhulst, 2018:62; Shah, Kanchwala & Mi, 2016:2; Curran, 2018:2) discuss blockchain's potential to facilitate ethical government intervention in the voting process and outlines how citizens can engage via the digital interface when casting their vote. Bear in mind, these are two of the three qualities needed to provide the function of a government-citizen interface as outlined in the analytical framework. Hjálmarsson and Hreiðarsson (2018) highlight this:

> *The Admin dApp allows election administrators to set election policies, create ballots, establish registration rules and open and close voting. The Voter dApp is used by individual voters for registration, voting and can be integrated with other devices (such as biometric readers) for voter identification* (Hjálmarsson & Hreiðarsson, 2018:4).

Arguments put forward by Hjálmarsson and Hreiðarsson (2018) and Curran (2018) indicate that a blockchain-based e-voting system can offer governments administrative privileges to intervene in election processes and furthermore allows citizens greater ease of accessibility to cast votes. This can result in greater citizen engagement as citizens would be more likely to vote if they can do so from the comfort of their home. This is supported by Anwar (2017) who conducted a study on the "Advantages and Disadvantages of e-Voting in Estonia". He found that e-voting can save voters time and costs by allowing them to vote independently from any location. This, he continues, could increase overall voter turnout. Citizens who could benefit the most from electronic elections are those living abroad, living in rural areas far away from polling stations and the disabled with mobility impairments (Anwar, 2017:9). Khoury, Kassem, Kfoury and Hard (2018) point out that in addition to easier accessibility, other features could also be realized to ensure better citizen engagement:

> *A mobile application can be used by voters to register themselves in the system and then vote. It provides the users the ability to fetch events, view questions and options, and visualize in real-time the results. Moreover, the application provides a detailed report showing the voting event statistics related to the frequency of votes per time slot and location* (Khoury *et al.*, 2018:226).

To test the validity of the argument put forward by Khoury *et al.*'s (2018), blockchain e-voting projects were examined to determine how blockchain can fulfil the functions of a government-citizen interface within the context of national elections. In the United States, an e-voting start-up *Voatz* created a system which allows for blockchain based voting. Voatz piloted the use of blockchain in three different projects: the first was in 2016 at the Massachusetts Democratic State Convention; the second was in 2017 at Tufts Community Union Senate and the third was in 2018 for West Virginian Uniformed and Overseas Citizens Absentee Voting. For the Massachusetts Democratic State Convention and Tufts Community Union, voters either downloaded the Voatz app (Figure 9) onto their own mobile device or used tablets provided onsite by Voatz staff to register for an election and vote. Zhang, Young and Verhulst (2018) highlight that the Voatz app is an example of how blockchain e-voting can create an opportunity for governments to ethically regulate election processes: "The Voatz platform includes an admin interface for election officials to view ballots, add voters, and/or publish results." (Zhang *et al.*, 2018:4).

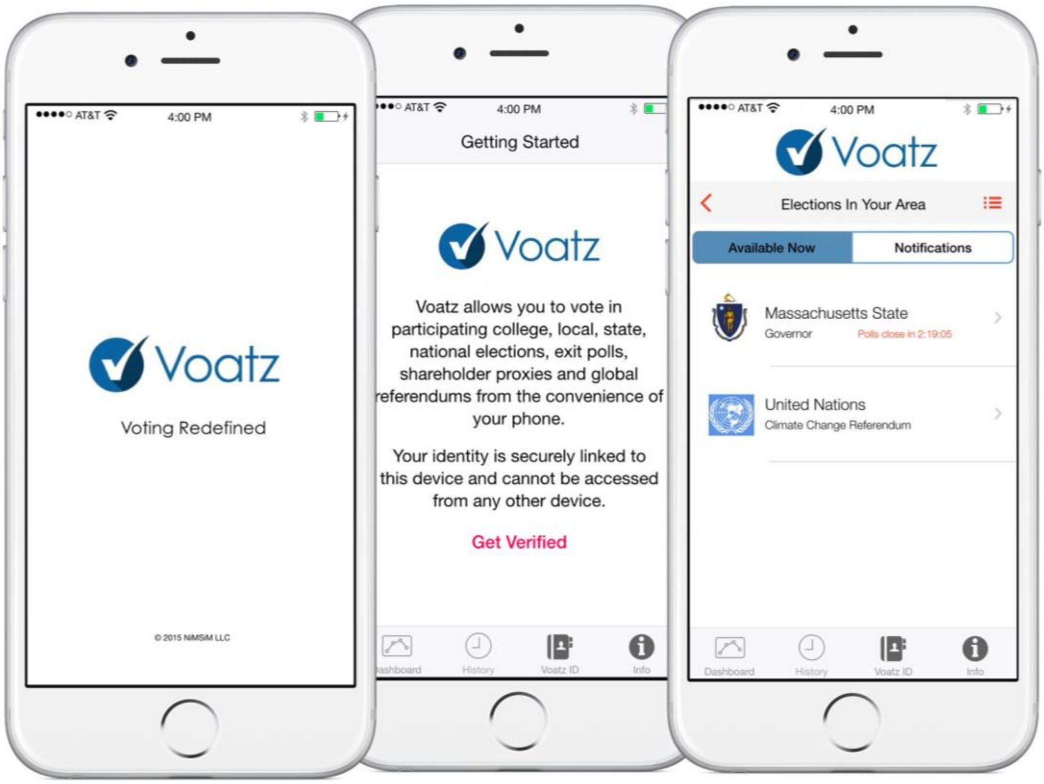

Figure 9: Voatz Smartphone Application Interface (Source: Voatz.com)

A report by Moore and Sawhney (2019:5) on the West Virginia general election was an important finding as it provided quantitative data on how blockchain-based voting can improve citizen engagement as a result of improved accessibility. Remote American voters were given the option to either vote by mail, fax or online. Of the 183 registered voters, 87% (160) requested to vote online and downloaded the Voatz application. Of the 160 who downloaded the application, 147 (92%) of voters completed the authentication process via the blockchain network and successfully submitted their ballot to be counted via the application interface (Moore & Sawhney, 2019:6). This shows that the majority of voters opted to rather make use of an online voting interface and successfully cast their vote via the blockchain network.

Several other cases were found where blockchain had facilitated the functions of a government-citizen interface for national elections. Estonia (Kshetri & Voas, 2018:2), South Korea (Bulut, Kantarci, Keskin & Bahtiyar, 2019) and Sierra Leone (Zambrano, Young & Verhulst, 2018) have all tested blockchain for voting via a smartphone application or website. Estonia which is considered to be "the most advanced digital society in the world" (PricewaterhouseCoopers, 2018:2) is the only country in the world where citizens have voted online in the municipal, national and European elections (Kitsing, 2011:1). This highlights how Estonia has successfully utilized blockchain to facilitate interactions between citizens and state. South Korea and Sierra Leone have implemented blockchain similarly to Estonia.

In closing, when integrated with a graphical user interface (GUI) blockchain can fulfil the functions of a government-citizen interface as an information and communications technology (ICT). Blockchain's peer-to-peer functionality can offer a secure and anonymous voting experience for citizens. A website or decentralized application (dApp) allows for government to interface with citizens during the election and regulate election policies through administrative privileges made possible by the blockchain. This was observed in the case of both the United States of America and Estonia. A blockchain-based e-voting system also provided improved government responsiveness and citizen engagement, as it gave voters the ability to cast votes, monitor the voting process and communicate with government if necessary, from any location as long as they have access to an internet connection.

4.3.2 Can blockchain organize social relations?

Answer: *Blockchain can act as a social technology in the context of national elections and has the potential to influence social perceptions between citizen and state and partially influence socio-political environments and social relations among voters.*

Democracies are highly dependent on the integrity of their national elections and "citizens should always be able to trust their electoral system" (Wojtasik, 2013:25). If the opposite is the case, then the prospects for a true democracy quickly diminish, which in turn leads to a decline in citizens participation *if they no longer believe their vote will make a difference*. This was pointed out by Sipinen (2016:2), who determined that political trust and voter turnout go "hand in hand". Therefore, if citizens do not trust the mechanisms and institutions through which they elect their leaders, this creates an environment of political distrust and resentment, which has a direct impact on voter turnout. Traditional paper-based elections have long been subject to tampering, rigging, double voting and coercion, which has resulted in a decline in trust toward electoral commissions (Bronack, 2018:1). In developing countries especially, "fears of violence and electoral corruption has created a social environment of distrust on election day", rather than a time for celebrating the opportunity to exercise one's democratic rights (Zambrano *et al.*, 2018:2).

Blockchain technology is proposed (Kshetri & Voas, 2018:3; Shahzad & Crowcroft, 2019; Sadia, Masuduzzaman, Paul & Islam, 2018:2) as "a technology which can help to (re) build trust among a society" (Atzori, 2015:3), and in doing so has the potential to influence social relations within the context of national elections. As previously mentioned, blockchain is considered a social technology which can be described as "a way of using human, intellectual and technological resources to influence the social structures of society, social relations, and interactions" (Nelson & Nelson, 2002:265). As a social technology, blockchain offers features to both citizens and state that were not previously possible for electoral systems. Immutability, transparency, and decentralization of votes were identified as the main qualities within blockchain's configuration which can influence social relations. These qualities, according to Lander and Cooper (2017: 6), can create "an environment of increased trust and engagement" which could influence government-citizen relations. Curran (2018) highlights this:

> *A Blockchain architecture specifically addresses one of the most difficult factors challenging electoral integrity – trust. Blockchain ensures trust is distributed amongst a set of mutually distrustful parties, all of whom are potentially adversarial, that participate in jointly managing and maintaining the cryptographically secure digital trail of an election. By distributing trust in this way, blockchains create a trustless environment whereby the amount of trust required from those participating in an election is minimized. Trust is inherently created by having the user in control over their data with the added assurance of integrity* (Curran, 2018:2).

This indicates that blockchain can influence the level of trust between citizen and government when elections are no longer controlled by a central authority, but instead distributed to be managed and maintained in a joint effort by various agencies. This allows for "a voting system where citizens do not need to blindly trust government" (Loebbecke, Lueneborg & Niederle, 2018:4) to conduct the process of collecting, counting and presenting results in an ethical manner. Instead, the fact that a blockchain is immutable, transparent and distributed could provide assurance to participating voters that concrete mechanisms are in place to ensure the integrity of election results (Villalobos, Altamirano & Chandra, 2019:3). This is further explained by Kostal, Bencel, Ries & Kotuliak (2019):

> *A challenge in voting is the lack of transparency in the functioning of the system, leading to a lack of voters. Blockchain provides total transparency in a way that allows everyone to see the stored data and processes such as how their data is handled* (Kostal *et al.*, 2019:1).

Therefore, the distribution of authority, partnered with the potential for 1) "any citizen or agency to audit the functionality of the voting system" (Curran, 2018:2; Villalobos *et al.*, 2019:7; Barnes, Brake & Perry, 2016:10) and knowing that 2) "votes are counted by a computer in real time" (Arun, Dutta, Rajeev & Mathew, 2019:830) can help combat distrust in electoral results and post-electoral disputes. This indicates that "blockchain can allow for the regulation of social relations through code and technical configuration", rather than human subjectivity. This is known as "trust-by-computation" (Quintais, Bodó, Giannopoulou & Ferrari, 2019:3).

Interestingly, blockchains ability to influence social relations between government and citizens was found to be stronger than its ability to influence social behaviour between citizens. This could primarily be due to the fact that "*the act of voting is a personal matter between a citizen and the state*" (Lardy, 1997:75). Keep in mind that blockchain's ability to configure social relations remains dependent upon the attitude of citizens as to whether or not they believe the features offered by blockchain can "fix everything" (Manrique, 2018:32). If voters do not trust the functionality of blockchain, this will hamper its potential to organize social relations. Educating citizens to truly understand the functionality that blockchain can offer elections is therefore a factor which can influence the success of this technology's ability to increase trust in electoral processes (Manrique, 2018:33). Irrespective of this point, this limitation does not diminish blockchains ability to influence the relationship voters have with government and the electoral system. If voters are able to personally audit the election results and receive proof that their vote has been counted in an immutable manner, it certainly can influence the perception of voters about the legitimacy of the electoral process.

In summary, new features such as auditability, decentralization and transparency are all qualities which can be integrated into existing (or future) digital voting systems through a blockchain. These qualities can facilitate a voting system where very little trust is bestowed upon government officials as most of the administrative actions are calculated by nodes (computers). When comparing developing and developed countries, it was found that blockchains potential to organize social relations is more probable in developing countries, where issues of voter fraud, coercion and vote tally corruption is of greater concern among voters. In developing countries especially, societal distrust about national elections can be influenced by the checks and balances set in place by blockchain’s technical configuration. Blockchain demonstrates the ability to influence social relations between citizens and government is particular. It was not found, however, to provide the function of configuring social behaviour among citizens. Yes, blockchain can set the stage to bring to light any irregular behaviour or inconsistencies in the voting process, but the social behaviour citizens display amongst each other is not something that blockchain can directly organize in this case. It was therefore concluded that blockchain technology can partially fulfil the function of organizing social relations within the context of national elections.

4.3.3 Can blockchain create structures of opportunity for actions and achieving goals?

Answer: *Blockchain demonstrates the ability to create opportunities for action, achieving policy goals and desirable outcomes related to voting in national elections.*

A function of blockchain technology which was continuously evident is its potential to provide sets of rules, achieve goals and create desirable policy outcomes in the context of national elections (voting). The first task was to assess if blockchain can achieve the fundamental policy goals of a national election. According to Villalobos *et al.* (2019), an election must achieve the following goals: 1) Only eligible voters should be able to cast a vote. This includes being a legal resident who is permitted to vote by law and being registered to vote on election day; 2) Each vote must be anonymous as to prevent extortion, blackmail or bribery; 3) The results of an election must be counted in a lawful manner free of corrupt activities which would otherwise influence the outcome of the election; 4) the results of an election must be verifiable by auditing ballots. Blockchain technology has evinced the ability to provide all these functions when integrated as an electronic voting system.

Only eligible voters should participate in elections – As discussed, blockchain technology can offer administrative privileges to governments to regulate all processes related to voting. One scholar writes: "Election administrators can set election policies, create ballots, establish registration rules and open and close voting" (Hjálmarsson & Hreiðarsson, 2018:4). Furthermore, through blockchains' inherent ability to regulate the validity of transactions (votes), "any illegal votes will be recorded, discovered, and discarded by the network" (Zhu, Zeng & Lv, 2018:2421). This indicates blockchain's ability to create sets of rules and regulations to influence opportunity structures. Smart contracts were found to be one of the most influential features in this regard, as they allow a government to pre-program a voting system to "only allow eligible voters to register for an election and only permit registered voters to cast a vote" (Zhu *et al.*, 2018:2418). Yavuz, Koç, Çabuk & Dalkılıç (2018) write:

> *The blockchain with the smart contracts, emerges as a good candidate to use in developments of safer, cheaper, more secure, more transparent, and easier-to-use e-voting systems* (Yavuz *et al.*, 2018:1).

Bear in mind, that "a smart contract is a computer protocol which can trigger actions when a preprogramed condition of a contractual agreement is met" (Crosby *et al.*, 2016:13). Therefore, if an illegal immigrant or unregistered voter attempted to vote, the blockchain network could deny this request as it would go against election policies set out by an electoral commission. This argument is confirmed by other scholars (Khoury *et al.*, 2018:226; Hu, Liyanage, Manzoor, Thilakarathna, Jourjon & Seneviratne, 2019:9; Bulut *et al.*, 2019:5). Villalobos *et al.* (2019) further highlights this point:

> *A vote can only be executed if it satisfies the contract's rules and the majority of the validator nodes in the blockchain network successfully approve that the account making the transaction has permission to do so* (Villalobos *et al.*, 2019:5).

It should be noted that not all blockchains (e.g. Bitcoin) are smart contract compatible. This needs to be considered when assessing blockchain's ability to provide this function. The *Ethereum blockchain* was identified as being the most suitable for this purpose (Zhu *et al.*, 2018; Yavuz *et al.*, 2018; Villalobos *et al.*, 2019).

Each vote must be anonymous – A key feature is blockchain's ability to provide anonymity during the voting process (Lapointe & Fishbane, 2019:50; Faour, 2018; Chaieb, Yousfi, Lafourcade & Robbana, 2018:2). In layman's terms, cryptographic primitives such as Elliptic-Curve Cryptography (ECC) and Identity-Based Encryption (IBE) can be used to ensure voter identity remains private and secure on a blockchain (Chaieb *et al.*, 2018:3). In basic terms, cryptographic primitives are the basic building blocks of a security protocol or system, and these algorithms can be implemented in the context of e-voting to anonymize votes being cast. Cryptography is used to anonymize the ballots by encrypting the connection of the voter's personal identity before the ballot is processed to be counted (Meter, 2015:17).

This process is explained by blockchain developers from Tunisia. Their project is called *Verify-Your-Vote* and they propose the following benefits of anonymity by implementing a blockchain for national elections:

> *Anonymity is ensured thanks to the use of Blockchain which is characterized by the anonymity of its transactions. Every voter is identified in the election Blockchain by a public key and address that have no relationship to their real identity. Only the blockchain can make the correspondence between the voter's real identity and their authentication parameters* (Chaieb *et al.*, 2018:11).

These data indicate that blockchain technology can facilitate anonymity and implement the necessary improvements to existing e-voting systems, which are "known to have issues with ensuring anonymity during the voting process" (Hamid, Radzi, Rahman, Wen & Abdullah, 2017:1). It should be noted that blockchain's potential to provide the 'ideal anonymity' explained above does not come without its limitations and technical difficulties. Although blockchain does have the potential to provide these functions in theory, in reality the data indicate that attempts to realize this feature have been more problematic. The projects that have been tested were conducted on a small scale (Yu *et al.*, 2018:2) and still require the involvement of a central authority, which could compromise anonymity (Meter, 2015:68). This finding does not diminish the fact that blockchain can achieve the policy goal of ensuring the anonymity of votes during an election, but it does raise the question of the extent to which it can do so on a large scale. This indicates that the technical issues would need to be addressed if true voter anonymity on a national level is to be achieved in the future.

Results of an election must be counted in a lawful manner – Human involvement in the tallying of votes has been identified as an issue in multiple countries, especially developing nations (Meter, 2015:1). A blockchain network functions on the principle of "trust-by-computation" (Quintais et al., 2019:3). If implemented, a blockchain can provide government with the ability to tally votes through computational calculations rather than drawing on human resources. Various scholars (Chaieb *et al.*, 2018: 3; Osgood, 2016:13; Sravani & Murali, 2019) outline how a blockchain can tally votes in real-time without the need for a controlling central authority. This means the vote count will go up as each vote is completed instead of voters having to blindly trust the authorities at the end of voting processes. At the end of an election day, “results can simply be viewed in a graph or other digital format in a user-friendly manner” (Sravani & Murali, 2019:1005) and voters are given the ability “to watch the election count progress in real time as votes are cast” (Chaieb *et al.*, 2018:3).

Additionally, the decentralized structure of blockchain was identified (Atzori, 2015, 2017; Choudhary, Datar, Kale, Roy & Padmavathi, 2019:85) as a fundamental improvement to existing methods of tallying votes. The process of counting votes would no longer be entrusted to a central authority, but instead votes would be calculated by the blockchain nodes in a digital format. These votes are verified by all distributed nodes on the network in a joint effort to calculate the final results of an election (Curran, 2018:2). This technical configuration can limit unlawful acts by corrupt authorities involved in the counting of votes, as each independent node calculating the votes must reach consensus on the results before they are presented. Keep in mind, “to decentralize these services through the blockchain does not mean to dismiss the state, but rather serves to promote good governance” (Atzori, 2015:9).

Election results must be verifiable by auditing – A recurring characteristic of blockchain technology is its immutable and transparent qualities (Sultan *et al.*, 2018:50; Hofmann, Wurster, Ron & Böhmecke-Schwafert, 2017; Landerreche & Stevens, 2018). In an ideal blockchain e-voting (BEV) system, as each vote is cast, it becomes immutable and verifiable to both electoral commissions and citizens. Once a vote has been cast, “this information can never be erased or altered from its original state and is constantly monitored by network nodes” (Crosby *et al.*, 2016:12). This creates a digital trail of all interactions that occurred during the voting process which can then be audited if necessary. Barnes *et al.* (2018) outline how a decentralized auditing of a blockchain e-voting system could be conducted:

> *Independent bodies will monitor and audit the voting process. These bodies will host or have access to a national node and will be able to verify that the unencrypted results (votes casted) match the encrypted votes (votes counted). Individuals and organisations can volunteer to be a national node. These applications are processed by the government to ensure that they meet the minimum requirements set by a governing body. These individuals will also act as miners during the counting process and when calculating the results* (Barnes *et al.*, 2018:10).

For citizens, blockchain also provide better accessibility to the auditing process to ensure that their vote has been counted correctly. This is explained by Hjálmarsson & Hreiðarsson (2018):

> *Each individual voter can go to his government official and present their transaction ID after authenticating himself using his/her electronic ID. The government official, utilizing district node access to the blockchain, uses the blockchain explorer to locate the transaction with the corresponding transaction ID on the blockchain. The voter can therefore see his vote on the blockchain, verifying that it was counted and counted correctly* (Hjálmarsson & Hreiðarsson, 2018:4).

This level of transparency and auditability has the potential to guarantee voters that their vote has been counted. This can also create desirable outcomes for government, as it "could increase voter turnout if voters had more confidence in the election process" (Turcanu, 2018:20). In light of this, blockchain does have the potential to perform the functions of existing electoral systems. It can also 'improve' both paper ballot systems and existing electronic voting systems. Importantly, the technical issues of blockchain do need to be addressed before a blockchain-based e-voting system would be fully functional on a national scale. That being said, irrespective of these limitations, blockchain shows that it can still at the very least achieve all four basic policy goals of an election process as outlined by Villalobos *et al.* (2019).

In addition to blockchain based e-voting (BEV) having the potential to achieve the core policy goals of a national election, additional data also indicated its ability to produce desirable outcomes related to *lower administrative costs*, *minimizing the time it takes to count ballots*, *protecting the integrity of election results* and *improved accessibility*. This s outlined in the table below. The left column stipulates the policy goal(s) and desirable outcome(s) that blockchain technology can provide, the middle column summarises the functions that blockchain performs which have the potential to create the opportunity structures needed to achieve these beneficial outcomes, and the right column lists the sources used to support the argument being made.

Policy Goals and Desirable Outcomes	Blockchain Function	Sources
Lower administrative costs	Blockchain's ability to partially eliminate the need for human resources in initializing, facilitating and regulating election processes could produce significant savings in administration costs.	Boucher (2016:1) Kovic (2017:7) Sravani & Murali (2019:1006)
Faster vote tally time	Time that is spent in counting votes will be saved. Using a blockchain electronic voting system, we could cast votes, secure them and count them during election day. This will change the old and ineffective system and bring a modern and effective system which can save lots of energy and money.	Boucher (2016:1) Kshetri (2018:94) Kshetri & Voas (2018:3)
Immutable and reliable election results	The technical configuration of a blockchain ensures that the ballot cannot be changed, duplicated or deleted once recorded. The integrity of voter results is therefore protected from vote tampering. The integrity of the vote is supported by the hashing technology in blockchain. Every ballot block is added and hashed in sequence. The Hash function is used to verify whether any ballot block has been tampered with in a way that was not intended.	Bulut *et al.* (2019:3) Hardwick *et al.* (2018:1561) Zheng Wei & Wen (2018:340)
Increased accessibility	"Traditional system requires people to stand in line for hours to get the chance to vote" (Inuwa & Oye, 2015:44). Blockchain e-voting can save voters time and costs by allowing them to vote independently from any location. This has the potential to increase overall voter turnout. Citizens living abroad, living in rural areas far away from polling stations and with mobility impairments can benefit most from this opportunity.	Anwar (2017:9) Hjálmarsson & Hreiðarsson (2018:10) Kostal *et al.* (2019:2)

In summary, blockchain technology can fulfil the function of creating opportunity structures for action, achieving policy goals and desirable outcomes related to voting in national elections. The key policy goals of an election, namely that only eligible voters should be able to cast a vote, each vote must be anonymous, the results of an election must be counted in a lawful manner and the results of an election must be verifiable by auditing ballots, can all be achieved by blockchain technology to some extent when implemented as the infrastructure of an electronic voting system. Smart contracts were identified as a key component to allow blockchain to fulfil these functions in the context of voting. Blockchain further has the potential to create various desirable policy outcomes related to lower costs, real-time vote counting, more reliable election results and increased accessibility; all of these factors can create an economic, social and political environment where government can better implement policy related to national elections.

4.3.4 Can blockchain solve problems?

Answer: *Blockchain technology can fulfil the function of solving and preventing policy problems in the context of national elections (voting).*

National elections have a long history of being open to illegal activities. Reports on countries such as Nigeria (Inuwa & Oye, 2015:44), the Democratic Republic of Congo (Bak, 2019:2), Venezuela (Jiménez & Hidalgo, 2014) and Kenya (Bigambo, 2016) indicate how they are among the many nations that have experienced turmoil during an election, when its outcome was disputed because of illegal actions by government or citizens. This problem causes "political instability, undermines good governance and hampers true democracy" in both developed and developing nations (Lehoucq, 2003:251) Such problems do appear to be significantly more evident in developing nations, however, and in some cases (Kenya, Mozambique and Nigeria) have resulted in the death or injury of civilians who publicly opposed the issues that influence their ability to elect leaders in a free and fair electoral process (Onimisi & Tinuola, 2019). Blockchain technology is proposed (Kostal *et al.*, 2019; Moura & Gomes, 2017; Fatrah, Haqiq, Kafhali & Salah, 2019; Inuwa & Oye, 2015) as a solution to some of the core problems faced during the electoral process. The main issues identified were electoral fraud by government (López-Pintor, 2010) and double voting by citizens (GAI, 2017).

Electoral fraud by government – Electoral fraud is defined as "the illegal interference in the process of a national election, either by increasing the vote share by adding ballots or depressing the vote share by removing ballots" (Donayre, 2015:27). It also includes any other illegal activities by government that purposely influence the outcome of an election. A fundamental feature of blockchain technology is its ability to limit or remove the need for a central authority as a result of its technical configuration. This is argued (Kostal *et al.*, 2019:1; Faour, 2018:4; Crosby *et al.*, 2016) to be applicable not only for voting, but in all "trusted-service" industries that depend on third parties or a bureaucracy (Xu *et al.*, 2019:27). In their research paper "*Blockchain E-Voting Done Right*", Kostal *et al.* (2019) outline how a blockchain could eliminate or limit the potential for internal electoral fraud:

> *An e-voting system which uses blockchain has the potential to manage all election processes. Its main advantage is that there is no need for confidence in the centralized authority that created the elections. This authority cannot affect the election results in our system as it is determined by nodes* (Kostal *et al.*, 2019:1).

Galen *et al.* (2018:21) similarly argue that blockchain-based voting systems can partially remove the need for a centralized authority to administer all processes, reducing the possibility of corruption and increasing trust between citizens and their government. This function is made possible by *nodes* which regulate input to create a voting system where *"unauthorized human interference is absolutely prohibited"* (Bulut *et al.*, 2019:2). Any input that cannot be considered as a credible vote will therefore be ignored in this system. "For such a system, stealing votes or changing votes are totally blocked." (Bulut *et al.*., 2019:2). Bear in mind that a node stores and validates all transactions of a blockchain and can be compared to 'a traffic control officer regulating and directing traffic.' Every node governs a blockchain network by containing an immutable and verifiable record of every transaction made on the network. Every transaction (vote) in the ledger is verified by the majority of nodes in the system through the consensus mechanism, which allows for data redundancy and consequential accountability (Ankalkoti *et al.*, 2017:1759). Blockchain's technical configuration therefore has a significant potential to be an alternative to traditional election procedures. It can address the central authority problem, because distributed nodes must work together before agreeing what the final vote count is.

Furthermore, the immutability of blockchain makes it significantly more difficult (if not impossible) for malicious actors to change information in a block, since it is protected by the hash function which maintains the chronological order of events, in this case votes. As outlined in Chapter One of this study, hash keys act as time stamps to maintain the chronological order of blockchain transactions. What this means is that each block on a blockchain network contains the hash key of the previous block all the way back to the "genesis block" which refers to the first data block created and validated by miners on that network (Maxwell *et al.*, 2017:4). If a corrupt entity attempted to alter the vote count within a block, the hash key of that block would change immediately, thus rendering the entire blockchain as invalid as it would no longer match the existing agreed upon chronological order of events. Consequently, blockchain can increase the security of election results by keeping all votes cast on distributed nodes in an immutable manner. This is highlighted by Patil, Rathi and Tribhuwan (2018):

> *To address voter tampering, blockchains generate cryptographically secure voting records. Votes are recorded accurately, permanently, securely, and transparently. So, no one can modify or manipulate votes. Although nothing is totally secure, tampering is nearly impossible with blockchains* (Patil *et al.*, 2018:51).

These data suggest that blockchain technology does have the potential to address the problem of electoral fraud by government. To what extent this can be achieved remains theoretical to a large extent. However, the *transparent*, *immutable* and *decentralized* capabilities of blockchain showed that it could prevent or at least deter internal corruption in the case of land registries (Georgia, Sweden) and can therefore also apply to elections. This is because both these blockchain applications involve the handling of sensitive digital information. As more real-world projects are implemented in countries known for their high levels of corruption (Sierra Leone, Russia, Ghana), blockchain's ability to address the issue of electoral fraud will become better understood.

Voter fraud/double voting – The act of double voting, which is a type of voter fraud, occurs when one person votes multiple times in their own name at different voting centres or casts multiple votes by using another citizen's name (Goel & Meredith, Morse, Rothchild & Shirani-Mehr, 2019:1). This problem has been recorded in both developed (United States, United Kingdom) and developing (South Africa, Nigeria) countries (Goel *et al*., 2019:).

Blockchain shows the potential to solve this common problem (Atzori, 2015; Bulut *et al.*, 2019; Faour, 2018). Firstly, the process of voting on a blockchain network would require citizens to obtain a unique identification key. This unique private key is generated randomly by election administrators and is provided to citizens when they register to vote (Pawar, Sarode, Santpure, Thore & Nimbalkar, 2019:818). This indicates that government authorities would still be partially involved in administrative processes, but their involvement is limited, as explained by Patil *et al.* (2018:51). The unique identification code is then preprogramed into the blockchain protocol or smart contract agreement as a credible vote. "Any input that is not considered as a credible vote will then be ignored by system" (Bulut *et al.*, 2019:2). Therefore, before transactions are added to the blockchain, the transactions are verified, and this prevents double voting (Zhang, Xue & Liu, 2019:8). Bulut *et al.* (2019) explains this:

> *A blockchain guarantees that a citizen can only vote one time. When a citizen casts a ballot, the e-government system will be informed without revealing any information about vote. Then, the e-government system marks that person's key as 'voted'. Since the system takes electorate data from e-government, it is not possible for a marked person to vote again* (Bulut *et al.*, 2019).

This method of preventing double voting through the blockchain protocol, smart contracts and nodes is discussed by Casado-Vara and Corchado (2018), Villalobos *et al.* (2019) and Osgood (2016). It should be noted, however, that multiple opposing arguments (Hardwick, Gioulis, Akram & Markantonakis, 2018:1567; Gupta *et al.*, 2017:20; Wu, 2017:24) have been put forward with regards to blockchain being able to solve these problems effectively at such an early stage of its development. In solving the before mentioned problems, blockchain can also create new ones. As mentioned, the problem of coercion becomes a greater risk when voting is conducted remotely. This could influence the outcome of an election if government officials or malicious groups were to force citizens to vote a certain way.

Several protocols have been proposed that aim at mitigating this threat. However, these proposals have remained largely academic (Krips & Willemson, 2019:216). Furthermore, although the blockchain itself is significantly more secure than current systems, the risk of hackers attacking the website or application from which votes are being cast can be altered to create confusion or enforce "denial of service attacks" when citizen attempt to vote (Estehghari & Desmedt, 2010). Finally, "in a worst-case scenario" as Yli-Huumo *et al*. (2016:15) state, if any attacker gained control of 51% of nodes on the network then it can manipulate the data. This is, however, "a near impossible task" (Bulut *et al.*, 2019:2).

In summary, blockchain technology can fulfil the function of solving and preventing problems within the context of national elections (voting). The issues of electoral fraud and voter fraud are present in both developed and developing countries, which indicates that this is a solution which all nations can benefit from regardless of their economic status. It was, however, found to be significantly more present in developing nations (Congo, Kenya, Zimbabwe). Finally, although many cast a positive light on how blockchain can solve existing problems, opposing arguments were also found criticizing blockchains potential to truly address these issues beyond theory and highlight new problems which arise with blockchain e-voting (BEV).

4.3.5 Conclusion

The evidence demonstrates that blockchain technology has the potential to fulfil three of the four functions of a policy instrument when implemented within the context of a national election (voting). Blockchain in partnership with a user interface (GUI) can offer significant benefits for both citizens and electoral commissions as a government-citizen interface. For government, a blockchain can generate administrative abilities to set election policies, create ballots, establish registration rules, and open and close voting. This can improve government intervention and regulation in election administration and overall responsiveness. For voters, blockchain's peer-to-peer functionality can provide a secure and anonymous voting experience, but also allow for improved citizen engagement and accessibility. This increased accessibility is realized as blockchain can create an environment where votes can be cast from computers or other electronic devices via an application or website from any location. Although this sounds ideal in theory, it was found that this could open the possibility of increased coercion by malicious actors. If a citizen decides to cast their vote from home, government has little authority to prevent a spouse, parent or criminal from forcing a voter to cast their ballot a certain way. Irrespective of this risk, blockchain still fulfils the function of a government citizen interface.

Its ability to provide the function of organizing social relations was only partially realized as little evidence was found to indicate that it can configure social behaviour among citizens. This could primarily be because the act of voting is a personal matter between a citizen and the state, which explains why blockchain's potential to influence social relations between citizens and government was more evident. Blockchain's ability to increase trust in elections by removing the uncertainty of a citizen's vote not being counted is addressed by the transparency and auditability of a blockchain e-voting system. This has the potential to increase voter turnout as it was found that there is a correlation between the level of trust in a countries electoral system and total voter participation.

The evidence further shows that blockchain can fulfil the function of creating structures of opportunity for achieving policy goals and desirable outcomes. The key policy goals of an election namely, only eligible voters should be able to cast a vote, each vote must be anonymous, the results of an election must be counted in a lawful manner and the results of an election must be verifiable by auditing ballots, can all be achieved by blockchain technology to some extent. Through blockchain's inherent ability to regulate the validity of transactions, any illegal votes will be recorded, discovered and discarded by the network. This shows blockchain's ability to create sets of rules and regulations to influence opportunity structures. Smart contracts were found to be one of the most influential features in this regard as they allow government to pre-program opportunity structures. Additionally, blockchain can also ensure lower costs, real-time vote counting, more reliable election results and increased accessibility. Technical issues of scalability and efficiency, however, were found to be limitations in blockchain's ability to deliver these functions at an ideal proficiency.

Finally, blockchain does have the potential to solve problems within the context of voting. The main problems identified were electoral fraud by government (this includes any illegal activities by government to influence the outcome of an election) and double voting by citizens. Citizens and *law-abiding* authorities could reap great benefits from this function of blockchain technology. The reason for saying that *law-abiding* authorities would benefit is that this technology would not be implemented by government officials who want to maintain a corrupt electoral process for their own benefit. Blockchain would simply expose their corrupt actions because of its immutable and transparent qualities. This should be recognized as an implementation issue. Furthermore, opposing arguments were found regarding blockchain's potential to completely solve these issues and the point is made that it can cause other problems to arise. Nevertheless, blockchain does still demonstrate the potential to at least address some of the existing problems and therefore fulfils the function of solving problems in the context of national elections (voting).

4.3.6 Summary of the findings

Blockchain Technology for National Elections (Voting)	Yes	Partially	No
1.) Can blockchain act as a government-citizen interface?	✓		
- Can blockchain enable government to communicate and respond to citizens?	✓		
- Can blockchain facilitate citizen engagement?	✓		
- Can blockchain facilitate government intervention?	✓		
Sources: (Oyelere *et al.*, 2019); (Suikkanen, 2017); (Tamilselvan *et al.*, 2012); (Sturgis, 2005); (Yi, 2019); (Osgood, 2016); (Zheng *et al.*, 2018); (Hjálmarsson & Hreiðarsson, 2018); (Wei & Chuah, 2018); (Curran, 2018); (Ayed, 2017); (Zhang *et al.*, 2018); (Shah *et al.*, 2018); (Curran, 2018); (Anwar, 2017); (Khoury *et al.*, 2018); (Moore & Sawhney, 2019); (Kshetri & Voas, 2018), (Bulut *et al.*, 2019); (Zambrano *et al.*, 2018); (PricewaterhouseCoopers, 2018); (Kitsing, 2011).			
2.) Can blockchain organize social relations?		✓	
- Can blockchain influence social relations between citizens?			
- Can blockchain influence government-citizen relations?	✓		
- Can blockchain configure social behaviour among citizens?			✗
Sources: (Wojtasik, 2013); (Sipinen, 2016); (Bronack, 2018); (Zambrano *et al.*, 2018); (Kshetri & Voas, 2018); (Shahzad & Crowcroft, 2019); (Sadia *et al.*, 2018); (Atzori, 2015); (Nelson & Nelson, 2002); (Lander & Cooper, 2017); (Curran, 2018); (Loebbecke *et al.*, 2018); (Villalobos *et al.*, 2019); (Kostal *et al.*, 2019); (Barnes *et al.*, 2016); (Arun *et al.*, 2019); (Quintais *et al.*, 2019); (Lardy, 1997); (Manrique, 2018).			
3.) Can blockchain create structures of opportunity for actions and achieving goals?	✓		
- Can blockchain provide rules and regulations to influence opportunity structures?	✓		
- Can blockchain provide opportunity for action and achieve policy goals?	✓		
- Can blockchain assist government in attaining desired outcomes?	✓		
Sources: (Villalobos *et al.*, 2019); (Zhu *et al.*, 2018); (Yavuz *et al.*,2018); (Crosby *et al.*, 2016); (Khoury *et al.*, 2018); (Hu *et al.*, 2019); (Bulut *et al.*, 2019); (Lapointe & Fishbane, 2019); (Faour, 2018); (Chaieb *et al.*, 2018); (Meter, 2015); (Hamid *et al.*, 2017); (Yu *et al.*, 2018); (Meter, 2015); (Quintais *et al.*, 2019); (Osgood, 2016); (Sravani & Murali, 2019); (Atzori, 2017); (Atzori, 2015); (Choudhary *et al.*, 2019); (Curran, 2018); (Sultan *et al.*, 2018); (Hofmann *et al.*, 2017); (Landerreche & Stevens, 2018); (Barnes *et al.*, 2018); (Hjálmarsson & Hreiðarsson, 2018); (Turcanu, 2018); (Boucher, 2016); (Kovic, 2017); (Sravani & Murali, 2019); (Kshetri, 2018); (Hardwick *et al.*, 2018); (Zheng *et al.*, 2018); (Anwar, 2017); (Kostal *et al.*, 2019).			
4.) Can blockchain solve problems?	✓		
- Can blockchain assist government to solve identified policy problems?	✓		
- Can blockchain help prevent future problems?	✓		
- Can blockchain allow policymakers to assess whether the systematic operations to solve an identified problem was successful?	✓		
Sources: (Inuwa & Oye, 2015); (Bak, 2019); (Jiménez & Hidalgo, 2014); (Bigambo, 2016); (Lehoucq, 2003); (Onimisi & Tinuola, 2019); (Kostal *et al.*, 2019); (Moura & Gomes, 2017); (Fatrah *et al.*, 2019); (López-Pintor, 2010); (GAI, 2017); (Faour, 2018); (Crosby *et al.*, 2016); (Xu *et al.*, 2019); (Galen *et al.*, 2018); (Bulut *et al.*, 2019); (Ankalkoti, 2017); (Maxwell *et al.*, 2017); (Patil *et al.*, 2018); (Osgood, 2016); (Pawar *et al.*, 2019); (Zhang *et al.*, 2019); (Casado-Vara & Corchado, 2018); (Villalobos *et al.*, 2019); (Osgood, 2016); (Hardwick *et al.*, 2018); (Gupta *et al.*, 2017); (Wu, 2017); (Krips & Willemson, 2019); (Estehghari & Desmedt, 2017); (Yli-Huumo *et al.*, 2016).			

4.4 Blockchain Technology for Citizen Identity Management

Identity management can be defined as a system to identify, authenticate and authorize individuals' identities (Roos, 2018:105). It encompasses the processes and policies involved in managing the lifecycle of identities for a particular domain (Dunphy & Petitcolas, 2018:2). Identity management is one of the most important public services governments offer their citizens. Providing proof that individuals are who they claim to be is subject to the quality and availability of government records; these records are of great significance as they are the prerequisites for any recognition of rights and provision of public and private services (Third, Quick, Bachler & Domingue, 2018:5). Identity management functions as the building blocks for interactions with the state, education, health, finance, voting and taxation, and hence maintaining a verifiable record of one's citizen identity is a fundamental pillar of day-to-day life (Fioravanti & Nardelli, 2008:1).

Governments are traditionally the administrators of all citizen identity information, which includes certifications of birth, marriage and death, national identity cards and passports. This data are used to track, verify and demonstrate identity in state-individual interactions and for private interactions (for example, proof of identity in taking out a loan). Asset registries, medical records, financial systems, educational certification and travelling all depend upon identity records of citizens, and so a lack of a verifiable identity makes it nearly impossible to participate in these activities. If identity management is done correctly, the rewards are remarkable; if done poorly, policy failure is inevitable (Pandey & Saini, 2013:51).

4.4.1 Can blockchain act as a government-citizen interface?

Answer: *Blockchain technology can fulfil the function of a government-citizen interface when integrated with a government website or citizen identity management applications.*

As seen in both national land registries and voting, blockchain similarly functions as an information and communications technology (ICT) in the context of identity management. Keep in mind that an ICT is defined as

> *a diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and manage information. ICT's enable Government-to-Citizen information flow and vice versa* (Bemile, 2015:115).

Considering government processes have become increasingly digitalised in the last two decades, bureaucracies have increasingly made use of ICTs to provide the public service of citizen identity management (Janowski, 2015). For identity management, the utility of blockchain as an ICT is especially showcased as the processes of identity management predominantly involve the "*accessing, storing, transmitting and editing*" of digital information (Tamilselvan *et al.*, 2012:15). Lips (2010) highlights how ICTs have influenced identity management:

> *The introduction and use of new ICTs for managing citizen identity information in public environments has led to fundamental changes in the informational foundations of citizen - government relationships* (Lips, 2010:1).

As an ICT, blockchain is identified as having the potential to create "*a new form of coordination and interaction between state and society, and creates the opportunity for a power shift to occur in how citizen identities are managed*." (Atzori, 2017:12). As discussed throughout this thesis, a fundamental feature of blockchain is its ability to "limit or remove the need for a central authority" as a result of its technical configuration (Xu *et al.*, 2019:27). This means "blockchain-based governance can decentralize identity management" and restructure how citizens engage with government (Liu, Zhao, Guo, Wang, Tan & Wang, 2017:2).

If implemented as proposed by Dunphy and Petitcolas (2018), blockchain could reduce the power of the institutions that currently control (and own) a significant amount of administrative power related to citizens' identities. This reduction of institutional power would change how citizens and governments interact with respect to identity management and allow for a *"bottom-up approach"* to identity administration, emphasizing self-governance and direct participation (Atzori, 2017:12). Datta (2019) outlines the potential of a blockchain based identity management model:

> *A citizen-centric digital identity model based on distributed ledger technologies could be used to consolidate disparate data that currently exists across multiple agencies and layers of government into a network centred around a citizen's or business' credentials, licenses and identity attributes. It would enable citizens to view their public service identity via an identity app on their smartphone and share relevant data with government to access public services* (Datta, 2019:9).

This shows that a blockchain-based identity management system can offer better citizen engagement in administrative processes by shifting away from existing methods of having to interact with government at administrative buildings, and instead make use of online portals. Interestingly, blockchain is discussed (Atzori, 2017:12; Haddouti & Kettani, 2019:1; Lesavre *et al.*, 2020:4; Guggenmos, Lockl, Rieger & Fridgen, 2018:2) as a means to decrease government intervention and create greater independence for citizens in how their identities are managed. This could lead to government services and public policies being managed by individual citizens through blockchains' peer-to-peer communicative abilities in a decentralized model of e-governance. To examine whether blockchain can provide these abilities, an analysis was done of existing projects and future projects where governments have or intended to utilize this technology for identity management. It was found that a number of countries have either tested the use of blockchain for identity management or plan to do so in the future.

Estonia – With 98% percent of citizens making use of a digital identity card (e-Estonia, 2020), the most developed government use of blockchain identity services is in Estonia. Estonians make use of an e-identity card which runs on the KSI (Keyless Signature Infrastructure) blockchain developed by the Estonian government as a response to cyber-attacks and potential internal threats (Third *et al.*, 2018:5). Estonia has the most developed national ID-card system in the world as it offers digital access to all of Estonia's secure e-services. The application for e-residency can be made via the internet from any location. Citizens are required to fill in a form stipulating all personal information (name, surname, address, identity number) as well as a scanned copy of their current national passport and ID photograph (Jacobovitz, 2016:4).

Figure 10: Estonian digital identity card and card reader (Source: e-Estonia.com)

Once verified, these details and documents are linked to the blockchain network. To ensure the authenticity of the data being processed there is a need for government intervention. Nágy, Peter, Hattyasy and Nyante (2018:36) explain that government authorities are provided with an *application interface* to initiate verification of users. This differs from Atzori's (2017) point that "blockchain could disempower the institutions" because a certain level of verification is still needed when data are initially recorded onto the blockchain network (Nágy *et al.*, 2018:36). The existence of an administrative application interface therefore indicates that blockchain can still facilitate government intervention, even if to a limited degree. Finally, once successfully registered, citizens are provided with an ID card and mobile application to provide front-end functionality to store and manage all identity documents conveniently. Nágy *et al.* (2018) explain the user experience as follows:

> *Estonian citizens are provided with a mobile app that implements a blockchain wallet to securely store and monitor claims generated from various identity providers. In this way citizens may decide which actors share their information and how that information is shared* (Nágy *et al.*, 2018:36).

This reveals the potential to improve citizen engagement when making use of a blockchain application (dApp) to communicate with government departments and private vendors. Interestingly, in the case of Estonia, a website or application is not the main form of interfacing with government as seen in the case of land registration and voting. Instead, a "digital identity card" (Figure 10) is linked to a profile stored on the blockchain which can be scanned by authorities or private vendors when it is necessary for a user to provide identification. The digital card also works in partnership with a website and application (Figure 11) to interact with government and vice versa (Jacobovitz, 2016:4).

Figure 11: Using the e-Estonian card (Source: e-Estonia.com)

These data demonstrate how in the case of e-Estonia blockchain successfully functions as a government-citizen interface in the following ways: 1) It facilitates communication between citizens and state; 2) provides a means for citizen to engage with government while having greater involvement in the handling of their personal information; and 3) it allows for government to intervene through administrative privileges via the blockchain network when necessary. These features confirm all three qualities needed to fulfil the function of a government-citizen interface as outlined in the analytical framework.

Switzerland – In 2017, the City of Zug launched a government-issued identity on the Ethereum blockchain, called *uPort*. The purpose of this project was "to provide citizens with a self-reliant and trusted blockchain-based identity to authenticate for e-government services and share personal data with third parties" (Allessie *et al.*, 2019:31). The initial implementation of uPort was to serve as a proof of residency, "but will eventually incorporate other services like e-voting, tax declarations or parking payments" (Allessie *et al.*, 2019:32).

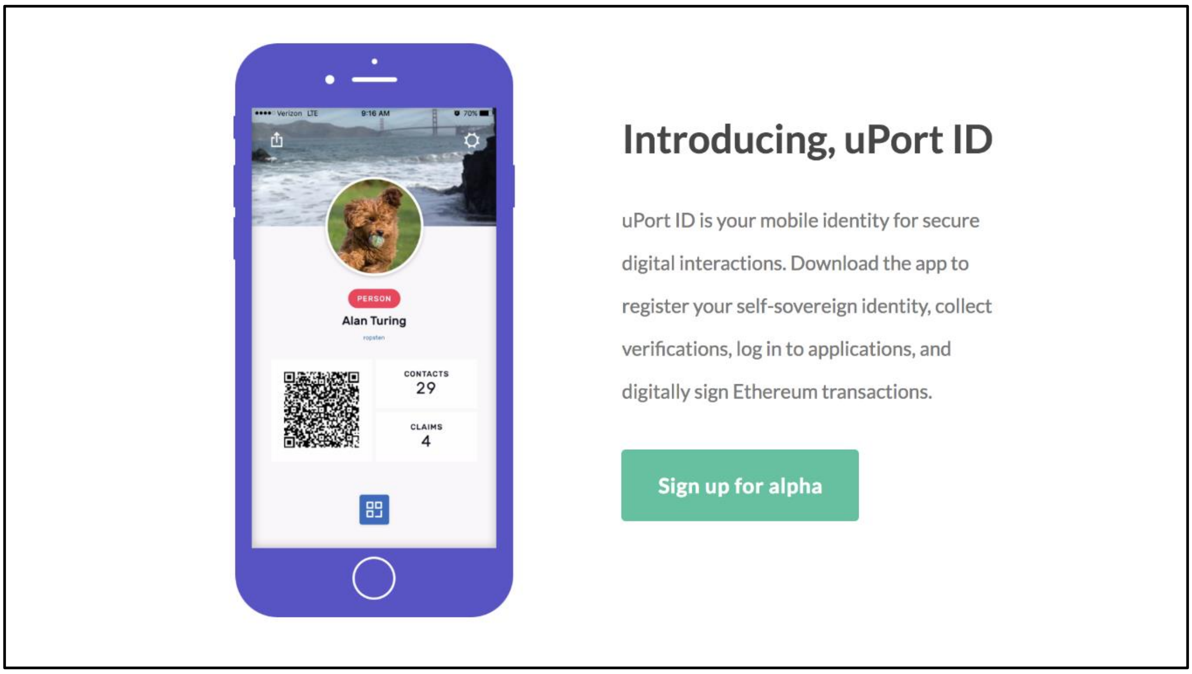

Figure 12: uPort Smartphone Application Home Page (Source: Medium, 2017)

In the case of Switzerland, blockchain similarly showed that it can fulfil the function of a government-citizen interface. The project makes use of blockchain to facilitate interactions between citizens and government, and communication takes place via a smartphone application (Figure 12). The application creates a unique address key on the blockchain for each user and links this to their smartphone application wallet to interact with the network. From a user's perspective, "the main interaction point with the system is the uPort application." The application is used for storing all personal data locally on the user's device which is hashed in and linked to the blockchain network as a way to verify that the information being provided is credible and represented on the network (Allessie *et al.*, 2019:33). This can be compared to a proof of registration and existence receipt. As discussed by Atzori (2017), this introduces a "decentralised model of identity management" and "represents a digital attestation from Zug, to the citizen that they are recognized as an active citizen" (Young & Verhulst, 2018:4).

Figure 13 makes it clear that a certain level of government intervention is still present, similar to the case of Estonia. The smartphone application grants Zug's city authorities admin rights in the uPort application. This, according to Allessie *et al.* (2019:32), is mainly to ensure the verification of identity information being recorded to the blockchain during the initial registration process. Young and Verhulst (2018:5) conducted an interview with the mayor of Zug, Dolfi Müller, to ascertain why they had implemented blockchain technology for citizen identity management. His response was "uPort seeks to push ownership of identity away from centralized services to individuals – so that the identities themselves are in control." This again signified the use of blockchain as a government-citizen interface to create improved citizen engagement in the handling of personal information and deciding who has access to this data. However, government remains the authenticator of initial data inputs.

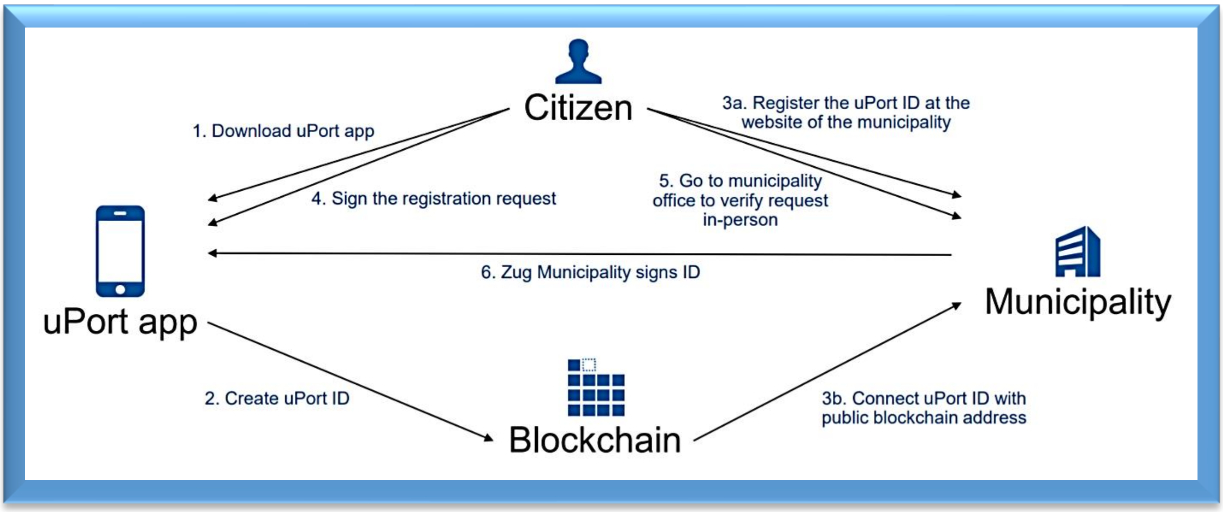

Figure 13: An outline of the uPort registration process (Source: Allessie et al, 2019)

Furthermore, blockchain projects in Finland (Lim *et al.*, 2018:1741), India (Deloitte, 2018:17) and the USA (El Haddouti & Kettani, 2019:4) are similarly underway to make use of blockchain for citizen identity management via government websites and smartphone applications. Here it was found that blockchain is used to facilitate communication with citizens and partially regulate administrative processes (Third *et al.*, 2018:3). All the projects examined by these scholars highlight blockchain's ability to facilitate the secure immutable flow of data to governments in a way that allows citizens greater control, usability, accessibility and openness (Lim *et al.*, 2018:1741).

In summary, the abovementioned cases, along with Estonia and Switzerland, indicate that at least five countries have displayed blockchain's ability to provide the function of a government-citizen interface within the context of citizens' identity management. A blockchain can ensure the flow of data between citizen and governments in an immutable and secure manner, while giving citizens the ability to have greater control of their personal information via a graphical user interface (GUI) in the form of a website or smartphone application. This creates a more bottom-up approach to citizen engagement. Finally, blockchain technology allows for government to participate in the verification of identity documents being registered to the network. This is made possible by back-end administrative privileges through the blockchain-based application or website. Governments are therefore able to communicate with citizens and intervene in public affairs, which further demonstrated this technology's ability to function as a government-citizen interface.

4.4.2 Can blockchain organize social relations?

Answer: *Blockchain acts as a social technology in the context of citizen identity management and has the potential to influence socio-political/economic environments, social behaviour among citizens and social relations between citizens, private vendors and state.*

Blockchain's ability to organize social relations was identified as the most prominent function within the context of citizen identity management, as the availability and integrity of one's identity data (e.g. financial background, medical history or criminal record) can influence the social outlook that other citizens, private vendors and the state have of you. Identity serves as a pillar for building trust in modern society and trust has been identified as "a mediator of every day, face- to- face relations" (Conviser, 1973:377).

In our digital world trust plays a critical role in the online environment. Users are faced with situations where they must rely on trust to overcome their risk perceptions as many online interactions require users to disclose personal information (Alkhalifah & D'Ambra, 2013).

> *Trust ... is never to be taken for granted….In our relation to the world, trust is always in conflict with mistrust. …yet if we are dominated by mistrust we cannot attend or interpret adequately, we cannot act accountably, and we will rupture, not strengthen, the solidarity of the community or communities we live in* (Bellah, Madsen, Sullivan, Swidler & Tipton, 1992).

Whether it be the buying or selling of a car, interactions on social media, applying for welfare payments, registering land or taking a loan from the bank, the ability to prove you are who you claim to be directly influences the social relations and the level of trust citizens have towards each other within a society (Ibrahim & Abubakar, 2016:1). "If data is falsified, obsolete or not verifiable, it is not possible to generate reliable communication or trust", which can be highly problematic for social, economic and political environments (BSI, 2014:7). To establish a reliable citizen identity management system, the authenticity of identity data is therefore of great importance to the social relations in a society.

Blockchain technology can function as a social technology within the context of identity management "to influence the social structures of society, social relations, and interactions" (Nelson & Nelson, 2002:265). Its ability to influence social relations, particularly "trust", is discussed by various scholars (Dunphy & Petitcolas, 2018:3; Borrows, Harwich & Heselwood, 2017:11; Wolfond, 2017:2; Mariappan, 2019:6286). The transparent, immutable and decentralized capabilities of blockchain were identified as the qualities able to ensure the integrity of identity data and, in doing so, it has the potential to influence the level of trust citizens share amongst each other, with government departments and private vendors.

Transparency – The transparency that blockchain can offer identity management systems is identified (Dunphy & Petitcolas, 2018:2; Deloitte, 2018:14; Allessie *et al.*, 2019:32) as having the potential to influence trust relations both among and between citizens and government. In contrast to existing centralized identity documentation systems, the ability to audit the validity of identity data via a smartphone application can give citizens greater confidence in how their identities are managed and shared. Additionally, blockchain would also bring to light if others were untruthful about their identities as its technical configuration "can easily detect if data have been tampered with" (Zhang *et al.*, 2019:16). This creates opportunity for both government and citizens to monitor the integrity of identity information, which can in turn increase the level of trust they have in the information shared between them.

Immutability – Blockchain can assure citizens that information such as their birth certificate, social security card, passport, drivers' licence and so forth are stored on a "tamper-resistant" network protected by the "highest levels of encryption" (Raikwar, Gligoroski & Kralevska, 2019:23). *Encryption* refers to the process of encoding a piece of information in a way that means only authorized parties can access it. This is significant because blockchain enables "a bottom-up approach to identity administration, emphasizing self-governance" (Atzori, 2017:12). Citizen's information can therefore be stored in an immutable manner and allows for greater control of the authorization processes. This immutability can increase the level of trust citizens have in the identity management system itself and guarantees citizens and government that the information presented is reliable and protected.

Decentralization – Existing identity systems are in most cases controlled and owned by an external administrative authority (Home Affairs, police departments or traffic departments). This is described as centralized identity management (Atzori, 2017:11). A blockchain network produces a decentralized network for identity management where identity data can be controlled by their 'owners' to limit the need for a third party (Mariappan, 2019:6285). This creates "a decentralised identity eco-system that not only facilitates the recording and exchange of identity data, but also the proliferation of trust among participating entities" by mitigating the risk of placing too much trust in any single authority (Dunphy & Petitcolas, 2018:3). Decentralizing citizen identity management systems also creates an environment within which data are distributed among various nodes to prevent the threat of intentional data corruption and cyber-attacks that hamper or degrade data integrity (Lim *et al.*, 2018). Kassem, Sayeed, Gisbert, Pervez and Dahal (2019:2) argue that "decentralization is a crucial turning point in identity management to safeguard the efficient management of identities and delegating authentication". Ensuring the integrity of data in this way, can provide all stakeholders with the assurance that identity information is stored in a secure and reliable manner.

If these features of blockchain can successfully enhance the level of trust in society, it can influence social relations in various way. First, trust is discussed by Nágy *et al.* (2018) as being "transitive". They argue that in general a person is more likely to trust you if they can personally verify your identity. Taking it a step further, they argue that trust can also be built if somebody they know can verify your identity. This implies that existing trust can build more trust. "If A trusts B, and B trusts C, then A can trust C to some degree" (Nágy *et al.*, 2018:47) This feature of trust is called transitivity. Considering this transitive nature of trust, if blockchain has the ability to ensure the integrity of identity documents as discussed (Borrows *et al.*, 2017:11; Wolfond, 2017:2; Mariappan, 2019:6286), then it can have an influence on social relations among citizens and how individuals are perceived by a community as a whole.

Furthermore, Hunter (2019:366) has established that there is a direct correlation between the availability of reliable identity documents and provision of services. Therefore, a blockchain-based identity management system which has the potential to "undoubtedly verify" (Aydar & Ayvas, 2019:7) the integrity of documents can have a direct influence on a citizen's social, political and economic relations within his/her country and the international community. This finding was significant as it was the first indication that blockchain has the potential to configure social behaviour among citizens to some degree. Mariappan (2019) writes:

> *Blockchain will influence how people and organizations communicate, how companies work with each other, how procedures and information are transparent, and eventually how our economy is productive and sustainable* (Mariappan, 2019:6291).

Finally, Allessie *et al.* (2019:11) and Aristidou and Marcou (2019:288) address blockchain's ability to influence social relations among citizens and government. Blockchain can influence social relations between government and citizens for a number of reasons. As matters currently stand, citizens have very little trust in the way that government handles their personal information (Edelman Trust Barometer, 2019). This view is supported by Borrows *et al.* (2017:5), who found that in the United Kingdom (a developed country) just thirteen percent of British people trust the government to use their data appropriately, while forty-six percent do not. On the other hand, governments have also become increasingly sceptical that people are in fact who they claim to be, as identity fraud has increased steadily with the introduction of online services (Irshad & Soomro, 2018). Blockchain's technical configuration and the qualities highlighted above show its potential to combat these trust issues by providing a reliable, immutable and verifiable identity database built on "*trust-by-computation*" (Quintais *et al.*, 2019:3). This is highlighted by Borrows *et al.* (2017).

> *Just like the Internet, blockchain will have a profound transformational impact on society. It could radically change the relationship between the individual and the state. For identity management this would mean helping to increase trust in how government uses people's data. Blockchain could deliver more efficient and secure experiences for citizens* (Borrows *et al.*, 2017:11).

In addition to the positive implications of implementing blockchain, a potential limitation on its ability to influence social trust among citizens and government was observed. Currently, people are used to placing their trust in third party authenticators (people). If you take this away and replace it with a trust-by-computation model system, "citizens are forced to put their trust in the concept of blockchain, which very few are familiar with" (Lesavre, Varin, Mell, Davidson & Shook, 2020:34) at such an early stage of this technology's development. The extent to which people are educated on the capabilities of blockchain technology can therefore have an influence on its ability to organize social relations.

In summary, as a social technology blockchain can influence the social structures of society, social relations, and interactions. This was found to be the case especially within the context of citizen identity management. Blockchain's ability to facilitate and regulate a transparent, immutable and decentralized identity management system presents a strong case for its potential to influence social relations, as the ability to prove you are who you claim to be can influence the level of mutual trust citizens have within a society. Blockchain further shows the potential to configure the social behaviour of citizens, as there is as a direct correlation between the integrity and availability of identity documents and the provision of services. An argument can therefore be made that blockchain technology does show the potential to provide the function of organizing social relations within the context of citizen identity management. Similar to what was observed in both land registration and voting, the extent to which blockchain can organize social relations cannot be measured at this early stage.

4.4.3 Can blockchain create structures of opportunity for actions and achieving goals?

Answer: *Blockchain has the ability to create opportunity structures for action, achieving policy goals and desirable outcomes related to citizen identity management.*

As mentioned, providing proof that individuals are who they claim to be is subject to the quality and integrity of government records and these records are of great significance to all actors in a country as they are the prerequisites for any recognition of rights and the provision services (Third *et al.*, 2018:5). How effectively governments provide citizen identity management has a direct impact on the social, economic and political position of a society (Figure 14), which can in turn influence governments' ability to achieve policy goals and attain desirable outcomes within its borders (Hunter, 2019:366).

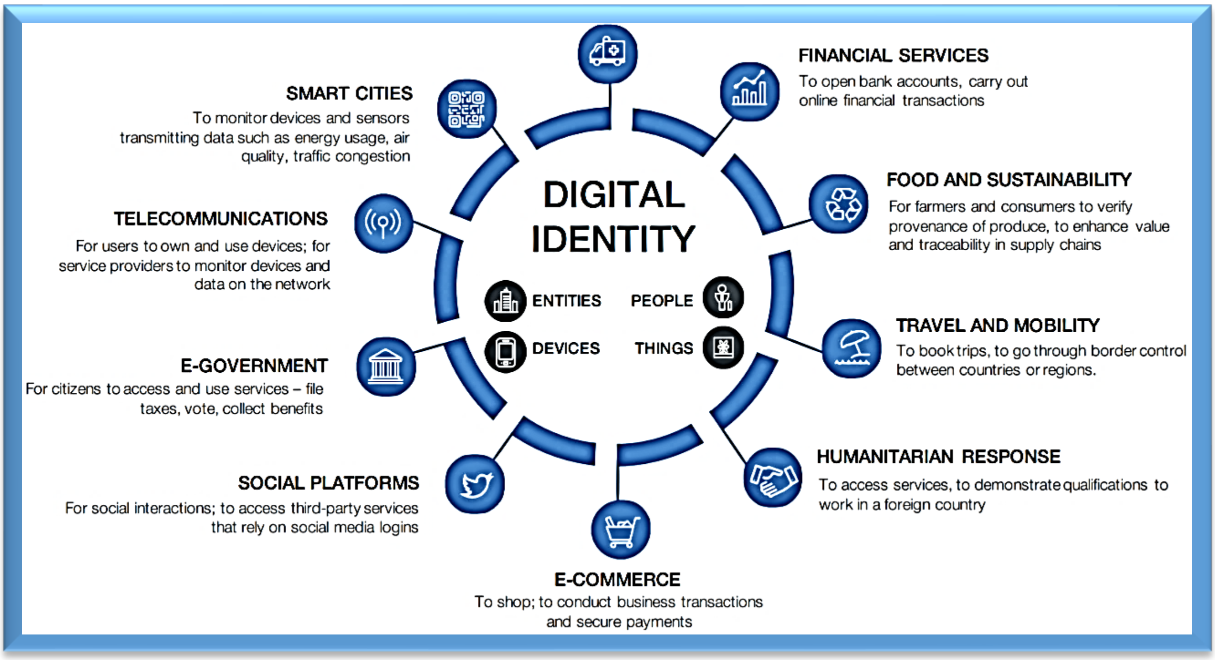

Figure 14: The Importance of Identity (World Economic Forum, 2018:10)

The first step in the analytical process was to identify the key stakeholders in identity management and determine if blockchain can achieve the basic policy goals required to ensure an efficient/effective identity data system for all stakeholders. Nágy *et al.* (2018:6) identifies three stakeholders and their needs in a digital identity management system:

The citizen – this refers to an individual whom the data is about, who owns the data and as a result would suffer losses if his or her privacy is violated. The main concern for citizens is having accessibility to identity documents to access or receive desired resources or services while simultaneously preventing privacy violations. Citizens may choose to relax their privacy policy to some degree, if they perceive that the gains (resources or services) are more valuable than their personal information. Citizens must have access to their identity documents "to exercise their rights and freedoms and demonstrate their eligibility to access services, while preserving the necessary degree of confidentiality" (World Economic Forum, 2018:5).

Blockchain technology successfully achieved these goals in the case of both Estonia (Priisalu & Ottis, 2017) and Switzerland (Young & Verhulst, 2018). Kassem *et al.*, (2019) and Roos (2018) discuss the potential for blockchain to successfully achieve these policy goals in theory. The way that blockchain achieved these goals in the case of Switzerland (uPort) is outlined by Allessie *et al.* (2019:31). They argue that implementing blockchain introduced a new solution for personal data management and identity conformation to the citizens of Zug. It decentralized the ownership, representation, attestation and management of identity data to ensure the citizens decide how their information is used.

This is called "*a self-sovereign identity*" (Young & Verhulst, 2018:3), which is supported by Roos (2018:107), who explains how the uPort system "enables citizens to create an identity, manage it together with its respective attributes and can get control back in the case of loss." With regards to ensuring privacy, blockchain also offers uPort users data encryption "whereby only authorized parties can access identity data" (Raikwar *et al.*, 2019:23). This is highlighted by Jacobovitz (2016):

> *Through blockchain solutions, consumers can simply use an app for authentication instead of using traditional methods. The solution will store their encrypted identity, allowing them to share their data with companies and manage it on their own terms* (Jacobovitz, 2016:3).

Furthermore, Estonia (KSI-Blockchain) is also an example of how blockchain can achieve the fundamental goals of identity management for citizens. Estonia's blockchain-based identity system demonstrates "a citizen's ability to hold a public service identity via their smartphone device and allows citizens to access a host of public services and digitally sign documents" (Borrows *et al.*, 2017:9). This confirms that citizens are provided with improved accessibility to exercise their rights and freedoms, and demonstrate their eligibility to access services. To protect the privacy of citizens and ensure control of personal information the KSI-blockchain system also offers individuals "the choice of what data they share for which interaction, with whom and for how long" through encryption and administrative capabilities (World Economic Forum, 2018:5). Based on this evidence, it was concluded that blockchain can achieve the basic goals of identity management for citizens.

The government – Government must be able to verify that citizens are who they claim to be or have what they claim to have. This could be verifying the services that a citizen is eligible for, if they are above a certain age, or have a particular nationality, marital status or criminal record. This information must be secured by government to prevent data manipulation or data loss, which could impact negatively on the personal interests of a citizen. Fundamentally, "government is responsible for the data information infra-structure, its security, confidentiality and accessibility when needed" (Priisalu & Ottis, 2017:447). Furthermore, government must have some administrative abilities to authenticate and regulate the validity of identity documents to ensure the integrity of data submissions and changes.

Blockchain technology successfully achieved these goals in the case of both Estonia (Priisalu & Ottis, 2017) and Switzerland (Young & Verhulst, 2018). Other scholars (Guggenmos *et al.*, 2018:5–6; Borrows *et al.*, 2017:8) also discuss the role of government in blockchain-based identity management, its ability to regulate identity data through administrative privileges, smart contracts and the security that can be provided by blockchain's technical configuration. Interestingly, the role of government in identity management is significantly reduced by the use of blockchain. This appears to be a key feature that blockchain can provide and various scholars (Atzori, 2017:15; Mariappan, 2019:6287; Nuss, Puchta & Kunz, 2018:12) emphasize how the goals of identity management can be achieved more efficiently, by decreasing the responsibility of government in administrating identity data.

Although there is "a power shift in the management of identity data" (Atzori, 2017:13), governments still retain administrative privileges to ensure the regulation and verification of identity documents. *Initial data verification procedures*, *back-end administrative privileges* via the smartphone applications and the programmability of *smart contracts* were identified as the core features that allow governments these regulatory benefits. In the case of both Estonia and Switzerland, it was found that the initial input of data to the blockchain must be done at a government office for verification (Switzerland) or verified via the smartphone application, where all submitted data are reviewed and authenticated by government (Estonia).

This indicates that governments are still necessary for initial verification. Allessie *et al.* (2019:31) explains that in Switzerland "citizens have to register the uPort identity with the Municipality of Zug which has to be done in person in the town hall." Young and Verhulst (2018:44) also confirm this: "Once a Zug government official verifies and cross-checks the individual's information, the resident's new digital citizenship credential is added to their uPort ID." The same was observed for Estonia, where "Citizens are required to fill in a form stipulating all personal information (name, surname, address, identity number) as well as a scanned copy of their existing national passport and an ID photograph" to be verified by government (Jacobovitz, 2016:4). This indicated that government does still have a role to play, if not the most important one, to ensure that the data being registered to the blockchain are in fact true. Blockchain does therefore achieve the goal of allowing government to verify that citizens are who they claim to be, or has what they claim to have.

With regard to government's ability to create sets of rules and regulations to influence opportunity structures, *smart contracts* and *back-end administrative privileges* were identified as the key enablers. Lesavre *et al.* (2020) explain that smart contracts based on the Ethereum blockchain can be used to communicate between stakeholders and it offers the government pre-programmable capabilities to regulate how interactions are conducted:

> *Rules and permissions based on a smart contract can be implemented to restrict the context in which data transfers take place. This way, parties that trust each other can transact securely and according to the agreed-upon rules. The system has rules that dictate how participants interact. These rules are implemented and enforced through smart contract code that is visible to all participants. Since the underlying blockchain enforces correct execution of the smart contract, users can trust that these rules are executed correctly* (Lesavre *et al.*, 2020:27).

Smart contracts are used in Switzerland allowing citizens to "interact with other uPort identities" (Allessie *et al.*, 2019:33). This programmability indicates that the government is given the ability to enforce sets of rules and conditions, while allowing citizens to self-govern their identities. Bear in mind, the ability to influence opportunity structures through sets of rules is one of the key functions of existing policy instruments (Hellström & Jacob, 2017:609). The use of blockchain in partnership with smart contracts is therefore an indication of how blockchain can offer a significant improvement to existing centralized identity data structures for both government administration and citizen engagement. Furthermore, administrative privileges via smartphone applications or websites were also identified as a means to provide sets of rules and regulations to influence opportunity structures. In Switzerland, "the city registration office has admin rights in the uPort application" to regulate the authentication of identity data being exchanged on the identity management system. This was also observed in the case of Estonia (Allessie *et al.*, 2019:33) Finland (Lim *et al.*, 2018:1741), India (Deloitte, 2018:17) and the United States of America (El Haddouti & Kettani, 2019:4).

Private vendors – Private vendors require access to identity documents to verify if an individual is who he or she claim to be. Banks, insurance companies, medical clinics and car dealerships are just some examples of private vendors. These vendors cannot blindly trust citizens; hence there is a need to verify an identity from an issuing institution (government). This can include criminal background checks, proof of address, nationality, marital status or other personal attributes required for the provision of private services. An identity management system must provide private vendors the ability to legally access a citizen's personal information, but only if permission is granted by the citizen so as to protect the privacy of individuals (Nágy *et al.*, 2018:6)

Blockchain technology demonstrates the ability to achieve the basic needs of private vendors who require verifiable identity data when serving customers. The World Economic Forum (2018:5) states that a blockchain system allows citizens "the choice of what data they share for which interaction, with whom and for how long" through encryption and administrative capabilities. If Raikwar *et al.* (2019:23) are accurate in their claims that blockchain is "tamper-resistant" and has the potential to "undoubtedly verify" (Aydar & Ayvas, 2019:7) the integrity of documents, it is not necessary for private vendors to place their trust in citizens or make use of an issuing institution to validate the authenticity of identity information. Via a mobile application or website, "citizens can securely store and monitor claims generated from vendors and decide which service providers may access their information and how that information is shared" (Nágy *et al.*, 2018:36). This suggests that blockchains ability to reconfigure how data are controlled can provide significant efficiency gains for private vendors and reduce the amount of government resources needed to facilitate the availability of identity documents.

In summary, many institutions and organizations have realized the potential of blockchain and are embracing the technology for storing various kinds of identity certificates. A core motivation for integrating blockchain is simply to capitalize on how this technology can improve the existing administrative processes for all stakeholders involved. Blockchain, like any new technological innovation, has been, and will be, implemented with the purpose of improving existing identity management processes. These findings along with the conclusions of various scholars (Deloitte, 2018:14; Mariappan, 2019:6287; Nuss *et al.*, 2018:12) provide evidence that blockchain does have the potential to create opportunity structures to facilitate the essential policy goals of an identity management system for all three main stakeholders: the individual, the government and private vendors (Nágy *et al.*, 2018:6).

In addition to blockchain having the potential to achieve the core policy goals of a citizen identity management system, additional data examined also indicated its ability to produce desirable outcomes related to *lower administrative costs*, *minimizing identity verification processing times*, *protecting the integrity of identity data*, *improved accessibility and preventing unnecessary data redundancy*. The table below outlines the observations made. The left column stipulates the policy goals and desirable outcomes that blockchain technology can provide, the middle column summarises the functions that blockchain performs which have the potential to create the opportunity structures needed to achieve these beneficial outcomes, and the right column lists the sources used to support the argument being made.

Policy Goals and Desirable Outcomes	**Blockchain Function**	**Sources**
Lower administrative costs and lower costs for citizens	A “self-sovereign identity” solution reduces the need for government to maintain centralized repositories of identity documents. Once verification of identities is shifted to citizens and blockchain, there is no need to host servers or databases for identity data. The number of public servants can therefore be reduced significantly, as governments are able to guarantee the integrity of documents without the cost of manual systems to do so. Estonia reported a 500-million-dollar cost saving in 2018 by utilizing the KSI-Blockchain. This is equivalent to nearly 2% of Estonia's GDP.	Guggenmos *et al.* (2018:6) Third *et al.* (2018:10) Young & Verhulst (2018:3) Wolfond (2017:35)

Minimize verification processing times	There are efficiency gains for citizens, government and private vendors. The new form of attestation generates substantial time savings in terms of accessing services and reduces the risk and friction of transacting digitally. If the majority of businesses and government departments made use of a specific blockchain's single identity solution for authentication and accessing their services, efficiency gains could be realized. Estonia reported that the acceleration of administration processes through X-Road (their blockchain-based distributed data exchange layer) collectively saved approximately 800 years of working time per year.	Allessie *et al.* (2019:34) Deloitte (2018:14) Guggenmos *et al.* (2018:6) Third *et al.* (2018:8) Wolfond (2017:36)
Immutable and reliable identity information	The immutable configuration of a blockchain ensures that identity data cannot be tampered with unless authorized by the identity owner and the state. This is ensured by the blockchain security protocols (hash-key function) and data encryption.	Allessie *et al.* (2019:9) Datta (2019:11) Dunphy & Petitcolas (2018:6)
Increased accessibility and control of identity data	The use of mobile applications and online websites to conduct day-to-day identity verification processes increase the accessibility and availability of personal information. This can make it easier for citizens, governments and private vendors to have access to verified identity data, while allowing citizens to control who has permission to see and use their information.	Atzori (2017:11). Mariappan (2019:6285) Datta (2019:7)
Reduce unnecessary redundancy to be more environmentally friendly	Paper-based identity management systems have a significant impact on the environment, according to Mukete *et al.*, (2016:13). The unnecessary duplication of identity documents across various govern departments is solved by the blockchain network. Maintaining a single verifiable, immutable and secure copy of identity documents accessible to all authorized stakeholders can remove the need to produce multiple copies of the same identity data.	Deloitte (2018:14) Omar (2020:2)

In closing, blockchain technology does have the potential to perform the function of creating structures of opportunity for actions and achieving goals. The evidence provided demonstrates blockchain's ability to achieve the basic policy goals required to ensure a proficient identity data system for all stakeholders. In addition to the essential functions, blockchain creates a new opportunity structure whereby government can enforce sets of rules through programmable protocols. Smart contracts and administrative privileges for both citizens and government authorities can have a major effect on how identity data are processed, how citizens interact with each other, the state and private vendors, and the regulation of such transactions. Smart contracts allow for preprogramed sets of rules and regulations which citizens and private vendors must abide by to participate in the identity management system. Blockchains therefore have the potential to regulate how citizens, government departments and private vendors interact. This can all be attained while enforcing a decentralized bottom-up approach where citizens maintain greater control of how their personal information is used, by whom and for how long. Finally, blockchain can create various desirable policy outcomes for all stakeholders involved in identity management. These outcomes are related to lower administrative costs, minimizing identity verification processing times, protecting the integrity of identity data, improved accessibility and preventing unnecessary data redundancy.

4.4.4 Can blockchain solve problems?

Answer: *Blockchain technology can fulfil the function of solving and preventing problems in the context of citizen identity management.*

As technology and the online community have progressed, the use of digital platforms to manage identity documents has become significantly more prevalent. The use of information and communications technologies (ICTs) has especially played a significant role in the flow of identity information, how it is used on a daily basis and for what services it can be used. This has placed security and privacy concerns at the centre of attention. It is no surprise, then, that identity management has received a great deal of attention from governments globally as an application of blockchain to solve problems. The key policy problems identified include cyber-attacks (Androulaki, Johnson, Vo & Bellovin, 2010; Abdu & Lechner, 2016), identity fraud (Tajpour, 2013; Finklea, 2014; Saroj & Patil, 2019) and data loss (Kumar & Bhardwaj, 2018:63). It should be noted that this section does not focus on problems faced in paper-based systems, but to ensure relevance, issues faced by government and citizens in the management of digital identity are addressed. This is where blockchain can potentially have the most impact. That being said, references are made where applicable to provide a basic understanding of the problems blockchain can solve for paper-based systems.

Cyber Security – Existing centralized systems are attractive to hackers as they have “a single point of failure (SPOF)” (Atzori, 2017:50). Various cases of cyber-attacks on identity management systems have been recorded in the last decade and in fact occur continuously on a day-to-day basis. In 2015 USA government databases were breached “which resulted in the theft of 19.7 million citizens’ identity information.” This included biometric information and social security numbers. The Tanzanian government system was similarly attacked in 2016, which led to “a loss of nearly 85 million US dollars” and Singapore was hacked in 2014, when fraudsters gained access “to create new businesses and apply for work permits illegally” (Elisa, Chao, Yang & Cao, 2018:2). This indicates that cyber-attacks are a persistent problem to citizens, government and private vendors within the context of digital identity management.

Blockchain technology is proposed (Nabi, 2017:50; Allessie *et al.*, 2019:10; Nágy *et al.*, 2018:69) as a potential solution to cyber-security attacks on identity management systems. The technical features of blockchain, specifically the decentralization of data storage, distribution of system functionality and immutable cryptographic primitives, were identified as being capable of solving these problems. First, with regards to blockchain’s decentralized structure, Allessie *et al.* (2019) suggest how it can address cyber-attacks:

> *The physical decentralisation of the storage of transaction details is argued to provide security integrated into the design of the technology stack. This feature eliminates the risk of a single point of failure, where one node is critical for the operation of the network and vulnerable for cyber-attacks* (Allessie *et al.*, 2019:10).

This is indicative of how blockchain can offer an innovative approach to storing information, executing transactions and performing functions without the need to store information in a central location that is vulnerable to hackers. Considering in the case of uPort Switzerland (Allessie *et al.*, 2019:33), it was observed that personal data are encrypted and distributed via citizens mobile devices, so there is no need for central government repositories for identity documents. This minimizes the risk of having millions of citizens’ identity information compromised simultaneously, as occurred in the USA, Singapore and the Tanzania. Additional arguments (Alladi *et al.*, 2019:20; Dong *et al.*, 2018:2; Taylor *et al.*, 2019) are also made identifying how blockchain’s decentralized structure, immutability and cryptographic configuration can address the issue of cyber-attacks on identity management systems and “make it significantly more difficult for hackers to infiltrate a government network” (Allessie *et al.*, 2019:14).

Identity fraud – This issue was identified in both digital and paper-based systems. Identity fraud occurs when "one person steals and uses another person's personal identity information, without authorization, for financial gain, committing a crime or to deceive others" (Koops & Leenes, 2006:6). A report by the USA Internet Crime Complaint Center outlines the number of online identity fraud cases that were reported between 2014 and 2018 (Figure 15):

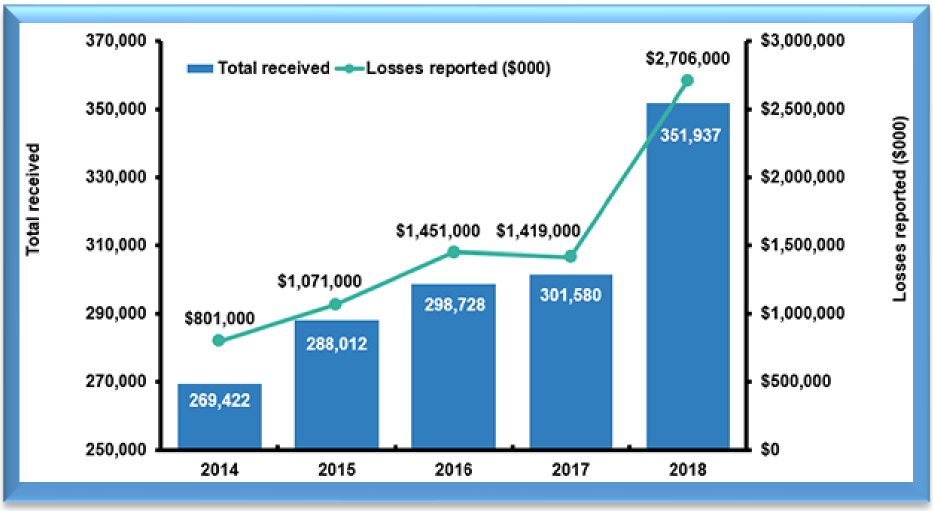

Figure 15: Number of online identity fraud cases and subsequent financial loss in the USA (Source: Internet Crime Complaint Center, 2019)

This steady increase and significant number of annual incidents shows that online identity fraud is an issue specifically faced by citizens, but is not being adequately addressed by current government law enforcement operations. As an infrastructure for more secure identity management systems, blockchain technology is proposed (Dunphy & Petitcolas, 2018:1; Allessie *et al.*, 2019:8; Anjana & Raman, 2018:12) as having core features which can address and minimize the problem of identity fraud/theft. The immutable tamper-resistant structure, data encryption abilities and transparency offered by blockchain are identified as having the potential to "completely overcome identity theft and suspicious activities" (Nabi, 2017:10).

Wolfond (2017:37) argues that a blockchain-based citizen identity management system can allow citizens to go about their "high-value and day-to-day transactions online", in a cost-effective and efficient manner while "reducing the risk of identity theft". This, he continues, will "improve public safety and confidence by making it more difficult to use identities fraudulently." The way this can be achieved is explained by Borrows *et al.* (2017):

> *Blockchain is safer than centralised databases. Information stored on the ledger is encrypted at all times and its distributed nature makes it very difficult to hack. Hackers*

> *would need to simultaneously hack into a majority of the devices used by the members on a network. This could reduce the risk of identity fraud* (Borrows *et al.*, 2017:7).

The transparency and encryption capabilities of blockchain are especially applicable in addressing the problem of identity fraud. By combining the decentralized principle of blockchain with identity verification, a digital identification is created similar to that of "a transparent and verified watermark" (Jacobovitz, 2016:3). This can allow stakeholders to "verify the identity of participants in real-time, eliminating a high rate of fraud" (Jacobovitz, 2016:3). Furthermore, the encryption provided by blockchain provides citizens the ability to "store and monitor claims generated from vendors and decide which service providers may access their information and how that information is shared" (Nágy *et al*., 2018:36). This limits the availability of identity data in a decentralized manner, which can reduce the potential to be a target of identity theft. Elisa *et al.* (2018) explains this in a more holistic way:

> *The blockchain technology enables the implementation of highly secure and privacy-preserving decentralized systems where transactions are not under the control of any third-party organizations. Using the blockchain technology, exiting data and new data are stored in a sealed compartment of blocks and distributed across the network in a verifiable and immutable way. Information security and privacy are enhanced by the blockchain technology in which data are encrypted and distributed across the entire network* (Elisa *et al.*, 2018:1).

If illicit attempts were made to obtain personal information, this would be easily detectable according to Liang, Zhao, Shetty, Liu and Li (2017:3) as the hash-key function "is an effective measure to detect changes so that once a piece of data is modified, the action can be detected easily". This along with the increased accessibility and transparency, suggests that citizens are able to better monitor the security of their personal information and determine whether it has been compromised. This can solve problems for both citizens and law enforcement. Finally, considering that government is able to regulate and intervene in the processes of authenticating citizen identity data, this allows them to detect if citizens are being dishonest about their information as they are "required in the initial input to authenticate information being recorded to the blockchain ledger" (Young and Verhulst, 2018:44).

It is also important to note that "blockchain cannot be viewed as the panacea for digital identity issues" (Anjana & Raman, 2018:12). Although it does provide the framework and accompanying benefits, like any technological system, it comes with limitations. In the case of

Switzerland (uPort), for instance, Dunphy and Petitcolas (2018) points out that blockchain does not completely resolve the issue of identity theft at this stage of its development. As the uPort application is used to store identity data on the user's mobile device to achieve decentralization, a risk is created where unauthorised access to the local device is possible. This irregularity cannot be prevented whereby the blockchain, as it would automatically accept that the application user has permission to access his or her own identity documents. "So while uPort does place more control in the hands of citizens, a layer of complexity and responsibility is inevitably handed to users." Bear in mind that this "will not provide a hacker accesses to specific identity information of an individual as this can be individually encrypted, but it can compromise relationships with identity providers and relying parties" (Dunphy & Petitcolas, 2018:5). That being said, while blockchain is not a complete answer to these vulnerabilities, it certainly can help bring down the risk and help create a safer environment for citizen identity management.

Data loss – If either citizen, government or a private vendor is unable to attain identity documents as a result of data loss, it can hamper their ability to receive or provide services. This is noted by Third *et al.* (2018:5), who explain how identity records are prerequisites for recognition of rights and provision of public and private services. Blockchain's immutable decentralized peer-to-peer configuration can directly address the issue of data loss as "user data is stored in different nodes and devices which guarantees the availability of the system by avoiding any single point of failure" (Elisa *et al.*, 2018:8). This argument is supported by at least three other scholars (Nágy *et al.*, 2018:34; Nabi, 2017:50; Wadhwa, 2019:63), who similarly point out the immutability, decentralization and distributive qualities of blockchain as a remedy for the problem of identity data loss.

In summary, blockchain technology can fulfil the function of solving problems. Its technical configuration allows for decentralization and transparency of data storage, distribution of system functionality and immutable cryptographic primitives to address the issues of cyber-attacks, identity theft/fraud and potential data loss. The evidence produced is indicative of how blockchain can not only solve problems for government in identity management, but also provide better protection and accessibility for both citizens and private vendors. It was further demonstrated that blockchain can help prevent future problems by ensuring the availability of a secure and tamper-resistant identity management system, which gives citizens greater control of their personal information and how it is used. The increased accessibility, auditability and transparency were found to be particularly valuable in this regard. Finally, although some limitations were identified, it is clear that blockchain does have the potential help reduce the risks of cyber-attacks, identity theft and data loss, which can in turn create a safer social, economic and political environment for citizen identity management.

4.4.5 Conclusion

Blockchain technology can fulfil all four functions of a policy instrument in the context of citizen identity management. Although only two countries have successfully demonstrated the use of blockchain for citizen identity management, the 'proof-of-concept' presents a clear argument that this technology can have a transformative effect on identity management and beyond. As citizens, governments and private vendors continue to advance technologically and conform to the digital age of online identities, the need for secure, reliable and lasting identity management systems will become increasingly more valuable for governments to ensure they have ability to implement policy and regulate the personal information of its citizens.

Blockchain in partnership with a user interface (GUI) can offer significant benefits for citizens, government and private vendors. For citizens, blockchain creates a power shift in how identification data are accessed, and it provides a secure immutable flow of data to governments in a way whereby citizens are given greater control, usability, accessibility and openness. This has the potential to increase citizens' engagement in the management of identity data. For government, a blockchain can open up administrative abilities to authenticate identity data being registered to the blockchain network. Governments are also able to communicate with citizens and intervene by making use of their administrative privileges through the application or website user interface. It can therefore fulfil the function of a government-citizen interface.

For the first time in the analytical process, it was observed that blockchain can successfully realize all the qualities needed to perform the function of organizing social relations. Blockchain's ability to facilitate and regulate a transparent, immutable and decentralized identity management system presents a strong case for its potential to influence social relations as the ability to prove you are who you claim to be can influence the level of mutual trust citizens have toward each other within a society. Blockchain further shows the potential to configure the social behaviour of citizens, as there is a direct correlation between the integrity and availability of identity documents and the provision of services. Interestingly, in the case of citizen identity management, the improve efficiency blockchain can offer is a secondary motivation for why scholars are advocating to implement this technology in this context of government. Increased trust and transparency were identified as the most appealing benefits that can be gained from implementing blockchain technology to facilitate the flow and regulation of identity information.

Furthermore, blockchain technology does have the potential to perform the function of creating structures of opportunity for actions and achieving goals. Blockchain has the ability to achieve the basic policy goals required to ensure a proficient identity data system for all stakeholders. These goals include citizens having access to their identity documents to exercise their rights and freedoms, and being able to demonstrate their eligibility to access services, while preserving the necessary degree of confidentiality. Government must be able to verify that citizens are who they claim to be, or have what they claim to have. Government is further responsible for the data information infrastructure and its security, and must be able to authenticate and regulate the validity of identity documents to ensure the integrity of data submissions and changes. Finally, private vendors must be able to legally gain access a citizen's personal information, if permission is granted by the citizen to verify their identity when accessing services.

In addition to these essential functions, blockchain creates a new opportunity structure where government can enforce sets of rules through programmable protocols. *Smart contracts* and *administrative privileges* for both citizens and government authorities can have a major impact on how identity data are processed, how citizens interact with each other, the state and private vendors, and the regulation of such transactions. This can all be achieved while enforcing a decentralized bottom-up approach where citizens retain greater control of how their personal information is used, by whom and for how long. Lastly, blockchain can create various desirable outcomes for all stakeholders involved in identity management. These outcomes are lower administrative costs, minimizing identity verification processing times, protecting the integrity of identity data, improved accessibility and preventing unnecessary data redundancy.

Finally, blockchain technology can fulfil the function of solving problems. Its technical configuration allows for decentralization and transparency of data storage, distribution of system functionality and immutable cryptographic primitives to address the issues of cyber-attacks, identity theft/fraud and potential data loss. Blockchain can solve problems for governments in identity management, but also provide better protection and accessibility for both citizens and private vendors. It was further demonstrated that blockchain can help prevent future problems by ensuring the availability of a secure and tamper-resistant identity management system, whereby citizens are given greater control of their personal information and how it is used. Although some limitations were identified, it is clear that blockchain does have the potential help reduce the risks of cyber-attacks, identity theft and data loss, which can in turn create a safer social, economic and political environment for citizen identity management.

4.4.6 Summary of the findings

Blockchain Technology for Citizen Identity Management	Yes	Partially	No
1.) Can blockchain act as a government-citizen interface?	✓		
- Can blockchain enable government to communicate and respond to citizens?	✓		
- Can blockchain facilitate citizen engagement?	✓		
- Can blockchain facilitate government intervention?	✓		
Sources: (Bemile, 2015); (Janowski, 2015); (Tamilselvan *et al.*, 2012); (Lips, 2010); (Atzori, 2017); (Xu *et al.*, 2019); (Liu *et al.*, 2017); (Dunphy & Petitcolas, 2018); (Datta, 2019); (Haddouti & Kettani, 2019); (Lesavre *et al.*, 2020); (*Guggenmos et al.*, 2018); (e-Estonia, 2020); (Third *et al.*, 2018); (Jacobovitz, 2016); (Nágy *et al.*, 2018); (Allessie *et al.*, 2019); (Young & Verhulst, 2018:4); (Lim *et al.*, 2018); (Deloitte, 2018).			
2.) Can blockchain organize social relations?	✓		
- Can blockchain influence social relations between citizens?	✓		
- Can blockchain influence government-citizen relations?	✓		
- Can blockchain configure social behaviour among citizens?	✓		
Sources: (Alkhalifah & D'Ambra, 2013); (Ibrahim & Abubakar, 2016); (BSI, 2014:7); (Dunphy & Petitcolas, 2018); (Borrows *et al.*, 2017); (Wolfond, 2017); (Mariappan, 2019); (Deloitte, 2018); (Allessie *et al.*, 2019); (Zhang *et al.*, 2019); (Raikwar *et al.*, 2019); (Lim *et al.*, 2018); (Kassem *et al.*, 2019); (Nágy *et al.*, 2018); (Wolfond, 2017); (Hunter, 2019); (Aydar & Ayvas, 2019); (Aristidou & Marcou, 2019); (Edelman Trust Barometer, 2019); (Irshad & Soomro, 2018); (Quintais *et al.*, 2019); (Lesavre *et al.*, 2020).			
3.) Can blockchain create structures of opportunity for actions and achieving goals?	✓		
- Can blockchain provide rules and regulations to influence opportunity structures?	✓		
- Can blockchain provide opportunity for action and achieve policy goals?	✓		
- Can blockchain assist government in attaining desired outcomes?	✓		
Sources: (Third *et al.*, 2018); (Hunter, 2019); (Nágy *et al.*, 2018); (World Economic Forum, 2018); (Priisalu & Ottis, 2017); (Young & Verhulst, 2018); (Kassem *et al.*, 2019); (Roos, 2018); (Allessie *et al.*, 2019); (Raikwar *et al.*, 2019); (Jacobovitz, 2016); (Borrows *et al.*, 2017); (Guggenmos *et al.*, 2018); (Atzori, 2017); (Mariappan, 2019); (Nuss *et al.*, 2018); (Lesavre *et al.*, 2020); (Lim *et al.*, 2018); (Deloitte, 2018); (Haddouti & Kettani, 2019); (Aydar & Ayvas, 2019); (Wolfond, 2017); (Datta, 2019); (Dunphy & Petitcolas, 2018).			
4.) Can blockchain solve problems?	✓		
- Can blockchain assist government to solve identified policy problems?	✓		
- Can blockchain help prevent future problems?	✓		
- Can blockchain allow policymakers to assess whether the systematic operations to solve an identified problem was successful?	✓		
Sources: (Androulaki *et al.*, 2010); (Abdu & Lechner, 2016); (Tajpour, 2013); (Finklea, 2014); (Saroj & Patil, 2019); (Kumar & Bhardwaj, 2018); (Swetha, 2019); (Atzori, 2017); (Elisa *et al.*, 2018); (Nabi, 2017); (Allessie *et al.*, 2019); (Nágy *et al.*, 2018); (Alladi *et al.*, 2019); (Dong *et al.*, 2018); (Taylor *et al.*, 2019); (Dunphy & Petitcolas, 2018); (Anjana & Raman, 2018); (Nabi, 2017); (Wolfond, 2017); (Borrows *et al.*, 2017); (Jacobovitz, 2016); (Liang *et al.*, 2017); (Young & Verhulst, 2018); (Anjana & Raman, 2018); (Third *et al.*, 2018); (Wadhwa, 2019).			

4.5 Chapter Four conclusion

This study concluded that blockchain technology can fulfil the functions of a policy instrument and should be studied by policy scholars for its current use and potential uses for policy implementation and public service delivery.

Can blockchain act as a government-citizen interface?

In the three government applications examined, namely 1) national land registry, 2) national elections (voting), and 3) citizen identity management, blockchain technology has demonstrated that it has both the ability and the potential to act as a government-citizen interface. This is achieved through a graphical user interface (GUI), which allows blockchain to function as an information and communications technology (ICT). Blockchain can enable government and citizens to communicate with each other; it provides citizens the ability to engage with government and facilitates government intervention when necessary through back-end administrative privileges.

Can blockchain organize social relations?

With regards to fulfilling the function of organizing social relations, within the context of national land registration and voting (elections), blockchain can partially carry out the functions of organizing social relations. Here it was observed that blockchain can partially influence social relations among citizens and directly influence government-citizen relations. In the context of citizen identity management, blockchain technology successfully fulfilled the function of organizing social relations. Interestingly, this was something which was not observed in the other two cases, as no clear indicators where identified that blockchain can *directly* configure social behaviour. In identity management however, blockchain has the potential to directly configure social behaviour among citizens due because of the important role that secure and verifiable identity documents have on establishing trust and ensuring access to public and private services.

Can blockchain create structures of opportunity for actions and achieving goals?

In all the three government applications blockchain technology fulfils the function of creating structures of opportunity for actions, and achieving goals and desirable outcomes. Blockchain demonstrated that it can achieve all the necessary policy goals to facilitate a national land registry, national elections (voting) and citizen identity management. Although technical issues of scalability, security and efficiency were identified as having an effect on the extent to which blockchain can achieve these goals, an argument can still be made that it successfully creates the necessary opportunity structures for action and meeting the fundamental requirements. In addition to the basic functionality, blockchain also created desirable outcomes for both government and citizens in all the applications examined. Smart contracts served a significant purpose in all cases examined and provided government with the ability to set rules and regulation to influence opportunity structures to better achieve policy goals. Desirable outcomes which can be realized by blockchain relate to increased overall efficiency in policy implementation, improved trust in administrative processes, lower administrative costs for government and citizens, the assurance of immutable and reliable digital information, and increased accessibility and control in how information flow is regulated and utilized.

Can blockchain solve problems?

Finally, blockchain technology can fulfil the function of solving problems in all three applications examined. The technical configuration of blockchain allows government and citizens the ability to address policy problems in a way that was not previously possible. In national land registries the problems of corruption and internal fraud, potential cyber-attacks and loss of land registry data through natural disasters and unequal accessibility to land registration processes were addressed and shows the potential to be solved by blockchain. In national elections (voting) the existing problems of electoral fraud by government and illegal double voting by citizens can be addressed by this technology and finally, in the case of citizen identity management, the issues of cyber-attacks, identity theft/fraud and data loss are similarly addressed. The main features which are proposed as remedies to these problems are blockchain's transparency of data and transactions, the immutability of data recorded, decentralization of authority, distribution and encryption of data. These features are all made possible by the blockchain architecture, which was not previously available in one system.

Chapter Five: Research Conclusion

The aim of this thesis was to explore *whether blockchain technology can fulfil the functions of a policy instrument* within the context of policy studies. This research was conducted in response to a lacuna in the research identified during the preliminary literature review of this thesis. The research gap was that, although blockchain showed the potential to function as a "*tool of government*" (Batubara *et al.*, 2018; Lewis *et al.*, 2017; Casino *et al.*, 2019; Osborne, 2017) and has been used by governments as an instrument to achieve goals and solve problems (Tapscott & Tapscott, 2016; Swan, 2018; Casino *et al.*, 2019; Jun, 2018; Atzori, 2017), no research was found where policy scholars had explored blockchain as a policy instrument. This raised the question of why this technology has not been analysed as a policy instrument when it showed the ability to carry out the core functions of what constitutes a policy instrument. It was therefore necessary to explore this technology as a new age policy instrument for our digital world. Before answering the main research question, it is necessary to recap the systematic approach followed to get to this point:

- Background was given on blockchain and the Fourth Industrial Revolution to position this research and indicate its relevance. This was followed by an explanation of the technical functionality of blockchain to provide an understanding of the features of this technology and why it is considered as being so disruptive to existing practices in our political, economic and social world.

- A literature review was conducted to identify what research has been conducted on blockchain, how it is understood by various scholars and in what industries it has drawn the most attention since its inception in 2009. This was followed by an in-depth look at how it has been researched within the context of government processes. This allowed the researcher to identify how blockchain has been defined by blockchain scholars and present an integrated definition of this technology and its core features.

- This was followed by an analysis of how public administration, public policy and policy implementation are understood within the context of government and policy studies. Finally, we at looked the core functions of policy instruments and how they are defined by policy scholars. This allowed the researcher to present an integrated definition of a policy instrument, which was formulated by identifying and explaining the core functions of a policy instrument as described by notable policy scholars.

- An analytical framework was constructed by which to analyse blockchain as a policy instrument. This analytical framework was called the īnstrūmentum framework. It was created by deconstructing the core functions of a policy instrument to its most basic components and then turning these components within these functions into questions. This allowed the researcher to generate four main research questions and a number of sub-questions which were systematically addressed to ultimately answer the main research question of this thesis.
- Finally, to answer the main question, data focused on three government applications of blockchain, – namely 1) national land registry, 2) national elections (voting), and 3) citizen identity management – were analysed by applying the īnstrūmentum framework. This allowed the researcher to determine whether this technology can perform the functions of a policy instrument when analysed accordingly.

5.1 Answering the research question

The main research question of this thesis is:

❖ *Can blockchain technology fulfil the functions of a policy instrument?*

Blockchain Application	**Policy Instrument Function**			
	Government-citizen interface	Organize social relations	Create structures of opportunity to achieve goals	Solve problems
Land Registry	✓	Partially	✓	✓
National Election Voting	✓	Partially	✓	✓
Citizen Identity Management	✓	✓	✓	✓

This thesis concluded that blockchain technology can fulfil the core functions of a policy instrument as conceptualized by policy scholars. In the blockchain government applications of *national land registries* and *national elections (voting)*, this technology successfully fulfilled three of the four identified functions of existing policy instruments. In its application within the context of *citizen identity management* the data successfully demonstrated that blockchain can fulfil all four core functions of a policy instrument to some degree. This demonstrates that blockchain technology can fulfil the functions of policy instruments and policy scholars should therefore study it accordingly.

Based on preliminary research conducted by the researcher and observations made during the literature review on the functions of blockchain, the findings of this study did confirm the null hypothesis of this thesis. Existing research had on multiple occasions indicated blockchain's 'potential' ability to improve public administration and related operations with the purpose of fulfilling and enforcing desirable policy outcomes (Swan, 2015; Jun, 2018; Tapscott & Tapscott, 2016; Hou *et al*., 2017). Blockchain has the potential to provide significant gains for both government and citizens not only to implement policy programmes and services related to them, but also to regulate and enforce the desired outcomes through the enhanced administrative abilities during the implementation and assessment of the related policy processes.

Blockchain not only has the ability to fulfil the functions of a policy instrument, but also to act as a mechanism by which public administration can be completely redesigned to allow for more efficient public service delivery. More importantly, this can be achieved while providing law enforcement and policy makers complete control of the policy implementation process, transparency of the process, who is involved and to what extent. This confirms the argument by Xu, Chen and Kou (2019:27) that blockchain can be understood as a general-purpose technology within public government administration, which consists of all the operations by government, government agencies and non-government actors aimed at implementing and enforcing public policy (Marum, 2016:15).

5.2 Theoretical and practical implications of the findings

Considering that this research has provided evidence that blockchain can fulfil the functions of policy instruments, various theoretical implications arise for policy scholars and practical implications for government administrations in both developed and developing countries.

5.2.1 Theoretical implications

First and foremost, from a theoretical standpoint, the findings produced by this research serves to build on existing blockchain research on government processes and creates a basis for policy scholars to consider this technology as a policy instrument. This has the potential to theoretically address future policy problems that have not been solvable previously in the absence of this technology. Furthermore, as noted in Chapter Two, research was found discussing the need for government to better understand the transformative effects that blockchain can achieve in government operations, and recommending that policymakers should strive to understand the basics of this new architecture (Shah & Chatterjee, 2017:4). Atzori (2017:50) identified state monopoly as a Single Point of Failure (SPOF) and called for academics to explore less top-down state-centric instruments to increase interaction among public, private and non-governmental subjects. Finally, Allessie *et al*. (2019:10) proffers the argument that blockchain should be considered under the new paradigm of governmental policy making and service delivery. The findings of this research build upon this research as it provided a basis for scholars to better understand the basics of this new architecture, reveals the potential for blockchain technology as a "less state-centric" policy instrument, and makes a case that this technology should be considered as an instrument under the new paradigm of governmental policy making.

Furthermore, this study establishes blockchain's importance as a policy instrument or at the very least a tool of government for the Fourth Industrial Revolution, as explained by Klaus Schwab (2015). According to Schwab (2015:7), governments, policymakers and bureaucratic agencies need to embrace the new revolution of disruptive change and open their structures to the necessary levels of *transparency* and *efficiency* required to remain competitive and survive in our digital age. He further calls for a shift away from physical technologies towards adaptive social technologies in order to influence social processes within society (Schwab, 2015:12), which describes the functions blockchain provided in the government applications examined. The findings produced in all three government applications examined therefore confirm the potential for blockchain to be understood as a social technology, as explained by MyungSan Jun (2018:2). Blockchain can therefore fit into Schwab's (2015) theoretical requirements for a policy instrument appropriate for the Forth Industrial Revolution.

5.2.2 Practical implications

According to McConnell (2010:345), a policy can be perfect in theory, but if not paired with effective and efficient implementation, it will never achieve its desired purpose. Policies are the building blocks that facilitate socio-economic and political progress and can only be realized through continuous political commitment, coordination and the necessary instruments (Ahmed & Dantata, 2016:63). This study posits that blockchain be considered as a policy instrument which can encourage less direct involvement of bureaucracy, while maintaining the desired level of regulation. As a policy instrument, blockchain can allow for an approach where government can "steer, and not row" (Peters, 2011:5) the implementation processes of public policy within the "real world" (Swan, 2015:63) of "practical politics" (Donovan and Larkin, 2006:12). Practical politics here refer to the implementation of policy based on quantitative evidence rather than political ideology alone.

In the background section and literature review of this study, it was observed that issues of transparency (Maropo, 2018), accountability (Shah & Chatterjee, 2017) low trust in bureaucracy (Levin, 2017:8), high costs (Chiang *et al.*, 2018), inefficiency (Osborne, 2017), high levels of corruption (Jun, 2018:2) and lack of appropriate technology for implementation (Ahmed & Dantata, 2016:63) are all problems that have given rise to bottlenecks and challenges for government attempts to implement and enforce public policy. These factors could therefore be identified as issues that hamper government's administrative ability to facilitate political and socio-economic progress to produce value for citizens and ensure national development (Ajulor, 2018:1500). This was especially evident within the context of developing nations where centralised government, inefficiency, corruption, lack of technological innovation and low trust in bureaucracy allowed for the misuse of public tax funding and hampered the effectiveness of policy implementation and achievement of policy goals (Levin, 2017:8). As a policy instrument, blockchain technology can help developing nations such as South Africa, Nigeria, Kenya, India and Brazil make significant leaps in development by assisting in the implementation of public policy in a more cost-effective way, while also allowing the authorities to maintain the necessary regulatory control in a transparent and efficient manner.

This study positions us to see that blockchain has the ability to address and solve a wide variety of issues that have been identified in public administration and its existing methods of policy implementation, regulation and evaluation. Blockchain can not only perform the functions of a policy instrument, but in doing so can also ensure efficiency gains, cost savings, improved trust, security and adaptability for the decision makers of both developed and developing nations. Blockchain can facilitate and regulate policy implementation in a digital format through back-end administrative abilities and smart contracts, which realizes the potential for better policy implementation to achieve desired outcomes. As a policy instrument, blockchain therefore potentially holds significant benefits and offers solutions for developing nations at a time when these issues have continued to hamper the efficiency and effectiveness of policy implementation.

Furthermore, the literature review found that there was a strong emphasis on increasing political decentralisation in contemporary times, where more areas of policy and service delivery are being moved outwards from state government levels to the municipal and community level. Alongside this trend towards decentralisation, however, there remains a desire for some centralisation and control in the centre of how public policy is implemented and regulated (Nzimakwe & Pillay, 2014:17). Blockchain can potentially offer both of these fundamental capabilities to the state government through its technical configuration. By making use of blockchain and programmable smart contracts, government at the state level can remain involved in regulating and monitoring the processes of public policy, while allowing for local management networks, which work more closely with citizens/consumers/voters to take lead on policy objectives and local implementation. As a policy instrument, blockchain could therefore allow for new distributed and decentralized structures of policy implementation, while maintaining the desired levels of trust, flexibility, regionalized management and organisational change.

In light of these findings and observations, this research is intended as further motivation for governments, decision makers and participating agents of both developed and developing nations to begin considering blockchain as an instrument within their policy implementation approaches, and especially within mixed policy instrument approaches to address the limitations and inefficiencies in existing policy implementation methods. Blockchain can serve as a potential policy instrument and general-purpose tool within public administration, which can be built on efficiency, transparency, trust and decentralized democracy, to influence how citizens interact with each other and participate with government agencies.

5.3 Recommendations for future research

In the light of the evidence to demonstrate that blockchain can fulfil the functions of policy instruments, this research project identified various avenues for future research.

- The first recommendation would be to explore where blockchain technology would fit in typologies of policy instruments. If the findings indicate what type of policy instrument blockchain could be, this will simplify the selection processes by government and better consolidate how blockchain can be understood within the implementation process and clarify its position within the sphere of policy studies.

- The second recommendation would be to explore which current policy instruments can be combined with blockchain technology in an integrated policy approach. Ryan (2007:737) suggests that the integration of policy instruments at a strategic level can potentially achieve benefits both by using instruments which reinforce one another, and by overcoming the barriers to implementation. If this is the case, it would be highly beneficial for policy scholars to determine which current policy instruments would be most beneficial when integrated with blockchain. Successful results could accelerate efficiency gains in public policy and provide major cost savings for both taxpayers and the state.

- To address a limitation of this research, it would be beneficial to conduct quantitative case studies once more government blockchain projects have been implemented in the context of national land registries, national elections (voting) and citizen identity management. Quantitative results would help determine in a more statistically reliable way to what degree blockchain is able to fulfil the functions of a policy instrument. This could provide results to help policy scholars and policy makers determine specifically how well blockchain can function as a policy instrument within different policy settings.
- Blockchain technology could be explored within the New Public Management (NPM) paradigm, as discussed by Hope (2001) within the context of Africa. NPM reformers experiment with using decentralized service delivery models, which directly relates to a key trait of blockchain technology as a policy instrument. Key themes in NPM are focused on financial control, increasing efficiency, identifying and setting targets and continual monitoring of policy performance (Hood, 1991:4). These themes were identified as some of the key functions produced by blockchain, which suggests it should be explored as a policy instrument for New Public Management (NPM).
- As the need for social technologies continues to grow, Jun (2018) as well as the results in this study identified the potential for blockchain as a social technology. It would be beneficial to further explore to what extent blockchain technology can influence social processes within society as a policy instrument for public administration.
- The Coronavirus pandemic (Covid-19) of 2020 has showed how important it is for governments to ensure they can provide reliable information and public service delivery from remote locations when there are high levels of uncertainty and limited resources. Although we currently find ourselves in unprecedented circumstances, it remains government’s responsibility to facilitate essential services such as land registries, social grant payments, national elections and citizens’ identity management. The findings of this research indicated how effective blockchain can be in facilitating policy implementation

with significantly less resources and ensure government functionality in a decentralized manner. It would therefore be interesting to research how useful blockchain technology's qualities can be as a policy instrument during global pandemics when countries are on lock down and social distancing is being practiced at a national level.

- A less specific recommendation for future research which set the basis for a new direction of study within policy studies would be to further explore how blockchain technology can be utilized by government and policy makers in the Fourth Industrial Revolution. As discussed in this research project, Schwab (2015) voiced concerns regarding the regulatory and administrative inefficiencies in existing top-down processes of public policy and policy administration. This research has showed that as a policy instrument, blockchain does have the ability to fulfil various functions of existing policy instruments in a digital format, while allowing government to maintain public administration in a more 'efficient' and 'transparent' bottom-up approach (Schwab, 2015:7). It would therefore be of great benefit to explore the impact blockchain could have as a policy instrument at a time when technological innovation is fusing the physical, digital and biological worlds.

5.6 Concluding remarks

This research project has served to create a foundation for blockchain researchers, policy scholars and government officials to study and understand this disruptive technology as a creative policy instrument for public administration. The need for technologically advanced techniques and policy instruments will continue to grow and influence governments' ability to either maintain their position as influential actors in socio-economic and political action or risk falling behind in matters of governance and service delivery. If governments, especially in developing nations, remain focused on traditional, linear and non-disruptive thinking they may be unable to think strategically about the forces of disruption and innovation shaping our future. This research produced evidence to understand blockchain technology as a new-age policy instrument for government and outlined how it can serve as a multi-purpose policy instrument to help government with the administration and implementation of public policy in contemporary times. Using blockchain can produce value for citizens and ensure the kind of national development which was previously unattainable. This research therefore encourages future exploration of this topic to expand our theoretical and practical understanding of this technology as a policy instrument for e-governance in the Fourth Industrial Revolution.

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