Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process

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Abstract
The emergence of blockchain technology has created a number of potential innovations in handling business activities across various industries. However, few studies discuss the potential influence of blockchain technology from a business process re-engineering perspective. This study focuses on the feasibility and inceptive application of supply chain processes. We proposed a blockchain-based framework along with the use of an affiliated technology, i.e., smart contracts, to derive the feasible benefits of the supply chain process design. Through the illustrative design of an integrated process, we provide an achievable use case of the disintermediation of business processes via a conceptual, shared information ledger. This ledger not only facilitates the sharing of tracking information but also promotes a network for multilateral collaboration among supply chain members. The pursuit of transparency and accountability across supply chain processes can potentially influence decentralization and automation. A comparative analysis of the current and proposed frameworks is conducted to support the core reasoning of this study. Additionally, future implications on managerial practice and academic research are explored to provide pervasive suggestions for similar attempts in different sectors. We conclude with an evaluation of the potential influence of blockchain technology on supply chain management.

Keywords: blockchain; supply chain management; smart contract; distributed ledger; business process re-engineering

1. Introduction

With the advent of process automation, business operations have been transformed from manual operations into electronic communication and processing using information and communication technology (ICT). However, process design has long been confined to a centralized framework. Centralized operations involve a number of challenges associated with appropriate adoption of technologies, such as electronic data interchange (EDI), value-added network (VAN), business intelligence (BI), and big data assimilation (Schneider, 2017; Acharya et al., 2018; El-Kassar & Singh, 2018). Issues, such as poor efficiency, poor synchronization, and low coordination mitigate the efficiency and interoperability that exist between business participants. The emergence of a distributed framework, namely blockchain, has enabled not just the achievement of transaction transparency and open collaboration but the recording of peer-to-peer (P2P) transactions on a shared ledger. This has, in turn, ensured that the flow of information and currency may rely on the consensus of participating nodes without the need for a third trusted party, such as banks and clearing houses. Business process operations are moving toward a more trustless, coordinated, and automated global network, while simultaneously being redesigned to reduce intermediaries (Goertzel, Goertzel, & Goertzel, 2017).

Presently, although business processes may operate well within a centralized mechanism managing internal activities with individual local databases, there still exists a demand for transparency across processes and trust relationships among players (Vigna & Casey, 2016). For instance, real-time tracking in supply chains has long been of interest to reduce the unnecessary wait for the confirmation of information. Better performance can be achieved by utilizing a distributed system. Moreover, the disintermediation of

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supply chain processes enhances the overall efficiency when dealing with hand-offs, such as the transfer of ownership or status changes between two parties (Cecere, 2017).

Based on the concept of distributed systems, this study tries to answer the following research question: how can a re-engineered tracking process based on blockchain technology achieve information sharing and synchronization in a supply chain? This study aims to investigate an alternative private-chain design to enhance the transparency and distributed collaboration of supply chain processes. The research objectives include: (1) investigating the feasibility of a blockchain-based tracking process; (2) establishing a blockchain-based business process re-engineering (BPR) framework; (3) evaluating the potential benefits and values of such framework; and (4) shedding light for creating blockchain-based applications in different industries. We made comparisons between the incumbent and proposed processes to provide preliminary feedback for potential applications. This study serves not only as an attempt to test the potential possibilities of a new blockchain-based process design but also as an informative reference for academic research relating to the practical issues of supply chain management (SCM).

The remainder of this paper is organized as follows. Section 2 reviews previous studies focusing on the three major subjects, i.e., blockchains, smart contracts, and BPR. Section 3 presents the proposed conceptual framework for a re-engineered tracking process. Section 4 provides a comprehensive discussion and analysis of the potential impact of the proposed framework along with a comparison to the traditional model while Section 5 provides the concluding remarks.

2. Literature Review

2.1 The blockchain revolution and its impact

The blockchain was first conceptualized by Satoshi Nakamoto to solve the double spending problem inherent in electronic transactions (Nakamoto, 2008). Blockchain technology comprises the core system of Bitcoin, a digital currency that runs on a P2P network without any trusted third parties (Pilkington, 2016). A blockchain refers to an open, shared, and distributed ledger that enables information disclosure and responsibility attribution, and it is suitable for dealing with valuable information (Pazaitis, De Filippi, & Kostakis, 2017). With unique characteristics, such as the transfer of proprietary property, access control, and activity logging, blockchains enable the tracking for product and service flow among enterprises and across borders (Ethereum, 2017; Maesa, Ricci, & Mori, 2017).

While blockchain technology enables the real-time tracking of business activities and the synchronization of critical updated documentation, it has several issues, such as block size, efficiency (transaction throughput and latency), scalability, security, and privacy, that still require technical solutions (Mougayar, 2016; Xu et al., 2016). In business, several consulting reports suggest that blockchains can be used to reduce business frictions and expense, solve the inefficiency and vulnerability of transactions, and transform the overall ecosystem into a trustless one (IBM, 2017b). Blockchains have potential applications in various sectors, such as medical record management, SCM, banking and financial services, accountability and liability management in insurance, Internet of things (IoT), sharing economy, and distributed access control (Azaria, Ekblaw, Vieira, & Lippman, 2016; Condliffe, 2017; Lorenz et al., 2016; Casey & Wong, 2017; IBM, 2017a; Treleaven, Brown, & Yang, 2017; Euroclear & Oliver Wyman, 2016; Christidis & Devetsikiotis, 2016; Pazaitis et al., 2017; Maesa et al., 2017).

A promising application of blockchain technology is relationship management in global supply chains to cope with the complexity and diversity of multiple shareholders (Casey & Wong, 2017). Blockchains enable the calibration of critical data originally located in local databases affiliated with proprietary stakeholders across the supply chain. Blockchains also provide better transparency in tracking the status of property during processes (such as manufacturing, delivery or payment) and better flexibility for capital exploitation to obtain business value (Swan, 2015). From the perspective of information sharing, blockchains are uniquely able to act as a record medium capable of logging necessary information from value production to value actualization (Pazaitis et al., 2017). Thus, by using blockchain technology, a more dynamic and real-time supply chain could better utilize its business resources and achieve successful BPR (IBM, 2017b).

2.2 Conception and application of smart contracts

Enabling the deployment and execution of contract agreements via programming logic, smart contract is one of the most critical elements in the design and application of blockchains (Szabo, 1997a; Szabo 1997b;

Swan, 2015). Ethereum is one of the most popular decentralized platforms for smart contract applications. Users may design their contracts by defining data structures and functions in each contract and subsequently deploy the contract on the blockchain. Contracts are able to communicate with each other through their individual Ethereum addresses and application programming interfaces (APIs) (Ethereum, 2017). While several studies have proposed the storage of the addresses of relevant information and data on the blockchain (Azaria et al., 2016; Tian, 2016), only a few of them discuss using smart contracts for the design and implementation of business applications.

The unique characteristics of smart contracts, along with the characteristics of blockchains, improve the potential for the synchronization and automation of business operations and processes. Smart contracts that act as wrappers to increase the value of property gain more potential when paired with blockchains or other ledger technology (Treleaven et al., 2017). Such potential would enable the enforcement of legal contracts that represent the shareholders' understanding and intentions (Magazzeni, McBurney, & Nash, 2017). In this sense, smart contracts incorporated with blockchains, which are common, shared ledgers, could automate the transfer of the various types of ownership of assets, property, and value. This, in turn, would facilitate process design for business operations and could lead to a more visible and less-intermediated working scheme.

Despite the benefits of blockchain and smart contracts in reforming the supply chain operations, certain challenges to their widespread adoption still exist. These challenges include legal issues, lack of standards and protocols, privacy issues, and error intolerance. Arguments that smart contracts are no panacea for all supply chain cases doubt the applicability of smart contracts to certain scenarios as far as agreement type, scale, and scope within supply chain processes are concerned (Cottrill & Harris, 2017).

2.3 Business tracking process re-engineering in supply chains

BPR refers to the "rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance, such as cost, quality, service, and speed" (Hammer & Champy, 1995). BPR is an important aspect to consider while implementing new technologies (e.g., cloud services) with significant changes in the way organizations execute routine operations (Gupta et al., 2018). Over decades of theoretical development and practical implementation, enterprises have focused on the flow rather than essence of business logic when considering BPR. Traditional BPR involves centralized governance that may not actually utilize the full potential of blockchain technology; however, a complete transformation of this core logic would be more conducive to unleashing the potential of blockchain innovation as well as realizing the true spirit of BPR.

Based on inherent attributes of blockchains, researchers have suggested certain scenarios for blockchain applications (Euroclear & Oliver Wyman, 2016). Private blockchains are regarded as more suitable for business-to-business (B2B) applications when privacy concerns, such as identity anonymity, business competition, are considered. Moreover, compared to public blockchain design, it is not necessary to log confidential data related to business strategies on the blockchain. Tian (2016) proposed an architecture that utilized blockchains and radio-frequency identification (RFID) to track a food supply chain. The interoperability between blockchains and IoT devices (such as the RFID device) is beyond the scope of this study and should be considered in future research with an aim to enhancing our digital lifestyle with smarter and better automated intelligence. In this study, we proposed a blockchain-based operating process for taking advantage of the benefits of smart contracts as described in the next section.

The accessibility of information originally stored in supply chain participants' internal, centralized databases depends on further communication with other participants to obtain the required non-local information (Xu et al., 2016). In a blockchain-based re-engineered design, on-chain records and off-chain repositories interoperate with each other on demand. According to Xu et al. (2016), blockchains can function as a connector for the transfer of data between on-chain and off-chain systems to achieve information sharing. By adopting this concept, on-chain and off-chain working schemes are integrated, leading to more flexible, efficient, and effective business operations.

According to IBM (2017b), incumbent ecosystems predominately face three major frictions: information, interaction, and innovation frictions; blockchains have the corresponding capabilities to mitigate these challenges and reform business operations. An increasing number of blockchain pilot projects have been initiated to enhance the efficiency and transparency of supply chains by several industries (Kshetri, 2018). Such pilot projects include the collaboration of Nestlé and Walmart with IBM regarding food safety and traceability, as well as other endeavors, especially by shipping companies, such as Maersk, UPS, and Fedex.

3. Conceptual Framework for the Blockchain-based Tracking Process

With the evolution of global supply chains, researchers have described the major players in supply chains and their functions in the previous literature. Figure 1 illustrates a typical supply chain process presenting the flow of information, goods, and money (Min & Zhou, 2002). For further insight into the interactions among supply chain participants, a simplified model explaining the functions of players with similar attributes is needed. Supply chain tracking formulates the backbone of the entire mechanism and represents the business logic behind each business process.

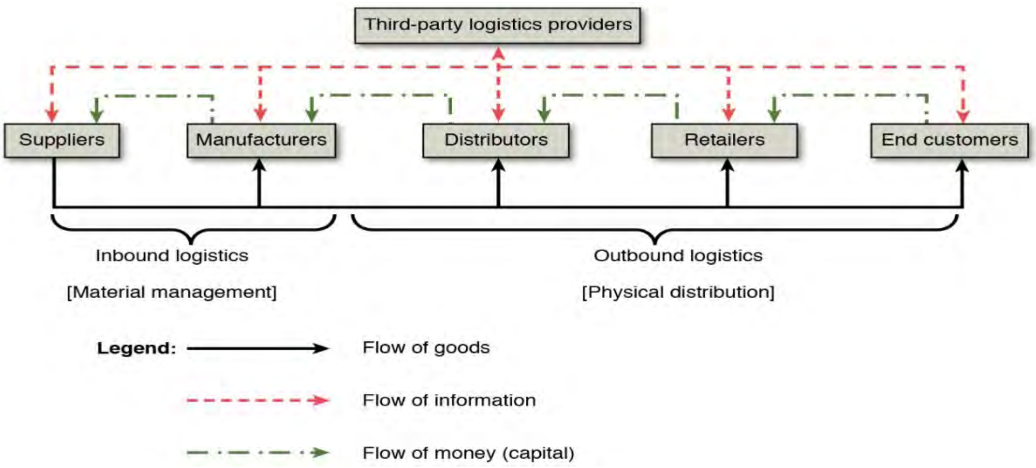

Figure 1 Illustration of typical supply chain process [Source: Min & Zhou (2002)]

Figure 2 illustrates the framework of the supply chain traceability mechanism that is widely used in business today. Traditional tracking utilizes tremendous labor resources for the confirmation and coordination of updated information regarding process status. Typical methods used for tracking range from phone calls, e-mail correspondence, and web-based services to advanced EDI, VAN or even enterprise resource planning (ERP) systems (Schneider, 2017). Enterprises utilize these different methods to manage the technical details of status tracking based on cost and strategic considerations. However, due to various factors, the use of a coordinated system based on the different available resources is not prevalent among incumbent enterprises, which in turn reduces the overall supply chain efficiency.

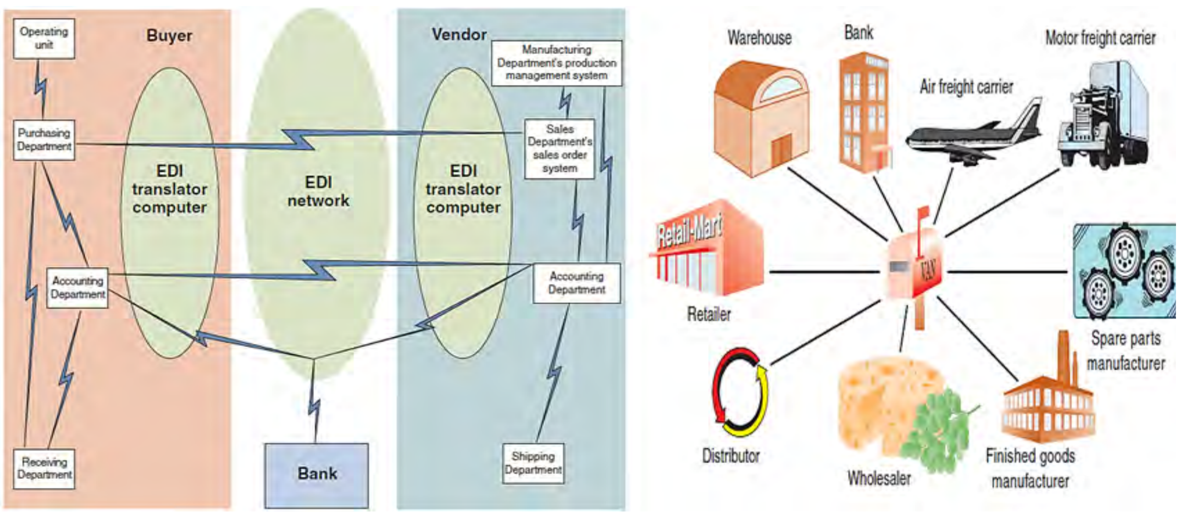

Figure 2 Traditional method of supply chain traceability (EDI and VAN) [Source: Schneider (2017)]

As a matter of fact, the current mechanism utilizes the pull system for the purpose of tracking. However, this method reduces transparency among supply chain participants. Data exchanges between multiple self-owned databases are often time consuming and expensive. A near real-time tracking system seems unavailable due to the business frictions that exist in each hand-off, while quick logistic status updates are difficult without manual queries and timely data updates. Prior research found that one third of business leaders would not trust the information they use to make decisions and large volumes of data sets were often required to identify useful underlying patterns from data-oriented activities in order to make efficient and effective business decisions (Acharya et al., 2018). Actually, from a managerial perspective, decision support along with the consecutive monitoring of process flow becomes difficult. For example, cash backlogs are created when inflexibility becomes an issue due to untimely delivery, which results in the inevitable loss of efficiency and potential profits.

3.1 The potential of blockchains in supply chains and their benefits in business processes

Several studies and consulting reports have described the key benefits of using blockchains in a supply chain environment (Kehoe et al., 2017; Laaper et al., 2017; Madhwal & Panfilov, 2017; Nowiński & Kozma, 2017; O'Byrne, 2017; IBM, 2017b). Most of them focus on the advantages of enhancing the transparency and visibility of tracking activities in business operations. Blockchains have several industrial applications in SCM, such as automotive supplier payment, meat traceability, electric power microgrids, contract bids and execution, cold chain monitoring, and IoT project (O'Byrne, 2017). A number of emerging use cases have been applied to the finance and insurance industries (IBM, 2017a; Schatsky, 2016). Cecere (2017) suggests seven use cases of blockchains in SCM, such as community registry, EDI replacement, lineage/track and trace, safe and secure supply chains, tracking social responsibility goals, supply chain financing, and document sharing. Similar efforts and studies also explored the use of blockchains with other auxiliary technology, such as the IoT and RFID (Christidis & Devetsikiotis, 2016; Condliffe, 2017; Kshetri, 2018).

With the growing interest in using blockchains and smart contracts, this study summarizes their potential capabilities and suitable use cases in SCM (see Table 1).

Table 1 Blockchain-based supply chain use cases [adapted from Euroclear & Oliver Wyman (2016)]

Type	Use Case	Supply Chain Example	Adoption Reasoning
Fundamental adoption	Property Tokenizing	Tangible/Intangible properties, e.g., products and services	Transparency and immutability
Independent use of blockchain	Data Sharing	Finance, insurance, and accounting	Irrevocable, node-verified mechanism
	Process Transaction	Transaction Payment	Disintermediation and simplified process
	Virtual-Reality integration	IoT application combined with smart devices, Logistics Tracking	Convenience and automation
Advanced adoption	Smart Contract	Business deals enforcement Property liquidities	Improved process, efficiency and capability
Critical mass of assets on blockchain	Monitoring of datasets	Supply and demand matching Data transits	Data comprehension and exploitation

Based on the adoption use cases and rationale for using blockchains and smart contract technology, in Figure 3 we outlined the benefits of using a blockchain-based supply chain process in accordance with the core value of ICT innovation.

3.2 Blockchain-based tracking process: rationale and design

To mitigate inevitable friction in business and potential causes of hand-offs, an integrated framework combining blockchain technology and the currently practiced process was proposed (see Figure 4). There exist challenges hindering the timely tracking of process status, which in turn increase the payment period. To address this situation, the blockchain system may mitigate inherent limitations in legacy processes and provide many economic incentives for participants. For suppliers and logistics, the exemption from lengthy delivery time and physical checks has a corresponding influence on payments, which can be made without concern for the inaccuracy of process status. For buyers, supply chain efficiency could be improved by reducing the duration of pending cash backlogs.

The proposed value-added tracking process comprises several features in terms of design. First, supply chain participants share the ledgers via the blockchain system. Second, smart contracts, theoretically serving as state machines (Azaria et al., 2016), are responsible for tracking the status changes of all logistics-related information. Through the mutual registration of dual participants on smart contracts, which define the terms of agreement, participants can track a status change triggered by an automated event mechanism. The most updated process status could be tracked by or responded to in a timely manner by the relevant stakeholders since smart contracts may automatically activate information push mechanisms.

This design delivers notifications of status alterations to stakeholders that are registered on specific smart contracts. Thus, the most recent real-time notification of information changes (related to the trigger event) is achieved via a push rather than pull mechanism. This proposed blockchain system achieves a better level of efficiency for logistics and cash flow operations. With this integrated design, supply chain participants can save the costs associated with manual operations for the confirmation of traceability as well as the establishment of expensive information sharing systems, such as EDI and ERP systems.

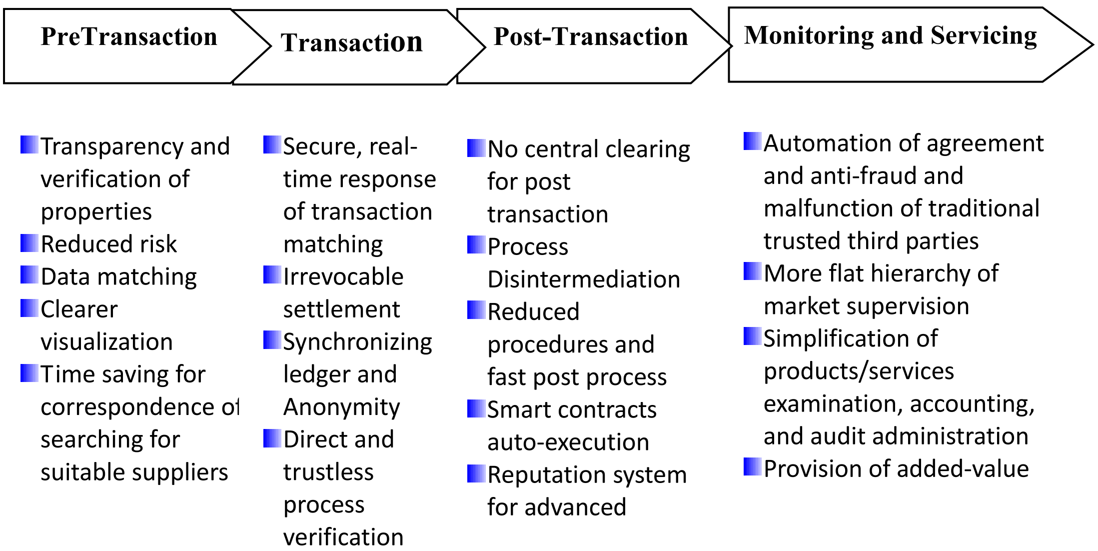

Figure 3 Benefits of using a blockchain-based process
[adapted from Euroclear & Oliver Wyman (2016)]

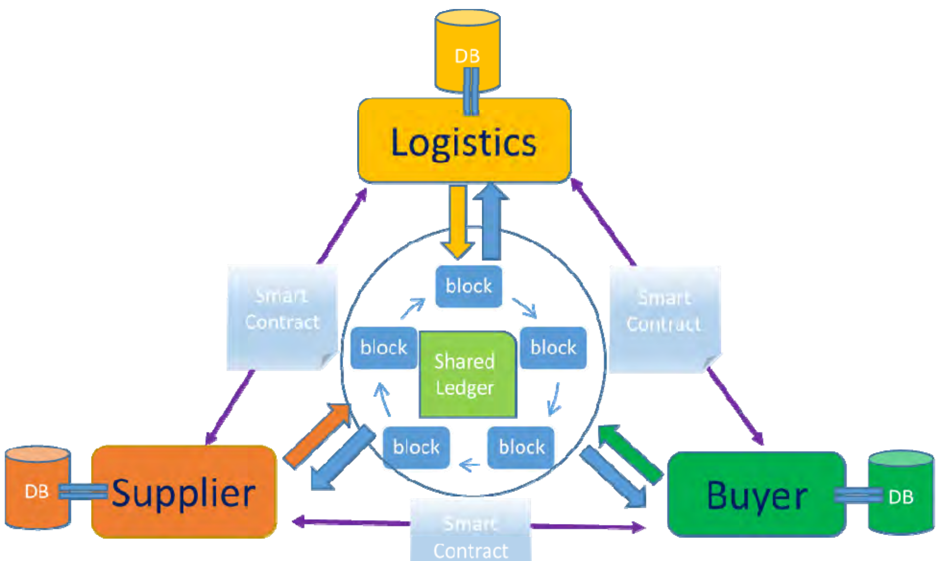

Figure 4 Conceptual framework of the blockchain-based tracking process (using push mode)

3.3 Process re-engineering with the proposed framework

Traditional tracking processes rely heavily on manual operations to achieve information synchronization among supply chain participants. Enterprises with more resources undertake expenditure to develop a centralized mechanism, such as an EDI or ERP system (Schneider, 2017; Gupta et al., 2018), to solve information synchronization issues among others. These systems improve efficiency but are unable to reduce the expenditure associated with the relevant ICT. Malicious alterations and cyber-attacks render difficulties for complete adoption of the whole ecosystem. Additionally, interference from centralized intermediaries that are supposed to increase the trust among participants, in turn causes uncertainty when they suffer system malfunctions due to tampering or fraud-related attacks.

Blockchain technology with its unique features provides the possibility to innovate process design. The main element required for building a decentralized network is the adoption of a shared ledger and the verification of transactions that comprise the contents of the ledger. Blockchain technology, as a distributed ledger technology, could leverage its potential to achieving synchronization of tracking information. This innovative thinking, along with the use of smart contracts, offers opportunities to reduce the endeavors and enterprise resources required to confirm process status, which in turn accelerates the execution of the next process. From a process re-engineering perspective, blockchain technology facilitates process automation and disintermediation via the use of smart contracts.

Smart contracts are computer codes that operate on the blockchain platform to execute the terms of agreement. Smart contracts, serving as state machines, are able to track the process status changes from suppliers, manufacturers, logistics service providers, distributors, and customers in a timely manner. Moreover, these contracts can be programmed to activate the commencement of the subsequent process, e.g., payment transactions. The core design of the proposed process is based on contract connections and interactions. Through the proper deployment of such contracts, labor forces and EDI systems could be more-or-less replaced or transformed to achieve process auto-execution. Nevertheless, process control points could be set for checking process status and thereby reduce costs associated with query and confirmation.

3.3.1 Tracking process redesign

From a macroscopic perspective, supply chain tracking focuses on the dynamic response of business activities from order to payment. In this study, we conceptually illustrate a centralized event-driven model (see Figure 5). Smart contracts are used by participants to connect and communicate with each other. Moreover, they provide delivery notifications of the latest updates regarding process status. In a centralized event-driven model, a specific contract is designated to function as an administrator that connects other smart contracts. Smart contract events, such as status changes from suppliers or logistics entities, are defined in every specific contract. Each of such contracts specifies various methods for updating state variables and maintains control of the system-level state variables. Any executed method will subsequently change the status and trigger events according to the pre-specified state transition events.

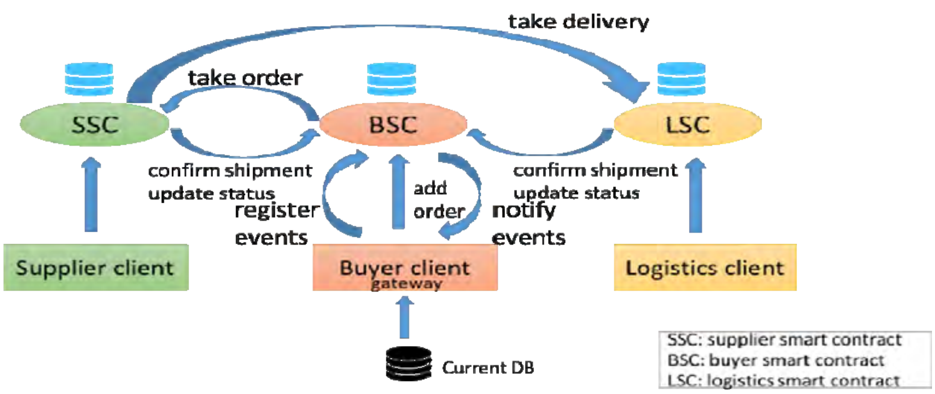

Figure 5 Centralized event-driven model [Source: Chang, Lu, and Chen (2017)]

When a user client registers the desired trigger events via a smart contract, the smart contract will trigger event notifications along with the status change. Traditional status inquiries are unnecessary since the smart contract pushes notifications to clients that are registered on the contract. The specific contract is responsible for the delivery of all pre-defined smart contract events. Any event-related information can be sent via the event mechanism to any clients who have registered for events on the specific contract.

As shown in Figure 6, the proposed framework implements six types of contracts that are embedded in the three major supply chain processes listed below:

1. Supplier, logistics, and buyer contracts in the transaction process
2. Payment contracts in the payment process
3. Query forwarder and query dispatcher contracts from external databases in the data accessing process.

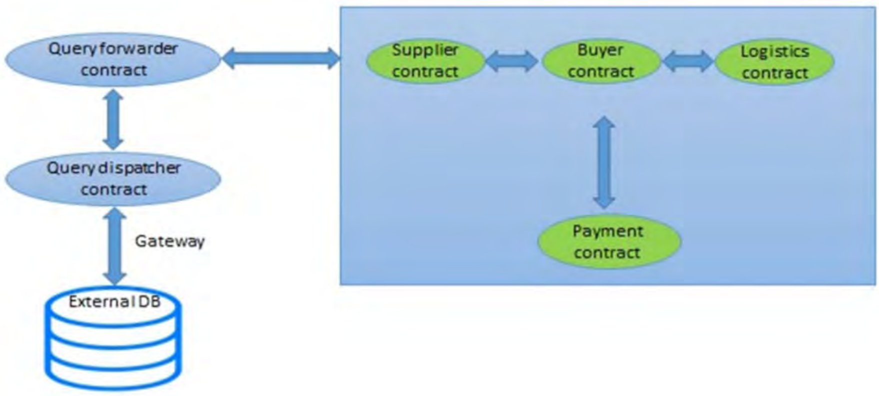

Figure 6 On-chain and off-chain data integration of the blockchain-based supply chain process [Source: Chang, Lu, and Chen (2017)]

These contracts are deployed to blockchain-based platforms, such as Ethereum or Hyperledger, and each contract plays a different role in the three major processes. The interactions and relationships between these contracts and their corresponding sub-processes are described as follows.

(1) The transaction process

In a B2B scenario, specific control points are introduced in the buyer contract's data structure to better track the supply chain processing status and to control overall efficiency. From the demand end, order identity (ID) and ordering time are recorded upon order placement. Next, the shipping process is activated, recording the shipping time once the suppliers, along with associated logistics entities, decide to accept the order. The inspection sub-process is started upon receiving the delivery status while the checking status (passed or not) and checking time are recorded. Finally, the buyer pays the suppliers and the logistics entities for the supply service, and then, payment status and payment time are recorded.

From a supply viewpoint, confirming shipping and delivery status, rather than setting control points to accurately updating buyers regarding status changes for each sub-process, are major concerns. To access status information or updates between contracts, necessary attributes, such as order ID, buyer, and each contract address, must be logged on to the chain. Additionally, the contract address and API must be provided to facilitate communication among contracts. Replacing and emulating the role of centralized administrator, the buyer contract specifies functions for the supplier and logistics contracts to update the status and to confirm shipment via event notifications. Similarly, once the physical inspection upon delivery is fulfilled and payment is completed, the buyer contract updates the latest status and issues related payment information to the suppliers and logistics entities.

(2) The payment process

The payment contract is specifically designed for the payment process to avoid incomplete payments. In the centralized event model, the buyer contract governs the authority to forward payments to supplier and logistics contracts. However, in the payment process, complete payment must be made without missing any items since payments have atomic characteristics. Therefore, to enhance the security and ensure completeness of payments, we propose a payment contract to execute payment activity. Consider the supplier and logistics contracts as a huge payment unit using the holistic payment method. In this payment contract, we execute a one-time payment to avoid payment incompleteness.

(3) The data accessing process

To enhance the data processing efficiency of blockchains, certain data is optionally selected to be maintained on-chain based on tracking concerns and smart contract structure, while others are left in off-chain databases. Integrating these on-chain and off-chain databases and considering the incapability of directly calling an external database's API, the proposed framework utilizes two additional smart contracts to connect the blockchain with external databases. To access the required data and provide feedback to the designated smart contract, query forwarder and dispatcher contracts were designed, and these are described in the next paragraph.

The query forwarder contract functions as an information carrier. This contract carries demands issued from the clients of each smart contract for gaining access to external data. As a channel that collects outgoing demands, the forwarder contract registers on the dispatcher contract for event notifications and data feedback. Other smart contracts' clients obtain status change notifications in the same manner once they register on the dispatcher contract. In this sense, the query dispatcher contract spreads and balances the contract's load capacity via scattering and distribution to different contracts to improve access efficiency when the data is too large to load. Finally, the dispatcher client acts as a gateway to access the data from off-chain databases when they are informed of new query orders. The above description elucidates the functions of the proposed framework and enables the communication between on-chain and off-chain databases.

3.3.2 Influences of the centralized intermediary on the distributed network

The transfer of property ownership and real-time traceability in supply chains have been topics of academic and practical interest. Based on the illustrative framework, the re-engineering process focuses on the transfer of value and how it is conducted through the realization of a more decentralized process design. Traditional hand-offs and business frictions have long been hindrances for supply chain participants. Due to these hurdles, a major concern of the centralized process is process efficiency and visibility. To eliminate centralized authority and enhance process transparency, the implementation of a more distributed process can affect the mode of collaboration among participants.

The overall supply chain process deals with huge amounts of data transfer. Traditionally, this task is conducted by a labor workforce or an EDI system. The major concerns regarding traceability, especially for shippers or third party logistics (3PL) industries, include obtaining real-time responses and information exchange. The growing demand of a dynamic marketplace cannot be met by an outdated EDI system or manual operations due to cost and efficiency considerations. The application of blockchain technology eliminates the need for a labor workforce and eliminates the reliance on EDI or ERP systems. By utilizing a shared ledger rather than EDI or ERP systems, businesses are more likely to collaborate based on synchronized information, thus lowering the costs associated with ICT maintenance. Greater efficiency and transparency are also achieved through inherent tampering-proof mechanism of blockchain technology.

Additionally, incorporating smart contracts facilitates the process workflows, such as event notifications, and transfer of value or property. Combined with blockchain technology, the proposed framework offers an alternative mechanism to cope with data stored individually on each participant's local system and the issue of synchronization. A similar design was illustrated by Hyperledger's business process management cases (Auberger & Kloppmann, 2018). Actually, blockchain technology can also solve issues of disclosure and accountability among unsynchronized parties (Casey & Wong, 2017). In other words, it provides a trust mechanism for the multiple players in the supply chain ecosystem. However, the pathway to the full adoption of such distributed ledger technologies is still blocked by several obstacles such as technological development and governance, interoperability, and legislative issues (Casey & Wong, 2017).

3.3.3 Process re-engineering on demand

Compared to the centralized, event-driven model, smart contracts could also be designed in a more distributed manner. In a self-contained event model (see Figure 7), each contract manages its own state variables, and should any status change occur, it sends event-related information to any clients who have registered for events in the specific contract. Each contract provides its own updated state variables for exchange in order to emit events. By defining the events that are triggered after any contract status change in the contract, desired notifications are sent out correspondingly. Any client needing an alteration alert can register for the events pre-defined on different contracts and can gain information from various sources.

Accordingly, clients shall gain access to different event notifications from different contracts. In this self-contained event model, every contract can control its status change and send corresponding event notifications. Regarding the payment process in such a distributed model, the suppliers pay the logistics entities, while the buyers pay the suppliers. Each supply chain participant can choose their favored payment method, either traditional currency or cryptographic currency.

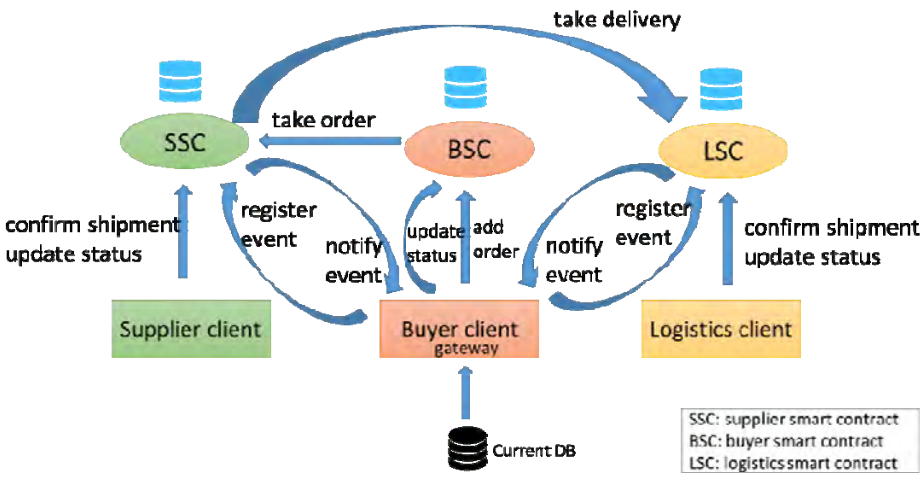

Figure 7 Self-contained event-driven model [Source: Chang, Lu, and Chen (2017)]

4. Discussion

4.1 Market value

Compared to the blockchain-based scheme, the current workflow possesses a lower level of automation in managing supply chain processes. Users need to query the real-time status of many processes via the pull mechanism. To improve the degree of automation, we proposed a blockchain-based framework to control the important steps in supply chain processes by using an automatic tracking mode (enabled by smart contract functions). Replacing the pull mechanism with the push mechanism can improve the efficiency of both business operations and SCM.

Traditionally, the centralized business model has long governed the trade world wherein the scale of transactions mainly focuses on B2B scenarios. However, with the advent of blockchain and smart contract technology, there are emerging prospects for a more efficient system than the traditional centralized business system. This study aims to provide a multi-faceted perspective based on the participants' demands. Supply chain participants, such as suppliers, logistics entities, and customers, can each issue his/her own demands to this decentralized platform. A more efficient response from the proposed framework could offer opportunities to manipulate the traditional business process. Without centralized authorities acting as intermediaries, transactions between brokers or arbitrators and supply chain players can be achieved upon automatic fulfillment of contract conditions. These contract conditions are designed based on the business logic underlying various business processes. Although confined to the current technological limitations, this study provides a possible parallel design using an incumbent database mechanism to access data that has not necessarily been requested to be put on-chain. In recent studies, such as Herbaut and Negru (2017), the service network chain has demonstrated various applications of smart contracts in different industries and in service delivery.

Furthermore, a request issuer can announce his/her order through status changes via the event notification mechanism. Players that are interested in these requests become aware of the demands from the issuer via automatic notifications based on the earlier registration of corresponding contracts. Supply chain information tracking could facilitate the flow of information among players. Moreover, it is possible to match suppliers and buyers through further transformation of this system. This timely response enables business process automation; the lack thereof has formerly been a hindrance for many incumbent players. This prototype enters the process flow into a brand new phase, thereby reducing the role of traditional intermediaries along with the costs of time and money.

The implementation of smart contracts creates more liquid cash or capital flows due to the automatic check inherent in the operation of such a system, which enables the forecast and prompt reply of logistics status. Previous studies have illustrated the potential of timely feedback in the provision of commodities or services via the implementation of IoT technology. Combined with the proposed system, businesses can facilitate their cash flows through the embedded automated characteristic of a distributed shared ledger, which records changes in logistic status, as it can control the flows of information and cash. A subsequent payment process can be initiated based on triggers defined in the contract to initiate payment to individual stakeholders in the supply chain.

In the applied scenario, the B2B model could be extended to multiple participants, wherein all interested parties in the supply chain are aggregated to join in the maintenance of the distributed ledger system. First, different parties issue their requests on the shared ledger system, i.e., via the event mechanism, and users get eligible responses from potential suppliers. With the automatic check with pre-set conditions, the supply of goods or services from suppliers is completed and activated through condition fulfillment. Next, business logic notes the progress of the flow of logistics or capital. Seamless and consecutive transactions are automatically conducted via smart contract technology. In such a design, the number of redundant intermediaries, such as brokers or arbitrators, can be reduced along with costs. Compared to the legacy incumbent system, the proposed system is free from concerns regarding artificial manipulations such as malicious tampering and transaction risks.

4.2 Evaluation of the proposed framework in regard to business operation

Since the proposed value-added blockchain system accesses the same order ID data existing in the current system, a parallel method can be used to compare the performance between the current and blockchain-based systems (see Table 2). By setting control points for the process from order placement all the way to payment, various important factors at various control points can be used to inspect advantages and disadvantages in the proposed blockchain-based system. Actually, the proposed blockchain-based process is not only a working prototype but a real business implementation to conceptually analyze and discuss potential influences on the supply chain. Therefore, the characteristics of the current and the blockchain-based processes are elucidated by checking typical factors, including traceability, data storage, privacy, cost reduction, cash liquidity, payment, and degree of automation, in the supply chain process.

Table 2 Comparison between traditional and proposed supply chain tracking processes

Process	Traditional	Centralized Event	Self-contained Event
Database Mechanism	Separate Local, Centralized	Distributed, Decentralized	Distributed, Parallel Method
Attributes, Pros, and Cons:			
Business pattern	Mainly B2B	Multi-users	Multi-users
Target	Vertical stream	Multi-players	Multi-players
Business Logic	Pulling	Pushing	Pushing
Time Cost	Waiting & pending	Saving	Saving
Orientation	Supplier (one way)	Customer (dual)	Customer (dual)
Participants	One-to-One	Many-to-Many	Many-to-Many
Media	Brokers; Catalog	Peer to Peer	Peer to Peer
Mechanism	Phone; E-mail; Website	Smart contract event notification	Smart contract event notification
Efficiency	Poor	Improved	Improved
Transparency	Low	High	High
Transaction	Time Consuming	Automated	Automated
Payment	Verification	Automatic	Automatic
Traceability	Poor	Instantaneous	Timely
Data storage	High	Low	Low
Privacy	Medium	High	High
Liquidity	Low	Moderate	High
Degree of automation	Low	High	High
Business process	Legacy centralized	Distributed	Distributed

Factor 1: Traceability

To solve the issues of real-time tracking, the proposed framework encourages participants to have their own smart contracts. A smart contract can communicate with other contracts to directly access information or even enable automatic notifications through the event mechanism. Therefore, a blockchain-based system enables instant tracking, which is faster and easier to use.

Factor 2: Data Storage

By combining on-chain data sources with off-chain systems, the recording of all data on the blockchain mapping table becomes unnecessary. To avert a waste of storage capacity and extra charges for transaction fees, only crucial data such as relevant logistics and payment status is logged on the blockchain. The proposed framework focuses on tracking shipment status changes, checking payments, and recording time.

Factor 3: Privacy

The current process performs reasonably well in maintaining privacy since data is stored in databases as compared to the public-chain based process. Information with confidential and personal privacy concerns is not suitable for storage on a public blockchain. Private-chain is favorable for enabling companies to manage their members' identities due to the need of privacy. Moreover, a private-chain running via a permission mechanism could achieve better access control by assigning different levels of permissions to users requiring access to authorized data. In so doing, private-chain users are well-regulated in accessing only pre-authorized data, thereby making information access more secure and effective.

Factor 4: Cost Reduction

The proposed process updates the status on smart contracts and records the delivery status on the blockchain. Frequent inquiries about tracking status are reduced and cost reduction is possibly attained with only carefully selected data logged on-chain.

Factor 5: Cash Liquidity

The buyers' payment reserve before the delivery of ordered goods has long been a supply chain pain point since cash liquidity is relatively poor. In a blockchain-based process, timely tracking enables the monitoring and controlling of the shipment status, consequently mitigating the cash backlog problem and improving cash liquidity.

Factor 6: Payment

Payments can be made utilizing traditional cash or an Ethereum wallet. Payment transactions are automatically conducted upon receipt of status updates regarding shipments and inspection confirmation. Transactions verified by smart contracts using the public key infrastructure mechanism can provide proof against anonymous tampering/forgery. Double spending and high transaction fees are expectedly averted.

Factor 7: Degree of Automation

Hurdles, such as business friction and hand-offs, affect the current incumbent process flow. Users need to query the real-time status of many processes utilizing the pull mechanism. The blockchain-based process enables the control of important steps in supply chain processes by using the automated tracking mode which is enabled by smart contract functions. Replacing the pull mechanism with the push mechanism for status updates can improve the efficiency of business operations and SCM.

4.3 Discussion on efficiency: a recap

Unless the efficiency of our blockchain-based system is acceptable, the system design will not be practical. Several efficiency concerns about blockchain system substantially influence the design of our system. First, a properly configured centralized database is, in many cases, more efficient (in terms of higher transaction throughput and lower latency) than a blockchain system (Christidis & Devetsikiotis, 2016). However, Zheng et al. (2018) found that a transaction using blockchain technology may achieve a practically acceptable level of service efficiency in a decentralized fashion, and private-chain has higher throughput and lower latency than public-chain. Accordingly, our proposed decentralized system uses private-chain for achieving service efficiency at an acceptable level in a distributed environment. Second, current SCM requires an extensive amount of manual inspections and paper-based transactions, which involve numerous intermediaries and inevitable business frictions, thus resulting in low service efficiency (Kuo & Liang, 2016). As described earlier in this paper, our blockchain and smart contract based approach can reduce manual interventions and automate SCM flows involving manual and paper-based transactions, thus greatly reducing business frictions and improving the service efficiency of SCM.

In terms of further efficiency improvement, we can explore alternative blockchain configurations including (1) blockchain platforms (e.g., Bitcoin, Etherreum, and Nxt), (2) consensus protocols (e.g., Proof-of-Work, Proof-of-Stake, and Byzantine Fault Tolerance), (3) on-chain/off-chain data storage and computation, (4) block sizes, and (5) degrees of centralizations (Cocco, Pinna, & Marchesi, 2017; Zheng et al., 2018). Indeed, research into such blockchain configurations has the potential to achieve higher efficiency, especially for creating desirable blockchain-based systems.

4.4 Theoretical contributions

Our study results provide theoretical contributions to academic research relating to blockchain-based applications design, especially with the demonstrated BPR approach to change incumbent business services and enterprise applications from centralized architecture to distributed peer-to-peer architecture inherent from the innovative blockchain technology. Theoretically speaking, the contribution of our paper does not lie in a radical change of the conceptual background but in the expansion of it to incorporate the emerging blockchain technology into a feasible distributed architecture with applications. In effect, we have demonstrated that the renovation of existing services and applications could be conducted by the proposed BPR approach to re-engineer the relevant and applicable portion of a business process instead of overhauling the entire process. In sum, our research demonstrates that we can not only design and implement blockchain-based services and applications using the proposed BPR approach but also integrate blockchain technology into existing BPR to harvest valuable benefits enabled by blockchain.

4.5 Managerial implications

The application of smart contracts and blockchain technology in SCM enhances transparency and trust among the participating parties. Major advantages, such as process simplification through re-engineering, enable business management with less intermediation. Maintaining distributed records in a shared ledger enables the flow of process status information without an exclusive centralized authority. Therefore, a more transparent and automatic ecosystem, which improves the operational efficiency of overall process in terms of cost reduction, time efficiency, and system automation, is established. Supply chain stakeholders act as participating nodes in the distributed network to enhance the scalability of the system.

It is foreseeable that businesses will focus on the development of smart contract systems that operate with or without the traditional systems. As a re-engineered design for business process could be conducted either with or without traditional systems, it is foreseeable that there might be “hybrid” or “pure blockchain” system designs in the progress of reforming business processes. However, a streamlined process that best meets the various demands requires more verification under practical circumstances. Businesses are encouraged to determine what information should be included on the chain and what should stay in the legacy system.

The proposed system, to some extent, applies the concept of BPR. Business processes are partly or wholly connected to the smart contract based operating environment. The application of blockchain and smart contract technology in SCM could transform the scope of business logic and practical operations.

From several online research sources, technical reports, and white papers from consulting firms, it is evident that there is a tendency toward using blockchains and smart contracts to revolutionize traditional thinking regarding business processes. A smarter, faster, and diverse participant feature has become the design focus of new architecture and business processes. Several studies or forecasts from consultant research have found that the incumbent system is inefficient due to black holes in the process. Black holes inherently exist in process flow interfaces, which are often inaccessible and difficult to modify. The major occurrence of black holes, such as handshakes and application interface points, stems from the transfer of ownership or status changes between two parties. Typical hand-off points, for example, shipment receipt, ownership transfer, returns or change in status, and others, become hindrances to information flow, and they tend to be a result of poor data translation and a lack of transparency among business processes.

The tendency for business applications to adopt blockchain and smart contract technology has emerged in applications in different industries, such as medical records, supply chain logistics tracking, insurance process simplification, and sharing economy. In the future, blockchain applications in different sectors could be integrated to facilitate an automated community or ecosystem. For example, SCM could be incorporated with healthcare and insurance sectors to formulate an integrated health bulk system. Smart contracts running on the blockchain platform can be used to track demand, supply, logistic status, medical documenting, and insurance claims, in a more streamlined service-supply process.

5. Conclusion and Future Research

This study aims to contribute to academic research by providing conceptual guidelines for practical business system design and implementation. With the proposed blockchain-based process, real-time tracking of logistic status and reduced costs associated with cash backlogs would be achievable. In this study, it was found that an alternative payment method using digital currency is feasible and may reduce payment lead time. Indeed, value creation can be achieved by incorporating a blockchain-based framework into the current business processes.

Additionally, this study provides business managers with not only a better event evaluation model from a smart contract perspective but also better efficiency from an operations management viewpoint. Using the proposed blockchain-based framework with smart contracts, supply chain managers can track the progress of logistics and cash flows and consequently develop corresponding strategies to mitigate inefficiency. In conclusion, the participants of the proposed process can benefit from transparent tracking and timely controls in the supply chain. Moreover, a speedy payment process and improved convenience can also reduce the costs of maintaining a money reserve.

The ability to incorporate blockchain technology into various business processes to improve the operational performance of supply chains in different industries in the foreseeable future is promising. When beginning the process implementation phase, order information can be obtained from off-chain databases and then the efficiency of the blockchain-based process can be compared to the current process to further investigate and confirm the performance of the proposed framework. After all, it is always more convincing for managers to choose the more efficient method. Using the proposed blockchain-based process to track the supply chain process in a timely manner and enhance the degree of supply chain process automation might be a good starting point for future research regarding the improvement of supply chain performance.

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