UNIVERSITY OF TARTU
Institute of Computer Science
Innovation and Technology Management Curriculum

Lilit Stepanyan

Business Process Redesign Heuristics in The Context of Blockchain-Based Solutions

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Supervisor(s): Fredrik P. Milani

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Abstract: The blockchain technology was introduced with a promise to deliver ground-breaking changes to the world. Thus, the businesses are looking for opportunities to implement the technology and exploit suggested benefits. Nevertheless, mere substitution of existing technologies with a more innovative one does not guarantee a radical improvement. To achieve the desired outcome, existing business processes need to be redesigned with the consideration of the new technology specifics. This paper contributes to the "how-to" aspect of redesigning business processes to implement blockchain technology. Best practices of business process redesign are analysed in the context of blockchain technology and adapted into redesign heuristics. The applicability of the proposed heuristics is evaluated with a case study. The proposed heuristics are considered to be applicable as guidelines by the practitioners when redesigning processes for blockchain. The paper describes 4 essential focus areas for the redesign: (i) using the blockchain for shared data storage among different counterparts and hence change the scope of the process from within organization to larger scale inter-organizational processes; (ii) exploiting the potential of smart contracts for data storage, task completion and linking sub-processes; (iii) transferring data via blockchain; and (iv) exploiting tokens for asset management. The paper is concluded with the review of potential limitations to the adapted approach, along with potential opportunities for further research.

Keywords: business process management, blockchain, business process redesign

CERCS: P170 Computer science, numerical analysis, systems, control

Plokiahelal põhinevate lahenduste äriprotsesside ümberkujundamise heuristika

Lühikokkuvõte: Plokiahela tehnoloogia avastamine ja juurutamine on toonud maailmale murrangulise tähtsusega muutusi. Sellega seoses otsib ärikeskkond võimalusi antud tehnoloogia rakendamiseks ja lubatud eeliste ärakasutamiseks. Siiski, olemasoleva tehnoloogia asendamine uuema vastu ainuüksi ei paku radikaalseid parendusi. Soovitud tulemuse saavutamiseks tuleb ka olemasolevaid äriprotsesse täiustada ja ümber disainida. sealjuures arvestades plokiahela eripäradega. Käesolev töö keskendub äriprotsesside ümberkujundamise “kuidas” faasiile äriprotsesside ümberkujundamises, selleks et ettevõtetel oleks võimalik rakendada plokiahela tehnoloogiat. Äriprotsesside ümberkujundamise parimaid näiteid analüüsitakse plokiahela tehnoloogia kontekstis ja kohandatakse ümberkujundamise heuristikaga. Kavandatava heuristika rakendamise võimalusi hinnatakse vastavas juhtimisuuringus. Väljatöödeldud heuristika rakendusvõimalusi on hiljem võimalik kasutada juhendina plokiahela äriprotsesside praktilisel ümbertöötlemisel. Käesolev töö keskendub neljale ümberkujundamise alale: (i) plokiahela kasutamine jagatud andmete säilitamise eesmärgil erinevate osapoolte vahel ja sellest tulenevalt ettevõtte siseprotsesside laienemine ettevõtete vahelisteks protsessideks; (ii) nutilepingute rakendamine andmete säilitamiseks, toimingute lõpetamiseks ja alamprotsesside sidumiseks; (iii) andmete edastamine plokiahela kaudu; ja (iv) tokenite kasutamine varahalduses. Töö järeldus koosneb kohandatud lähenemisviisi võimalike piirangute ülevaatamisele ning pakub välja potentsiaalseid võimalusi edasiseks uurimiseks.

Võtmesõnad: äriprotsesside juhtimine, plokiahel, äriprotsesside ümberkujundamine

CERCS: P170 Arvutiteadus, arvutusmeetodid, süsteemid, juhtimine (automaatjuhtimisteooria)

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1 Introduction

Over half of the executive managers, with the knowledge of blockchain technology, admit that the failure to adopt it will put their companies at a competitive disadvantage in the future [1]. Some think of blockchain as *"the new internet"* [2], others present it to be a disruptive technology [3] that is expected to alter and even revolutionize the ways organizations conduct their businesses and run their business processes.

In 2008 blockchain was introduced as the underlying technology for Bitcoin [4] enabling digital currency transactions in an untrusting environment, without central authorities. Essentially, blockchain is a decentralized ledger shared across a peer-to-peer network. The ledger holds chronologically chained encrypted blocks. These store verifiable data synchronized throughout the entire network. In a broader manner, blockchain is a new paradigm of data architecture [5] that **encompasses the ability to solve the problem of authenticity in a digital network**, enables independent verification of data irrespective of the source within the network, and rules out the necessity of trusting other counterparts [4]. Also, blockchain can be equipped with smart contracts. These are self-executing scripts running on blockchain and completing different predefined tasks. Smart contracts hold the potential to facilitate decision management, model design, and process execution [6].

Two generations of blockchain technology distinguish two main directions of blockchain implementation; the first one aiming at the elimination of intermediaries and facilitating transactions between untrusting parties (e.g. cryptocurrencies) and the second to enable collaborative processes which currently do not exist or are complex and demanding because of the lack of trust between participants and the absence of reliable traceback mechanisms [6]. To meet specific needs for each of these directions various configurations and adaptions of blockchain are offered, e.g., public or private blockchains, storing data on or off the chain, usage of smart contracts, etc. In the context of this thesis, the second direction of blockchain implementation is considered since with the usage of smart contracts blockchain encompasses the potential to support inter-organizational processes [7].

By taking out the factor of trust from the equation, blockchain creates a multitude of opportunities for inter-organizational collaboration. Proper implementation of the technology can facilitate business processes between different organizations making them more efficient and less prone to mistakes. For example, in the health insurance industry, the insurance company and the medical institutions can use blockchain for secure storage and transfer of personal data about the insured, their claims, and relevant medical documents, while smart contracts can make decisions about claims or execute the payments if all the predefined criteria are met.

Mere substitution of technology in existing business processes does not guarantee a substantial improvement in a company's performance [8]. Added value is achieved when technology-based strategies are traded for business-based ones [9]. It is credible to argue that the same principles apply to blockchain-based solutions. Thus, it is valuable to explore the best practices of business processes redesign in the light of enabling capabilities of blockchain technology. In the scope of this thesis, best practices identified, systemized, and assessed by Reijers and Mansar [10] are studied. Particularly, the focus of our study is to establish how these best practices can be applied to facilitate the redesign of business processes to achieve maximal results from the implementation of blockchain technology. In the light of this context, the following research question is tackled: ***"How can best practices of business process redesign be applied to inter-organizational processes in the context of implementing blockchain and smart contract technology?"***

The contribution of this thesis is to examine, analyse and contextualize the best practices of business process redesign for applying blockchain technology to business processes. This requires an appropriate understanding of both best practices as well as knowledge of blockchain and how it can enable inter-organizational processes. Contextualized guidelines can be particularly helpful for business analysts, project managers, and other innovators who are working on introducing blockchain-based solutions. These guidelines can facilitate the creation of new business processes and potentially contribute to the better quality of new processes (achieve more efficient business processes than with simple replacement of existing technology by blockchain technology). We introduce a case around the audit of timber-to-charcoal process. This is a real-life case that exhibits an inter-organizational process between several collaborators including private companies, a governmental agency, and a non-profit organization. We study the existing process and how it can be redesigned using contextualized best practices. All the models are created with the purpose of enhancing communication and providing visual and conceptual context when discussing the guidelines. With that said, additional analysis is required to prepare the models for actual execution.

The rest of this thesis is structured as follows: Chapter 2 provides a background on the components and features of blockchain technology, introduces their enabling characteristics for business processes, as well as discusses the best practices of business process redesign. The chapter is concluded by the discussion about the related work. Chapter 3 introduces the business process redesign heuristics contextualized around the usage of blockchain technology. The following chapter (Chapter 4) shares the insights into the case study, its setting and design. The results are discussed in Chapter 5, which also tackles the issue of validity. Chapter 6 presents the conclusions discusses possible areas of future work.

2 Background and Related Work

2.1 Blockchain as an Enabler

Blockchain is a digital ledger shared across a network, usually the Internet, where data are distributed amongst the nodes of the network and each node replicates the ledger. New transactions are transmitted to other nodes, and if all transactions are accepted as valid, after some intensive computations, they form a block [11]. Each new block consists of a block header and body. The header includes information about the version of the block, the hash value of transactions in the block, a timestamp, target threshold of a valid block hash, a nonce, and a parent block hash, which connects the block to the previous one, therefor forming a chain of blocks [12]. Because of the heavy computational work required for appending a new block to the chain, the transactions are practically immutable. The longer the chain the more secure and irreversible are transaction records, since changing one transaction will require computational effort to update all the following blocks. As several nodes can simultaneously collect new transactions, generate a block, and suggest it to the network, the system creates a computational task based on the existing chain, and the first block, which successfully solves the task, is then appended to the blockchain. This is a so-called distributed consensus model which was named the "most important invention since the internet itself" [13].

On the global web, the lack of trust amongst independent parties results in the necessity of intermediaries and higher transaction costs. Blockchain can potentially solve this problem both for massive networks such as the Internet itself and private networks of one or more companies. Based on this distinction of whether participation is permissioned or not, blockchain is categorized into two types: private and public. In case of public or open blockchain, anyone can become a participant and can make transactions with any other participant. The identity of the participants can be anonymous or pseudonymous. This type of blockchain provides little to no privacy, all transactions can be viewed by other users. To join the network of private (permissioned) blockchain, new participants need to gain access either from a regulatory authority or a group of participants (consortium) or comply with a set of predefined rules. After validation of new participants, they become part of the network and ensure the decentralized essence of blockchain. Permissioned blockchain provides necessary privacy for participants and transactions and enables control over the types of transactions each participant is allowed to perform. This type of blockchain is easier to scale up and holds a greater potential for usage in different industries such as financial, supply chain management, and insurance [14].

Blockchain as an economic platform holds the potential of transforming and even revolutionizing existing organizational and management models of businesses, consequently changing everyday business processes and activities [15]. Blockchain technology offers a variety of features that benefit *consumers, businesses* and *governments* [15]. For example, blockchain can be used to create Trusted user interfaces which would improve the personal data control for individual consumers, by providing a secure access to records like identity and citizenship validation documents, health, and educational data, etc. For businesses, Provenance tracking would be a good example: Everledger and Provenance are the companies which work towards streamlining the supply chain by creating solutions for asset ownership, tracking and traceability management. Governments could use blockchain technology by introducing a Digital storage, authentication, and maintenance for identity management of the country. This could impact the immigration policies, election and voting, and help to reduce the identity fraud [15]. A baseline for successful implementation of blockchain technology and related to that redesign of business processes lays in understanding fundamental properties of blockchain, their impact on software system performance and its quality attributes, as well as considering possible limitations of implementing blockchain [16].

The fundamental properties of blockchain include *data immutability* (once transaction is committed it becomes virtually immutable as more transactions are recorded), *non-repudiation and integrity of stored data* (due to cryptographically signed historical transaction chain), *transparency* (enabled by public access), *equal rights* (participants have similar permissions to manipulate the blockchain), and ultimately *trust* (eliminating the necessity of intermediaries). Non-functional properties include *data privacy* and *scalability* which might bring limitations to the usage of blockchains [17]. Specifically, on public blockchains, all the data are accessible for all the participants. This hazards the privacy of corporate data and limits their implementation potential for inter-organizational processes; scalability limitations relate to the storage size of the data, transaction processing rate, and latency of data transmission [17]. Because of these limitations, blockchains standalone do not comply with requirements in all use-case scenarios (e.g., the cases when real-time processing is required). Blockchain then should be considered not as a replacement of existing software systems, but rather as a provider of software architecture and a software connector where a shared infrastructure for data storage and computation is introduced [18]. Tokens are part of such architecture, they digitally represent physical assets and money [18].

2.1.1 Storage of Data on Blockchain

Blockchain provides a structure for an immutable storage of data. All transactions that ever occurred within the network are recorded in chronologically ordered blocks which cannot be edited or deleted. The only way to update recorded data is by submitting a new transaction [19]. On the other hand, the computational capacity and storage space of blockchain are oftentimes limited. The costs related to implementing and maintaining a blockchain emerge in a different model from conventional systems. Therefore, in order to ensure cost efficiency, best performance, and flexibility of the system, not all the data is reasonable to be stored on-chain [17]. A common practice would be, for example, storing big and private raw data off the chain, while metadata is stored on-chain [19]. Such redistribution of data also solves the problem of public accessibility of private data.

Blockchain provides two different options for appending data to the chain, adding it as part of a transaction or including it in the smart contract storage. In both cases, data are recorded on the blockchain as part of new blocks with the hash of the last appended block [19]. Together with the limitation on computational capabilities and the scheme of incentives for generating new blocks, revision and tampering of stored data on the blockchain are practically not feasible [16]. Nevertheless, public, and private blockchains provide different immutability levels for transactions and stored data. In a public blockchain, the records are duplicated amongst many participants which practically prevents any options of data tampering. In consortium or private blockchain, data immutability is not completely guaranteed since the number of participants is limited [12]. When compared to centralized, shared data storage systems, which provide a Create-Read-Update-Delete interface, blockchain lacks the last two, instead, it supports the creation of new transactions to update information. This property of immutability of stored information enhances blockchain with a unique capability to traceback on all the assets recorded on the chain [19].

Blockchain oftentimes offers only limited computational power or control over the read accesses. These complications may be overcome by elements of applications implemented off the blockchain by storing off-line data and application logic [16]. Data stored on-chain takes the form of approved transactions which are consolidated in systemized blocks. A similar pattern refers to on-chain code. They both are written in Turing-complete programming language which required peer validation and consensus of network and results in append-only changes. On-chain data, therefore, is recorded on the blockchain as a shared database and cannot be rewritten. The process of transaction endorsement, seeking a consensus protocol, and running a decentralized program requires communication and execution costs as well as time [20]. Moreover, miners are incentivized to complete the computations, so each validation also incurs financial expenses. Ultimately, the scalability of the system is affected. Besides, privacy is also an issue: everything on a (public) blockchain is intrinsically visible and transparent which means that on-chain storage of transactions and data does not provide privacy or confidentiality.

The concept of off-chaining was introduced to diminish these limitations. Data and computation off-chaining offers to move those from the blockchain to another server, datastore, or system. This would noticeably reduce the required computational effort and improve system performance. Nevertheless, the characteristics that make blockchain unique and valuable, like trust and transparency, may be compromised or in some cases even unacceptably violated, leading to jeopardizing trust towards the system [20].

2.1.2 Computational Services on Blockchain

Smart Contracts are programs executed in a tamper-proof manner in an untrusting environment. In 1994 the concept of a smart contract was introduced by Nick Szabo and was defined as “a computerized transaction protocol that executes the terms of a contract”. Contractual clauses are translated into scripts of code and embedded into the chain; therefore, each smart contract has its unique address. This address is then used to trigger the smart contract and execute it independently from any central authority. Smart contracts require a set of preliminary conditions which must be met in order to execute the contract. This feature excludes the occurrence of malicious or accidental exceptions and makes smart contracts efficient, transparent and precise [21]. The precision originates from the prior settlement between all network participants upon the characterization of clauses of the contract. To ensure this kind of precision, contract terms must be evident, open, and verifiable. As a result, smart contracts are unambiguous for all nodes in the network. Blockchain technology and traceability of all transactions ensure that the conditions cannot be manipulated, altered, or cancelled, which makes smart contracts secure and tamper-proof. Therefore, smart contracts are executed correctly and not simply executed based on the trigger. Additional security of smart contracts is ensured through an event log, which logs all executions of the contacts and relevant information related to specific executions.

For blockchain technology, another important aspect of smart contracts is the fact that they also serve as repositories of data essential for the participant parties. The data may include agreements, contacts, ownership proofs, medical records, voting results, etc. [22]. This feature enhances smart contracts with a wide range of use cases and enables them to act as self-executing autonomous agents in cases with complex conditional logic [20].

2.1.3 Communication Services on Blockchain

Blockchains are closed systems and sometimes due operations of smart contracts require information from outside of the system. The network and smart contracts receive such information via what is called oracles. Depending on whether a smart contract requires external data to be executed or not two types of smart contracts are distinguished: deterministic and non-deterministic. Oracles enable two-sided communication, they connect the blockchain and smart contracts on one side, and the real world on the other [23]. In a blockchain network, oracles represent programmable agents which ensure that a smart contract received all the required data (inbound oracles). Also, they act on behalf of smart contracts by passing information from the network to outside systems (outbound oracles). Oracles, like smart contracts, can store data and pass to smart contracts only what is important and relevant. This feature improves efficiency and ensures high privacy and security within the network.

Business processes oftentimes require communication with other counterparts, which might not necessarily be part of the blockchain network. As a result, the desired functionality of a smart contract often includes a portion of non-determinism and, hence, requires employing an oracle. Oracles provide a secure passage for necessary information and hence, once oracle is federated, the risk of fraud using smart contracts is greatly reduced, allowing them to map well into legacy systems [24].

2.1.4 Asset Management and Control on Blockchain

Blockchain allows to track the movement of economically valuable assets with the implementation of a token. A token, in essence, is a piece of code, issued by a predefined smart contract, which represents a real-life asset, both tangible or intangible, in form of a programmable asset and reflects the real-life ownership of the asset through access rights of the cryptographic one. To access and manipulate the token blockchain participants receive a private key of the address of the token on the chain [25].

2.2 Best Practices for Business Process Redesign

Though there is no lack of methods aiming to support analysts in their pursuit of business process redesign, these do not seem to cover all the stages of the redesign project with an equal level of detail. Particularly, while they provide insightful specifications for the preliminary and the final stages of the project, they frequently miss the middle steps, i.e., how to transform the existing business process into a more efficient one [26]. This phenomenon became known as the ATAMO procedure ("And Then A Miracle Occurs") [27]. To address this issue, Reijers and Mansar [10] created a comprehensive list of best practices for business process redesign which could be used by the practitioners as guidance for redesigning business processes. The authors focused on the execution stage of redesign supporting it with relevant techniques and best practices. They describe the best practices discovered through a systematic literature review and supplemented with the authors' real-life experiences. To present the best practices more holistically, several frameworks have been reviewed and combined into a single comprehensive one (see *Figure 2.1*). The framework exhibits 6 different elements of business process and the links between them. The best practices are then arranged around those. The first element is the **customers** of the business process, both and external, and the best practices evolve around improving the contact with them. Then element of **products** (services) is considered, improvements are suggested from *operational view* (workflow of the process, tasks in a job, the nature, and the size of the tasks, etc.) and *behavioural view* (when is the process executed? the order of the tasks, scheduling of the jobs, etc.). The element of **participants** of the business process is discussed from the perspective of *organizational structure* with its departments, roles, and users and *organization population*, the people. The next element is **information**, the data created and obtained by the business process. **Technology** as an element is the enabler of the business process improvement. And the last element is the **external environment,** opportunities of which are suggested to be exploited through communication and cooperation with third parties.

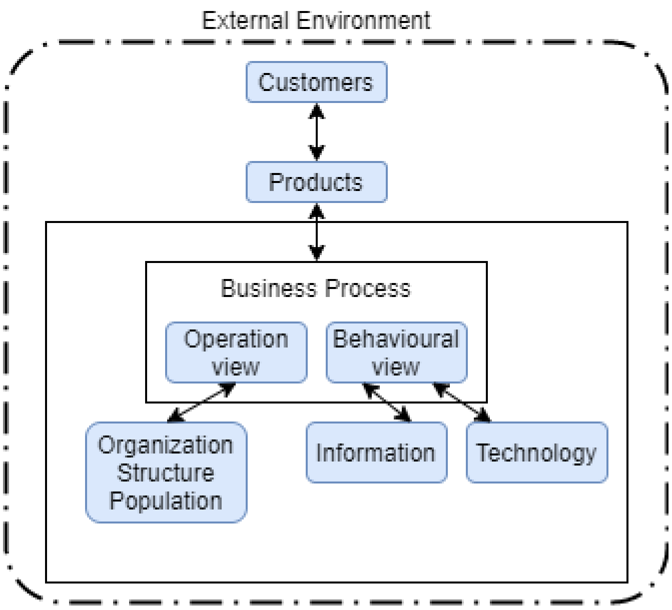

Figure 2.1 *Reijer's and Mansar's framework for BPR (source [10])*

The authors concluded a list of 29 best practices that revolve around the above-mentioned elements. These strongly vary on the level of abstraction at which they view the business process. Particularly, some heuristics refer to the redesign of the whole process, while others provide instructions specifically on an activity level. The best practice of integration, for example, suggests finding possibilities to integrate one's business processes with their customers or suppliers. This can take different forms, but the expected outcome is the same: more efficient execution from time and costs perspectives. Similarly, the best practice of centralization calls for treating physically dispersed resources as if they were available in the same location. This best practice can provide flexibility in committing the resources to different tasks, thus improving the utilization and even the throughput time. Other heuristics, such as resequencing or parallelism, propose focusing on the order of the task or completing them simultaneously. These best practices take into consideration the dependencies of the tasks or arranging similar tasks to follow each other to reduce the set-up time.

With this, we can state that the best practices embody both transactional and radical redesign. While transactional redesign aims at a gradual improvement of the process, accepting its fundamental setup to be sufficient, radical redesign questions the underlying assumptions of the process and pursues to completely transform it [26]. As blockchain has been positioned as a revolutionary technology [2], [3] then the best practices supporting radical redesign are strongly applicable. On the other hand, when considering a detailed level of processes and their redesign then transactional improvements also become relevant. And thus, the implementation of blockchain technology can be enhanced with the best practices grouped in either of those two groups.

Ideally, a best practice should propose the best approach for a specific problem and should be replicable in any condition and setting, but perceiving a best practice as something that *"needs to be adapted in skilful ways in response to prevailing conditions"* can result in a more efficient outcome [10]. The following chapter presents the best practices of business process redesign contextualized and adapted for implementing a blockchain-based solution.

2.3 Related Work

The usage of blockchain technology and smart contracts as a source of innovative solutions has been discussed in different research papers. Yet, there is a lack of research on the topic of how to redesign a business process to reap the maximum benefits from employing a blockchain-based solution.

Blockchain is positioned to disrupt the established ways of running businesses. Thus, different researchers have investigated the opportunities that blockchain may offer to enhance different industries. Some of the most common domains being discussed for the application of blockchain technology are personal data protection, healthcare, supply chain, internet of things and its security, electronic voting, and sustainability. In the insurance industry, for example, Gatteschi et.al. [28] explore possibilities to exploit blockchain technology for creating new types of insurance products, addressing fraud in the industry, automating tasks and processes, as well as customer identification. Hans et.al. [29] discuss blockchain and smart contracts in the context of payment and claims handling systems. These and other available papers describe the concept of what the process with a blockchain-based solution would look like, yet they do not provide any insights into how the existing processes should be redesigned.

Some papers discuss innovative solutions with the implementation of blockchain for given use cases. Chen [30] introduces the idea of using blockchain to make the process of capital raising for entrepreneurial activities more democratic. A new concept of a business process management system based on blockchain technology is introduced by López-Pintado et.al. [31]. And while these papers provide essential input about where blockchain technology can be exploited, they do not share any insights on how these new processes should be designed.

Xu et.al. [18] explore actual use cases of blockchain implementation and present a thorough summary of matters which should be taken into account when a process is being designed to run on a blockchain. Some of the common patterns are considering communication with the external environment, data management, software structure for smart contracts, and their security. These patterns provide invaluable insights and guidance for the implementation of blockchain-based solutions. But again, they do not shed any light on how the business process should be redesigned to exploit the enabling power of blockchain and smart contracts.

3 Business Process Redesign Heuristics for Blockchain

In this chapter, we draw the connection between blockchain capabilities, and the best practices described previously. And based on these findings., the business process redesign heuristics for blockchain-enabled processes are presented.

In general, the best practices are broad which enables their wide application towards a variety of business processes. Hence, the implementation specifics of the best practice diverge in each case, subject to the skills and experience of the practitioner, as well as the technology being used. New technologies, particularly those which bring disruptive innovation (such as blockchain), may raise a question on how the best practices can be applied. This issue can be addressed by contextualizing the best practices for the implementation of blockchain technology and adapting and fine-tuning them into redesign heuristics explicitly for blockchain-based solutions.

To adapt the best practices to blockchain technology, we consider looking at its enabling capabilities. Blockchain is then viewed as an element or a component of a software system [19], which provides technical capabilities of storage of data, computation, communication, and asset management [16]. Each of the best practices has been studied to identify which blockchain capability can it be most correlated to. Let us have a look at a few specific examples. The redesign practice of centralization calls for considering physically distributed resources as if they are centralized. This approach can be supported by the capability of blockchain to provide a shared data storage. If the data is on the shared ledger, then all the participant-firms involved in the process can have access to it. The (blockchain) technology then virtually becomes the enabler of prevailing over geographical restraints when accessing data. Thus, we can draw a connection line between the best practice of centralization and the capability of shared data storage. The best practices are then discussed in a similar manner and, once the connection with the blockchain capability is identified, are turned into a redesign heuristic. Each of the heuristics may involve one or several best practices.

Several best practices guide in improving the business process through optimization of the (human) resource usage, examples of those are flexible assignment, split responsibilities, extra resources, or specialist-generalist. The best practice of flexible assignment, for instance, suggests designating the available resources in a way that will ensure maximal flexibility, i.e., if the job can be completed by both existing resources, then the most specialized one should be assigned to execute it. The more general resource then remains free to execute other incoming jobs which may not have been possible to execute using the specialized resource. This setup allows removing bottlenecks of process execution related to human resources. When it comes to blockchain, resource constraints are primarily a technical challenge and can be tackled when defining the non-functional requirements of the system. Hence, some of the best practices are not included in the proposed heuristics. In the remainder of this chapter, we present the contextualized heuristics within the matrix of enabling capabilities of blockchain.

Starting with the shared data storage as the initial enabling capability of blockchain, we introduce the first group of redesign heuristics - collaboration of entities. The guidelines summarized in this group depend on data shared across different participants of the process. The next group of heuristics is called Case management structure. These reply on the smart contracts as the powerhouses of computational capabilities of blockchain. Hence, the guidelines in this group focus on the redesign of the inter-organizational process itself. The third group is based on the communicational capabilities of blockchain and combines heuristics related to the improvement of the information flow. It is called Data management. And the last group, i.e., tokenization, uses the capability of asset management. This grouping does not characterize the inter-organizational process, and not even the blockchain-based solution. Instead, the heuristics can perhaps assist the practitioners in their ideation process around introducing the blockchain technology and redesigning the business processes. Having a set of participants in an inter-organizational process demands access management functionalities from the implemented blockchain solution. These are presumably accommodated by specific platforms for permissioned blockchain.

3.1 Collaboration of Entities

The collaboration of entities, as a heuristic, calls for viewing all participant organizations as if they were one interconnected unified entity. To enable this collaboration, the blockchain then provides the architecture of a shared data ledger, which can store a range of verified transactions. The stored data is immutable as it is firstly verified, and only then amended to the chain with the usage of cryptographic hashes. Thus, the distinct participants can cooperate in the environment of a shared trustworthy data ledger. Within the first group of heuristics, we introduce two redesign guidelines which are derived from several best practices introduced by Reijers and Mansar [10], such as centralization, integration, interfacing, and outsourcing, as well as integral technology.

The best practice of centralization is based on the utilization of the advantages provided by Workflow Management Systems [32]. With this system installed in the organization, the objective of the business process can be accomplished regardless of the physical location of the resources. Hence, geographically distributed resources can be engaged in the execution of the same business process [33]. With the introduction of blockchain technology, the separate participants of an inter-organizational process can be viewed as being centralized, since now they have access and can share process-relevant data on the chain. Hence, the best practice of centralization is contextualized for the introduction of a blockchain-based solution to the inter-organizational process, as the following redesign heuristic: *view the participants of an inter-organizational process as if they are united in one entity.*

The next best practice is integration which proposes engaging the customers or the suppliers in the business process of the company. Integration best practice comes from the opportunity to utilize the concept of supply-chain [34]. If the business process involves separate parties, it is reasonable to review and share the information while executing the process versus controlling the outcome of the process [10]. The features of underlying technology strictly define the extent of a potential integration with the perspective of feasibility and cost efficiency [35]. As a result, this best practice is most frequently employed with a linear inter-organizational process, i.e., when the potential suppliers or customers can be meticulously picked out [36], [37]. When discussing blockchain as the underlying technology to enable integration, the list of potential participants can be expanded to include parties other than just the customers or suppliers. With the blockchain providing easily accessible data, virtually any participant of the process can be integrated, and the complete process can be executed in an integrated manner. Thus, the next redesign heuristic is derived from the best practice of integration: *integrate the business processes or activities of distinct participants of the inter-organizational process.*

3.2 Case Management Structure

Case management structure comprises the second group of redesign heuristics. The concept is to view the smart contracts as the building block of the process being redesigned. This group of heuristics is enabled by the computational capability of blockchain. As discussed in the Background smart contracts can not only store and transfer data but also carry out transactions [16]. It is possible to predefine the parameters of smart contracts which can then run autonomously and create the desired output once the relevant input data is accessible on the chain. From this perspective, smart contracts can act both like a specific task or a sub-process. In the case management structure, we introduce some redesign heuristics which help to identify the scope and usability of potential smart contracts.

Reijers and Mansar [10] introduce several best practices, such as case manager, order assignment, customer team, and numerical involvement, which propose to focus on the output of the business process rather than on a specific task [33]. The best practice of a case manager applies to those business processes which run through several departments within an organization. A case manager is assigned to each iteration of such process to oversee the completion of sub-processes and tasks and improve the external quality [38]. The best practice of order assignment suggests one resource to complete as many steps of the process as possible, thus, ensuring a higher quality of performance, and reducing the throughput time by elimination of setups. A variation of order assignment is the practice of customer teams. The essence of this best practice is to create teams of specialists from different departments who would handle distinct types of cases [39]. Numerical involvement as a best practice calls for reducing the number of recourses engaged in the business process. All four practices discussed are aimed towards making the coordination efforts more efficient and thus improving the quality of the outcome and increasing efficiency. With the implementation of blockchain technology, smart contracts can replace the resources necessary to carry out the tasks. For example, a standalone smart contract can access the vital data on the chain and execute specific tasks based on the predefined requirements. It can also perform several consequent tasks as per order assignment practice. An interconnected group of smart contracts may act like a customer team where each executes specific types of tasks. Another smart contract would control the order of the execution and potential errors becoming a case manager. We summarized these practices into one redesign heuristic: *establish the new process with the focus on the outcome and utilize smart contracts as task executor-resources.*

Outsourcing as a best practice calls for complete or partial outsourcing of the business process or sub-process to a third party. The latter generally completes the outsourced tasks more efficiently. This approach goes hand in hand with performing the tasks where they are relevant the most [40]. In an inter-organizational process, the participants can completely or partially outsource their tasks to the blockchain. If there are tasks that are stretched across several participants or repeated from one entity to another, then these should be unified and completed only once. The process can be executed on the blockchain with the usage of smart contracts. The best practice of outsourcing is, hence, contextualized for the implementation of blockchain as follows: *outsource the business processes completely or partially to the* *blockchain, and assign smart contracts for their execution. Consider specifically the process duplicated by several participants.*

One of the most common best practices is task elimination. The goal is to get rid of duplicated tasks, control tasks, and those which do not add any customer value, like redundant tasks, etc [10]. It is worthy to consider eliminating these before the introduction of smart contracts as the executors of the process. For example, if a task is duplicated by several participants of the process, then it is reasonable to execute it with only a single smart contract versus copying the process in numerous ones. Similarly, control tasks need a critical review with the purpose of elimination. Task elimination is tailored as: *in the inter-organizational process eliminate tasks which provide no additional value.*

Triage suggests dividing one task into multiple smaller ones or combining several smaller tasks into a composite one [10]. Another best practice, order types, examines all the tasks within one process to ensure that they are specific to the process they are part of. If the outcome is that the task does not belong with the process, then they are moved to a new order type. Using a combination of process decomposition heuristics [41] and the best practice of order types it is possible to determine the scope of the smart contracts. The redesign heuristic is modified as: *identify different versions of the process flow and introduce a smart contract for each version.*

Generally, smart contracts are considered self-executing programs. Nevertheless, a suboptimal setup can reduce their efficiency and require additional inputs from humans or other systems. The following best practices can assist in the creation of highly automated and optimal smart contracts. Empowering – the practice of authorizing the workers to make decisions. Allows to remove middlemen and shorten the throughput time. Task automation – focuses on automating separate tasks or technologically assisting the resource with its completion. Exception – proposes to pick out exceptional cases from the normal flow and handle them separately. And, contact reduction – which aims to lessen the contacts with the customers and third parties [10]. Since smart contracts can store data and autonomously perform tasks based upon it, then it is feasible to empower them to make decisions without (or with fewer) external interventions. To enable this level of autonomy and automation, there is a need to handle exceptional cases separately. These four best practices are combined into one redesign heuristic: *when designing the smart contracts ensure that they are enabled to make autonomous decisions based on the available data, with no or fewer interventions from humans.*

The last heuristic in the group of case management structure touches upon the order in which smart contracts are executed. The best practice of resequencing aims at identifying the maximum optimal execution order of the tasks. It takes into account task dependencies, similarities of tasks, etc. Parallelism is a particular type of resequencing that proposes simultaneous execution of 2 or more tasks [10]. While these best practices refer to tasks, we consider them applicable to smart contracts. Similar to tasks, it is possible to validate what is the better sequence for smart contracts to be carried out on a blockchain-based system. To summarize these best practices, we propose the following heuristic: *identify smart contracts feasible to execute parallelly and consider resequencing the order of execution to achieve maximum efficiency.*

3.3 Data Management

The next group of contextualized best practices is called data management. This group stands on communication services enabled by blockchain. Blockchain as a software component features communication of data, thus allowing data transfer between participating entities [17], [19]. Blockchain ledger provides an architecture for data storage, but the platform allows also recording and retrieving data from other participants and external sources. This enables an easy flow of data between all engaged companies. Data management group combines the best practices of capturing data once and at the source, trusted parties, control addition, and buffering [10].

The practice of trusted parties suggests using results created by a third entity with the same available data. It calls for not repeating the task processing internally and not trying to reproduce the same outcome [10]. An example can be a bank that accepts a client's creditworthiness assessment completed by a different bank. This can create a dependency on the quality of work done by the third party, but it can also reduce the costs and processing time. For an inter-organizational process, a blockchain-based solution can enable the usage of output from one participant for the needs of the other, thus removing the necessity of repeated processing. This best practice can be contextualized as: *utilize the outcomes produced by process participants instead of recreating them.*

Another interpretation of the trusted parties can be capturing data from trustworthy sources. If there is a need for information from outside of the inter-organizational process, then oracles can play the role of a trusted party. Hence, an alternative adaptation of this best practice could be – *use oracles as a trusted source of external data*. Nevertheless, oracles not always can provide reliably accurate data. Sometimes they would need to refer to several sources for information, then gather and merge those data, and as a result, compile incomplete or incorrect data. To ensure desired quality, the control addition best practice can be employed. This best practice calls for adding control checks midway through the process to monitor the quality of inputs, proper processing, and the correctness of the outputs [10]. Originally control addition referred to production materials, but it can also be used for data quality control [26]. Within the domain of control, the practice of control relocation should also be considered, as it proposes the optimal order of the control tasks in the business process, e.g., during earlier stages of the process, or more towards customers. These best practices can be summarized into the following redesign heuristic: *use controls to ensure completeness and accuracy of the data, consider locating the controls near the data entry point*.

It is possible the information necessary to carry out the inter-organizational process is not regularly used or instantly accessible with the oracles. The best practice of buffering tackles this issue by proposing to buffer information from the external sources and subscribe to updates, rather than querying it for every execution of the process [10]. For blockchain-based solutions, frequently used but seldomly changing data can be stored on the chain and only be updated if necessary. The best practice of buffering can be contextualized as – *store most often used but least often changing data on the chain and subscribe to updates.*

Each participant of an inter-organizational process has their internal information system which requires data collection. Oftentimes, the participants collect and store the same data repeating the data entry process multiple times, causing higher costs, time spent, and potential mistakes [33]. Blockchain has the capacity to share the data amongst participants, making it unnecessary to capture it more than once. The oracles can assist in obtaining the data from external sources. For manual data input, a standard interface can be used as per homonymous best practice [10]. Standard interfacing contributes to the quality and the speed of the captured data, and potentially reduces rework. These best practices as combined into the heuristic of – *capture the data only once and from its original source, use oracles if needed.*

3.4 Tokenization

The fourth group of redesign heuristics is called tokenization, and it rests upon the enabling power of asset management. Blockchain system allows controlling tokens with the usage of smart contracts. Tokens are essentially the digital equivalents of actual valuables [16]. Smart contracts can then store and update the statuses of legal contracts, physical and intangible assets by storing and updating the status of the corresponding token [42].

Integral technology as a best practice suggests implementing technological innovations to overcome physical obstacles within the process [10]. Combined usage of the Internet of Things (IoT) and oracles, can supply the blockchain with robust data about all steps of the inter-organizational process [19]. For example, IoT can assist in the automatic detection of the whereabouts of an object, thus eliminating the necessity to physically locate it [40]. The best practice of integral technology is adapted in the context of tokenization and asset management, into the following redesign heuristic: *create digital equivalents of assets engaged in the inter-organizational process using blockchain tokens.*

3.5 Summary

Above we presented **14 redesign heuristics for introducing blockchain technology to an inter-organizational process** and explained (1) how they are derived from well-known and widely used best practices of process redesign and (2) how they are related to the enabling capabilities of blockchain. We summarize the heuristics in Table 3.1. The next chapter will exhibit a case study with the application of proposed heuristics.

Table 3.1 *Redesign heuristics for implementing blockchain.*

Collaboration of Entities	
H1	View the participants of an inter-organizational process as if they are united in one entity.
H2	Integrate the business processes or activities of distinct participants of the inter-organizational process.
Case Management Structure	
H3	Establish the new process with the focus on the outcome and utilize smart contracts as task executor-resources.
H4	Outsource the business processes completely or partially to the blockchain and assign smart contracts for their execution. Consider specifically the process duplicated by several participants.
H5	In the inter-organizational process eliminate tasks that provide no additional value.
H6	Identify different versions of the process flow and introduce a smart contract for each version.
H7	When designing smart contracts ensure that they are enabled to make autonomous decisions based on the available data, with no or fewer interventions from humans.
H8	Identify smart contracts feasible to execute parallelly and consider resequencing the order of execution to achieve maximum efficiency.
Data Management	
H9	Utilize the outcomes produced by process participants instead of recreating them.
H10	Use oracles as a trusted source of external data
H11	Use controls to ensure completeness and accuracy of the data, consider locating the controls near the data entry point
H12	Store most often used but least often changing data on the chain and subscribe to updates.
H13	Capture the data only once and from its original source, use oracles if needed.
Tokenization	
H14	Create digital equivalents of assets engaged in the inter-organizational process using blockchain tokens.

4 Case Study

A specific reality can be studied within its actual environment with the help of qualitative methods; this is a case study [43]. The approach is most reasonable when taking apart the object of the study and its environment is practically unfeasible [44]. Conducting a case study can pursue a variety of purposes, such as for reinforcement of a hypothesis, or using it for descriptive purposes [43], [45], or for the assessment of a new methodology introduced in the field of information technology [46]. In this chapter, we carry out a case study to assess the business process redesign heuristics presented in the previous chapter.

To fulfil our aim of evaluating the proposed heuristics, the case had to (i) be relevant for implementing a blockchain-based solution to an inter-organizational process and (ii) provide the information, necessary for building the case and the evaluation. The information can be made accessible through sharing relevant files and/or communicating with the domain professionals. Our selection falls on the process of auditing the timber-to-charcoal process. The outcome of which is the validation of the process participants certificates by comparing information in issued invoices. This case fulfils both criteria mentioned above. First, the participant companies have to share confidential information about their processes and finances, thus, there is a solid need for a trustworthy environment that can be achieved with a blockchain-based solution [47]. Second, we were provided with all necessary information and had the opportunity to communicate with the domain experts. A detailed description of the case study follows below.

4.1 The Setting of The Case Study

The case study is set up from the perspective of authorized certifiers who audit the process of producing charcoal from timber. The case study was constructed in collaborated with an international non-profit called Nepcon[1] (currently Preferred by Nature). Nepcon is focusing on supporting those human choices which would lead to a sustainable future. In the scope of their operations, they train and certify companies that produce charcoal and other timber-based products. They predominantly work with companies located in the EU, Australia, or the USA, as these countries have better-regulated markets.

A label “certified” can be used for a charcoal product only if it has been processed by certified companies at all stages of the production, from timber to charcoal. The first stage of production is sourcing (felling the trees). The timber is then purchased by the manufacturers directly or via intermediaries. Manufacturers carry out the process of pyrolysis which turns timber into charcoal. Technically it requires heating the timber in a low-oxygen environment. As a result, the initial timber volume reduces by around 80% and gives 20% of charcoal. This is called the conversion rate. Next, the charcoal goes through the process of packaging into bags (this is often done by a company different from the manufacturer). Bagged charcoal is sold in bulk or directly to retailers, where end-users can get the final product.

A sourcing company, charcoal producer, or seller needs to go through a certification process by an authorized certifier, such a Nepcon. The companies are evaluated upon their compliance with the predefined criteria, and, if successful, are issued a certificate. They also need to provide their agreement to an annual onsite audit of their premises. Figure 4.3 exhibits

[1] See https://preferredbynature.org/

the complete process. First, an auditor from Nepcon sets up an appointment for an onsite visit. This requires agreement on the date from the company being audited. Then the auditor sends out the relevant documents to be pre-filled by the time of the visit. During the visit to the premises the auditor investigates incoming and outgoing invoices to evaluate their compliance, they compare the overall volume of purchased and sold timber and review several randomly selected invoices on paper. Review of invoices includes making sure that the correspondent buyer or seller is also certified. The latter is achieved via a query to the Forest Stewardship Council (FSC) database which stores the information about all timber processors and the statuses of their certificates. Another factor taken into account is the conversion rate, it is calculated based on the provided information about aggregate volumes and compared to the industry standard. The outcomes of the audit are documented in a report which is then reviewed by a second auditor. The findings from the audit determine either prolongation of the certification or its temporary or permanent suspension.

There are multiple problems related to the presented process. The invoices and information on them can easily be manipulated and would be hard to detect without reviewing all the invoices. The process of audit is predominantly manual, thus time-consuming, and prone to mistakes. The audit is conducted retrospectively only once per year. This leaves a window of up to 12 months of potentially fraudulent activity without being detected. As the information available in the invoices is sensitive and confidential, the companies are hesitant with allowing this data outside of their premises. This strictly restricts the opportunities for the auditors to compare and cross-check the information with mentioned suppliers and buyers.

4.2 The Design of The Case Study

The design of the case study went through five steps as exhibited in the Figure 4.1. The aim of the first step was **understanding of the domain**. Data gathering was done using the triangulation method, i.e., collecting data from different source and conducting comparative analysis. One meeting and a workshop were conducted with Nepcon. During the meeting, an interview was conducted with the Nepcon representative and domain expert Roman Polyachenko[2]. He provided insights into the industry specifics, Nepcon's internal operations, and an overview of their processes. In addition, supporting materials were provided for further review and analysis, like examples of audit reports, certificates, templates for summarizing the timber and charcoal volumes (confidential and personally identifiable information was redacted).

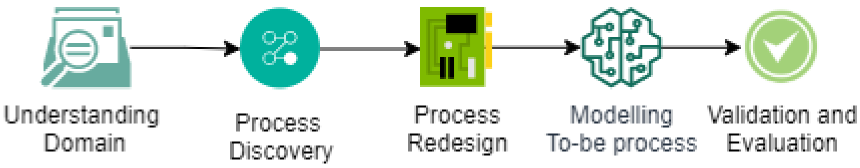

Figure 4.1 *The Process of the Case Study Design*

Next came **process discovery**. Based on the data collected during the workshop, the process model of the timber-to-charcoal process was created. The model went through multiple

[2] At the time Director of NEPCon Estonia and Chain of Custody Program Manager. Has relevamt knowledge about blockchain and smart contracts

rounds of refinement. Once the initial draft was ready, details and clarifications were provided either through answering questions by Nepcon or finding details in the documentation provided by them. The final version of the model went through review and verification of Nepcon. The model helped to further understand the process. The outcome is presented in sub-section 4.3 and Figure 4.3.

The third step was **redesigning the as-is process**. A workshop was conducted for requirement elicitation for the to-be process, and to understand the scope of redesign. Contextualized heuristics for business process redesign were applied to facilitate the brainstorming activity for creating the to-be process. The approach was to firstly focus on the four main groups of the redesign heuristics and outline the large-scale changes, after which more detailed discussion was held focused on the 14 individual heuristics in each of the groups. The results were summarized after the workshop and provided solid material for modelling the to-be process.

The fourth step was **modelling the to-be process** and was essentially similar to the process discovery. The ideas elicited in the previous step were used to create the draft of the to-be process. The model then went through several stages of reiterations and refinements before the final version was created.

Once the to-be model was ready, it was discussed and **validated** with Nepcon to make sure that all the concerns raised during the initial stages were met. The final to-be model is presented in sub-section 4.4 and Figure 4.4. The **evaluation** of the model included review of the process performance metrics, such as time, cost, quality, and flexibility. The method of simulation is used to measure the throughput time for the current versus redesigned timber-to-charcoal audit process. Cost, quality and flexibility are discussed using the parameters provided by Reijers and Mansar [10].

As part of the case study execution, 2 meetings and 2 workshops were conducted in total with the representatives of Nepcon. The duration of meetings was around 40-45 minutes and 90 minutes for the workshops. The creation and further definition of both the current and the redesigned process models required six distinct contacts in form of questions and answers sessions during which specifics of the process and the requirements were clarified. Each of the sessions took on average 30 minutes. Also, there was ongoing online communication for smaller questions. As the design of the case study has been drawn, we then describe the execution of it. In the next sub-section, the proposed redesign heuristics are applied to the process and the redesigned process is described.

4.3 Applying Blockchain Redesign Best Practices

This sub-section presents a detailed overview of how the timber-to-charcoal auditing as-is process is redesigned with the application of proposed heuristics. We follow through the same logic which was applied to group the heuristics into 4 categories: collaboration of entities, case management structure, data management, and tokenization.

Collaboration of entities – this group bases upon blockchain capability of shared storage of data and calls for viewing all participant-organizations as if they are one interconnected, unified entity. The first heuristic in this group (H1 in Table 3.1) prompts to view the participants of an inter-organizational process as if they are united in one entity. To employ this heuristic, we need to understand what the main goal of the discussed process is, and then to pinpoint the key players without whom this goal will not be possible to accomplish. During the process discovery step, we establish that the objective of the process is conducting the audit of the timber-to-charcoal process across all the participants in the supply chain. We then focus on the list of participants of the process.

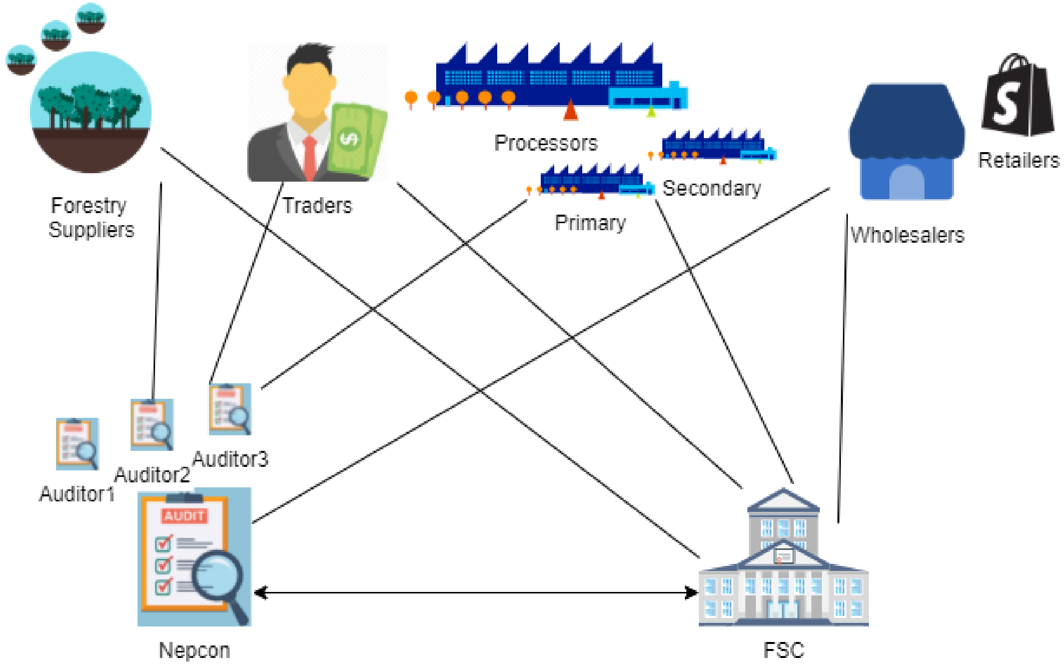

Figure 4.2 *Participants of timber-to-charcoal process*

Figure 4.2 visually represents all key participants of the timber-to-charcoal process grouped based on their business activity. Nepcon stands out as a key participant since they are conducting the audit process. It is important to note that not only Nepcon but other certifying organizations working in the industry also are considered. The involvement of FSC is essential as they control the database with the certificate holders' data and the validity of the certificates. The rest of participants are the organizations which are being audited and certified across the supply chain. These include forestry suppliers, traders, primary and secondary processors, wholesalers, and retailers.

H2 in Table 3.1 suggests - integrate the business processes or activities of distinct participants of the inter-organizational process. At this point, we discuss the specific processes, sub-processes, or tasks that are relevant to be integrated. In the timber-to-charcoal process, we aim to discover possibilities for integration by understanding the dependencies within the process. Dependencies conditioned by the order of the processes are easily recognized as one process uses as an input the output of another process. In the timber-to-charcoal process, the auditing company sends relevant audit templates before the onsite visit to the company. The company needs to fill in the required information into the provided templates, to enable the auditors to examine the aggregated volumes on the day of the visit. This is an example of how two participants run sequentially dependent processes. To eliminate the dependency, we consider integrating the preparation part of the process into the audit itself. Now, tasks that were divided between two distinct participants are combines into one.

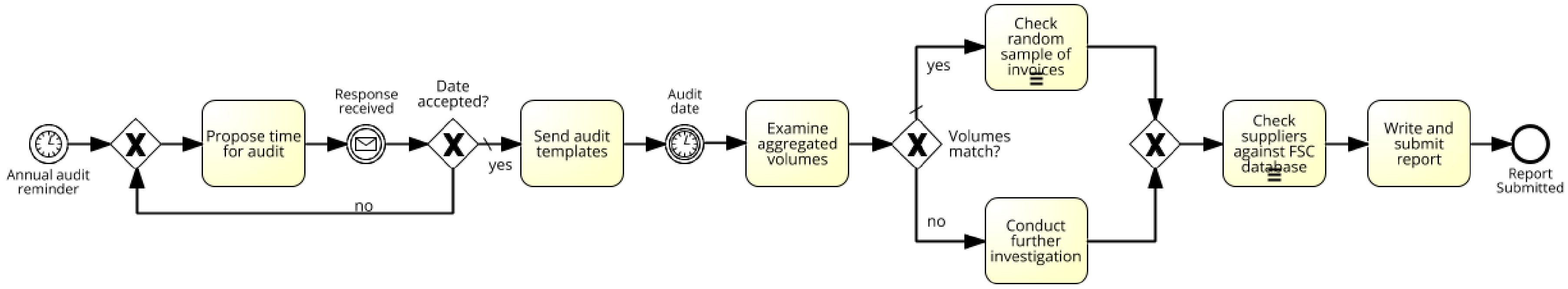

Figure 4.3 *The As-Is Process of Annual Audit and Certification*

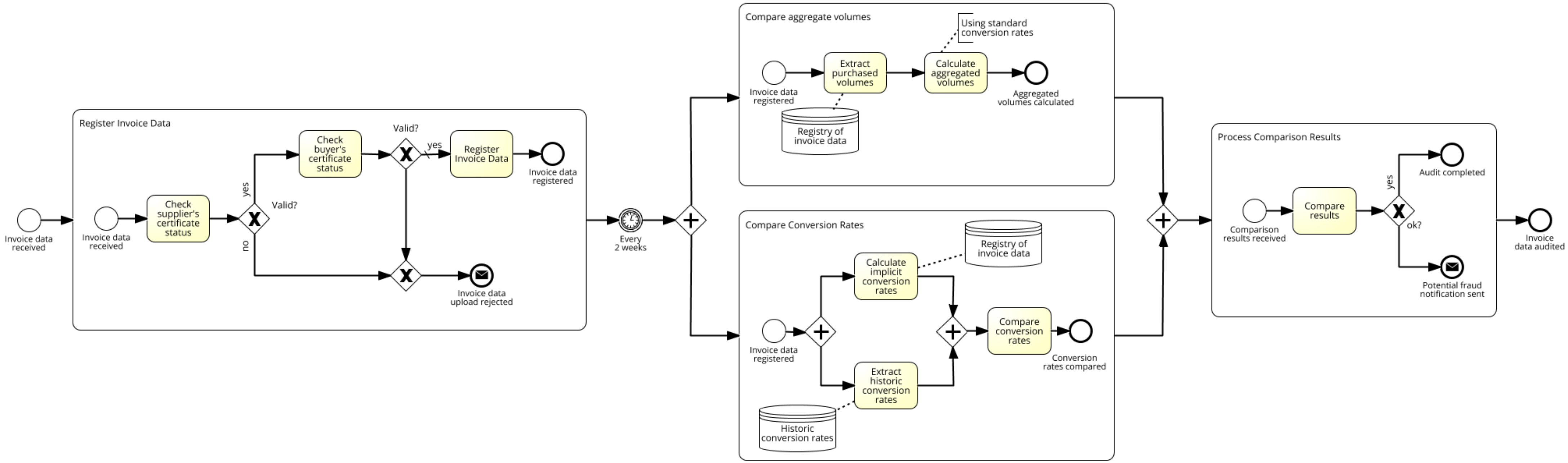

Figure 4.4 *Annual Audit and Certification To-Be Process with Implementation of Blockchain Technology*

Another opportunity for integration can be discovered from the data perspective. Here, we aim to find processes that require the same information to carry out but are performed by separate participants. As blockchain provides secure access to data belonging to other participants, it enables integration vis usage of one participant's data by another. In the timber-to-charcoal process, the integration with the certifiers can gain secure access to the processing companies' invoice data. Case management structure – this group of heuristics evolves around the enabling power of smart contracts and calls for employing them as the building blocks of the inter-organizational process. The third heuristic (H3) proposes to establish the new process with the focus on the outcome and utilize smart contracts as task executor-resources. The first step would be then to define the main outcome. Based on the workshops we identified that the most important outcome is to escalate cases of any suspicious activity and create a warning for the certifiers. With this in mind, we discussed the process to clarify the key steps and stages at which the warning should be raised. We identified the following key steps – recording the invoice data, validate the partner organizations' certificates against the NFC database, estimate the aggregated volumes based on the conversion rates, and raising warnings in case of suspicious activity. Each step is essentially a sub-process that contributed to the main outcome of the inter-organizational process and is carried out by an individual or a set of smart contracts.

Pursuing the implication of the next heuristic (H4), we look for (duplicated) processes to outsource to the blockchain. So, we examine the whole process to uncover cases when a task or a process is repeated by several participants. What stood out to us was that each certifier, just like Nepcon, replicates the process of analysing the invoices, aggregating the bought and sold volumes, verifying the validity of partner organizations' certificates, and then raises warnings in cases when suspicious activity is detected. In the redesigned process the identified activities become part of the inter-organizational process. We then introduce 3 smart contracts to compare aggregated volumes, check the validity of suppliers' and customers' certificates, and raise a warning when fraud is detected based on pre-defined rules.

Our next target is to eliminate tasks that provide no additional value (H5). We focus specifically on those activities which become obsolete as blockchain is added to the picture. Since the process of audit can be carried out by a smart contract, the necessity to schedule a date for an onsite visit disappears. Also, there is no longer a need for the processor companies to prepare for the audit. Thus, these activities are primary candidates for elimination.

Potentially different flows of the process (variants) are proposed to be carried out by distinct smart contracts (H6). The key to the success of those contracts lies in enabling autonomous decision-making based on the available data, with no or fewer interventions from humans (H7). And to improve the efficiency even further, the order of these smart contracts is taken into account (H8). Our first step is then to differentiate these potential variants. We create two variants of sub-processes that carry out the aggregation of volumes with respect to conversion rates. In the first sub-process, the volumes are aggregated based on the standard conversion rates. The second flow calculates the actual conversion rate based on the volumes of timber bought and the charcoal sold and compares the results to the previous rates of the same company as well as the industry average rates (H6). To ensure no manual intervention, we decided to limit the scope of these smart contracts to complete the calculations only (H7). Thus, another smart contract was created to escalate the suspicious cases and send out notifications. The results from both variants of the smart contracts are then taken as input by a third one. This smart contract aims to identify whether there is a need to raise a warning and if yes who should the recipient be based on the predefined criteria. The further analysis of suspicious cases and potential suspension of the certificate needs extra data and discussions. Thus, this part of the process is purposely not included in the last smart contract. With this intentional exclusion of the certification status update, we facilitate the smart contract to make independent decisions (H7), which would otherwise require manual input. Another thing to note here is that the two variants of conversion rate calculations can run simultaneously. So, we design the smart contracts to carry out the tasks autonomous from one another (H8).

The data management group of heuristics is empowered by communication as an enabling capability of blockchain. The discussion starts with the utilization of the outcomes produced by other process participants instead of recreating them (H9). Firstly, the focus is on discovering the data produced by each participant which can be potentially required by others. In this quest, insights useful for carrying out the inter-organizational process were identified. These insights were created by the participant entities as well as third parties. For example, if a timber processor purchases new equipment which has a higher efficiency this can have an essential impact on the conversion rates. The standard conversion rates need to be updated so that the process of audit detects fraudulent cases. The equipment manufacturers or other auditing companies can provide information about improved equipment and efficiency. Once some of the auditing companies in the industry have already examined and evaluated the efficiency of new equipment during their onsite visits, these insights can contribute to validating the new conversion rates. Another reference point can be the conversion rate estimate provided by the producers of the new equipment.

Oracles are a trustworthy source for bringing external data to the blockchain system (H10). For the timber-to-charcoal auditing process, the data about certified companies and the statuses of their certificates are available in an external FSC database. This type of trusted providers of data (FSC, other certifying organizations, equipment manufacturers) shares the information to the blockchain with the means of oracles. As the validity statuses of processor and supplier certificates are something used quite frequently, it is reasonable to save this information and subscribe to updates as per the 12th heuristic (H12). Thus, the certificate validity statuses and industry-standard conversion rates are saved on the chain.

The 11th heuristics calls for using a control mechanism with the purpose of complete and accurate data collection. These control mechanisms should be located closer to the data entry point. In addition, data should be captured only once and at the source (H13). With these two guidelines in mind, the focus is on revealing when and where the information is submitted to the process, and where the control mechanism location makes the most sense. In the timber-to-charcoal auditing process, the invoice data is submitted to the system by timber processing companies. The invoices contain information about the volumes of sold verified timber. There is a need for a control mechanism here, as for the data to be usable in the further process it must be complete, it must include details like date, name of the buyer, type of the product, and volume). As the timber products are certified only if all links in the supply chain are certified, then it is reasonable to establish another control that checks against the database if companies presented in invoices are certified. The proposed control checks the validity status of the supplier's and buyer's certificates before recording the invoice data on the chain. In case the certificate is suspended, the invoice registration is denied. Another potential source of mistake can be duplicated entry of data. So, a control mechanism is in place to catch repeated entry of the same invoice and ensure that the data is captured once and at the source (H13).

Tokenization – the final group of redesign heuristics includes only 1 guideline, which proposed to create digital equivalents of assets engaged in the inter-organizational process with the blockchain tokens (H14). To apply this heuristic, the assets involved in the process need to be pinpointed. The first instinct pointed out to timber. Nevertheless, in the timber-to-charcoal process, there is a transformation from wood to charcoal which makes it unfeasible to use tokens. The discovery is that the certificates of timber-processing companies and their statuses can easily be represented with a token. The certificate can have two distinct statuses "active" and "suspended". With every attempt to register invoices, a smart contract can ensure that the supplier and buyer have active certificates by checking the status against the token.

4.4 The To-Be Process

Previously, we have already introduced the timber-to-charcoal as-is process. We also discussed the problematic areas of the existing process. Next, proposed redesign heuristics were applied to create the to-be process. This sub-section presents what the final version of to be process looks like.

Blockchain technology enables a true collaboration between the certifiers, such as Nepcon, and the companies that produce timber and charcoal. The to-be process requires only the data included in invoices, such as product name, volume, who is selling, and who is purchasing, as well as the date. The process starts with the timber processing companies uploading their invoice data into the system (see Figure 4.4). Data upload happens with the help of oracles. The uploaded information is encrypted and sent to the blockchain. The to-be process is practically completely executed on the blockchain. Invoice data is recorded on the chain using a smart contract which also checks out the validity of certificates for the suppliers and buyers. If all certificates are valid the data is successfully registered. A supplier certificate may be suspended then all invoices are denied, and a notice is sent to the certifying organization. If a buyer certificate is not valid, then the particular invoice with the specific buyer is denied and the certifier is notified.

The to-be process includes a sub-process called "compare aggregate volumes" and concluded into a smart contract. It compares the purchased amount of timber to the sold amount of charcoal with regard to the conversation rate. If the comparison brings out that higher volumes of charcoal are sold versus the volumes of timber bought, then potentially fraudulent activity is detected. In parallel, the smart contract "compare conversion rates" is analysing the conversion rates. In case there is a large difference between actual and standard conversion rates, then potentially fraudulent activity is detected again. As the process requires information about incoming invoices from suppliers and outgoing invoices issued to buyers, processing singular invoices is not feasible. A bi-weekly timer was introduced to the process to overcome this issue. The outputs of aggregate volumes comparison and conversation rates comparison are sent to the third smart contract, "process comparison results".

The smart contract sends out warnings and notifications whenever a fraudulent activity is detected.

The proposed to-be process tackles the constraints related to the manual completion of the auditing process. Firstly, the information about invoices needs to be provided within two weeks, it is encrypted and stored on the chain, thus, making data manipulation extremely hard, and as a result, constraining the opportunities of noncompliance. Second, with the introduction of automated audit, all invoices are registered and reviewed by the system (versus only a random sample in case of onsite visit), hence the results are trustworthy and more accurate. Third, as the need to focus on invoices is eliminated, the time previously required for this process is now available for auditors to conduct a more thorough audit of aspects other than invoices. Finally, as the frequency of audit is much higher (biweekly versus previously annual), any non-compliance is detected earlier, and corresponding actions can be taken to stop further trade on uncertified timber or charcoal.

This chapter concluded the case study and the proposed process enabled by blockchain technology. The discussion about the performance of the proposed to-be process is presented in the following chapter.

5 Discussion

In this chapter, the redesigned timber-to-charcoal audit process is studied with the application of widely used performance metrics to evaluate the process. A business process is usually measured based on four criteria: time, quality, costs, and flexibility [26]. To assess the throughput time, the business process simulation method was used. While quality, cost, and flexibility of the process are discussed based upon Reijers' and Mansar's [10] summary. The chapter includes a review of the validity of the proposed heuristics and limitations related to the work. To state that a redesigned process is improved, the throughput should be faster (process carries out in a shorter time), the quality should be higher (fewer mistakes), the costs are lower and the process is more flexible to accommodate variants and exceptions [10], [26]. Nevertheless, if we map these criteria alongside a coordinate plane, they often face opposite directions, i.e., improvement in speed may result in a quality decrease, or higher flexibility may increase the costs [10]. For example, empowering employees can reduce time and costs, but it may also result in lower quality of the process output. Such compromise is also known as the "devil's quadrangle" [10].

To evaluate the time of the new model business process simulation method was used as it provides extensive quantitative measurement of key performance indicators of the process [48]. In addition, a successful simulation ensures the validity and completeness for the underlying process, as in case of incomplete processes simulation tokens can be stuck in specific tasks or the simulation may not run at all. The processing time for each activity is presented in Table 5.1 for both existing and redesigned processes. The parameters of simulation for the existing process were defined in accordance with the data provided by Nepcon. This is an important aspect, as using expert opinions contributes to more accurate results [26]

The simulation was run for a one-year-period and 25 audits to be completed by one auditor. This means the parameter of interarrival rate was 80 working hours (2 workweeks) with the standard deviation of 16 workhours (2 workdays). As the to-be process assumes that all (or majority) certifying companies are part of the solution, the simulation was run for four companies and 100 audits (25 per company). In the to-be process, invoice data needs to be updated on a biweekly basis. Meaning that each company makes approximately 24 uploads per year. That is why the to-be process simulation is run for 2400 instances. The interarrival rate is 0.88 (with a standard deviation of 0.2 working hours). The results of the simulation reveal that the redesigned process has a shorter average cycle time, **approximately 47%.** Particularly, the average cycle time for the existing process is 288 working hours, while the to-be process runs in 153 hours. In the as-is process manual review of a random sample of invoices is time-consuming, and other contributors to longer cycle times are the scheduling activities and waiting time. In the case of the redesigned process, the processing time is minimal as most activities are automated and carried out by smart contracts, thus the tasks are carried out in a matter of seconds. Yet, due to the necessity to have a two-week waiting time, the average cycle jumps to 153 hours.

Table 5.1 Simulation Parameters Per Activity

Tasks	Duration Mean (Std Deviation) Units	Tasks	Duration Mean Units
Check a random sample of invoices	60 (15) min	*Sub-Process: Register Invoice Data*	
Check suppliers against the FSC database	20 (5) min	Check buyer's certificate status	2 sec
Conduct further investigation	180 (60) min	Check supplier's certificate status	2 sec
Examine aggregated volumes	40 (10) min	Register Invoice Data	2 sec
Propose time for the audit	7 (2) min	*Sub-Process: Compare aggregate volumes*	
Send audit templates	7 (2) min	Calculate aggregated volumes	2 sec
Write and submit a report	240 (30) min	Extract purchased volumes	2 sec
Gateways	**No/Yes**	*Sub-Process: Compare Conversion Rates*	
Exclusive gateway (XOR): Date accepted?	10%/90%	Calculate implicit conversion rates	2 sec
Exclusive gateway (XOR): Volumes match?	5%/95%	Compare conversion rates	2 sec
Intermediate events	**Mean (Std Deviation) Units**	Extract historic conversion rates	2 sec
Audit date	10 (2) days	*Sub-Process: Process Comparison Results*	
Response received	120 (10) min	Compare results	2 sec
		Gateways	**No/Yes**
		Exclusive gateway (XOR): Valid? (Sub-Process: Register Invoice Data)	3%/97%
		Exclusive gateway (XOR): Valid? (Sub-Process: Register Invoice Data)	5%/95%
		Exclusive gateway (XOR): ok? (Sub-Process: Process Comparison Results)	5%/95%
		Intermediate events	**Duration Distribution**
		Every 2 weeks	0.1-13 Days, uniform

The ideal **quality** of the timber-to-charcoal auditing process requires discovering and preventing all cases of fraudulent activity, such as selling non-certified timber or timber-related products as if they are certified. In the redesigned process, the frequency of audits is changed from once a year to once every two weeks, contributing to better quality from 2 different angles. First, in the redesigned process the invoices are checked on a bi-weekly basis, so any non-compliance can be detected within 2 weeks, while in the existing process a fraudulent activity can go undetected for up to 12 months. Second, in the to-be process, all invoices are audited while in the current process only a random sample is reviewed manually. This leaves less room for mistakes. And, as the supplier's and buyer's invoices are compared against each other, then it is less likely that the invoices can be tampered with.

When it comes to the **costs**, the introduction of the new process and new software solution requires large investments, increasing overall audit costs. Nevertheless, the new software solution and scaling up the auditing process would not be possible without the investment. Also, it is noteworthy that the structure of costs changes drastically from salary costs for manual tasks to hardware and software maintenance costs for the new systems.

The **flexibility** of the process is decreased. The current process being predominantly manual allows very high flexibility. The proposed to-be process, on the other hand, runs on smart contracts that are built based on sets of pre-defined business rules and logic. This leaves little room for deviation and exceptions. Yet, it is important to note, that in an audit process it is more critical to strictly comply with the procedures and regulations rather than the flexibility of the process.

Table 5.2 *The impact of the heuristics on performance parameters*

Heuristics	**Impact direction based on underlying best practices** (↗ -improvement, ↙ -worsening)				**Impact of the heuristic on the timber-to-charcoal to-be process.**
	Speed	**Quality**	**Cost**	**Flexibility**	
H1	↗		↙	↗	Viewing the participants as one entity improves the speed and the flexibility, yet can result in higher costs to maintain inter-organizational communication.
H2	↗		↗	↙	Integrating the processes improves throughput time by minimzing the need to handover between organizations and results in less costs. Flexibility of the process can suffer.
H3	↗ ↗ ↙	↗ ↗ ↙ ↙	↙ ↗ ↗	↙ ↙	Focusing on the outcome of escalating suspicous cases allows to increase the speed of the process, and somewhat improve the quality. The flexibility again will be lower as suspicious cases would have to be handled separately.
H4		↙	↗		Using the blockchain to outsource business processes can contribute to less costs but may have a negative impact on quality.
H5	↗		↗	↙	

H6	↗ ↗	↗ ↙	↗ ↗	↙ ↙	When looking at the processes with a bigger scope, task elimination, triage or requencing and parralelism become applicable to larger number and larger scale activites. This can strongly contribute to improvement of the thoughput times, as well as quality and costs.
H7	↗ ↗ ↗ ↗	↙ ↗ ↗ ↗	↗ ↙	↙ ↙	
H8	↗ ↗	↙	↗ ↙	↙	
H9	↗		↗		Utilizing trusted parties and using oracles to get the information from them can help to improve the speed of the process with less costs.
H10	↗		↗		
H11	↙	↗ ↗	↗ ↙		Introducing controls for data accuracy may have a negative impact on time, but it would strongly contribute to the quality of the data, thus the process.
H12	↗		↗		Storing often used data may help to improve time and reduce costs of obtaining the data for every transaction.
H13	↗	↗	↗		Uzing oracles for data capture and sharing it amongst the participants can contribute to speed, quality and reduce costs.
H14	↗	↗ ↙			Uzing blockchain tockens for asset management can improve the speed but may have somewhat negative impact on quality.

The Table 5.2 displays the impact of each employed heuristic on speed, quality, cost, and flexibility considering the underlying best practices for the specific heuristic. Since some of the heuristics combine several best practices, then the impact can potentially also have different direction. In the last column of the table, we discuss the impact of each heuristic on the timber-to-charcoal to-be process.

5.1 Threats to Validity

In the previous chapter, the applicability of the proposed redesign heuristics for a blockchain-based solution was exhibited with a case study. Though the contextualized best practices have been introduced, nevertheless, the contribution of this paper can be limited due to several factors. A case study as a research method brings its own threat to validity as its reliability and external validity are questionable [43]. The latter refers to the generalization of the results and findings of the case study outside of its setting. Since the usability of heuristics was demonstrated with a case study, the generalization of the results can be restricted. Another factor is that the outcome is reliant on the practitioners and the objective of the study. Thus, the repetitiveness can also be limited. Redesigning a business process entails a certain level of creativeness, meaning that each process analyst can bring their own experience and approach. Thus, the redesign process can be replicated yet the outcome may be different.

When discussing reliability, the key aspect that stands out is how strongly the outcome is reliant on the researcher. The question is whether the results produced by other researchers would resemble the one proposed in this study. To address this issue, domain experts were involved with the purpose of validation of the proposed heuristics. Nepcon is also considering the proposed case study solution as a prototype for a blockchain-based solution.

6 Conclusions

In this research, the most well-known best practices of business process redesign were contextualized to become usable for redesigning inter-organizational processes with the implementation of blockchain-based solutions. The best practices were studied, and adapted intro redesign heuristics enabled by the capabilities of blockchain and smart contracts. The heuristics in the first group are enabled by the capability of blockchain to provide immutable shared data storage. They call for shifting the perspective from business processes within one organization to a larger scale inter-organizational process. The heuristics in the second group rely on the computational capabilities of blockchain, and call for using smart contracts to store data, carry out process activities, or sub-processes, and connect different parts of the process. The third group includes heuristics which focus on data management. These guidelines utilize the possibility of communication between untrusting parties enabled by blockchain. The fourth, and last, group of heuristics employs the capability to digitally represent physical assets.

The usability of proposed heuristics was investigated by applying them to a case study. In this case study, the process of auditing the invoices in the supply chain of certified charcoal and timber-related products was redesigned with the application of proposed heuristics to run on a blockchain-based solution. Even though the results of a case study cannot be fully generalized, the findings exhibit that the adapted heuristics are applicable to employ the enabling capabilities of blockchain and smart contracts while redesigning the business process.

A case study as a research method comes with restraint to which extent the findings from a case study can be generalized, thus, the contribution of this research can be limited as well. Nevertheless, the redesign heuristics can fuel the thinking process of the analysts and practitioners while they work on introducing a blockchain-based solution and encourage them to not just replace the existing technology but rather innovate the process itself. The research can be further continued in the context of proving the relevance of proposed redesign heuristics by executing the solution on Hyperledger Fabric.

7 References

[1] L. Carlozo, "What is blockchain?," *J. Account.*, vol. 224, no. 1, p. 29, 2017, [Online]. Available: https://search.proquest.com/openview/6aeb105a9f99672496ae2fc72dc53c2e/1?cbl=41065&pq-origsite=gscholar.

[2] V. Vallois and F. A. Guenane, "Bitcoin transaction: From the creation to validation, a protocol overview.," 2017.

[3] J. Mattila, "The Blockchain Phenomenon – The Disruptive Potential of Distributed Consensus Architectures," 2016. [Online]. Available: https://www.etla.fi/wp-content/uploads/ETLA-Working-Papers-38.pdf.

[4] S. Nakamoto and others, "Bitcoin: A peer-to-peer electronic cash system," 2008.

[5] Y. Yong and F.-Y. Wang, "19th International Conference on Intelligent Transportation Systems (ITSC)," in *Towards Blockchain-based Intelligent Transportation Systems*, 2016, pp. 2663–2668, [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7795984&tag=1.

[6] J. Ladleif, M. Weske, and I. Weber, "Modeling and Enforcing Blockchain-Based Choreographies BT - Business Process Management," 2019, pp. 69–85.

[7] J. Mendling *et al.*, "Blockchains for business process management-challenges and opportunities," *ACM Trans. Manag. Inf. Syst.*, vol. 9, no. 1, p. 4, 2018.

[8] F. Milani, L. García-Bañuelos, and M. Dumas, "Blockchain and business process improvement.," *BPTrends Newsl.*, 2016.

[9] N. D. P., "Managing benefits from information technology," *Inf. Manag. & Comput. Secur.*, vol. 3, no. 5, pp. 29–35, Jan. 1995, doi: 10.1108/09685229510793022.

[10] H. A. Reijers and S. Liman Mansar, "Best practices in business process redesign: An overview and qualitative evaluation of successful redesign heuristics," *Omega*, 2005, doi: 10.1016/j.omega.2004.04.012.

[11] Ž. Turk and R. Klinc, "Potentials of blockchain technology for construction management.," *Procedia Eng.*, no. 196, pp. 638–645, 2017.

[12] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends," 2017, [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8029379.

[13] M. Crosby, Nachiappan, P. Pattanayak, S. Verma, and V. Kalyanaraman, "BlockChain Technology: Beyond Bitcoin," *Appl. Innov. Rev.*, no. 2, 2016.

[14] Morkunas, V. J., J. Paschen, and E. Boon, "How blockchain technologies impact your business model.," *Bus. Horiz.*, 2019, [Online]. Available: https://reader.elsevier.com/reader/sd/pii/S0007681319300096?token=A6622F34BA1409FD82447BDD0A3CFB9A0966A9FE5A156F83BA70234AD349EF2A5D232C5C0B7AB3EE3B6E85C78C31C7A7.

[15] P. Grover, A. K. Kar, and P. Vigneswara Ilavarasan, "Blockchain for Businesses: A Systematic Literature Review," in *Challenges and Opportunities in the Digital Era*, 2018, pp. 325–336.

[16] X. Xu, I. Weber, and M. Staples, *Architecture for blockchain applications.* Berlin,

Germany: Springer, 2019.

[17] X. Xu *et al.*, “A taxonomy of blockchain-based systems for architecture design,” in *2017 IEEE International Conference on Software Architecture (ICSA)*, 2017, pp. 243–252.

[18] X. Xu, C. Pautasso, L. Zhu, Q. Lu, and I. Weber, “A Pattern Collection for Blockchain-based Applications,” in *Proceedings of the 23rd European Conference on Pattern Languages of Programs - EuroPLoP ’18*, 2018, pp. 1–20, doi: 10.1145/3282308.3282312.

[19] X. Xu *et al.*, “The blockchain as a software connector.,” in *2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA)*, 2016, pp. 182–191.

[20] J. Eberhardt and S. Tai, “On or Off the Blockchain? Insights on Off-Chaining Computation and Data,” in *Service-Oriented and Cloud Computing*, 2017, pp. 3–15.

[21] K. Christidis and M. Devetsikiotis, “Blockchains and Smart Contracts for the Internet of Things,” *IEEE Access*, vol. 4, pp. 2292–2303, 2016.

[22] A. Ramachandran and M. Dr.Kantarcioglu, “Using blockchain and smart contracts for secure data provenance management.,” 2017. [Online]. Available: https://arxiv.org/pdf/1709.10000.pdf.

[23] D. Florian and L. Guida, “A service-oriented perspective on blockchain smart contracts.,” *IEEE Internet Comput.*, vol. 23.1, pp. 46–53, 2019, [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8598947.

[24] V. MORABITO, *BUSINESS INNOVATION THROUGH BLOCKCHAIN: The B3 Perspective*. SPRINGER, 2019.

[25] V. Shermin, *Token Economy: How Blockchains and Smart Contracts Revolutionize the Economy*. 2019.

[26] M. Dumas, M. La Rosa, J. Mendling, and H. A. Reijers, *Fundamentals of Business Process Management*, 2nd ed. 2018.

[27] A. Sharp and P. Mcdermott, “Workflow Modeling. Artech House,” *Inc., Boston, USA*, 2001.

[28] V. Gatteschi, F. Lamberti, C. Demartini, C. Pranteda, and V. Santamar\’\ia, “Blockchain and smart contracts for insurance: Is the technology mature enough?,” *Futur. Internet*, vol. 10, no. 2, p. 20, 2018.

[29] R. Hans, H. Zuber, A. Rizk, and R. Steinmetz, “Blockchain and smart contracts: Disruptive technologies for the insurance market,” 2017.

[30] Y. Chen, “Blockchain tokens and the potential democratization of entrepreneurship and innovation,” *Bus. Horiz.*, vol. 61, no. 4, pp. 567–575, 2018.

[31] O. López-Pintado, L. Garc\’\ia-Bañuelos, M. Dumas, and I. Weber, “Caterpillar: A Blockchain-Based Business Process Management System.,” 2017.

[32] W. M. P. van der Aalst and K. M. van Hee, “Workflow Management: models, methods and tools,” *Coop. Inf. Syst. MIT Press. Cambridge*, 2002.

[33] M. Hammer, “Reengineering work: don’t automate, obliterate,” *Harv. Bus. Rev.*, vol. 68, no. 4, pp. 104–112, 1990.

[34] R. K. Oliver, M. D. Webber, and others, “Supply-chain management: logistics

catches up with strategy," *Outlook*, vol. 5, no. 1, pp. 42–47, 1982.

[35] M. Attaran, "Exploring the relationship between information technology and business process reengineering," *Inf. Manag.*, vol. 41, no. 5, pp. 585–596, 2004.

[36] V. Scuotto, G. Santoro, S. Bresciani, and M. Del Giudice, "Shifting intra-and inter-organizational innovation processes towards digital business: an empirical analysis of SMEs," *Creat. Innov. Manag.*, vol. 26, no. 3, pp. 247–255, 2017.

[37] X. Zhang, D. P. Van Donk, and T. van der Vaart, "The different impact of inter-organizational and intra-organizational ICT on supply chain performance," *Int. J. Oper. Prod. Manag.*, 2016.

[38] W. M. P. van der Aalst and K. M. van Hee, "Framework for business process redesign," in *Proceedings 4th IEEE Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE'95)*, 1995, pp. 36–45.

[39] J. Peppard and P. Rowland, *The essence of business process re-engineering*. Prentice-Hall, 1995.

[40] M. Hammer and J. Champy, *Reengineering the Corporation: A Manifesto for Business Revolution*. HarperCollins Publishers, Inc, 2002.

[41] F. Milani, M. Dumas, R. Matulevičius, N. Ahmed, and S. Kasela, "Criteria and heuristics for business process model decomposition," *Bus. Inf. Syst. Eng.*, vol. 58, no. 1, pp. 7–17, 2016.

[42] M. Westerkamp, F. Victor, and A. Küpper, "Tracing manufacturing processes using blockchain-based token compositions," *Digit. Commun. Networks*, vol. 6, no. 2, pp. 167–176, 2020.

[43] P. Runeson and M. Höst, "Guidelines for conducting and reporting case study research in software engineering," *Empir. Softw. Eng.*, vol. 14, no. 2, pp. 131–164, 2009.

[44] R. K. Yin, *Case study research and applications: Design and methods*. Sage publications, 2017.

[45] B. Flyvbjerg, "Five misunderstandings about case-study research," *Qual. Inq.*, vol. 12, no. 2, pp. 219–245, 2006.

[46] B. Kitchenham, L. Pickard, and S. L. Pfleeger, "Case studies for method and tool evaluation," *IEEE Softw.*, vol. 12, no. 4, pp. 52–62, 1995.

[47] T. Koens and E. Poll, "What blockchain alternative do you need?," in *Data Privacy Management, Cryptocurrencies and Blockchain Technology*, Springer, 2018, pp. 113–129.

[48] M. G. C. A. Cimino and G. Vaglini, "An interval-valued approach to business process simulation based on genetic algorithms and the BPMN," *Information*, vol. 5, no. 2, pp. 319–356, 2014.

8 Appendix

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