Blockchain-based Smart Contracts in Waste Management: A Silver Bullet?

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Blockchain-based Smart Contracts in Waste Management: A Silver Bullet?

GUIDO ONGENA, KOEN SMIT, JARNO BOKSEBELD, GERBEN ADAMS, YORIN ROELOFS & PASCAL RAVESTEIJN

Abstract Blockchain technology may have the potential to fundamentally change society and we might currently witness the dawn of a cryptographically secured trust-free transactions economy. One relatively unexplored application domain is waste management. Incorrect waste management practices may lead to illegal pollution or enable fraudulent transactions. Using a design science approach, we formulate problem areas and evaluate the applicableness of using a blockchain solution to mitigate the problems identified. Our results indicate that it is important that the organization and its infrastructure is prepared for the use of blockchain. There are several conditional challenges that must be overcome to realize blockchain technology’s full potential. Further research is needed in order to grasp a full understanding about the situations in which blockchain technology is beneficial or not.

Keywords: • Blockchain • Smart contracts • Waste management •

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1 Introduction

The design of bitcoin was first described in a self-published paper by Nakamoto in 2008 (Nakamoto, 2008), after which an open-source project was registered on SourceForge. Propelled by its capricious quotation, the bitcoin received tremendous media attention recently. It is difficult, if not impossible, to open a popular publication today, and not run into a reference to bitcoin, cryptocurrency or some combination thereof. The bitcoin was the first attempt to solve the double-spending problem in the context of digital currency by means of blockchain technology.

Blockchain technology, often referred to as distributed ledgers, is the underlying technology that stores the same information at different nodes and the information will only be added when the nodes have reached consensus. New transactions can be added, but previous information cannot be removed enabling all nodes to track the history. This reduces the dependency on a central actor and the risk of manipulation or system failure as all nodes have all the information available (Ølnes, Ubacht, & Janssen, 2017). Beyond cryptocurrencies like bitcoin, blockchain technologies may have the potential to fundamentally change society and we might witness right now the dawn of cryptographically secured trust-free transactions economy (Beck, Czepluch, Lollike, & Malone, 2016). It is this potential disruptiveness that the venture capitalist Marc Andreessen (2014) even coined as the most important invention since the advent of the Internet.

The potential beneficiaries triggered many organizations to experiment with this technology. In 2016 alone, 26,000 new projects were started with this technology as a basis (Trujillo, Fromhart, & Srinivas, 2017). Recent literature, for example, describes implementations for the insurance market (Hans, Zuber, Rizk, & Steinmetz, 2017), crowdlending platform (Schweizer, Schlatt, Urbach, & Fridgen, 2017), and digital crime prevention (Smith & Dhillon, 2017). These instantiations are primarily situated in the private domain. It is however stipulated that blockchain technology is also a tool to increase efficiency and economic growth (Chapron, 2017). There is thus a need to address and learn from governmental initiatives to seek the blockchain’s potential in this context (Ølnes, 2016). The aim of this study is to contribute to a discussion about blockchain in a governmental setting by exploring the potential use of blockchain and to provide a nuanced view of its use in the field of waste management in a Dutch municipality. This also fills the gap of the need to inquire the use of blockchain in the domain of waste management as Saberi, Kouhizadeh, & Sarkis (2018) stipulate. Or to paraphrase the authors: “move beyond the hype to make this technology a productive tool for society”.

Waste has always been generated due to human activities. Waste hasn’t been a major issue as the human population was relatively small and nomadic. It, however, became a serious problem with urbanisation and the growth of large conurbations. Poor management of waste led to contamination of water, soil and atmosphere and to a major impact on public health (Giusti, 2009). Concerns about lack of controls, inadequate legislation, negative impact on the environment and human health were triggered due to
several serious and highly publicised pollution incidents, for example, see the work of Triassi, et al. (2015). These incorrect waste management practices forced many national and federal governments to introduce new regulatory frameworks to deal with hazardous and unsustainable waste management operations. According to the United Nations, waste management entail activities including (a) collection, transport, treatment and disposal of waste, (b) control, monitoring and regulation of the production, collection, transport, treatment and disposal of waste and (c) prevention of waste production through in-process modifications, reuse and recycling (United Nations, 1997). The latter will not be taken into account in this study. In this study, we evaluate the applicability of blockchain technology in the domain of waste management in the area of Utrecht, the Netherlands. To do so, we address the following research question: How can blockchain technology be utilized by municipal bodies to process transactional waste management data?

2 Blockchain: distributed ledgers

Blockchain is an ongoing growing list of registrations of transactions that are divided into blocks. Every block refers back to the last block which shapes a chain, hence the name blockchain. Iansiti & Lakhani, (2017) describes it as: “an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way”. The main idea is that the information that is contained in a block is verifiable and permanent as it’s impossible to change or mutate.

Blockchain offers new possibilities for controlling and sending information in, for example, a supply chain. However, when trust and robustness are no issues for an information system then blockchain is not always favorable to a traditional database (Greenspan, 2016). There are several differences between the traditional way and new methods developed on blockchain technology. Table 1 summarizes the advantages and disadvantages of blockchain technology versus traditional database systems.
Table 1: Blockchain vs. traditional database system

<table>
<thead>
<tr>
<th>Advantages of the blockchain technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Blockchain can prove the authority and validity of its own transaction instead of using a central administrator that has to validate and take responsibility. Transactions through a Blockchain can, therefore, be fully automated independently and verifiably executed (Swan, 2015).</td>
</tr>
<tr>
<td>• Blockchain, just like any other (database) system, has to be run on physical hardware. However, unlike other systems, there isn’t any owner since it’s physically impossible for a Blockchain to run on 1 node. In this case, there isn’t any single entity that has the power to change or mutate any information that’s stored in the Blockchain. This means that a blockchain is less sensitive to corruption or fraud. By effect, this means that the parties involved in the Blockchain can all trust the information stored in such a way.</td>
</tr>
<tr>
<td>• Information stored in a Blockchain is transparent for all parties involved. There’s always a way to check the history of all the transactions in a Blockchain. This also means that audits for a Blockchain system are easier and always reliable (Underwood, 2016; Atzori, 2015; Swan, 2015).</td>
</tr>
<tr>
<td>• The data isn’t stored in a single location. So there is not one person responsible for the security surrounding the data. That means that there isn’t any need for a security specialist that has to take responsibility for the database and govern and proof the integrity of the data (Ølnes, 2016; Underwood, 2016; Gervais, et al., 2016).</td>
</tr>
<tr>
<td>• Because of the inherent technology of Blockchain, there is a very low risk of system failures. Blockchain has a much higher robustness compared to tradition database system because it’s run on multiple systems in multiple locations. If one node fails or breaks down the other nodes will take over instantly. There is no extra configuration or actions required because each node has a copy of the whole Blockchain. This also means there is no expensive backup system required. (Ølnes, Ubacht, &amp; Janssen, 2017)</td>
</tr>
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Disadvantages of the blockchain technology

- Blockchain is always slower than a traditional database system. In theory, it’s also always more expensive because it costs more energy, hardware and infrastructure capacity (Eyal, Gencer, Sirer, & van Renesse, 2016).
- For every new request regarding a new peer-to-peer connection, there also has to be proof of the validity and integrity of the source. This is done by a digital signature. This means that for every new connection it’ll take more time and computing power compared to the traditional database systems where you can send information instantly (Gaetani, et al., 2015).
- Blockchain technology intends to work on the basis of a consensus between parties. A transaction will only be authorized if at least 50% of the nodes validate the transaction. This process takes time because each working node needs to communicate to other nodes to check for a verdict. This will take considerably more time depending on the size of the Blockchain and the quality of the infrastructure.
- Blockchain's main strength is based on how many different nodes and unique parties are involved. The more different nodes the stronger the blockchain is. A traditional database system doesn’t require such a scale (Gaetani, et al., 2015).
- Blockchain has to validate and authorize each transaction but for each transaction, there are heavy calculations involved because it is encrypting all the information, with a traditional database system it’s possible to skip this and therefore gain much more speed with less hardware and computing power involved.
- It’s very difficult to expand the capacity of an existing blockchain (Ølnes, 2016). This means that a blockchain system is less flexible. This has proved to be a problem with the enormous growth of Bitcoin where the sheer number of users are causing many problems (Filippi & Loveluck, 2016).

3 Problem Identification and Motivation

Our study can be best characterized as design science research (Hevner, March, Park, & Ram, 2004) as a potential new artefact, represented by a blockchain solution, is the focal point of the study. It, however, must be noted that there is no actual demonstrator build during this research as this is research in progress. In line with common design science approaches, our research starts with the identification and description of a practical relevant problem (Peffers, Tuunanen, Rotherberger, & Chatterjee, 2007). To acquire deeper knowledge about the process of waste management, interviews were held with both the local authorities as well as the waste station.

Four key stakeholders are identified. The disposer, a mediator (usually the municipality – in this case, Utrecht), logistics and the processor (waste station). Naturally, the process is triggered by a request from the disposer that notifies the municipality through a so-called guidance letter. This letter is used by the driver to check its weight. Then the waste is weighed at the waste station after which the waste is deposited. Thereafter, a weighing note is sent, together with an invoice, to the mediator. This simplified process is illustrated in Figure 1 by BPMN (OMG, 2011).
Figure 1: The process of waste management

Sharing of information in this process is digitally supported by an ERP-system. Data is manually entered into the system. This results, for instance, in the guidance letter. The process is governed by several stakeholders. NIWO is also a key stakeholder. The NIWO is the licence provider for road transport in the Netherlands. A national governmental body (ILT) that monitors the licenses of waste processors. Authorities on provincial level who provides licenses to waste processors. Hence, several (non-)governmental bodies are installed to monitor the process of waste management.

Based on the interviews, five main problem areas were identified. Table 2 provides an overview of these deficits and provides a short description of how this can be exemplified in the process of waste management.
Table 2: Deficits in the current process

<table>
<thead>
<tr>
<th>Problem area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraud and manipulation</td>
<td>Payments per kilograms are made when getting rid of waste. However, the local authorities cannot check the number of kilograms as they don’t possess a weighbridge. In the past, some flows of waste that generate a lot of money were fraudulent. This was done by sharing incorrect information that couldn’t be checked by means of a weighbridge.</td>
</tr>
<tr>
<td>Wrong or loss of information</td>
<td>Guidance letters and are physical papers that pass by all the activities of the current process. In the process, these papers sometimes get lost. It so happens that the papers literally fly out of the window during transport or the wrong letters are given on departure.</td>
</tr>
<tr>
<td>Manual processes</td>
<td>When implementing the ERP system, it was intended that data such as the weighing tickets would be automated. This wasn’t done. As a result, the employees of the municipality must enter the data manually in the ERP system.</td>
</tr>
<tr>
<td>Lack of knowledge about technology</td>
<td>Knowledge about, and the ability to work with, technology is rather limited. As a result, the ERP system does not come to fruition.</td>
</tr>
<tr>
<td>Lack of control</td>
<td>Periodic governmental inspection at the waste division station takes a lot of time. Since the resources are limited, data is not fully monitored</td>
</tr>
</tbody>
</table>

4 Field of Application: A Current Use Case

To strengthen our possible design, we draw on prior experiences. The Human Environment and Transport Inspectorate (ILT) initiated a pilot a few years ago. The aim of this pilot was to develop an improved process for the cross-border transport of waste by means of blockchain technology (Donata, 2016). The reason for choosing blockchain technology is that at the moment several parties have separate closed accounts and there is not a plausible party that could (or would like to) arrange the administration process of all parties involved. In other words, there is no trusted third party within the process. As is shown in Table 2 this can cause problems in areas such as 'lack of control' and 'fraud and manipulation'.

The working prototype of ILT has proven that blockchain works as the technology can perform the tasks it has been given. It is, therefore, possible to implement a blockchain in
a supply chain such as waste processing. However, the pilot shows that it is difficult to get everyone involved with the project. Some parties were very enthusiastic and proactive, while others were totally uninterested. This is partly due to a lack of knowledge about blockchain, or more generally a low IT maturity of the organisation influenced this attitude as well. This ‘lack of knowledge about technology’ has also been identified in Table 2 above. The branch of waste depositing is rather conventional and thus offline communication still characterizes the process of sharing of information between parties. This corresponds with two other possible problem areas that we have identified: ‘manual processes’ and ‘wrong or loss of information’.

Hitherto, the pilot is still running. The project leader indicated that it hopes to achieve the following benefits with the blockchain solution:
- The ILT establishes a key position as they control accessibility to information;
- They can then better map the waste flows and take action if needed;
- Faster handling and fewer administrative burdens so that bank warranties can be released earlier.

5 Discussion, and Implications for Theory and Practice

The working prototype of ILT has proven that blockchain works as a technology. It is, therefore, possible to implement blockchain technology in a supply chain such as waste processing. However, this study not only aimed to strive for the confirmation that a blockchain solution is applicable; it strives for an evaluation whether a blockchain solution is beneficial compared to the current situation, as proposed by Gregor and Hevner (2013). Thus, reflecting on the problem areas in the process of waste management (as depicted in figure 1) and the characteristics of the blockchain technology and whether the latter is beneficial to the deficit. The results and corresponding explanations are illustrated in Table 3.
Table 3: Can blockchain overcome deficits?

<table>
<thead>
<tr>
<th>Problem area</th>
<th>Blockchain solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraud and manipulation</td>
<td>With blockchain technology, it is important that the data entered are correct, since it is not possible to change it afterwards (Xiaoqi, Jiang, Chen, Luo, &amp; Wen, in press). The waste separation station does not have the correct (automated) solutions to ensure that these source data are correct. They are too dependent on another party, which is not confidential enough to use as source data. Blockchain technology is not going to solve this problem and, in fact, a solution has to be found before blockchain can be implemented.</td>
</tr>
<tr>
<td>Wrong or loss of information</td>
<td>Once something is entered in a blockchain, it is immediately safe. Since the guidance letters and weighing vouchers are digitally entered with a blockchain solution, they cannot be physically lost. A blockchain implementation is the right solution to overcome this problem.</td>
</tr>
<tr>
<td>Manual processes</td>
<td>Blockchain technology itself does not directly offer the solution for automating data processing. However, it offers multiple options with the help of other IT solutions.</td>
</tr>
<tr>
<td>Lack of knowledge about technology</td>
<td>Blockchain technology is not going to introduce a change in the current maturity of knowledge and expertise in IT.</td>
</tr>
<tr>
<td>Lack of control</td>
<td>If organizations save the data using Blockchain and organizations ensure that this is done in the right way, it is possible to use the Blockchain technology as a &quot;trust factor&quot;. The data contained in it cannot be changed and if it is entered correctly you can guarantee that the information is reliable (Crosby, Pattanayak, Verma, &amp; Kalyanaraman, 2016). This offers a solution for inspection services such as ILT, because everything is digital.</td>
</tr>
</tbody>
</table>

Overseeing the problem areas, one should take into account that almost all of these problems are not solved by blockchain technology. For instance, Control mechanisms must be installed to ensure correct data. Or sufficient infrastructure must be in place to implement a blockchain solution between different parties. In this, the municipality can have a key role as they can impose the use upon stakeholders. In other words, they can guide the development, execution, maintenance and adaptation of blockchain architectures and applications (Ølnes, Ubacht, & Janssen, 2017).

There are several limitations that have to be pointed out. First, since blockchain is a relatively new technology, there is still a general lack of knowledge on its benefits and limitations. Therefore, the amount of people with deeper insights into the blockchain phenomenon is limited and restricted to a small group of innovators. Second, the study didn’t fully complete the cycle of design science research. Building a demonstrator and evaluate this with the stakeholder would leverage our knowledge (and theirs) about the potential benefits or limitations of blockchain technology in this context. Thirdly, the
logical component of waste management is not fully considered in this research. In the Netherlands, there are only a few parties concerned with waste transport and these are often innovative. In this branch, they can, therefore, act as an accelerator for blockchain technology.

Despite these limitations, this research contributes a valuable discussion about the use of blockchain technology as its applications are still in its infancy. Further research is needed in order to grasp a full understanding about situations in which blockchain technology is beneficial or not. A multiple case study of current blockchain initiatives would support this understanding.

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References


