Production Planning & Control
The Management of Operations

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tppc20

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To cite this article: Atanu Chaudhuri, Manjot Singh Bhatia, Nachiappan Subramanian, Yasanur Kayikci & Manoj Dora (2024) Socio-technical capabilities for blockchain implementation by service providers: multiple case study of projects with transaction time reduction and quality improvement objectives, Production Planning & Control, 35:9, 978-991, DOI: 10.1080/09537287.2022.2128865

To link to this article: https://doi.org/10.1080/09537287.2022.2128865

Published online: 10 Oct 2022.

PRODUCTION PLANNING & CONTROL
2024, VOL. 35, NO. 9, 978–991
https://doi.org/10.1080/09537287.2022.2128865

Socio-technical capabilities for blockchain implementation by service providers: multiple case study of projects with transaction time reduction and quality improvement objectives

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ABSTRACT

The objectives of this paper are to analyse how blockchain can help in transaction time reduction and quality improvement in supply chains. It also aims to identify the social and technical capabilities needed by the service providers for blockchain implementation and how those capabilities vary between the projects. To achieve the above mentioned objectives, a multiple case study approach is followed, and data are collected from the service providers that have implemented blockchain technology with their customers. We conduct task-technology fit (TTF) analysis to assess the suitability of blockchain to address the tasks to be completed, considering customer needs. The TTF analysis shows that some additional technological solutions related to communication support and user experience design need to be implemented together with the blockchain platform. We then identify common social and technical capabilities, such as empathising with customers and system design, to facilitate implementation and contingent capabilities that vary across different types of blockchain implementation projects. We also develop a process model, a generalisable framework for blockchain implementation and related propositions. The findings from this study will provide guidance to the blockchain service providers to emphasise social and technical capabilities for quality improvement and transaction time reduction from blockchain implementation.

ARTICLE HISTORY
Received 17 April 2021
Accepted 19 September 2022

KEYWORDS
Blockchain; transaction time reduction; quality improvement; task-technology fit; socio-technical capabilities

1. Introduction

Blockchain is considered one of the promising technologies and has the potential to cause significant disruption in supply chains (Queiroz, Telles, and Bonilla 2019; Wamba and Queiroz 2022). Blockchain is defined as 'a digital, decentralized and distributed ledger in which transactions are logged and added in chronological order with the goal of creating permanent and tamperproof records' (Treiblmaier 2018). It is a peer-to-peer transaction platform that employs a shared data infrastructure that gets updated in real time, and has the capability to process as well as settle transactions quickly, without the involvement of any third party (Wang, Han, and Beynon-Davies 2019; Kamble, Gunasekaran, and Arha 2019). Blockchain can help in logging the action of each entity, together with location and time where a specific action has been performed (Kshetri 2018). Blockchain also allows entities to track the progress of shipments and deliveries, inducing trust among the supply chain entities (Kshetri 2018), and can reduce the overall cost associated with moving and tracking of products in a supply chain (Wong et al. 2020). The improvement of visibility in supply chains enabled through blockchain therefore facilitates legitimacy and authenticity (Wang, Han, and Beynon-Davies 2019). The visibility aspect can also ensure appropriate working conditions for the workers who are involved in manufacturing of products (Benstead et al. 2022).

A transaction is an exchange or transfer of goods, services, or funds; many business transactions involve multiple steps. The operations powered by blockchain require fewer manual steps in aggregating, amending, and sharing data, or providing regulatory reporting and audit documents. Therefore, blockchain can reduce the transaction cost and time for the respective parties (Tian et al. 2022). Moreover, quality assurance as a process can also involve multiple steps and can take time. Traceability and ensuring availability of process and product information using blockchain can help in quality assurance and improvement, and the time and costs associated with quality assurance. This may be achieved by using smart contracts (Morkunas et al. 2019).

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Product quality is one of the main requirements that customers have for products, especially when sourced from small organisations. Quality needs to be assured when delivering the products to customers. The real-time availability of product data on blockchain for every operation conducted at suppliers' premises can ensure that supplier conforms to the required quality standards (Wamba and Queiroz 2020). Therefore, product quality is perceived as a key performance measure, which can be assured by the use of blockchain (Karamchandani et al. 2021; Xu et al. 2022), and overall improvement in quality can be observed due to implementation of blockchain. Further, Vafiadis and Taefi (2019) found that different blockchain technologies have different strengths with regard to quality improvement in the supply chains. There is a need for in-depth study on the relationship between blockchain and quality improvement in supply chains. Furthermore, traceability of products requires quality assurance information where lack of trust between supply chain partners is a major concern. However, most of the studies are technology-driven and focus on technical feasibility aspects. There is a need to understand both the social and technical capabilities needed for implementing blockchain with the objectives of reducing transaction time and improving quality. Attaining transaction time reduction and quality improvement will require organisational work practices that ensure an alignment between social and technical systems underlying the blockchain implementation project. The attractiveness of using Socio-Technical Systems (STS) theory to analyse blockchain implementation projects is that the social core and technical core can be blended to investigate their concomitant effects on performance (Chaudhuri and Jayaram 2019).

However, despite the several benefits, the implementation of blockchain posts several challenges for organisations, such as concerns regarding privacy, lack of technical knowledge, high costs and data governance (Kamble, Gunasekaran, and Arha 2019). Most firms are in the early phases of realising the potential of blockchain in supply chains (Pournader et al. 2020). Although blockchain can bring potential positive effects to supply chains, the literature on applications and the effect of blockchain on supply chains is scarce (Queiroz, Telles, and Bonilla 2019; Van Hoek, 2019; Cole, Stevenson, and Aitken 2019, Kamble, Gunasekaran, and Arha 2019; Kamble, Gunasekaran, and Sharma 2020; Saberi et al. 2019). There have been few studies that have discussed blockchain pilots and use-cases (Kshetri 2018; Van Hoek, Fugate, and Davelshin 2019; van Hoek 2019). Moreover, there is limited research on capabilities needed by blockchain service providers to implement blockchain, or on the specific role of blockchain in transaction time reduction and for quality improvement in supply chains. For instance, Ladleif and Weske (2020) stressed that the traceable execution of business processes is important but largely neglected the important aspect of time and other temporal constraints. Similarly, Rahmadika et al. (2020) emphasised that transaction time plays a significant role in terms of stability and performance in the decentralised systems. Their study identified that delay in operations can potentially provide opportunities for attackers to manipulate protocol. Additionally, Huh, Cho, and Kim (2017) pointed out that transaction time and its implication on blockchain is a critical research gap that needs addressing.

Therefore, the objectives of this paper are:

i. to understand the blockchain characteristics that can help in transaction time reduction and in quality improvement in supply chains;
ii. to identify the social and technical capabilities needed by the service providers for blockchain implementation; and
iii. how those capabilities vary between projects with primary objectives of transaction time reduction and quality improvement.

To achieve the above objectives, a case study approach is followed and data are collected from service providers that implemented blockchain technology with their customers. We use task-technology fit (TTF) analysis to assess the suitability of blockchain to address the tasks at hand, considering customer needs. The analysis shows that some additional technological solutions need to be implemented together with the blockchain platform. Using the data from the case companies, we then identify the social and technical capabilities across different phases of the blockchain implementation projects and develop a process model for blockchain implementation. The process model outlines the different social and technical capabilities needed over the phases of blockchain implementation projects with the outcomes of transaction time reduction and quality improvement. This leads to a framework that shows that social and technical capabilities can lead to improvement in operational performance, contingent upon the type of the project with specific objectives and phases of the project and some related propositions.

The findings from this study will provide guidance to the blockchain service providers to emphasise the specific social and technical capabilities across different phases of the project to generate the quality improvement and transaction time reduction outcomes from blockchain implementation. We elaborate STS theory by considering the role of social and technical capabilities for blockchain implementation projects considering the contingent effect of type and phase of the projects.

In Section 2, we summarise the literature on blockchain in supply chains, its role in efficiency improvement, and socio technical systems for efficiency improvement. Section 3 describes the methodology used for achieving the objectives, while Section 4 identifies the inefficiencies in the existing supply chains. In Section 5, the social and technical capabilities needed to implement the blockchain enabled solutions are analysed, and Sections 6 and 7 discuss the theoretical and practical contributions.

2. Literature review

2.1. Blockchain and its impact on operations

Blockchain's core characteristics are immutability, transparency, programmability, decentralisation, consensus, and distributed trust (Treiblmaier 2020). Immutability implies something that cannot be changed. Transparency allows users read-only access to previous transactions. Immutability and transparency are both highly desirable if products need to be tracked across the supply chain. Decentralisation implies no central authority is needed to validate transactions between peers. Blockchain enables the distribution of the trust such that it does not necessitate high levels of confidence in a single authority (Treiblmaier 2020).

Blockchain can provide benefits on several operational performance indicators such as speed, quality, cost, dependability, etc. (Bai and Sarkis 2020). It provides mechanisms to reduce costs through the elimination of paper-based processes (Kshetri 2018). It can also be integrated with other technologies such as the Internet of Things (IoT), and aid in creating a permanent record of every movement of a product in a supply chain, thus improving overall efficiency (Wang, Han, and Beynon-Davies 2019). Blockchain can also eliminate intermediate entities; this contributes to an increase in the efficiency of operations, reduction in costs (Kshetri 2018), and increased reliability in operations (Kouhizadeh, Zhu, and Sarkis 2020).

As blockchain has the capability to generate records of actions, firms can forecast more accurately, thereby effectively managing resources and saving on the inventory carrying costs (Kamble, Gunasekaran, and Arha 2019). Blockchain offers mechanisms through which the quality of products can be assessed and ensured (Kshetri 2018; Xu and He 2022). It can enhance quality management by providing visible and easily accessible information about batches, thereby facilitating decisions for product recall and reducing illegal counterfeiting by providing information of the origin of a product (Cole, Stevenson, and Aitken 2019). Through tracking and traceability, blockchain solutions can enhance customers' confidence in products, such as that they are of genuine and appropriate quality, and they may be more willing to make a purchase (Kshetri 2018). It can also help in assessing the quality of products during transportation. For example, supply chain entities can analyse the data related to a product during transportation, and identify the product's condition. Such information can be extremely crucial for refrigerated products that can easily deteriorate if left in a warm environment (Kshetri 2018).

It is expected that the application of blockchain can bring reductions in errors, fraud, and shipping costs, and reduce spoilage and waste (Bai and Sarkis 2020); this is because it can ensure data consistency and data immutability. In a blockchain, therefore, it can be assumed that errors in the form of mistakenly recorded data and other types of inconsistencies are minimised or even completely eliminated (Hald and Kinra 2019; Nandi et al. 2020). When errors occur and are corrected, updates will take place automatically in every place at once, rather than the current situation that requires the contacting of each individual note in the network (O'Dair and Beaven 2017). Blockchain can also drive a reduction in costs and increase in efficiency in operations for logistics (Dutta et al. 2020) and transportation providers, through the integration of systems, thereby reducing the paperwork (Kouhizadeh, Zhu, and Sarkis 2020) and facilitating faster transactions (Kayikci et al. 2022).

2.2. Socio technical systems (STS) for lean and quality improvement

Socio-technical systems (STS) recognise the interrelatedness and joint optimisation of social elements (e.g. people and organisation) and technical elements (e.g. technology and machines) to optimise performance (Trist 1981; de Bruijn and Herder 2009). Social systems include people working in an organisation, relationships among people, and other attributes such as values, skills, and attitudes. Technical systems comprise of technologies, tools, and processes to produce the required output (Trist 1981). The social and technical systems are linked such that improvement in one system also requires improvement in the other system to achieve the desired level of performance (Trist 1981; Hadid and Mansouri 2014). It implies that placing more emphasis on social systems and neglecting the technical systems, or vice versa, will not result in an optimum result (Fox 1995). Therefore, social and technical systems are expected to interact, resulting in superior performance (Xiang, Archer, and Detlor 2014).

Waste is anything that adds cost, but not value, to a product (Ohno 1988). Such waste can be classified as overproduction, inventory, waiting, over-processing, transportation, excessive human motion, and defects (Ohno 1988). Shah and Ward (2007) defined lean production as 'Lean production is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability'. Six primary performance measures for lean production are productivity, quality, cost, delivery, safety and environment, and morale (Dennis 2007). Therefore, lower transaction time, related to cost and delivery, and quality improvement are key outcomes of lean processes.

Technical and social aspects of Total Quality Management (TQM) can individually add value, but better performance can be expected when they are implemented together through interactions with each other. Therefore, synergistic effects of TQM and STS must be pursued to improve outcomes (Manz and Stewart 1997). STS theory has been extensively used in operations management literature for understanding the development of social systems to support the adoption of manufacturing systems (Zhang et al. 2017), and explaining the performance effect of implementing improvement programmes (Hadid, Mansouri, and Gallear 2016). Das and Jayaram (2007) applied STS theory to the examination of the synergetic effects of sub-systems in advanced manufacturing systems. In the context of the services sector, Hadid, Mansouri, and Gallear (2016) used STS theory and highlighted the importance of combining technical and social systems for achieving financial and operational performance from lean service systems. Lean service technical practices, customer value factor and error prevention were positively related to internal and external customer satisfaction and processing time. Although the technical side of the lean service did not significantly relate to financial performance, the social side of the system was found to improve both operational and financial performance (Hadid, Mansouri, and Gallear 2016). Chaudhuri and Jayaram (2019) proposed a theoretical model, grounded in STS theory, and tested the effect of technical and social facets of work practices on sustainability and quality improvement performance.

STS theory is considered as appropriate for explaining the effects that occur with the adoption and implementation of new technologies (Liu et al. 2020), such as blockchain implementation. Sony and Naik (2020) proposed the use of STS theory for implementing architecture for implementing Industry 4.0. The success of blockchain projects may require the combined effect of social and technical capabilities in generating outcomes. As lean systems and TQM has been modelled as STS, and specifically, our objective in this study is to understand blockchain implementation for transaction time reduction and quality improvement, STS can be considered as the appropriate theoretical lens to study the effect of social and technical capabilities on outcomes from the studied blockchain implementation projects. However, we can conclude from our review that use of blockchain specifically for transaction time reduction and quality improvement has not been studied.

3. Methodology

A multiple-case study method was used to achieve the objectives of the research. Case studies are useful in an exploratory context to develop new research propositions (Childe 2011; Xu et al. 2022). The case-study method is appropriate if there is limited research on the topic (Yin 2014), when early exploratory investigation is needed (Voss, Tsikriktsis, and Frohlich 2002; Yin 2014), and when a phenomenon needs to be understood in its actual contextual setting to develop insights (Yin 2014; Eisenhardt and Graebner 2007). For the purpose of our research, therefore, a case study approach is used for the following reasons: (i) there is limited research on the role of blockchain for transaction time reduction and quality improvement, and (ii) our study is an early exploratory investigation into blockchain implementation for transaction time reduction and quality improvement. Our research purpose is to empirically observe and understand the phenomenon of blockchain implementation in its actual contextual setting and develop insights.

We use Task-Technology-Fit (TTF) analysis to first assess the suitability of blockchain to address the tasks related to transaction time reduction and quality improvement. We then seek to identify the socio-technical capabilities needed for blockchain implementation and how those vary between the projects and across project phases (Edmondson and McManus 2007). We use a theory elaboration approach to enrich STS theory for our problem context. This context of blockchain implementation for transaction time reduction and quality improvement is not mature enough to deduce testable hypotheses using general theory (Ketokivi and Choi 2014). Theory elaboration is the process of conceptualising and executing empirical research using a theory as the basis for developing new insights (Fisher and Aguinis 2017). Therefore, theory elaboration is suitable when the researcher is able to apply an existing general theory (STS for the context of this research), but the context is not known well enough to obtain sufficiently detailed premises to deduce testable hypotheses (Ketokivi and Choi 2014). Theories can be elaborated by introducing new concepts, by analysing the relationships among concepts, or by examining boundary conditions (Whetten 1989). In this research, we focus on understanding the role of social and technical capabilities across different phases of the projects to obtain the desired outcomes from different types of blockchain implementation projects.

3.1. Case selection and description

Factiva was used to search news articles on blockchain implementation in supply chains using keywords *Blockchain* AND *supply chain* AND *efficiency OR Lean OR quality* up to December 2020. This process resulted in 19 unique cases. We evaluated the news articles to identify whether those blockchain implementation projects mentioned either transaction time or process lead time reduction or cost reduction or quality improvement. Finally, 16 cases were identified as suitable for our study as these service providers implemented blockchain solutions with specific objectives of transaction time reduction and quality improvement for their customers. We contacted the Founder or Chief Technology Officer or senior executives of those companies through LinkedIn and by sending email to the 'contact us' email IDs from their websites. Out of these, five companies responded while we did not receive any response from the other companies. We provide a brief overview of the five cases, including the rationale for the implementation of blockchain enabled solutions in Table 1.

Although all the cases focussed on process efficiency using blockchain, they can be classified into two broad categories. The trigger for process efficiency offered by 'A' and 'C' for its customers was difficult, time-consuming and costly legacy process in assuring quality, while for 'B', 'D' and 'E', the motivation to develop blockchain solutions was to reduce the transaction time for its customers.

3.2. Data collection and analysis

Data were collected by conducting online interviews and by collecting other news articles, press releases and LinkedIn posts by the case companies for triangulation purposes. By combining both the interviews and secondary sources of material, a consolidated case document was created for analysis. The interviewees were provided with an overview of our research and sent an interview protocol prior to the interview (Appendix A). The details of the interviews conducted are shown in Table 2. Two interviews were conducted with each interviewee. The first interview focussed on understanding the customer challenges, the inefficiencies in the existing processes and to understand the need for blockchain implementation. We conducted the TTF analysis based on the information received from the first interviews; these were presented to the interviewees for validation in the second interview. In the second interview, we also asked about how the case companies implemented the blockchain

Table 1. Overview of the cases.

Case company	Profile of case company	Rationale for customers to implement blockchain enabled solutions	Characteristics of the blockchain solution implemented
A	Provides an online marketplace for used aircraft parts that brings together buyers and sellers in the aerospace industry	Lack of trust between buyers and sellers to execute an online trade of an aviation part because of: • Opaque or low transparency of prices on listings • No product images • Lack of quality documentations • Ghost listings with intermediaries posing as sellers	• Verifies that the quality documents and images match the specific part offered for sale • A private permissioned network • A separate smart contract is created for each lifecycle event of every part, traded using the platform
B	Online marketplace for international agricultural commodity trading	• Agricultural commodity trading mired by inefficient process conducted over phone calls with difficulties in price discovery, uncertainty in trade execution, and long lead-time	• Uses a state-of-the-art cryptographic hash algorithm to secure a single version of the cargo documents via blockchain, guaranteeing all parties to the trade – including banks – access to its documentation • Contract is time bound and the platform includes an execution module to execute the trade using the e-template provided within the specified time
C	Provides end-to-end supply chain visibility for global businesses, ensuring the traceability and tracking of business documents, goods and services with every transaction on its platform	• Due to the disconnected visibility in the supply chain, the tropical fruit industry pays a heavy cost for trade disputes, food safety breaches and wastage	• Developed a Track and Trace blockchain platform that integrates with supply chain workflows and existing systems to create traceability and accountability for each of the fruits from farms, factories, cold chain to distribution channels and end consumers • Allows fruits farms and packaging companies to share verified documents and data with its partners on a single platform
D	Technology service provider offering a Decentralised Process Management solution whose goal is to utilise distributed ledgers (DLTs)		• The solution developed is built upon an existing process engine technology and incorporated the blockchain consensus capability to it. • The blockchain solution used is a closed permissioned system
E	A technology company that aims to digitise mining and metals supply chains by digitising the currently paper-heavy and costly processes into fast, electronic interactions	• Selling and delivering a cargo of minerals requires couriering or emailing paper documents that are subject to interception, fraud and cyber threats. • Complying with a rising number of industry and regulatory standards results in laborious manual and paper-based due diligence processes	• The blockchain enabled platform connects the industry participants into a network and provides real-time flow of information and products along the entire supply chain—from mine to market.

Table 2. Details of interviews.

Case company	Designation of the person interviewed	Number of interviews (duration – minutes)	Additional documents used
A	Senior R&D Manager	2 (30, 56)	News articles, press releases, LinkedIn posts
B	Chief Operating Officer	2 (32, 52)	News articles, public interviews by the CEO
C	Chief Operations Officer	2 (28, 46)	News articles, press releases, LinkedIn posts
D	Managing Director	2 (35, 45)	LinkedIn posts and videos
E	Co-founder	2 (30, 44)	News articles

solution. During each interview, at least two researchers were present. In addition, interview transcripts were compiled together with other material for each case and the consolidated case document was shared with the interviewees for verification and possible edits. This ensured construct, internal and external validity at the data collection stage. The interviewees were fully knowledgeable about the specific blockchain implementation projects and, wherever needed, also consulted other concerned personnel in their companies to provide complete information.

Data analysis was conducted in parallel to the interview phase (Eisenhardt 1989). The first step involved an in-depth analysis of the case documents that were entered into NVivo 11 software for analysis. Data analysis was carried out by three researchers coding the data. The coding helped in identifying the first-order categories of codes; these expressed the views of respondents in their own words. In the second step, using pattern-matching logic (Yin 2018), the links between the first-order categories were used to identify the second order themes. These were further collapsed into overarching dimensions, e.g. wastages in the existing processes, the tasks to be performed, social and technical capabilities needed for blockchain implementation. The relationships between the social and technical capabilities over the phases of the projects, with different objectives, were identified using NVivo 11 and were used to develop the process model for blockchain implementation. The inter-rater reliability for the 20 first-order codes (related to the wastages, tasks to be performed, social and technical capabilities) was 0.90. Where there was disagreement regarding the coding, this was resolved by discussion with other authors.

4. Wastages identified in the existing supply chains

The wastages observed in the legacy supply chains for the case companies were waiting time, excess processing, rejects and quality disputes. These are summarised below.

4.1. Excess waiting time

Wastages related to the waiting time included time spent in seeking more information as observed in the aviation spares supply chain, time spent in negotiation over phone to finalise transactions for the agricultural commodity supply chain, and waiting to comment, seeking more information for approval as observed in procurement contracting processes. For example, 'B's' COO noted '*Problems with phone based dealing is that parties may not meet deadlines. They say that they will come back in 15 minutes but they don't come back until few hours and lot can change in that period*'.

4.2. Excess processing

Excess processing was needed in the tropical fruit supply chain in the form of customer claims' assessment. Excess processing increases lead-times for processing and adds costs. Similarly, the current process for finalising a procurement contract also requires a lot of processing steps. For example, 'E's' co-founder noted, '*… if you have to look for everything everywhere and not sure of its authenticity, as a small business, you are not even counting hours for all this excess work trying to find the right information*'. Similarly, Managing Director of 'D' remarked, '*As soon as you have the offer, then this starts to travel between people, who has to approve it, comment on it, and then it goes to the customer. It has a lot of stops*'.

4.3. Rejections and quality disputes

There were also wastages due to rejections or in settling quality disputes with customers. There were instances of ghost listings of aviation spares with intermediaries posing as buyers with possibilities of spurious quality. The tropical fruit supply chain also experienced frequent quality disputes with retail customers, even though the fruit was in perfect condition while being packed. 'C's' COO noted, '*1 container is worth US$60-80000. For each container, claims are around 3-5% from customers because of quality disputes. This eats into the margins of suppliers*'. Quality problems also appear in the aviation spares trade because of lack of transparency. 'A's Senior R&D Manager noted, '*Many part listings did not have pictures. Also ghost listings were there where intermediaries posed as owners*'.

4.4. Assessment of blockchain to meet the requirements

There are certain tasks that need to be performed to remove the wastages in the existing supply chain. The suitability of blockchain to perform the tasks and to meet the users' requirements need to be assessed. We use TTF analysis to make such an assessment. The fit between the task at hand and the support provided by the technology to address it is a critical determinant of the system's success (Goodhue and Thomson, 1996). In the TTF model, 'task-technology-fit' is defined as the degree to which the functionality of a technology matches the task as well as the abilities of the individual who performs the task (Goodhue and Thomson 1995; Goodhue 1998). In Table 3, we show the specific tasks that needed to be performed in the context of each of the case companies, and the technology characteristics that help in executing the task. The TTF analysis shows that blockchain characteristics of transparency, immutability and programmability are very useful for addressing the tasks that need to be performed while meeting user needs. However, additional characteristics, such as automation, user-experience design, and communication support also need to be provided.

5. Socio-technical capabilities for blockchain implementation projects to improve quality and reduce transaction time

The case companies developed and implemented blockchain solutions to improve quality and reduce transaction times for their customers. Such blockchain implementation projects include two broad phases, project initiation and project execution and delivery. The project initiation phase involves understanding the challenges customers are facing and deciding on the requirements of the solution that needs to be implemented. The project execution and delivery involves developing or customising the solution, suited to customer needs, pilot testing the solution, and implementation. In the following sections, we identify the social and technical capabilities required by the service providers over the two phases of the projects. These are obtained by coding and analysing the case documents.

5.1. Social capabilities

The social capabilities identified for the blockchain implementation projects were empathising with customers, and customer communication and stakeholder management. These are summarised below:

5.1.1. Project initiation: empathising with customers' problems and needs

While implementing a technology solution such as blockchain, whose technical characteristics may be difficult for customers to understand, it is important that the real

Table 3. Task-technology fit analysis for blockchain implementation.

Case	User characteristics and needs	Tasks to be performed	Wastages that the tasks can address	Technology characteristics needed to perform the tasks
A	Buyers from aviation companies needing hassle free experience	Ensure that the buyers receive price, product images, and quality documents for a product to be listed for sale	Waiting time associated with verification	Transparency
		Ensure that the buyers receive authentic parts at the best prices	Waiting time associated with verification	Immutability
		Reduce error in maintenance documentation	Rejection and quality disputes	Programmability, *automated quality control(not a blockchain characteristic and has to be designed separately)*
	Technology-savvy users needing user-friendly interface	Ensure that the buyers can navigate the platform as they do for personal buying	Excess time spent in navigating the platform	*User experience design (not a blockchain characteristic and has to be designed separately)*
B	Buyers want to execute the trade fast and be certain of transaction	Provide a detailed history of all actions and exchange documents needed for executing a commodity trade	Waiting time	Transparency, immutability
	Buyers and traders want ease of use and hassle free experience	Provide all information and documentation in the same platform	Waiting time	Transparency
C	The fruit packing company would like to avoid spending resources in resolving quality disputes	Capture and share the image of fruit during packing	Rejection and quality disputes Excess processing to resolve quality disputes	Transparency, immutability
	Retail buyers would like to have transparency and avoid spending resources in quality checks	Capture the condition of the fruit during transit and making it visible	Rejection and quality disputes Excess processing to resolve quality disputes	Transparency, immutability
D	Users want to avoid excess work in ensuring auditability of all transactions	Put together pieces of information from the transaction history and align that with process that has to be audited	Waiting time	Transparency
E	Employees of user companies share data with each other using multiple channels - emails, social media, messaging services, etc. They should be allowed to chat or send message using a common platform	Consolidate all the communication channels and providing only one place where the data reside	Excess Processing	*Streamlining business processes and communication support (not a blockchain characteristic and has to be provided separately)*
	Users are wary of security breach	Ensure data security	Loss of data and sensitive information	Cyber security

problems faced by the customers are understood and how blockchain can specifically address those pain points are explained. In the words of 'B's' co-founder, '*we need to be very open and flexible to feedback and address customer pain points*'. Similarly, 'D's' co-founder also noted '*It's not important to convince people, but it maybe it's important to take them with you*'.

Senior Manager-R&D at 'A' made an interesting observation, that customers demand that procuring aircraft spares online should have similar experience as buying personal products. '*Millennial employees will like to have the same experience while buying and selling aviation parts as they would like to have for personal buying. We needed to keep that in mind while designing the platform*'. 'C's' COO also noted the importance of understanding the customers' processes. '*Going down to the Thai jungles to better understand the process, workflows and get on-the ground research done allowed us to understand their process and build the solution around those needs*'.

5.1.2. Project execution and delivery: customer communication and stakeholder management

It is also important to communicate to customers about how the system works and how it provides benefits. This was articulated by Senior Manager-R&D at 'A': '*We communicate and explain how the system works with all our partners*'. 'C's' COO also mentioned, '*Getting the user buy-in was very important. We need to spend time to go through the iterations with the customers. We did many iterations of the product over 2-3 months to understand how the users use the product and made modifications accordingly. This also gave them the confidence that the solution will work*'. Similarly, 'D's' managing director mentioned '*You will have to communicate with all stakeholders and make sure that they understand what you are trying to do. Stakeholder management is extremely important. Maybe the most important part than the technology itself*'.

5.2. Technical capabilities

The technical capabilities identified are development of tracking and data login systems, system design to facilitate implementation and handle exigencies, development of own middleware and systems, development of automated quality assurance and ability to evaluate different platforms.

5.2.1. Project execution and delivery: development of tracking and data logging systems to suit the needs

Development of tracking and data logging systems was considered key for 'A' and 'C'. 'C' needed it to track every carton box. In the words of 'C's' COO, '*We paired an IoT device with QR code for every carton box in the packing facility. The device automatically scans the QR code and capture the image of the fruits. Now, the suppliers can safeguard themselves against any quality complaints. We also installed data loggers in the containers to capture temperature, humidity, and even vibration or impacts. We designed the device in such a way that it is a fly-away kit and we didn't need to be there to install it. We fine-tuned it to an extent that it was acceptable to them*'.

Similarly, 'A' records every aerospace spare part via a serialised number: '*We are setting some of our own protocols for the industry as we are building a record of an aerospace spare part via its serialised number. All events related to that serial number will be logged and recorded on chain so that any prospective buyer will have access to all of those events*'.

5.2.2. Project execution and delivery: system design to facilitate implementation and to handle exigencies

'B' ensured the system is very user-friendly for the traders. They interacted with the traders during the pilot, observed the difficulties they faced and incorporated their feedback to improve the filtering algorithm by different commodities, and provided a dark background on the screen so that the traders could easily observe the notifications. 'B' developed a trade-execution module with e-template to facilitate adoption by traders. According to a commodities trader who used 'B's platform, '*The platform created a customised execution e-template for us, exactly as per our contract terms, with all of the main details and notifications in one place and always in front of our eyes, which basically enabled us to effect a much more streamlined trade execution than the usual old way*'.

'E' realised that controlling data residence is important as cyber security elements are key; they therefore needed to have an understanding of specific constraints related to data residence related regulations. 'E' also provides hosting services as a default and within a day the customer can start using the services. 'C' designed systems to work with limited network connectivity. In the words of its COO, '*We designed our system to handle exigencies related to limited network connectivity. We used mash technology to connect multiple devices for minimal coverage so that we can work in rural areas. We needed to understand the work-processes in packing the fruit. We listened to the concerns of the people packing the fruits and realised we need to develop the solution which should create minimum disturbance to their workflow and make it easy for them to use*'. 'A' also developed its own blockchain services, a middleware to unpack networks and nodes. This is made available for ecosystem partners and enabled for them so that they do not have to worry about hosting the nodes.

5.2.3. Project execution and delivery: streamlining business processes

By empathising with customers, 'E' realised that its customers' employees use different communication channels to share information and data with each other and these are used for decision-making. Having such disparate communication channels through which the data is transferred results in increased time for decision-making. This will make it difficult to integrate on the blockchain platform. Therefore, streamlining the communication and data sharing was considered as a precursor to blockchain implementation. 'E' facilitated implementation by consolidating all communication channels. In the words of the co-founder, '*Consolidating all the communication channels, wechat, whatsapp, email, courier, etc., into only one place where the data resides was key for implementation. We provided a chat function within the platform. Data is pulled from the source system or uploaded* *directly. Everything that the operation team needs is on the platform*'.

'D' developed solutions that can combine decentralisation and process management in specific Business-to-Business contexts. 'D's' system ensures that the rapid application of business process management solutions is kept intact, allowing for a collaborative visual representation and configuration of the data model, business logic that should not be lost in the process of decentralisation. This makes it easier for users to use the system as they do not lose any functionality of any business process management system.

5.2.4. Project execution and delivery: development of automated quality assurance systems

By interacting with sellers and buyers of aircraft parts, 'A' realised that if there are errors in the documentation on the maintenance history of parts, use of such documents, despite use of blockchain, will create challenges in the execution of the sale of the parts. Therefore, 'A' developed an artificial intelligence (AI) based system for automated quality assurance of documents: '*Errors may creep in the paperwork. We have introduced automated quality checking process of the paperwork which otherwise would have taken a lot more time. Some sensitive information might be inadvertently released due to wrong naming of the file. These are now avoided*'. Similarly, 'C' is developing a solution to check the rate of ethylene release and then use AI to understand the level of ripeness of fruit. This will ensure picking of fruit with optimal quality.

6. Summarising the findings across the cases

In this section, we compare the two groups of cases, one that focussed on quality improvement and the other group on transaction time reduction and summarise the findings in Table 4. Our analysis shows that the quality improvement cases required social capabilities of empathising with customers and technical capabilities of automated quality assurance systems, system design to facilitate implementation, and development of tracking and logging systems. For the transaction time reduction focussed cases, the social and technical capabilities needed to generate outcomes were empathising with customers, system design to facilitate implementation and streamlining business processes. Unless processes are streamlined, for example, using the platform to channel all communication as developed by 'E' or 'D' for their customers, it will be difficult to ensure immutability and transparency using blockchain. We can therefore conclude that empathising with customers and system design to facilitate implementation are the common social and technical capabilities observed across the studied cases. These can be considered as core capabilities needed by blockchain service providers to implement the solutions. For the technological solution to generate the desired outcomes, it is important that customer needs are fully understood and efforts are made to adapt the solution to their needs rather than adapting customer needs to the technological solution. Therefore, customer pain points should be clearly understood and attention should be paid to how a blockchain-based solution can help address those specific pain points. This finding is similar to that of Kayikci et al. (2022) who concluded that blockchain implementation has to be customised to the needs of an enterprise. Blockchain is likely to be implemented where the existing processes are inefficient and opaque because of legacy systems of working. Failure to understand the user needs will result in user expectation mismatch and may result in failure.

For case 'B', outcomes obtained include reduction of paperwork and efficient negotiation of deals, thereby reducing the time and costs of execution with a detailed history of all the actions and documents exchanged. Similarly, for case 'D' as a result of implementation of the solution, the process execution time has been improved significantly from a few weeks to a few days; customers and traders no longer have to wait for signed paper contracts. Implementation of the solution by case 'E' streamlined post-trade operations, financing and logistics, and eliminated delays.

Developing tracking and data logging and automated quality assurance systems are needed only by the quality improvement focussed cases. A key feature of the system used by both 'A' and 'C' is the capture of the image of the products, i.e. fruit while it is being packed for 'C', and for the spare parts that are ready to be sold on the platform for 'A'. 'C's' system also logged in data about the fruit's moisture content, etc., which are key to ensure quality. Therefore, when the customer receives the fruit, they can verify the quality with that captured during packing. In case of damage, they could find out where it occurred, for example, during transit. This significantly reduced the quality disputes that fruit packing units had with retail customers.

Similarly, having the real images of the parts being sold on the platform brings credibility that, together with digital documentation of part history, ensures quality. For case 'A', the buyers have access to transparent and trusted information to make their decisions faster, reduced from months to days. Use of blockchain has also significantly reduced the costs as the intermediaries who sometimes charge up to 25% are removed. Wrong documentation can still be uploaded to the system, and to avoid this, 'A' created an AI-based tool to check for documentation errors. 'C' checks the level of ethylene and then uses AI to understand the level of ripeness of the fruit to further assure quality. The above capabilities avoid man-hours being spent in resolving quality disputes and the associated costs. Customer communication and stakeholder management was observed in the quality improvement focussed cases ('A' and 'C') and one transaction time reduction case ('D'). Although the other companies focussing on transaction time reduction did not spend enough time on customer communication and stakeholder management during implementation, they also recognise that, in future, they would like to emphasise these areas.

7. Discussion

7.1. Framework and proposition development

Our analysis shows that in the initiation phase of the projects, understanding the real problems by empathising with

Table 4. Summarising the findings across the cases.

Type of cases	Technical capabilities needed	Social capabilities needed	Outcomes obtained
Quality improvement focussed (A,C)	System design to facilitate implementation and to handle exigencies Developing tracking and data logging systems Developing automated quality assurance systems	Empathising with customers Customer communication and stakeholder management	Improved quality assurance, man-hour savings, reduced risks
Transaction time reduction focussed (B,D,E)	System design to facilitate implementation and to handle exigencies Streamlining business processes	Empathising with customers	Transaction time reduction, cost reduction, man-hour savings

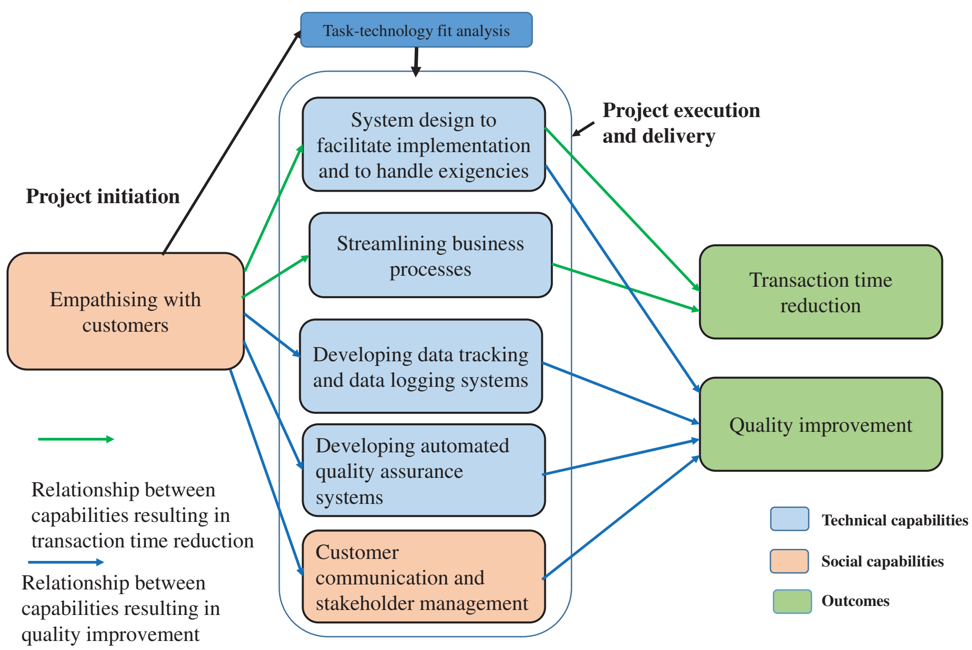

Figure 1. Process model for blockchain implementation for transaction time reduction and quality improvement.

customers is necessary for all blockchain implementation projects. Service providers who focus on the technology without trying to assess the suitability of the fit of the technology in addressing customers' problems will not be addressing those problems; it could also result in an expectation mismatch with the customers. This can be followed by a TTF analysis that will inform the service providers about the technology characteristics of blockchain. This will be useful for addressing customer requirements and any additional technical characteristics that need to be provided, such as a user-friendly interface, business process streamlining, and automation. During the implementation phase, the service providers can focus on using the respective socio-technical capabilities as shown in Figure 1.

Customer communication and stakeholder management were also found to be key, particularly for quality improvement projects. Such customer communication and stakeholder management was not actively followed by the service providers focussing on transaction time reduction projects and this may be an area of improvement for them. By identifying the relationships between the social and technical capabilities from Section 5, we develop the process model for blockchain implementation in Figure 1. We elaborate STS theory in the context of blockchain implementation projects for transaction time reduction and quality improvement by showing the role of social and technical capabilities, and considering the contingent effect of different types of projects in terms of their objectives and the different phases of the project - project initiation and execution.

We further develop a framework and testable propositions. Our findings show that technical capabilities to implement blockchain combined with social capabilities will lead to operational performance improvement. Such capabilities will vary between projects with different objectives, i.e. transaction time reduction and quality improvement and between different phases of the project leading to propositions 1 and 2. Therefore, the contingent effects of the type of projects, as well as requirements over different phases of the project, assume importance in the context of blockchain implementation. The role of type and phase of project in the relationship between social and technical capabilities and operational outcome of Blockchain implementation is shown in Figure 2.

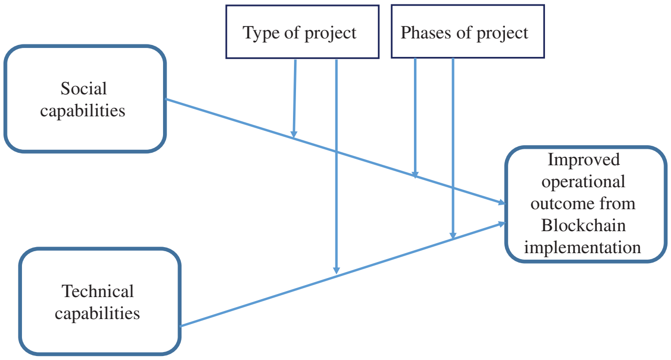

Figure 2. Contingent framework for improving operational performance using blockchain.

Proposition 1: Social and technical capabilities needed to implement blockchain to improve operational performance will vary between phases of the project.

Proposition 2: Social and technical capabilities needed to implement blockchain, together with other technological solutions to improve operational performance, will vary between types of projects with different objectives.

7.2. Theoretical contribution

The findings of this research show that, to achieve quality improvement and transaction time related benefits from blockchain, social and technical capabilities are needed and reinforce each other for blockchain implementation. This is consistent with findings from the literature on the use of IT for lean and process improvement (Ward and Zhou 2006), in the context of broader strategic initiatives using technology (Li et al. 2020), and with Kull, Ellis, and Narasimhan (2013) who posited that behavioural constraints arise when technical integration commences without appropriate *a priori* consideration for the social implications.

We identify the social and technical capabilities across different phases of the blockchain implementation projects and for different types of projects. What makes our findings unique is the emphasis on empathising with customers to develop a detailed understanding of their problems at the early stage of the projects, and developing a solution to facilitate implementation considering the challenges faced on the ground (e.g. fruit packers or commodity traders) and exigencies (limited network connectivity). Trying to speed up the process of implementing technological solutions, these aspects are sometimes neglected. While Treiblmaier (2018) called for theory driven research on the impact of blockchain on supply chain, he did not consider the perspective of service providers implementing blockchain, nor did he refer to STS theory. Our research shows the need to analyse blockchain implementation from the perspective of the capabilities needed by the service providers.

7.3. Practical implications

The TTF analysis shows that some additional technological solutions need to be implemented together with the blockchain platform, e.g. automation, user experience design, and communication support. Therefore, blockchain service providers should also try to identify the customer requirements that will be needed to get the desired benefits from the blockchain implementation. Companies implementing the blockchain solutions can also demand justification of how blockchain and other technological solutions will address their needs and the specific tasks that need to be performed. The findings from this study will provide guidance to blockchain service providers to emphasise the specific social and technical capabilities needed to generate the quality improvement and transaction time reduction outcomes from blockchain implementation across different phases of the projects. They should design systems to facilitate implementation, handle exigencies and empathise with customer needs. The service providers should also explore possibilities of including IoT devices and data loggers together with the blockchain to address customers' needs (Wang, Han, and Beynon-Davies 2019).

8. Conclusions

The contribution of this research is twofold: (1) assessing the suitability of blockchain to reduce transaction time and improve quality using TTF analysis, and (2) identifying social and technical capabilities needed by service providers to implement the blockchain solutions across different phases of the project and for different types of projects. The research has certain limitations as it is based on five case studies. Both in-depth longitudinal case studies of specific implementation projects and further empirical validation of the propositions from a larger number of cases will be needed; surveys are also required. For the cases considered in this research, the wastages related to over-processing, waiting time and quality defects were observed, and how blockchain can help address that waste was analysed using TTF analysis. Future studies should explore blockchain's role in addressing other waste, such as unnecessary inventory, transport, unnecessary motion and inappropriate processing. Future studies should also consider other objectives, such as improving environmental and social sustainability and reduction of risks across the supply chain.

In this research, we considered only two phases of the projects, i.e. project initiation and project execution and delivery. Future studies could focus on multiple phases of the project, i.e. project initiation, solution design, solution testing and validation, and solution implementation, and assess the interplay of social and technical capabilities across each of the phases. Moreover, this study only attempted to identify the social and technical capabilities needed by the service providers to implement the blockchain solutions. Future studies should also try to identify such capabilities needed by the user organisations that will implement blockchain solutions with the help of the service providers. They should consider the service provider and the user as part of two separate socio-technical systems, as considered by Kull, Ellis, and Narasimhan (2013). There are also opportunities to understand in detail the processes involved in finalising the procurement contracts, finalising commodity trading deals and processes to ensure quality of documentation, as well as the products being sold and how such processes change after the adoption of blockchain. This also has implications in the upgrading of employees' training and skills in order for them to use the blockchain platform, as well as implications for job enrichment as employees can avoid monotonous tasks such as documentation checking or making repeated phone calls, etc.

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References

Bai, C, and J. Sarkis. 2020. "A Supply Chain Transparency and Sustainability Technology Appraisal Model for Blockchain Technology." *International Journal of Production Research* 58 (7): 2142–2162. doi:10.1080/00207543.2019.1708989.

Benstead, A. V., D. Mwesiumo, H. Moradlou, and A. Boffelli. 2022. "Entering the World behind the Clothes That we Wear: practical Applications of Blockchain Technology." *Production Planning & Control* : 1–18. doi:10.1080/09537287.2022.2063173.

Chaudhuri, A., and J. Jayaram. 2019. "A Socio-Technical View of Performance Impact of Integrated Quality and Sustainability Strategies." *International Journal of Production Research* 57 (5): 1478–1496. doi:10.1080/00207543.2018.1492162.

Childe, S. J. 2011. "Case Studies in Operations Management." *Production Planning & Control* 22 (2): 107–107. doi:10.1080/09537287.2011.554736.

Cole, R., M. Stevenson, and J. Aitken. 2019. "Blockchain Technology: Implications for Operations and Supply Chain Management." *Supply Chain Management: An International Journal* 24 (4): 469–483. doi:10.1108/SCM-09-2018-0309.

Das, A., and J. Jayaram. 2007. "Socio-Technical Perspective on Manufacturing System Synergies." *International Journal of Production Research* 45 (1): 169–205. doi:10.1080/00207540500381039.

De Bruijn, H., and P. M. Herder. 2009. "System and Actor Perspectives on Sociotechnical Systems." *IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans* 39 (5): 981–992. doi:10.1109/TSMCA.2009.2025452.

Dennis, P. 2007. *Lean Production Simplified*. New York: Productivity Press.

Dutta, P., T. M. Choi, S. Somani, and R. Butala. 2020. "Blockchain Technology in Supply Chain Operations: Applications, Challenges and Research Opportunities." *Transportation Research. Part E, Logistics and Transportation Review* 142: 102067. doi:10.1016/j.tre.2020.102067.

Edmondson, A. C., and S. E. McManus. 2007. "Methodological Fit in Management Field Research." *Academy of Management Review* 32 (4): 1246–1264. doi:10.5465/amr.2007.26586086.

Eisenhardt, K. M. 1989. "Building Theories from Case Study Research." *The Academy of Management Review* 14 (4): 532–550. doi:10.5465/amr.1989.4308385.

Eisenhardt, K. M. and Graebner, M. E., 2007. "Theory building from cases: Opportunities and challenges". *Academy of management journal*, 50(1), 25–32. doi:10.5465/amj.2007.24160888.

Fisher, G., and H. Aguinis. 2017. "Using Theory Elaboration to Make Theoretical Advancements." *Organizational Research Methods* 20 (3): 438–464. doi:10.1177/1094428116689707.

Fox, W. M. 1995. "Sociotechnical System Principles and Guidelines: Past and Present." *The Journal of Applied Behavioral Science* 31 (1): 91–105. doi:10.1177/0021886395311009.

Goodhue, D. 1998. "Development and Measurement Validity of a Task Technology Fit Instrument for User Evaluations of Information

Systems." *Decision Sciences* 29 (1): 105–138. doi:10.1111/j.1540-5915.1998.tb01346.x.

Goodhue, D., and R. L. Thompson. 1995. "Task-Technology Fit and Individual Performance." *MIS Quarterly* 19 (2): 213–236. doi:10.2307/249689.

Hadid, W., and S. A. Mansouri. 2014. "The Lean-Performance Relationship in Services: A Theoretical Model." *International Journal of Operations & Production Management* 34 (6): 750–785. doi:10.1108/IJOPM-02-2013-0080.

Hadid, W., S. A. Mansouri, and D. Gallear. 2016. "Is Lean Service Promising? A Socio-Technical Perspective." *International Journal of Operations & Production Management* 36 (6): 618–642. doi:10.1108/IJOPM-01-2015-0008.

Hald, K. S., and A. Kinra. 2019. "How the Blockchain Enables and Constrains Supply Chain Performance." *International Journal of Physical Distribution & Logistics Management* 49 (4): 376–397. doi:10.1108/IJPDLM-02-2019-0063.

Huh, S., S. Cho, and S. Kim. 2017. "Managing IoT Devices Using Blockchain Platform." 19th International Conference on Advanced Communication Technology (ICACT), IEEE, 464–467. doi:10.23919/ICACT.2017.7890132.

Karamchandani, A., Srivastava, S.K., Kumar, S. and Srivastava, A., 2021. "Analysing perceived role of blockchain technology in SCM context for the manufacturing industry". *International Journal of Production Research*, 59(11), 3398–3429. doi:10.1080/00207543.2021.1883761.

Kamble, S. S., A. Gunasekaran, and R. Sharma. 2020. "Modeling the Blockchain Enabled Traceability in Agriculture Supply Chain." *International Journal of Information Management* 52: 101967. doi:10.1016/j.ijinfomgt.2019.05.023.

Kamble, S., A. Gunasekaran, and H. Arha. 2019. "Understanding the Blockchain Technology Adoption in Supply chains-Indian Context." *International Journal of Production Research* 57 (7): 2009–2033. doi:10.1080/00207543.2018.1518610.

Kayikci, Y., N. Subramanian, M. Dora, and M. S. Bhatia. 2022. "Food Supply Chain in the Era of Industry 4.0: blockchain Technology Implementation Opportunities and Impediments from the Perspective of People, Process, Performance, and Technology." *Production Planning & Control* 33 (2-3): 301–321. doi:10.1080/09537287.2020.1810757.

Ketokivi, M., and T. Choi. 2014. "Renaissance of Case Research as a Scientific Method." *Journal of Operations Management* 32 (5): 232–240. doi:10.1016/j.jom.2014.03.004.

Kouhizadeh, M., Q. Zhu, and J. Sarkis. 2020. " Blockchain and the Circular Economy: potential Tensions and Critical Reflections from Practice." *Production Planning & Control* 31 (11–12): 950–966. doi:10.1080/09537287.2019.1695925.

Kshetri, N. 2018. "Blockchain's Roles in Meeting Key Supply Chain Management Objectives." *International Journal of Information Management* 39: 80–89. doi:10.1016/j.ijinfomgt.2017.12.005.

Kull, T. J., S. C. Ellis, and R. Narasimhan. 2013. "Reducing Behavioral Constraints to Supplier Integration: A Socio-Technical Systems Perspective." *Journal of Supply Chain Management* 49 (1): 64–86. doi:10.1111/jscm.12002.

Ladleif, J., and M. Weske. 2020. "Time in Blockchain-Based Process Execution." 24th International Enterprise Distributed Object Computing Conference (EDOC), IEEE, 217–226. doi:10.1109/EDOC49727.2020.00034.

Li, A. Q., Rich, N., Found, P., Kumar, M. and Brown, S. 2020. "Exploring product–service systems in the digital era: a socio-technical systems perspective", The TQM Journal, Vol. 32 No. 4, pp. 897–913. doi:10.1108/TQM-11-2019-0272.

Liu, Y., S. Dong, J. Wei, and Y. Tong. 2020. "Assessing Cloud Computing Value in Firms through Socio-Technical Determinants." *Information & Management* 57 (8): 103369. doi:10.1016/j.im.2020.103369.

Manz, C. C., and G. L. Stewart. 1997. "Attaining Flexible Stability by Integrating Total Quality Management and Socio-Technical Systems Theory." *Organization Science* 8 (1): 59–70. doi:10.1287/orsc.8.1.59.

Morkunas, V. J., Paschen, J. and Boon, E., 2019. "How blockchain technologies impact your business model". *Business Horizons*, 62(3): 295–306. doi:10.1016/j.bushor.2019.01.009.

Nandi, M. L., S. Nandi, H. Moya, and H. Kaynak. 2020. "Blockchain Technology-Enabled Supply Chain Systems and Supply Chain Performance: A Resource-Based View." *Supply Chain Management*." *Supply Chain Management: An International Journal* 25 (6): 841–862. doi:10.1108/SCM-12-2019-0444.

O'Dair, M., and Z. Beaven. 2017. "The Networked Record Industry: How Blockchain Technology Could Transform the Record Industry." *Strategic Change* 26 (5): 471–480. doi:10.1002/jsc.2147.

Ohno, T. 1988. *Toyota Production System: Beyond Large-Scale Production*. Cambridge, MA: Productivity Press.

Pournader, M., Y. Shi, S. Seuring, and S. L. Koh. 2020. "Blockchain Applications in Supply Chains, Transport and Logistics: A Systematic Review of the Literature." *International Journal of Production Research* 58 (7): 2063–2081. doi:10.1080/00207543.2019.1650976.

Queiroz, M. M., R. Telles, and S. H. Bonilla. 2019. "Blockchain and Supply Chain Management Integration: A Systematic Review of the Literature." *Supply Chain Management*." *Supply Chain Management: An International Journal* 25 (2): 241–254. doi:10.1108/SCM-03-2018-0143.

Rahmadika, S., S. Noh, K. Lee, B. J. Kweka, and K. H. Rhee. 2020. "The Dilemma of Parameterizing Propagation Time in Blockchain P2P Network." *Journal of Information Processing Systems* 16 (3): 699–717. doi:10.3745/JIPS.03.0140.

Saberi, S., M. Kouhizadeh, J. Sarkis, and L. Shen. 2019. "Blockchain Technology and Its Relationships to Sustainable Supply Chain Management." *International Journal of Production Research* 57 (7): 2117–2135. doi:10.1080/00207543.2018.1533261.

Shah, R., and P. T. Ward. 2007. "Defining and Developing Measures of Lean Production." *Journal of Operations Management* 25 (4): 785–805. doi:10.1016/j.jom.2007.01.019.

Sony, M., and S. Naik. 2020. "Industry 4.0 Integration with Socio-Technical Systems Theory: A Systematic Review and Proposed Theoretical Model." *Technology in Society* 61: 101248. doi:10.1016/j.techsoc.2020.101248.

Tian, X., J. Zhu, X. Zhao, and J. Wu. 2022. "Improving Operational Efficiency through Blockchain: evidence from a Field Experiment in Cross-Border Trade." *Production Planning & Control* : 1–16. doi:10.1080/09537287.2022.2058412.

Treiblmaier, H. 2018. "The Impact of the Blockchain on the Supply Chain: A Theory-Based Research Framework and a Call for Action." *Supply Chain Management: An International Journal* 23 (6): 545–559. doi:10.1108/SCM-01-2018-0029.

Treiblmaier, H. 2020. "Toward More Rigorous Blockchain Research: Recommendations for Writing Blockchain Case Studies." In *Blockchain and Distributed Ledger Technology Use Cases*, edited by H. Treiblmaier and T. Clohessy, 1–31. Cham: Springer.

Trist, E. 1981. *The Evolution of Socio-Technical Systems: A Conceptual Framework and an Action Research Program*. Ontario: Ontario Quality of Working Life Centre.

Vafiadis, N. V., and T. T. Taefi. 2019. "Differentiating Blockchain Technology to Optimize the Processes Quality in Industry 4.0." 5th World Forum on Internet of Things (WF-IoT), IEEE, 864–869. doi:10.1109/WF-IoT.2019.8767288.

Van Hoek, R. 2019. "Exploring Blockchain Implementation in the Supply Chain:: Learning from Pioneers and RFID Research." *International Journal of Operations & Production Management* 39 (6/7/8): 829–859. doi:10.1108/IJOPM-01-2019-0022.

Van Hoek, R. 2019. "Unblocking the Chain–Findings from an Executive Workshop on Blockchain in the Supply Chain." *Supply Chain Management*." *Supply Chain Management* 25 (2): 255–261. doi:10.1108/SCM-11-2018-0383.

Van Hoek, R., B. Fugate, and M. Davelshin. 2019. *Integrating Blockchain in the Supply Chai*. London: Kogan Page.

Voss, C., N. Tsikriktsis, and M. Frohlich. 2002. "Case Research in Operations Management." *International Journal of Operations & Production Management* 22 (2): 195–219. doi:10.1108/01443570210414329.

Wamba, S. F., and M. M. Queiroz. 2020. "Blockchain in the Operations and Supply Chain Management: Benefits, Challenges and Future Research Opportunities." *International Journal of Information Management* 52: 102064. doi:10.1016/j.ijinfomgt.2019.102064.

Wamba, S. F., and M. M. Queiroz. 2022. "Industry 4.0 and the Supply Chain Digitalisation: A Blockchain Diffusion Perspective." *Production Planning & Control* 33 (2–3): 193–210. doi:10.1080/09537287.2020.1810756.

Wang, Y., J. H. Han, and P. Beynon-Davies. 2019. "Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda." *Supply Chain Management*." *Supply Chain Management: An International Journal* 24 (1): 62–84. doi:10.1108/SCM-03-2018-0148.

Ward, P., and H. Zhou. 2006. "Impact of Information Technology Integration and Lean/Just-in-Time Practices on Lead-Time Performance." *Decision Sciences* 37 (2): 177–203. doi:10.1111/j.1540-5915.2006.00121.x.

Whetten, D. A. 1989. "What Constitutes a Theoretical Contribution?" *The Academy of Management Review* 14 (4): 490–495. doi:10.5465/amr.1989.4308371.

Wong, L. W., G. W. H. Tan, L. H. Lee, K. B. Ooi, and A. Sohal. 2020. "Unearthing the Determinants of Blockchain Adoption in Supply Chain Management." *International Journal of Production Research* 58 (7): 2100–2123. doi:10.1080/00207543.2020.1730463.

Xiang, J., N. Archer, and B. Detlor. 2014. "Business Process Redesign Project Success: The Role of Socio-Technical Theory." *Business Process Management Journal* 20 (5): 773–792. doi:10.1108/BPMJ-10-2012-0112.

Xu, X., and Y. He. 2022. "Blockchain Application in Modern Logistics Information Sharing: A Review and Case Study Analysis." *Production Planning & Control* : 1–15. doi:10.1080/09537287.2022.2058997.

Xu, X., L. Tatge, X. Xu, and Y. Liu. 2022. "Blockchain Applications in the Supply Chain Management in German Automotive Industry." *Production Planning & Control*: 1–15. doi:10.1080/09537287.2022.2044073.

Yin, R. K. 2014. *Case Study Research Design and Methods* (5th ed.). Thousand Oaks, CA: Sage.

Yin, R. K., 2018. "*Case Study Research and Applications: Design and Methods*", 6e, Sage Publications.

Zhang, J., Yao, X., Zhou, J., Jiang, J. and Chen, X. 2017. September. Self-organizing manufacturing: Current status and prospect for Industry 4.0. In 2017 5th international conference on enterprise systems (ES) (pp. 319–326). IEEE.

Appendix A. Interview protocol

1. Can you explain the inefficiencies in the legacy processes, which motivated the development of the solution provided by your organisation?
2. Can you elaborate on the solutions provided by your organisation?
3. Can you talk about the key characteristics of the Blockchain platform to deploy the solutions?
4. Using examples of specific projects, can you explain the outcomes obtained using your platform?
5. Did you conduct any pilot projects and what challenges did you face or what feedbacks did you obtain? How did you respond to those?
6. Did you face any technical challenges? How were those dealt with?
7. What kind of technical capabilities are needed to deploy the solutions on the ground?
8. What kind of social capabilities are needed to deploy the solutions on the ground?
9. What kind of infrastructural support is needed to deploy the solutions on the ground?