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CHAINING THE BUILDING BLOCKS FOR BLOCKCHAIN IMPLEMENTATIONS IN SOUTH AFRICA'S PUBLIC SECTOR

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ABSTRACT

The emergence of the 4th industrial revolution has brought about several technological advancements in which blockchain fulfils a prominent role. To most people, the notion of blockchain is merely synonymous with the popular cryptocurrency Bitcoin. However, blockchain is not a cryptocurrency *per se*, but rather provides the backbone for the existence of cryptocurrencies. Blockchain has multiple inherent and potential benefits, especially so for governmental use-cases with the governments of Dubai, Estonia and Gibraltar already investing in such implementations. Blockchain applications include healthcare, identity management, voting, and banking services, among others. Since records on the blockchain cannot be altered, it is deemed to be a secure option for many of these implementations. The contribution of this paper is twofold. Firstly, it provides a description of the use of smart contracts, a form of self-executing contract, based on predefined rules between buyers and sellers. It describes how these contracts can potentially be used in South Africa to eradicate corruption in governmental processes by improving accountability and transparency. Secondly, it provides a blueprint of the use of Industrial Engineering tools and techniques to adequately design and implement blockchain use-cases, especially in the public sector.

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1. INTRODUCTION

It is almost daily that we hear of, or experience, one or more public service delivery protests. The delivery of essential public services is either lacking in quality, does not have a transparent process, or has an obvious corrupt element involved. To better respond to basic service demands, with more transparency and trust, government needs assistance. The advances in technology, more specifically related to the fourth industrial revolution, could potentially assist in this regard.

In the Industry 4.0 report, Deloitte states that South Africa, like other developing countries, still faces challenges in terms of connectivity and accessibility, which slow down advanced technological adoption [24]. While these phenomena are evident, applications could be developed in such a way as to ease the learning curve, increase accessibility, and make it user-friendly to interact with. The report, furthermore, states that industry leaders and policy makers are increasingly acknowledging that increased effort is required to adopt these technologies. Affordable internet and smartphone penetration are increasing and advanced technological solutions should be developed well in advance to ensure that when internet and mobile usage become common-place, the solutions are in place. Smartphones are key to the adoption since payment gateways, applications, and access to information are increasingly moving to mobile phones for increased accessibility.

The fourth industrial revolution has seen various technological advancements in multiple domains, such as: machine learning, the Internet of Things (IoT), and blockchain. However, not all these advancements have been favourably received, especially not by governments.

1.1 Governments and the use of blockchain

Even though some governments have banned certain blockchain applications, there are other governments that have become increasingly interested in the technology as a means to better regulate, maintain, control, and report on certain public services. For example, the government of Gibraltar is the first government to approve a blockchain exchange to trade cryptocurrencies on. They are also the first to issue licenses for fintech firms to operate using the blockchain and cryptocurrencies as a recognised means of transaction records and an accepted mechanism of payment [1].

Estonia has already implemented multiple blockchain solutions in an integrated electronic solutions environment, with applications ranging from legislation, to managing court procedures, to more effective policing systems [2]. Estonia is recognised as a leader in eGovernment, with their most prominent contribution being the development of a digital signature system, *Keyless Signatures Infrastructure*® (*KSI*), a real-time authentication system for digital assets. This system is used to verify government processes and improves trust and transparency in services to the public.

Dubai is set to become the first blockchain-powered government by 2020 through its blockchain strategy, which was developed in 2016. Dubai plans to harness blockchain technology for everything through a Smart City Platform that integrates everything from license renewals, to visa applications and the payment of bills and eventually to be completely paperless [4].

1.2 Other smart city blockchain implementations

Digital Town aims to provide turn-key solutions that relate to smart governments, civic engagement, digital inclusion, and smart tourism. The platform allows the city and its citizens to connect digitally and to promote local production and consumption. Citizens can be rewarded in fiat currency or cryptocurrency, which they can again spend at local suppliers; this promotes the development of the local economy. The platform, furthermore, connects municipalities, local businesses, e-commerce merchants, residents, developers, and start-ups to create a large ecosystem, all powered by the blockchain [5].

1.3 Blockchain adoption in South Africa

The South African Reserve Bank has recently started to test the blockchain as a means to transfer funds and settle transactions in a quicker and cheaper manner than what is currently available [6]. This is, however, aimed at developing an understanding of the pros and cons of using blockchain for financial transactions so as to develop relevant policies and regulations on the use of cryptocurrencies.

The South African government has also implemented some electronic systems to improve certain processes, with the most prominent being the smart identification card system, which replaced the previous identity books. The major hurdle, however, still remains in the processes that govern some of the systems and the many processes that aren't transparent. It is still too easy to circumvent policies and procedures, since the systems that govern the processes can be tampered with or ignored completely. Various opportunities are still available to use blockchain technology in South Africa to eradicate corruption and fraudulent transactions in the public sector.

The contribution of this paper is twofold. Firstly, it aims to give an overview of governmental processes that are prone to corruption and that face the most protest action. Secondly, it aims to describe the working of blockchain technology in terms of transactions, transfer of ownership, and smart contracts, to set the scene for how these can be used to improve governmental processes in terms of transparency, public participation, and improved efficiency. It indicates that Industrial Engineers are well-suited to play various roles in implementing blockchain solutions in the public sector in South Africa.

2. GOVERNMENT PROCESSES

Section 195(1) of the Constitution of the Republic of South Africa, 1996, governs the activities and services of public institutions and places an ethical duty on all spheres of government to achieve and uphold a fair, transparent and honest administration, which serves the general interests of the public. In terms of section 85 of the 1996 Constitution, all government institutions must provide public services impartially, fairly, equitably and without bias. People's needs must be responded to in an accountable manner because government creates expectations among the public that public services will be provided. Government may not fail to deliver public services because this will disrespect the principles of the Bill of Rights in chapter 2 of the Constitution, 1996 [7].

Unfortunately, today and for a number of years, South Africa experiences and has experienced public service delivery as insufficient and with a high level of corruption. This situation usually leads to protests against poor public service delivery. Government institutions are unable or unwilling to prioritise the welfare of the public. It also appears that all levels of government are relatively unwilling to make use of, or are uninformed about, the availability of alternative public service delivery techniques that can improve the public service delivery process. Furthermore, the government does not appear to have any intention of addressing the reasons and underlying causes for the protests. This is clearly a lack of responsiveness and accountability towards the public and also a matter of moral concern because the ministerial head of departments must ensure that government functions are properly performed. Should this process of service delivery fail, public service delivery together with government's legitimacy suffers [8].

To ensure the proper use of public money, Government established the office of the Auditor-General in terms of the 1996 Constitution, Section 181(1)(e). In an interview with City Press (a South African Sunday newspaper) on 25 May 2018, the Auditor-General, Mr Kimi Makwetu, presented facts exposing irregular expenditure at municipalities. He stated that poor governance and leadership were the main factors that caused municipalities to malfunction. Although the Auditor General has given advice to these institutions, such advice was not being implemented or is ignored as the same bad practices persist. He mentioned that many financial officials were placed in their positions without having the required skills, thereby enabling people inside and outside the municipality to abuse its coffers and create a "free for all" situation. South Africa has 257 municipalities and the Auditor-General exposed an increase of 75% in irregular expenditure (amounting to R28-billion) for the financial year of 2016-2017. He pointed out that the South African fiscus simply cannot afford to lose such finances due to the fact that total government debt is currently R2.3 trillion, which accounts for 50% of the Gross Domestic Product (GDP) [9].

Public institutions are obliged to ensure that all public activities and expenditures are exercised with adherence to supply chain management regulations. There is also a distinction between the way in which authority is structured and the way in which it is applied. The first is dependent on formal organisational structuring whereas the latter is a personal orientation [8]. This indicates that a balance is expected to be maintained between the authority that is granted to the executive institution and the manner in which such authority is exercised.

The Auditor-General mentioned that the worsening financial state of the country's municipalities has become a concern [10]. Of the R350-billion total expenditure budget for 257 municipalities, 3.5% (or R12.2-billion) of the budget was irregular expenditure mainly due to non-compliance with supply chain management regulations. This

meant that support programmes to improve financial management in municipalities had to be introduced. In a situation such as this, irregular expenditure and non-compliance with regulations can also be linked to irresponsible, unaccountable and corrupt activities that need to be curbed and prevented.

Besides the South African municipalities, the South African education system is also in a crisis situation. The number of state owned schools declined by 12% between the years 2000 and 2016. In the same period, the number of private schools increased by 91%, from a number of 971 to 1 855 schools [11]. The problem is that private schools have to generate their own income by means of school fees and these are usually higher than that of state owned schools. There are, however, some private schools that charge fees that are affordable to parents. The additional problem is that parents need to have a choice of the school for their children. The Institute of Race Relations proposes the introduction of a voucher system, whereby parents are given a voucher for each of their children. This is to be taken out of the Government Education Budget and a voucher will be to the value of about R12 000. Parents will then have the choice about which school to send their children to and will be able to use the voucher at private or state schools [12]. This financial procedure is another example that needs careful, responsible and accountable management as well as transparency or it could easily become another mismanaged and corruptive practice.

All public procedures, especially those involving public finances, must be transparent and served by trained, informed and honest public officials. Faced with these challenges, governance in South Africa has to comply with the demands. The time has come for the South African public bureaucracy to transform into a dynamic and flexible organisational entity capable of responding quickly to a changing environment [8]. Such a transformation should include modern and current systems such as blockchain to create surety in processes and to eradicate corruption in governmental processes by improving accountability and transparency, which, in turn, will improve trust from citizens.

3. BLOCKCHAIN AND THE NOTION OF SMART CONTRACTS

This section provides an overview of blockchain technology with specific emphasis on how it enables smart contracts. A more technical and detailed discussion is also provided on smart contracts with an emphasis on key features that can facilitate governmental processes.

3.1 Overview of the workings of the blockchain

The notion of *blockchain* can be divided into two parts: *blocks*, which refer to a specified number of validated transactions; and *chain*, which refers to all the historical blocks of transactions chained together. There is no central authority (such as a bank) that controls blockchain transactions. The blockchain is, rather, an example of distributed ledger technology (DLT) in which storage and computation are shared between the member users (referred to as the nodes) who are connected on a peer-to peer network; the members contribute to and control the network [14]. It can therefore be thought of as a distributed database that records every single transaction that has ever occurred on the blockchain network. Once a block has been created and appended to the blockchain, it is almost impossible to change or reverse these transactions. An illustrative example of how the blockchain works is provided in Figure 1 and its content is discussed in the remainder of this subsection.

A ledger is a term used in accounting that describes a document that reflects all of the completed transactions of a business. As mentioned, blockchain is an example of a distributed ledger and thus implies that all of the transactions on the blockchain are similarly recorded as would be the case in an accounting system. The ledger in the case of blockchain is, however, not maintained by any central authority. Any updates to the ledger are constructed independently and also recorded by each node. Currently, the majority of cryptocurrencies use the concept of *Proof of Work* (PoW) to validate a block of transactions. This requires a complex mathematical problem to be solved, which is known as a *hash function*. A hash function is any function that can be used in order to map data of an arbitrary size to data of a fixed size. A hash function is said to be secure if the output is indistinguishable from random.

Transaction validators (other participants on the network), also referred to as nodes, all then try to solve this complex mathematical problem, since a reward is offered to the node that first validates the transaction. This problem requires a lot of computational resources in the form of electricity and CPU processing time. The difficulty of the calculation that has to be solved is adjusted according to the demand and number of nodes. Once a node has obtained a solution to this mathematical problem, the solution is broadcasted to the network in order for all of the other nodes to validate that the solution is correct. The nodes then vote in order to

determine if the transactions are indeed authentic. This process of voting and agreement between the nodes on a version of a ledger is referred to as *consensus*. An alternative to PoW, is *Proof of Stake* (PoS), which does not require any additional work (as is the case with PoW), but instead investors are rewarded simply based on the number of coins that they hold. The interested reader is referred to Zheng et al. [15] for more information on these concepts.

Blockchain has attracted a lot of attention due to its potential for facilitating transactions among unknown parties, without the need for a trusted third party [16]. This is due to its key characteristics of decentralisation, persistency, anonymity and auditability [15]. This removal of the need for a third party significantly reduces the cost and time associated with completing a transaction and also significantly expands the potential market, as the risk is reduced or eliminated and transparency is increased.

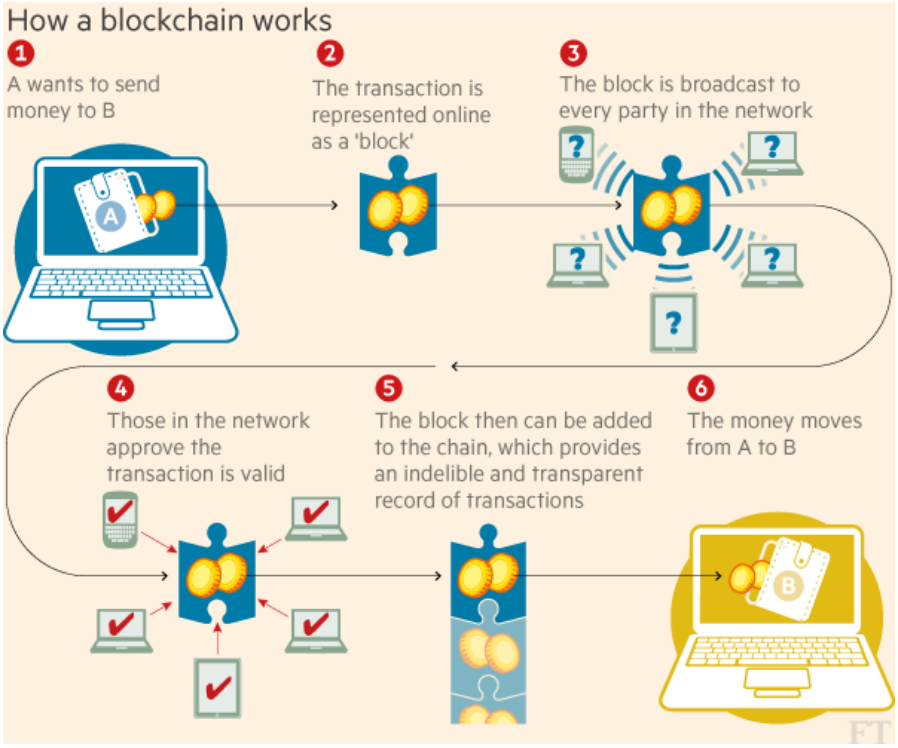

Figure 1: High level workings of the blockchain [23]

A blockchain can be classified as a private or public blockchain. In the case of a public blockchain, any anonymous user is allowed to join the network, read the blockchain's content, participate in a transaction, or be allowed to verify the correctness of each new block. Bitcoin and Ethereum are examples of public blockchains. Private blockchains can only be accessed by users with permission. A company, or a group of companies, usually gives this permission. An example of such a private blockchain is that of *Ripple*.

It is frequently stated that the blockchain is completely immutable and unchangeable, but this is slightly misleading. A more accurate description would be that it is "Mutable-By-Hashing-Power", which means that if (and only if) one entity owns more than 50% of all computing power that contributes to the blockchain, then only can the blockchain be changed by someone. This is, however, a highly unlikely scenario which has not been encountered by any current blockchain network [14].

3.2 Smart Contracts

Smart contracts are an application of blockchain technology that is believed to have the potential to revolutionise the way in which business and administration is done across the globe. A smart contract is defined as an executable piece of code that is run on the blockchain and used to execute and enforce the terms of a

specific agreement [16]. Smart contracts allow for the automatic execution of the terms of an agreement as soon as specified conditions are met.

This technology, therefore, eliminates the need for expensive and time-consuming third party legal systems in order to monitor the progress of a contract and to enforce its terms. It also promises to significantly reduce the cost and risk of conducting business across the globe. This could be specifically advantageous to Small, Medium and Micro-sized Enterprises (SMME's) that do not have the funds to obtain substantial legal support and are therefore often prone to exploitation. Smart contracts can be used for a myriad of applications including the transfer of any physical asset such as a house and even to act as a voting system [17]. It is thus a prime candidate to facilitate a number of public processes in South Africa.

The concept of a *smart contract* has been around since 1994 and was originally proposed by Szabo [18]. As with current smart contracts, he proposed that cryptographic and other security mechanisms could be used to enforce electronic contracts. The concept was, however, not explored to any great extent until the emergence of blockchain technology, which provided the necessary functionality [16].

A smart contract consists of an account balance, private storage of funds as well as executable code. A contract's state consists of the storage and the balance of the specific contract. It is this state that is stored on the blockchain and is updated every time that the contract is called or invoked.

Once the contract has been deployed onto the blockchain, the content or code of the contract cannot be changed or tampered with. Every contract is assigned to a unique 20 bytes address that acts as the account for the contract. The code is executed when a transaction is sent to the contract's unique address. Each node on the blockchain will then run the code in order to reach a consensus on the output. Once consensus is reached, the contract will be in a new state, which will be updated accordingly on the new block created.

Smart contracts can be classified either as deterministic or non-deterministic. A deterministic contract does not require any additional information external to the blockchain in order to execute any terms. A non-deterministic contract requires information from a party external to the blockchain. Necessary mechanisms should, thus, be put in place in order to execute contracts that require external input.

Non-deterministic contracts currently pose a challenge, since the verification of the accuracy of external data can be troublesome [17]. It is, however, believed that with the rise of the 4th industrial revolution and the Internet-of-Things (IoT) coupled with advances in machine learning, that this would become less of a stumbling block in the near future.

3.3 Cryptocurrency

One of the first applications of blockchain technology was the development of cryptocurrency as a peer-to-peer (P2P) payment solution. The first cryptocurrency to be developed after the creation of blockchain technology was Bitcoin and was created by the mysterious Satoshi Nakamoto in 2008. Since then many new cryptocurrencies have been developed, which are known as *altcoins* (alternative coins), which include Ethereum and Ripple. These altcoins still use similar cryptographic technology but have employed different algorithmic designs in order to address some of the perceived concerns and limitations of Bitcoin. At its peak, cryptocurrencies had a market valuation in excess of $800 billion [19].

Cryptocurrency is a subset of digital currency, which is not issued by a central authority and thus is not confined to a specific geographical area and is not tied to any specific fiat currency. An example of a centralised electronic currency is a loyalty token or some sort of reward points that are earned. The use of a decentralised P2P payment system promises to resolve many of the shortcomings of centralised fiat currency systems such as increased capacity, better security, faster settlement and lower transaction costs [19].

Since cryptocurrencies run on P2P networks, transactions take place directly between users without an intermediary party. The transactions are recorded on the ledger after verification as discussed earlier, which prevents double spending and also allows the prevention of any alterations to a transaction. These cryptocurrencies therefore allow for transparent, flexible, decentralised transactions with low transaction fees. This is an ideal payment system for use in the public sector.

3.4 Transfer of ownership and voting

Cryptocurrencies can be used to transfer the ownership of assets including financial assets or even to cast a vote. As indicated earlier, blockchain technologies have several advantages over a centralised system. The advantages over a traditional system will be explained with the use of a few simple examples.

The first example is that of the differences between the traditional trading securities market and the securities market as created by smart contracts. The former is very complex and requires a plethora of intermediary processes, brokers, and institutions. The typical process is illustrated in Figure 2.

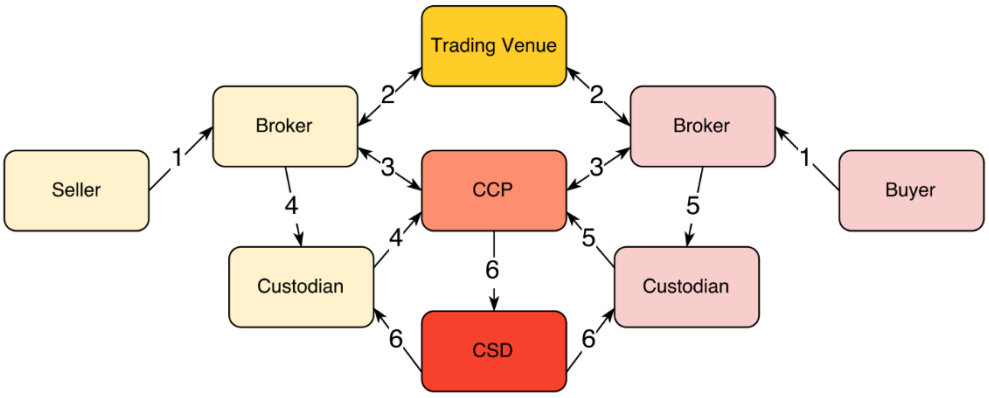

Figure 2: Illustration of the financial entities involved in a typical securities trade [20]

As illustrated in Figure 2, the buyer and seller first have to contact their own stockbrokers. The two stockbrokers will charge a commission and then subsequently introduce the buyer and seller to the second middle man, which is called the Central Counterparty Clearing House (CCP). The CCP's job is to ensure that none of the contracting parties default on their obligation. The CCP will charge its own commission in order to proceed to taking the asset from the seller's broker through the seller's custodian and also then receive money from the buyer's broker through the buyer's custodian. The CCP will then instruct the Central Security Depository (CSD) to credit the buyer's custodian with the transferred assets and the money in the case of the seller's custodian in order to conclude the transaction [17]. This is a very complex, time consuming and expensive process, which is needed in order to minimise risk between the two parties.

In the case of a smart contract, no intermediaries are required at all. Instead, the smart contract code is executed on the blockchain and the transactions and transfer of ownership are recorded on the ledger. It is, therefore, evident that this would lead to a substantial reduction in processing time as well as much lower transaction fees, which increases market size and access.

Smart contracts are also ideally suited to develop voting systems on the blockchain as a transaction can simply be sent to the smart contract to cast a vote. Various smart contract code options are available but the generic process will subsequently be discussed.

The election administrator owns the smart contract that will facilitate the voting process. The election administrator is responsible for enlisting the candidates or possible resolutions, authenticating all the voters by using their user-controlled account and subsequently updating the list of eligible voters. Certain timers are specified in the smart contract to ensure that the process occurs in a timely manner and has a definite stop time after which votes should be tallied. Only eligible voters are allowed to register and subsequently cast their vote. The administrator will then change the state from registration to voting. At this point the registered voters will be allowed to cast their single vote. This vote can either occur with the transfer or a specified amount of cryptocurrency or by publishing a unique key assigned to each voter during registration [21].

Due to the fact that each registered voter's identity is stored on the blockchain via the smart contract, no duplication of votes can occur. The system can be made even safer by having an end-to-end system where the results are sent to the voter, who can then validate that their vote has been correctly recorded.

4. BLUEPRINTS OF USING BLOCKCHAIN IN THE PUBLIC SECTOR

Smart contracts have the potential to substantially reduce corruption and irregular spending in South Africa's public sector whilst simultaneously improving service delivery. The auditability of the blockchain also implies that the public sector can easily be audited, which would bring about significantly more accountability in South Africa. Blockchain technology has already been successfully used by the South African Reserve Bank during June 2018 in order to deal with real-time gross settlements. The project was a huge success and the typical transactional volume experienced in South Africa was processed in less than two hours [6]. This will set the scene for blockchain regulation and the use of blockchain for other applications in the public sector.

The rest of this section provides a few ideas as to how blockchain can be used in the public sector. It is, by no means, considered the golden bullet to completely eradicate corruption nor solve all problems, but it will provide a means to improve the control of public sector processes, enhance transparency, and reduce the opportunity for corruption. At the very least, if it does not reduce corruption, it will enhance accountability through the fact that everything that gets captured on the blockchain, is forever stored and malicious processes will be flagged and denied.

4.1 National elections and voting in public hearings

Blockchain technology also provides superior performance in the case of voting. In traditional voting systems, there is a need for an independent third party that will facilitate the entire process, for example the Independent Electoral Commission (IEC). This third party is responsible to verify the identity of voters, tally the votes, and audit the results, which can be a tremendously tedious exercise. This third party must then also create all of the material necessary to record votes, ensure no double voting occurs, no unrecorded votes enter the system and no votes are removed or tampered with. They are also responsible for counting the votes and making the results known. It is evident that this system is very complex and introduces numerous possible points of failure and is very susceptible to corruption and tampering.

In the case of a blockchain-based voting system, various options are available to facilitate a more efficient process. Firstly, the Know Your Customer (KYC) capabilities can be used to verify identities of individuals by utilising a service such as *Civic*, a blockchain identity verification technology, conceived and co-founded by South Africa's Vinny Lingham [22]. A cryptocurrency transaction between the voter and the voting system can be used to cast a vote. Due to the various key properties of the blockchain, this vote would be free of any possibility of duplication, tampering or elimination as the transaction is recorded on the distributed ledger. The transaction is also easily auditable and the network has built-in capabilities to automatically tally the votes as they are cast.

In the case of public hearings, it is often the case that few to no people at all pitch up, since the hearings aren't advertised properly. The public is often disillusioned due to the fact that they did speak up and voice their opinions, but that these weren't adequately captured and reported and that the public sector just implemented projects according to their own political agendas. By using the blockchain in public hearings, would again improve the process tremendously as follows. Firstly, the event itself can be put on the blockchain to ensure that there is a record that it took place. KYC can again be used to verify the identity of those present. The smart contract can be set up in such a way as to require a minimum number of public participants at the event or the event has to be rescheduled, which would prompt the public sector to make a bigger effort to involve the public. Once the proposed projects have been presented, the participants can give inputs that are recorded on the blockchain, whereafter participants can cast their votes. The votes are automatically tallied and the outcome determined by the smart contract. It would be possible to still allow a central authority, such as National Treasury, to set up the smart contract, but even in this case it would be beneficial to involve the public to set the rules of the hearings and in doing so enhance the trust and participation of the public.

The potential process for such voting is presented using the Business Process Modelling Notation in Figure 3. The two swimlanes with grey blocks and a star (*) next to the role player are functions that could be executed purely on the blockchain with minimal external input.

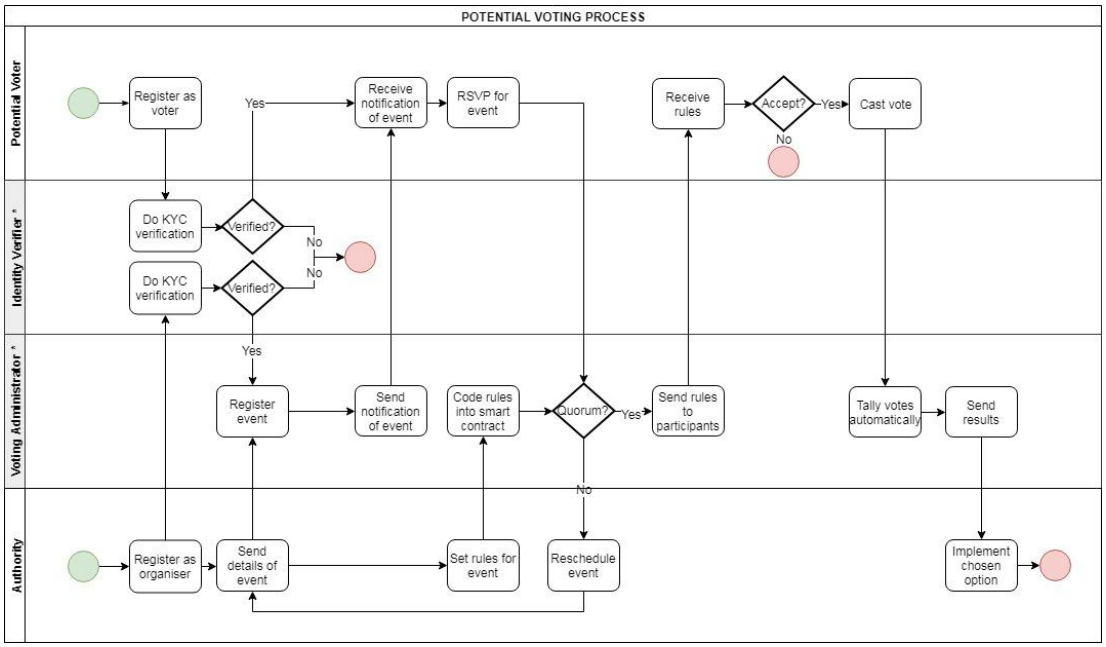

Figure 3: Potential voting process with blockchain as the backbone

4.2 Subsidies, housing provision, bonds

The backlog of housing provision is causing a lot of uprise. Furthermore, government is struggling to keep track of who has applied for subsidised housing, how long they have been waiting, and when transfer of ownership took place. This also makes it extremely difficult to report on progress made in line with what was planned in the major infrastructure projects, such as the National Development Plan [25] and the 9 Point Plan [26].

By introducing a blockchain application, each applicant can be registered on the system using KYC technology again. If this application is integrated with the national identification system and South African Revenue Service, up to date information on household income levels can also be automatically obtained to determine whether the household qualifies for subsidised housing; the smart contract will take care of all of these checks. Finally, when a house or a subsidy is awarded to a citizen, this is recorded on the blockchain and this will eliminate duplicate awards or corrupt transfer of funds.

Blockchain could also play a valuable role in the “willing buyer, willing seller” housing market. During the 4th quarter of 2017, the average value of a residential home bond in South Africa was valued at R1.11 million for 36 943 bonds [28]. Assuming these values remained constant during 2017, approximately R165 billion worth of bonds were approved during 2017. The typical costs associated with obtaining a bond of R1.11 million at one of South Africa’s largest banks is provided in Figure 4, using an online calculator [29]. The table contains a comparison between the costs associated with a theoretical bond with and without using blockchain.

Using blockchain technology, all (or most) of the administrative functions can be automated and therefore the administrative costs reduced. By saving the initial admin fees and saving service fees, it is expected that the total cost can be reduced by approximately 5.4% if all other factors remain constant. This calculation does not even consider the costs associated with respect to time and inconvenience for the applicant.

Extrapolating these savings to the approximate R165 billion worth of bonds approved in 2017, the savings for residential bonds could amount to R21.2 billion rand over a period of 20 years or R1.06 billion per annum. These savings would result in higher disposable income for households and could stimulate the economy. This just highlights the possible impact of blockchain technology on one small case study, not to mention the potential savings from other forms of asset sales including automobiles and commercial property. Savings of this magnitude would have a substantial impact on the South African economy.

Bond Cost Comparison with and Without Blockchain		
	Bond with all costs	**Bond without admin costs**
Value of the bond required	R 1 110 000	R 1 110 000
Deposit	N/A	R 53 697
Value of bond taken	R 1 110 000	R 1 056 303
Interest rate	10%	
Bond period	240 months	
Once off fees		
Transfer costs	R 23 830	N/A
Bond costs	R 23 830	N/A
Initiation fee	R 6 037	N/A
Transfer duty	R 6 000	R 4 390
Total including transfer duty	R 59 697	R 4 390
Total excluding tranfer duty	R 53 697	R 4 390
Monthly payment		
Repayments	R 10 615.24	R 10 097.05
Service fees	R 69	N/A
Total	R 10 684.24	R 10 097.05
Bond comparison		
Total payments	R 2 623 914.60	R 2 481 379.00
Total savings		R 142 535.60
% savings		5.4%

Figure 4: Bond cost comparison with and without blockchain

4.3 Local economies and loyalty programmes

As mentioned in Section 1, the Institute of Race Relations proposes the introduction of a voucher system for education purposes, whereby parents are given a voucher for each of their children. By using smart contracts for these purposes, predefined rules can be put in place that will ensure that parents do not receive more than they should, cannot override the system or use the money for anything other than education purposes.

In the greater *smart city* realm, families or households can be rewarded with cryptocurrency for services that they render for the greater public good, such as recycling. This currency can then also be used to reduce school fees, for public transport or even for entrance to certain sites. It essentially acts as a subsidy, but with complete control as to where it can be spent and transparency on how and when it was spent. Reporting will also be greatly enhanced as all transactions are captured on the blockchain network and standardised reports can be developed on top of the network. This can facilitate improved monitoring and evaluation by municipalities on how funds are used and this information can better be used to report to National Treasury. An example of such planning and reporting by municipalities (with the role of Industrial Engineers) is that of the Built Environment Performance Plan (BEPP) and the subsequent implementation, monitoring and evaluation of infrastructure projects, as described in Van Heerden and Van Heerden [27].

All of this can be included in a drive to support local producers and shop-owners, essentially stimulating local economies. This could be highly beneficial for township economies, but also for cities that try to, in general, enhance the local economy and economic competitiveness. The Digital Town, as described earlier in this paper, could facilitate this drive to include public-private-partnerships, public sector initiatives, and the public themselves.

5. CONCLUSION

South Africa's public sector is often criticised for its inefficiencies and the number of public service delivery protests echo these issues. This paper touched on some of the most prominent contributors to these issues with special emphasis on processes that are prone to corruption and easy to circumvent.

Technological advances including the Internet of Things, machine learning, and blockchain enable many smart applications to be developed to potentially assist government to better deliver services. The problem, however, is that many of these applications are too complex to implement and require deep understanding of both the public sector processes and the technological solutions to be implemented so as to effectively design these solutions. This paper introduced blockchain as a possible solution to many of the problems faced by the public sector.

It is easy to get lost in the complexities of technology and we need to collectively steer the fourth industrial revolution to improve trust in government as well as assist government to improve service delivery. Industrial Engineers are well-suited to play various roles in implementing blockchain solutions in the public sector in South Africa. Firstly, through proper business process mapping and re-engineering. An example of a possible process was provided in this paper. Furthermore, since a lot of data and information will need to be captured, analysed, and maintained, requires proper user requirements analysis, database design, and analytics skills. Industrial Engineers can also play an interfacing role between various entities in the whole process, ranging from public sector officials, to technical implementation teams, to real estate developers, to project and programme management, to name a few.

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