Designing an Effective Blockchain-Based Service Supply Chain using Integrated FANP-QFD under Uncertainty

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Abstract

This study purposes to identify the key Design Requirements (DRs) for effective Blockchain adoption in the service Supply Chain (SC). It focuses on the challenges as Customer Requirements (CRs), and the best practices as DRs, to overcome the challenges. First, the challenges and solutions were identified by review the literature. Then, the experts were asked to confirm those one that could be related to service SCs. The hybrid approach of Fuzzy Analytical Network Processing (FANP) and Quality Function Deployment (QFD) is applied to prioritize each challenge and solutions based on their relations. Results show that "value chain cooperation" is the most important requirements; and to achieve it, providing processes' details by all stockholders, short-value chain, and collaboration with value chain participants in a non-competitive initiative could be effective, respectively. The research has attempted to identify the non-technical challenges and their related solutions. It prepares an insight for service sector managers to identify and improve the key design requirements that their SC members have to meet for attaining the potential benefits of Blockchain. This paper contributes to the limited amount of empirical research on challenges and solutions of effective applying the Blockchain technology in the service SC.

Keywords: Blockchain, Service Supply Chain, Technology Adoption, Fuzzy Analytical Network Process (FANP), Quality Function Deployment (QFD)

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1. Introduction

Nowadays, access to more accurate and real-time information is increasingly demanded by Supply Chains' (SCs') different stakeholders. This information may include the products' origin, purchase journey, and producing conditions. Relying on information systems is a complex issue for managers in an environment that there isn't any mechanism for verification, especially, when they have to deal with sensitive information such as economic transactions by virtual currencies. The development and application of Blockchain technology have a high potential to help meet the above demands. It is able to dramatically change trading methods by providing clear and immutable evidence to actors. This technology is creating a great movement in operations management. It has attracted a lot of attention due to its connection to crypto-currency and its ability to create a reliable trading platform. Recently, SC managers recognize the potential of this new technology. SCs consist of different actors that leads to complexity in SC networks and calls into question the effective and safe monitoring. Blockchain has the capability to increase transparency in SCs. Leveraging this technology is timely because customers ask for transparency in the SC. Applying blockchain can be helpful for knowing that what actions are performed by whom at what time and location [1]. This emerging technology has been applied to various SCs [2]. Some of the promising benefits that can be realized for the blockchain-based SCs include safety and cyber-security, transparency, trust, traceability, efficiency, and etc. in all transactions [3]. However, due to the little understanding of the nature of this emerging technology, its adoption in the SCs is still limited and unknown. For achieving competitive advantages, the companies should accomplish this evolution through appropriate strategies [4]. The lack of understanding and knowledge about this novel technology makes its adoption be a risky proposition [5].The effectiveness of blockchain implementation is different in degrees and there are some challenges that should be overcome when applying this technology in different SCs [6]. The prerequisites of a successful transfer of blockchain should be precisely investigated in advance. However, as the rates and level of this technology adoption are still limited, most of related researches are conceptual or qualitative. So, there is a need for more test and study in this domain [7;8]. That is to say, the related literature is immature and many questions remain about Blockchain effective adoption. This made our first motivation for this study. In this regard, after reviewing the literature, we try to extract the experts' opinions to identify and prioritize the challenges and the related solutions for the effective applying of blockchain in the SC.

On the other hand, features of different SCs could affect their operations management [9;10]. Owing to the special characteristics of service systems, service SC management needs particular attention from managerial researchers [11]. Given the servitization of the world's economies, SCM is increasingly founded on service management. Nowadays, service sector managers should organize their companies in value co-creation networks through coordination with varied actors [10;12]. Collaboration requires information sharing as a tool for coordination. So, the functioning of a service SC/system depends on information availability and sharing [13]. As blockchain enables collaboration among different actors, it has the potential contribution in the service systems [14]. While, the service SCM related studies are immature and emerging. Due to the significant role of service industries in the countries' macroeconomics [15], any effort to prosper the performance of service sectors could create levered improvement in respect to the worlds' economic growth. This issue is the second motivation of this study. So, we focus on identifying and prioritizing the challenges and required practices for blockchain effective adoption in service SCs.

To totally achieve the mentioned advantages reported by recent researches in the service sector, this study has reviewed the literature and adopted the opinions of service sector specialists as the effort to identify and prioritize the challenges and the best practices. In this regard, firstly, these were extracted by the literature review and confirmed by experts' opinions. Then, to link the challenges and their best practices, a House of Quality (HOQ) has been formed. The challenges of a blockchain-based SC are assumed as Customer Requirements (CRs) and their related solutions are assumed as Design Requirments (DRs). The purpose of the HOQ is to determine the priorities of the DRs that are obtained by the relative importance of CRs, considering the interrelations. So, the pair-wise comparison of Fuzzy

ANP was applied in QFD for answering this main question: What are the best practices and their priorities to reduce the risks in achieving the advantages of blockchain-based SCs in the service sector?

Section 2 presents the research background. Subsequently, the steps of applying FANP and QFD are presented in section 3. The case study is presented in section 4. Finally, the finding and conclusions and future research directions are presented in section 5 and 6, respectively.

2. Research Background

2.1. Blockchain technology

Blockchain is a technology for creating an immutable, secure, and distributed database of transactions. This technology was originally created to develop a distributed list of financial transactions without relying on the central bank or financial institutions [16]. It is a distributed user interface that is protected by cryptography and is governed by a social mechanism. Blockchain is not only a record of digital events but can also include unlimited smart contracts stored in a Blockchain and executed without risk of corruption, censorship or fraud. Applications that were previously applied only through intermediaries can now be decentralized and be confident as yet by using Blockchain [17]. This emerging technology strengthens the relationship between the consumer and the producer. For example, it communicates between the end consumer and the producer from two different countries [18]. Blockchain allows a group of independent members to work with global data sources, which is automatically shared by all participants. Data ownership and transaction licenses are granted through public or private key technology without the need for human interaction, endorsement, or arbitration. Public Blockchain provides access rights for all participants and allows them to add new blocks. In contrast, private Blockchain can be applied in an environment that should restrict who is permitted to contribute to the network.

This technology involves the establishment of algorithms that can perform smart contracts in an automatic manner; auto-operating, auto-executing, auto-verifying, and auto-limiting. This makes it possible to create decentralized autonomous organizations and programs that can operate without central commands [19]. Blockchain functions are the reason that some researchers refer to this technology as a decentralized network [20; 21]. These functions are peer-to-peer network, real-time processing, immutability, fail-safety, cryptography, chronological chain, consensus-mechanism, and smart contracts. These can help improve reliability and, in addition, provide authentication mechanisms that do not require central commands and traditional intermediary tasks [22; 23]. Seebacher and Schüritz [14] have identified the attributes of this technology through the literature review. These attributes are as follows: trust, transparency, the integrity of data, immutability, decentralization, privacy, reliability, and versatility.

Many applications that help the world to be digitized can be upgraded with Blockchain technology. Blockchain-based applications were primarily used in the financial sector, but other managers also have paid attention to this technology and are rapidly applying it to serve their customers and achieve competitive advantages. This technology is capable and adaptable to the key needs of SCs.

2.2. Benefits of Blockchain for SCs

Modern SCs are interlinked. The inherent challenges in an SC are associated with this nature. Today's SCs need to rely on trust, reliability, efficiency, and resilience to tackle these challenges. An ideal SC requires: end-to-end visibility to increase efficiency and ensure traceability; the flexibility to rapidly adapt and respond to issues; the inferred trust of system security to collect and provide accurate data; and the control as the primary necessity. It is perceived that the main challenges of SCs are related to trust and information sharing. Fortunately, the properties of Blockchain provide some opportunities to cope with these challenges [1; 23]. Blockchain is able to eliminate some of SCM disruptions; it can eliminate fraud and errors, reduce paperwork delays, improve inventory management, identify SC's suspected cases, reduce shipping costs, and improve trust between different partners [24]. Recently, Blockchain adoption is studied in different SCs, such as, *agricultural food SCs* [25-31], *coffee SC trade*

[32], *fashion SC* [33], *construction industry* [34; 35], *energy sector* [36;37], *aircrafts' parts business* [38; 39], *hospitality* [40], *diamond authentication* [41], *healthcare SC* [3;42], *supplier evaluation* [43], *battery SC* [44], etc.

Various solutions of Blockchain for SCs might typically focus on the physical flow of goods. While it will facilitate SC processes in several ways [6]. These potential advantages that make SC managers eager to transfer this technology could mainly be classified as performance expectancy, decentralization, transparency, and trust. The performance expectancy is the managers' belief about that applying the system could help to attain better performance. Blockchain transparency in SC is about the manner of communicating information of SC to the stakeholders. Trust of SC stakeholders is the tendency of a stakeholder to be vulnerable to another's actions, by expecting that the other party will make a specific action to the trustor, without any monitor or control. Table 1 has presented the main advantages of Blockchain adoption in the SCs, summarized from recent studies.

Insert here: Table 1- Advantages of Blockchain for SCs

Blockchain could promote the performance of ***"Service SCs"***. Forming a setting for trusted interactions along with establishing a decentralized network make the basis of Blockchain [14]. These aspects also constitute substantial aspects of service SCs/systems. Information sharing is essential for SCs' coordination. A proper function of a service system depends on real-time and accurate information [13]. As mentioned before, Blockchain could facilitate collaboration between different members of SCs. So, it has the potential to promote coordination in the service SCs towards value co-creation between the different parties. Interactions in the service SCs entail governing authority for verifying and ensuring that shared rules and agreements are followed by SC's members. Applying the Blockchain in a service SC evokes a transparent and trusted setting, where all SC parties have insights into all processes and can rely on the accuracy of immutable data. As a result, it makes a third party be unnecessary and also solve the problems which are caused by inadequate information [14]. Blockchain provides a platform, in which the participants of service SC can interact with each other in a transparent and precise manner. Definition of coded contracts could be an example that might facilitate these transactions. Both automation and standardization improve productivity and reduce the cost of transactions in service systems [13]. Applying blockchain, as a transparent system, enables a high potential for it and has a valuable impact on coordination in the service SCs. This technology also could accelerate interactions and reduce manual mistakes.

2.3. Challenges of Blockchain Adoption in SCs

Achieving all promised benefits of Blockchain faces some challenges in SCs. As Verhoeven et al. [52] have found, the technology is sometimes adopted first, and the problem is applied to its solution afterward. It requires providing some prerequisites and policies to overcome the inhibiting factors. Some of the challenges are identified in recent studies. Rabah [53] has reviewed the opportunities and challenges of Blockchain in the healthcare systems. The inhibiting factors, in this research, include the immature infrastructure, high costs for development, risks of patient-controlled data, and scalability constraints for the transactions' volume and the power of computers for its processing time. Queiroz and Wamba [47] have investigated the challenges of Blockchain adoption in SCs. They have empirically investigated the main drivers of this technology adoption in the USA and India. According to their findings, they suggest SC managers do sufficient effort to develop the needed infrastructure for facilitating blockchain implementation, especially in developing countries. Also, they propound paying more attention to increase the users’ productivity by the system. Kshetri [1] indicates some of the significant challenges to overcome. First, global SCs operate in a complex environment that requires complying with diverse and old regulations, laws, and institutions. Second, bringing all the relevant parties together is needed for blockchain implementation. Third, blockchain can potentially address manipulative and fraudulent activities. Because the boundary between virtual and physical worlds may be a bit lawless. Forth, concentrating the power in a handful of entities in corporate-designed blockchains causes to lack the decentralized structure. Fifth, because of the high degree needed for computerization, developing and least developed countries are not ready to participate in blockchain-based solutions in SCs. Saberi, et al. [50] have classified the barriers for blockchain consideration into the organizational barriers; SC related barriers; technological barriers; and the external barriers. OECD [6] has classified these challenges into technical and non-technical categories. The technical challenges are asset digitization, interoperability, and the challenge of transparency vs. privacy of data. The non-technical potential challenges include data standardization, governance, collaboration, informal members' incorporation, and responsibility. Hald and Kinra [54] explored the enabling and constraining effects of Blockchain on SC performance; which may potentially emerge from the same architectural properties or design of the technology. They mentioned that when the Blockchain constrains, it hinders the SC and reduces its performance through increasing surveillance and the enforcement of power, segregating SC, reducing SC adaptability, reducing worker skills and SC competencies. Van Hoek [6] explored how the RFID implementation may inform the consideration of Blockchain in the SC. In another study in 2020, he has organized a workshop with managers to empirically explore the levels of Blockchain adoption and the drivers and barriers of implementing this technology. The more concerns of participant managers were about how to adopt and roll the Blockchain out well, such as integrating Blockchain into their existing processes, its potential benefits, costs, and ROI, and etc.; their concerns were less about the technology itself [8]. Aghababayi, et al. [55] have reviewed the challenges of applying Blockchain in the industrial markets. They have categorized the identified challenges as internal area (technical, educational, and structural challenges) and outer area (market, infrastructure, and legal challenges). A list and summary of these studies is presented in **Table 2**.

Insert here: Table 2- summary of related studies

3. Research Methodology

Each environment of a problem requires a special approach for modelling [55-58]. This study is going to link the challenges of Blockchain-based SC as CRs and their related solutions as DRs. The goal of a House of Quality (HOQ) is to determine the priorities of the DRs that are obtained by the relative importance of CRs considering the interrelations of CRs and DRs. The inter relations between variables effect on the results of decisions [59]. To assume the inter/intra-dependencies; ANP was applied in QFD in several studies. For example, Subbaiah, et al. [60]; Lam [61]; Bottani, et al. [62]; Chang & Cho [63]; and Satar & Roghanian [64].

On the other hand, applying QFD under a fuzzy multi-criteria environment is successfully approved in several studies, especially its integrated approach with Fuzzy ANP. For more study, see: Zaim, et al. [65]; Yolanda, et al. [66]; Ahmadizadeh, et al. [67]; Ozgörmüs, et al. [68]; and Haiyun, et al. [69].

In this study, the type of target is applicable and the library studies, interviews and questionnaires are used for data collection. A series of pair-wise comparisons were done to collect the experts' opinions. The 4 questionnaires were for pair-wise comparison of: CRs with respect to the goal, DRs with respect to each CR, CRs with respect to each CR, and finally the pair-wise comparison of DRs with respect to each DR.

3.1. The steps of Fuzzy QFD-ANP

Reference from Lam [61], Büyüközkan and Berkol [70], and Bhattacharya, et al. [71] the steps of the hybrid Fuzzy QFD-ANP applied in this research are as follows:

Step 1- Identifying the CRs and DRs: Detecting the Customer Requirements (CRs) and Design Requirements (DRs) for blockchain adoption in SCs.

Step 2- Obtaining the eigenvector (W_1): Determining the CRs' degrees of importance by conducting pair-wise comparisons.

Step 3- Obtaining the eigenvector (W_2): Determining the DRs' degrees of importance by conducting pair-wise comparisons with respect to each CR.

Step 4- Obtaining the eigenvector (W_3): Determining the CRs' inner dependency matrix by conducting pair-wise comparisons with respect to each CR.

Step 5- Obtaining the eigenvector (W_4): Determining the DRs' inner dependency matrix by conducting pair-wise comparisons with respect to each DR.

Step 6- Determining the CRs' priorities (W_C): Multiplying the W_3 and W_1 to calculate the inter-dependent priorities:

$$w_C = w_2 \times w_1 \tag{1}$$

Step 7- Determining the DRs' priorities (W_A): Multiplying the W_4 and W_2 to calculate the inter-dependent priorities:

$$w_A = w_4 \times w_2 \tag{2}$$

Step 8- Determine the DRs' overall priorities (W_{ANP}): Multiplying the W_A and W_C to calculate the overall priorities of the DRs:

$$w_{ANP} = w_A \times w_C \tag{3}$$

4. Case Study

This study has focused on identifying and prioritizing the non-technical challenges of the service sector and the best practices to reduce the risks in achieving the advantages of blockchain-based SCs. The extracted factors from the literature review were distributed to the 7 experts to confirm and identify those ones that could be related to service SCs. This panel included specialists with PhD degrees and managerial experience in the related field. The experts were asked to propose if they would suggest merging, modifying, or adding the factors. After summarizing their view, to form the HOQ matrix, the lists of the challenges (customer requirement) and best practices (design requirement) have been provided for pair-wise comparison. The detailed steps are as follows:

***Step 1- Identifying the CRs and DRs*:** To build a HOQ, in this study, the *CRs* are the potential needs of a SC for effective adoption of blockchain solutions.

The focus of our study is on the non-technical challenges. These challenges constitute the potential needs of SCs for a successful implementation of this technology; that are called as "WHATs" in HOQ. **Table 3** shows the detected *CRs* for blockchain adoption in SCs.

Insert here: Table 3 - Customer Requirements (WHATs)

Also, the *DRs* supported by the related literature constitute the best practices of SCs to overcome the challenges that are called as "HOWs" in HOQ. **Table 4** shows the confirmed *DRs* related to the above-mentioned *CRs*.

Insert here: Table 4 - Design Requirements (HOWs)

Step 2- Obtaining the eigenvector (W_1): **Table 5** shows the comparison to determine the relative weights of *CRs*.

Insert here: Table 5 – Pairwise Comparison of CRs and the eigenvector (W1)

Step 3- Obtaining the W_2: To construct the HOQ, in this step, the *DRs'* degrees of importance have been determined by conducting pair-wise comparisons with respect to each *CR*. An example of these pair-wise comparisons matrix is provided in Appendix I. **Table 6** shows the extracted weights related to each *CR*.

Insert here: Table 6 – The weights of DRs respect to each CRs (W2)

Step 4- Obtaining W_3: the *CRs'* inner dependency matrix by conducting pair-wise comparisons with respect to each *CR* is determined in this step (See **Table 7**).

Insert here: Table 7 – The inner dependency matrix of CRs (W3)

Step 5- Obtaining W_4: the *DRs'* inner dependency matrix by conducting pair-wise comparisons with respect to each *DR* has been determined in this step (See **Table 8**).

Insert here: Table 8 – The inner dependency matrix of DRs (W4)

Step 6- Determining the CRs' priorities (W_C): the inter-dependent priorities of *CRs* is calculated by multiplying the W_3 and W_1 as follows:

$$w_C = w_2 \times w_1 = \begin{bmatrix} 0.2062 \\ 01763 \\ 0.1914 \\ 0.2381 \\ 0.1872 \end{bmatrix}$$

Step 7- Determining the DRs' priorities (W_A): the inter-dependent priorities of *DRs* multiplying the W_4 and W_2 as follows:

$$w_A = w_4 \times w_2 = \begin{bmatrix} 0.2037 & 0.1003 & 0.1039 & 0.0817 & 0.1954 \\ 0.0276 & 0.1397 & 0.0633 & 0.0628 & 0.0419 \\ 0.1301 & 0.3053 & 0.1011 & 0.0608 & 0.0683 \\ 0.1559 & 0.0899 & 0.1726 & 0.0827 & 0.0657 \\ 0.1889 & 0.1809 & 0.2687 & 0.4463 & 0.2499 \\ 0.0693 & 0.0243 & 0.0720 & 0.1305 & 0.0389 \\ 0.1891 & 0.0927 & 0.1710 & 0.1034 & 0.1648 \\ 0.0355 & 0.0663 & 0.0485 & 0.0318 & 0.1773 \end{bmatrix}$$

Step 8- Determine the DRs' overall priorities (W_{ANP}): the overall priorities of the *DRs* are calculated by

$$W_{ANP} = W_A \times W_C = \begin{bmatrix} 0.1356 \\ 0.0652 \\ 0.1273 \\ 0.1130 \\ 0.2753 \\ 0.0707 \\ 0.1436 \\ 0.0691 \end{bmatrix}$$

multiplying the W_A and W_C as follows:

The HOQ of design requirement for blochchain adoption in Service SC is presented in **Figure 1**.

Insert here: Figure 1- The House of Quality (HOQ)

5. Findings

The calculation results of Fuzzy QFD-ANP are presented in the structure of HOQ in **Figure 1**. The column of W_c presents the relative weights of the requirements of a successful Blockchain-based SC is the service sectors. It shows that value chain cooperation (*VCC*), *0.238*, and embedding responsible business conduct (*0.206*) are the most important requirements to have effective blockchain solutions in the service SC. Standardized data model (*0.191*), future governance of Blockchain (*0.187*), and inclusion of informal actors (*0.176*) are respectively the next priorities.

According to **Table 6**, to achieve *VCC*, providing processes' details by all stockholders (*0.339*), short-value chain (*0.299*), and collaboration with value chain participants in a non-competitive initiative (*0.102*) could be effective, respectively.

The most important practice (*DR*) to meet responsible business conduct is involvement in a multi-stakeholder group (MSG) (*0.338*). Providing processes' details by all stockholders (*0.18*), Collaborating with Value Chain Participants (*0.169*), and Identifying Right Partners (*0.1*) take the next priority to meet RBC, respectively.

The finding of this table shows that the best practices (*DR*) to meet the challenge of Standardized Data Model will be Collaboration with value chain participants in a non-competitive initiative (*0.306*). Providing processes' details by all stockholders (*0.187*) and selecting Right Infrastructures (*0.111*) are the next priorities.

Regarding the Governance of the Blockchain-based SC, defining a process to decide on future of governance model (*0.269*), relevant incentives with goals and needs of participants (*0.213*) are the most important *DRs*. short-value chain (*0.116*) and providing processes' details by all stockholders (*0.101*) are the next priorities.

The most effective solution (*DR*) for Inclusion Informal Actors will be Identifying Right Partners (*0.297*) and selecting Right Infrastructures (*0.282*).

The row of overall priorities of *DRs*, in HOQ (**Figure 1**), represents the relative importance of each perquisite (design requirement) to overcome the challenges (customer requirements). The overall priorities of these best practices are as follows: short value chain (*0.275*), relevant incentives with goals and needs of participants (*0.144*), involving in multi-stakeholder groups at the origin (*0.136*), identifying right and trusted partners (*0.127*), collaboration with value chain participants in a non-competitive initiative (*0.113*), providing processes' details by all stockholders (*0.071*), defining a process to decide on future governance (*0.069*), and selecting the right infrastructure such as mobile, etc. (*0.065*). The findings show the importance of the relations structure between the actors of service SC. Creating an environment for trusted interactions, information sharing, and collaboration are important needs of service SCs. These aspects are the promised advantages of blockchain that drive service SCs' managers to implement this technology towards value co-creation between their parties. The results show the main expectation of service SC managers: blockchain should provide a transparent and trusted platform for facilitating coordination and collaboration. It seems to be as the result of the emphasis on coordination and collaboration among stakeholders of service SC as the essence of Blockchain-based SCs. The parties and their intention to collaborate have a direct impact on the effectiveness of a blockchain solution. Paying attention to bring the relevant parties together is needed for Blockchain implementation. A short value chain, that contains a smaller number of members, could reduce the complexity and facilitate the collaboration and coordination among SC partners. Previous researches, such as Kshetri [1] and OECD [6], confirm our findings. The lack of understanding and knowledge about this novel technology makes its adoption be a risky proposition [5]. It can be the reason for our findings on the importance of identifying the right partners. Selecting the partners who are informed and responsible about blockchain-based mechanisms could reduce the related risks. Also, a short value chain makes it be more practical to identify right and informed partners or meeting the educational requirements for short chains' partners.

6. Conclusions and Future Research Directions

In recent decades service industries have accounted for a significant contribution to economic performance. However, the literature on service operations management, especially on service SC management, is still remained immature. There are lots of potential benefits from adopting Blockchain in the SC reported in the literature. However, as the rates and level of this technology adoption are limited, many questions remain about Blockchain effective adoption in SCs. For successfully adoption of blockchain in the service sectors, it is necessary to identify its challenges and provide proper solutions for them. This could be the theoretical contribution of this research to the literature of both service SC and blockchain-based SC.

To be applicable, this study has applied the integrated ANP-QFD in the Fuzzy environment for prioritizing the best practices, as design requirements, to develop a draft table for reducing the risks in achieving the advantages of Blockchain solution for service SCs. As a practical implication, the findings suggest the principal aspects that should be considered by service SCs' managers to have successful blockchain adoption.

The results show that Value Chain Cooperation (*VCC*) is the most important. According to the findings, providing processes' details by all stockholders, short-value chain, and collaboration with value chain participants in a non-competitive initiative could be effective to achieve proper *VCC*. Also, “Collaboration with value chain participants in a non-competitive initiative” and “providing processes' details by all stockholders” are, respectively, the most effective solution to meet the challenge of the Standardized Data Model (*SDM*). That is to say, focusing on these solutions could provide simultaneous improvement for these 2 challenges.

In addition, the results show that embedding responsible business conduct is the second important requirement to have effective blockchain solutions. The most important practice (*DR*) to meet responsible business conduct is involvement in a multi-stakeholder group (*MSG*).

This study prepares an insight for service sector managers to identify and improve the key design requirements that their SC members have to meet for attaining the potential benefits of blockchain. We hope that this study could help both academics and industry specialists to identify where there is more need to focus, think, and practice in this area.

However, our study has some limitations. There are a lot of opportunities to be explored in future researches. Due to the lack of related literature and experience, SC managers may still have a lot of questions to be answered. We have attempted to identify the non-technical challenges and their related solutions. So, our list of challenges might not contain all the relevant challenges. Further study should support the progress of this study and focus on technical concerns, too. Also, an extension of this study could be accurately developing the stated customer/design requirements, according to the characteristics of various service sectors, such as airports, hotels, banks, etc., for meaningful empirical analysis.

Appendix I

The pair-wise comparison matrix of DRs respect to RBC

RBC	MSG			RI			IRP			CVP			SVC			IPD			RGN			DGM			W_3
MSG	1.00	1.00	1.00	3.82	5.91	7.52	2.39	4.75	6.51	1.87	4.02	6.06	3.82	5.91	7.52	1.87	4.02	6.06	3.82	5.91	7.52	4.42	6.51	8.08	0.372
RI	0.13	0.17	0.26	1.00	1.00	1.00	0.17	0.25	0.53	0.14	0.19	0.31	0.53	1.00	1.00	0.17	0.25	0.53	0.29	0.73	1.00	0.53	1.00	1.00	0.031
IRP	0.15	0.21	0.42	1.87	4.02	6.06	1.00	1.00	1.00	0.19	0.31	0.85	1.00	1.87	4.02	0.16	0.23	0.46	1.60	3.73	5.78	1.00	3.00	5.00	0.094
CVP	0.17	0.25	0.53	3.23	5.25	7.26	1.17	3.23	5.25	1.00	1.00	1.00	1.87	4.02	6.06	0.27	0.46	1.00	2.56	4.65	6.67	2.56	4.65	6.67	0.169
SVC	0.13	0.17	0.26	1.00	1.00	1.87	0.25	0.53	1.00	0.25	0.39	0.82	1.00	1.00	1.00	0.17	0.27	0.62	1.17	3.23	5.25	1.17	3.23	5.25	0.065
IPD	0.17	0.25	0.53	1.87	4.02	6.06	2.19	4.32	6.36	1.00	2.19	3.16	1.60	3.73	5.78	1.00	1.00	1.00	1.37	3.47	5.50	1.37	3.47	5.50	0.183
RGN	0.13	0.17	0.26	1.00	1.37	3.47	0.20	0.33	1.00	0.22	0.37	0.79	0.19	0.31	0.85	0.18	0.29	0.73	1.00	1.00	1.00	1.60	3.73	5.78	0.055
DGM	0.12	0.15	0.23	1.00	1.00	1.87	0.20	0.33	1.00	0.14	0.20	0.33	0.19	0.31	0.85	0.18	0.29	0.73	0.17	0.27	0.62	1.00	1.00	1.00	0.033

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Table 1- Advantages of Blockchain for SCs

Advantages	Descriptions	Supporting Researches
Disintermediation	Reduction in need for intermediaries or 3rd parties within the blockchain process.	[22; 36]
Automation/ Processing speed	The working mechanism of blockchains can replace manual labour tasks if the specific use case utilises automated interactions between parties.	[22]
Streamlined process	Under blockchain, business processes will become more standardized, transparent and streamlined as they are redesigned for the transition from traditional technologies	[22]
Cost reduction	The net effect of disintermediation and automation is a reduction in costs for those applications that can take advantage of blockchain.	[5; 22; 36; 45]
Transparency	how information of SC is communicated to the stakeholders	[22; 46; 48]
Non-repudiation	This benefit relates to the integrity of the blockchain where parties cannot deny or dispute their additions to the blockchain due to the integrity of the transaction history	[22]
Trust	Trust in the integrity of security and payment processing	[25; 47; 48]
Scalability	Scalability as the power of computation can be enhanced by the distributed peers in the network without using centralized systems	[22]
Traceability	Blockchain can reduce the workload and ensure traceability.	[22; 45; 48-50]
Cybersecurity	Blockchain provide a platform for storing all products information in a shared and transparent system for SC's members	[5; 51]

Table 2- summary of related studies

Researches	The Focus	Research Method
Rabah [53]	Reviewing the challenges and opportunities for Blockchain-powered healthcare systems	Review
Queiroz & Wamba [47]	Empirical investigation of the main drivers of Blockchain adoption in SC in India and the USA	empirical
Kshetri [45]	The role of Blockchain in meeting key SCM objectives	Multiple Case Study
OECD [6]	The role of Blockchain in responsible SC	Conceptual
Saberi, et al. [50]	Organizational barriers; SC related/intra organizational barriers; System related/technological barriers; external barriers	Conceptual
Hald and Kinra [54]	Exploring how the blockchain enables and constrains SC performance	Conceptual
Van Hoek [7]	Exploring how the RFID implementation may inform the consideration of blockchain in the SC	empirical
Van Hoek [8]	Exploring the levels of blockchain adoption and its focus areas in the SCs, and the drivers and barriers of implementing this technology	empirical
Kouhizadeh, Saberi & Sarkis [72]	Theoretically exploring Blockchain adoption barriers in the sustainable SC	Conceptual
Aghababayi, et al. [55]	Reviewing the challenges of applying Blockchain in the industrial market	Review

Table 3 - Customer Requirements (WHATs)

Acronyms	Customer Requirement
RBC	Embedding Responsible Business Conduct
IIA	Inclusion of Informal Actors
SDM	Standardized Data Model
VCC	Value Chain Cooperation
GB	Governance of the Blockchain

Table 4 - Design Requirements (HOWs)

Design Requirement	Brief Description
Multi-Stakeholder Groups (MSG)	Involving in multi-stakeholder groups at the origin of the initiative could effectively mitigate risks and facilitate the responsibility in a blockchain. These groups could include social communities, representatives of government, and etc.
Right Infrastructure (RI)	Carefully selecting the right infrastructure for Blockchain-based applications to incorporate different actors especially in upstream of the SC in developing countries.
Identifying Right Partners (IRP)	Identifying Right Partners who are trusted by informal actors especially in upstream of the SC, to facilitate their inclusion.
Collaborating with Value Chain Participants (CVP)	Collaborating with Value Chain Participants in a non-competitive initiative to create a common definition and language.
Short-Value Chain (SVC)	A small group of main stakeholders, i.e. a Blockchain short-value chain network could facilitate overcoming the potential anti-trust regulations and cultural barriers for transparency.
Internal Process' Details of participation (IPD)	Participation of all stakeholders in providing details about their workflows and internal processes.
Relevant incentives with goals and needs (RGN)	The incentives should be aligned and relevant to the participants' goals and needs over time.
Decide on Governance Model (DGM)	Developing a defined process to decide on future changes to the model of governance**.**

Table 5 – Pairwise Comparison of CRs and the eigenvector (W_1)

CRs	*RBC*	*IIA*	*SDM*	*VCC*	*GB*	W_1
RBC	1.00 1.00 1.00	1.37 2.97 4.37	1.27 1.99 3.39	0.51 0.85 1.13	0.50 1.00 1.26	0.238
IIA	0.23 0.34 0.73	1.00 1.00 1.00	0.47 0.79 1.66	0.53 0.86 1.42	0.18 0.29 0.73	0.128
SDM	0.31 0.54 0.92	0.60 1.27 2.14	1.00 1.00 1.00	0.50 0.92 1.66	0.47 0.67 1.32	0.166
VCC	0.89 1.17 1.94	0.70 1.16 1.88	0.60 1.09 1.99	1.00 1.00 1.00	1.13 1.72 2.47	0.233
GB	0.79 1.00 2.02	1.37 2.97 4.37	0.76 1.74 2.70	0.40 0.58 0.89	1.00 1.00 1.00	0.234

Table 6 – The weights of DRs respect to each CRs (W_2)

W_2	RBC	IIA	SDM	VCC	GB
MSG	0.338	0.093	0.091	0.032	0.093
RI	0.038	0.282	0.111	0.094	0.076
IRP	0.100	0.297	0.093	0.058	0.060
CVP	0.169	0.078	0.306	0.102	0.074
SVC	0.073	0.058	0.090	0.299	0.116
IPD	0.180	0.063	0.187	0.339	0.101
RI	0.062	0.077	0.076	0.049	0.213
DGM	0.040	0.051	0.047	0.027	0.269

Table 7 – The inner dependency matrix of CRs (W_3)

W_3	RBC	IIA	SDM	VCC	GB
RBC	0.49	0.091	0.09	0.144	0.126
IIA	0.145	0.59	0.09	0.117	0.103
SDM	0.069	0.114	0.457	0.202	0.16
VCC	0.203	0.143	0.215	0.395	0.187
GB	0.094	0.062	0.148	0.142	0.424

Table 8 – The inner dependency matrix of DRs (W_4)

W_4	MSG	RI	IRP	CVP	SVC	IPD	RGN	DGM
MSG	0.447	0.053	0	0	0	0.121	0.276	0.293
RI	0	0.484	0	0	0	0.051	0	0
IRP	0.089	0	1	0	0	0	0	0
CVP	0.203	0.121	0	0.420	0	0.065	0	0
SVC	0	0.251	0	0.299	1	0.255	0	0.249
IPD	0	0	0	0	0	0.385	0	0
RGN	0.261	0	0	0.281	0	0.123	0.504	0
DGM	0	0.092	0	0	0	0	0.221	0.458

Inner dependency of DRs (W_4)

Inner dependency of CRs (W_3)

CRs \ DRs	MSG	RI	IRP	CVP	SVC	IPD	RGN	DGM	W_c
RBC	0.338	0.038	0.1	0.169	0.073	0.18	0.062	0.04	0.2062
IIA	0.093	0.282	0.297	0.078	0.058	0.063	0.077	0.051	0.1763
SDM	0.091	0.111	0.093	0.306	0.09	0.187	0.076	0.047	0.1914
VCC	0.032	0.094	0.058	0.102	0.299	0.339	0.049	0.027	0.2381
GB	0.093	0.076	0.06	0.074	0.116	0.101	0.213	0.269	0.1872
Overall Priorities of DRs	0.1356	0.0652	0.1273	0.1130	0.2753	0.0707	0.1436	0.0691	

Figure 1- The House of Quality (HOQ)

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