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Considerations in Developing Blockchain-enabled Food Supply Chain Solutions: A Developer Perspective

Chi Pham
RMIT University, s3758885@student.rmit.edu.au

Arthur Adamopoulos
RMIT University, arthur.adamopoulos@rmit.edu.au

Elizabeth Tait
RMIT University, elizabeth.tait@rmit.edu.au

Thanh-Thuy Nguyen
RMIT University, thuy.nguyen21@rmit.edu.au

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Research-in-progress

Chi Pham
School of Accounting, Information Systems and Supply Chain
RMIT University
Melbourne, Australia
Email: s3758885@student.rmit.edu.au

Arthur Adamopoulos
School of Accounting, Information Systems and Supply Chain
RMIT University
Melbourne, Australia
Email: arthur.adamopoulos@rmit.edu.au

Elizabeth Tait
School of Accounting, Information Systems and Supply Chain
RMIT University
Melbourne, Australia
Email: elizabeth.tait@rmit.edu.au

Thanh-Thuy Nguyen
School of Accounting, Information Systems and Supply Chain
RMIT University
Melbourne, Australia
Email: thuy.nguyen21@rmit.edu.au

Abstract

There is currently considerable interest and activity in the adoption of blockchains in food supply chains (FSC) by both researchers and industry. Blockchain developers have to satisfy the requirements of multiple users and stakeholders as well as handle technical requirements from the underlying blockchain platform. Many prior studies are conceptual and theoretical and there is a need for both a deeper understanding of the problem space and also a need for insights from real-world perspectives, particularly in the FSC context. This study interviewed 14 experts from FSC blockchain application provider companies. The interviews were analysed using a Grounded Theory approach. The preliminary findings presented in this research-in-progress paper show that developers are concerned with: Technical aspects, cost-benefit aspects, management and operational aspects, end-user issues and societal aspects. These findings provide a deeper understanding of the issues involved in developing blockchain applications in FSC.

Keywords Blockchain platform, platform-as-a-service, blockchain application provider, blockchain application development, food supply chain

1 Introduction

There is currently considerable interest and activity in the adoption of blockchains in food supply chains by both researchers and industry. There are wide range of blockchain applications being developed in food supply chain to enable information sharing, collaboration, coordination, traceability and payment support (Kamilaris et al. 2019). Many of these applications are trying to streamline the entire food supply chain under a unified environment, improving connection between stakeholders.

While the blockchain network itself is a key foundation technology, there is much more to the applications being built (Feng et al. 2020). Blockchain developers have to satisfy the requirements of multiple users and stakeholders as well as handle technical requirements from the underlying blockchain platform (Bai et al. 2021). Food supply chain solutions also inherently need tracing mechanisms such as QR codes and IoT devices, as well user interfaces for multiple types of stakeholders and consumers (Feng et al. 2020).

A number of studies have looked at blockchain platform selection criteria as well as considerations of blockchain applications in the food supply chain context. A number of frameworks and selection criteria have been proposed. However, many of these studies are conceptual and theoretical and there is a need for both deeper understanding of the problem space and also a need for insights from real-world perspectives (Vu et al. 2021).

Hence, this study proposes the research question: '*What factors do application developers consider when developing solutions for blockchain-enabled food supply chains?*'. This paper reports the initial findings of a study which is investigating the experiences of blockchain development in food supply chains from the perspective of application developers and consultants.

2 Literature review

2.1 Blockchain platform evaluation and selection

A wide range of blockchain platforms have been developed and are constantly being developed (e.g. Ethereum, Hyperledger, Corda, Quorum, Vechain etc). When selecting a blockchain platform, each of which has different natures and characteristics, organisations need to make comparisons to find the platform that best meets their needs (Bai et al. 2021).

Some relevant studies have proposed a range of criteria to rank and select blockchain platforms. Key criteria identified in this research domain includes: popularity in the market (reputation), trustworthiness, adaptability (splitting data layers, on/off-chain, designing smart contract), information structure - accurate inputs, technical support (support features such as API, GUI etc), language and ease of use, blockchain maturity, transaction speed, innovation (connection to IoT, ERP, AI), security needs, interoperability, scalability and energy consumption (Bai et al. 2021; Farshidi et al. 2020; Nanayakkara et al. 2021). However, most of these studies are general to all blockchain applications and not specific to the food supply chain context.

2.2 Applying blockchain in food supply chains

Feng et al. (2020) propose a four-layer system as an example of a blockchain-enabled FSC ecosystem: 1. Physical layer: Food supply chain activities, including food product flows, 2. IoT layer: Events are captured by IoT devices to record the identity of food products, temperature and location. 3. Blockchain layer: Data from IoT layer is posted into the blockchain and/or edge computing, while maintaining business security and privacy through on/off-chain mechanisms. 4. Application layer: Specific applications are developed, which delivers relevant information to various stakeholders.

Review studies have identified considerations that should be taken into account when developing blockchain solutions in the food supply chain context (Feng et al. 2020; Kamilaris et al. 2019; Köhler and Pizzol 2020; Vu et al. 2021; Zhao et al. 2019). These include governance, inter-organisation management issues, technical limitations of blockchain adoption in enterprises, scalability, return on investment, adoption cost, implementation cost, policy adaptability, change management, efficiency, blockchain suitability, sustainability, operational scope, participation degree - acceptance rate (size of community), level of expertise, social responsibility concerns and job creation.

Recent empirical studies into blockchain-enabled FSC have also been conducted and are summarised in Table 1. Many have explored the perspectives of multiple stakeholders, such as FSC actors, academics, government, service providers and technology experts (software developers, blockchain providers).

Publication	Actors investigated	Findings
Hew et al. (2020)	FSC actors	The relationship of oriented strategy, perceived desirability and BCT adoption
Kamble et al. (2019)	Academia, developers, managers in FSC, banking	The enablers on databases, transparency and provenance-traceability etc
Saurabh and Dey (2021)	FSC actors	Factors on BCT adoption in grape-wine SC
Behnke and Janssen (2020)	FSC actors	Issues on business, SC, regulation for FSC traceability
Garrard and Fielke (2020)	FSC actors	Issues on technology & traceability for prawn SC
Stranieri et al. (2021)	FSC actors	BCT-enabled FSC performance: price, trust, control
Kayikci et al. (2020)	FSC actors, developers	BCT-FSC issues in technology, people, process, performance domains
Tsolakis et al. (2020)	FSC actors, developers, government	Data requirements in BCT-FSC: archetype, capture, consistency and operability domains
Rogerson and Parry (2020)	FSC actors	Issues on technology trust, fraud/human errors, governance and customers' willingness to pay
Sander et al. (2018)	FSC actors, government, 3rd transparency service providers	BCT-FSC issues on customers' quality perception, products' cost and trust among FSC stakeholders
Cao et al. (2021)	FSC actors, consumers	Requirements on tracing responsibility

Table 1. Empirical studies into blockchain-enabled FSC

The role of blockchain application providers (blockchain technology providers, software developers) is extremely important, as they have to possess up-to-date blockchain knowledge, communicate with other FSC stakeholders and support the FSC consortium to build blockchain solutions (Köhler and Pizzol 2020). There is still, however, a lack of in-depth studies that explore the complex nature of real-world implementation of blockchain enabled food supply chains (Vu et al. 2021). It is essential to explore how experts in blockchain application development firms perceive the criteria that influence their application developments, and how they handle these challenges.

3 Methodology

3.1 Research method

A qualitative research approach was deemed the most suitable to examine, in-depth, the different perspectives of blockchain application companies towards their blockchain platform selection and application development for food supply chain stakeholders. LedgerInsights.com was used to identify various use cases and identities of blockchain application companies. Invitations to identified top managers were sent via LinkedIn. 14 experts were recruited for this study (11 from blockchain application development companies and 3 from consultant companies).

The interviewees for this study were experts involved in a wide range of activities in blockchain projects and working with stakeholders across the entire food supply chain. Therefore, their insights helped to draw a deeper understanding of the issues involved in developing blockchain applications across the entire spectrum of the food supply chain.

Interviewee backgrounds and demographics are shown in Table 2. A wide range of industries and interviewee positions were represented, providing a substantial breadth to the data collected.

a. BCT platform	Firms (No.)
Ethereum	5
Hyperledger	5
Corda/Quorum	2
BitcoinSV/OriginTrail	2

b. Industry	No.
Cattle, poultry	5
Agriculture	5
Seafood	1
Consultancy	3

c. Position	No.
Founder	5
CEO	3
COO/CIO	3
Director	3

d. Firm size	No.
Large	3
Small	11

e. Gender	No.
Male	10
Female	4

f. Years of experience	No.
5-20	6
20+	8

Table 2. Summary of participant background and technology used: a. BCT platform distribution, b. Industry focus, c. Expert's position, d. Firm size, e. Gender, f. Years of experience

3.2 Data analysis

To analyse the data, we followed the basic elements of Grounded Theory. Grounded theory includes three major phases: open coding, axial coding and selective coding. In the open coding phase, a researcher reads the data sources line-by-line to identify concepts and categories related to the research topic. Low-level concepts (interviewees' ideas) with similar meaning are grouped into broader coherent concepts. This phase resulted in a list of concepts and categories that represent the factors relevant to the research phenomenon. The axial coding phase aims to find relationships between the concepts (factors) identified from open coding and re-assemble these concepts into themes arising from the data. Open coding and axial coding continued in a highly iterative fashion until the themes that emerged consistently represent the concepts discussed in all of the interviews.

As this study was not seeking to build a new theory but instead to analyse emerging themes, the selective coding phase was replaced by further analysis of the emerging themes. The themes that arose from the data are presented in the next section.

4 Findings

The themes that arose from the initial analysis evolved into five main categories: Technical aspects, cost-benefit aspects, management and operational aspects, end-user issues and societal aspects.

4.1 Technical aspects

4.1.1 Information quality

Information Needs: Each stakeholder in the supply chain has different information needs. For example, consumers may just want to check the provenance of products while the government needs to track the production and transport of produce to ensure a sufficient amount of tax is collected (I10). Integration of the blockchain system with existing stakeholder systems (e.g. ERP systems) can improve the quality of the data in the blockchain system, but system integration is an on-going task.

Information Accuracy: To ensure information accuracy, experts introduce analytical methods to detect anomalies, or use IoT and sensors for automation and to minimise human errors (I6, I9). According to interviewee 3, the blockchain application is a reputation-related and self-policing environment, when any cheating leading to data errors is immutably recorded and observed by all other stakeholders. Therefore, information sharing becomes more deliberate, accurate and acceptable.

Information Security: Security needs for information sharing is critical in the application. According to interviewee 14, there are two purposes to information sharing. The first is B2B operational, in which confidential information is shared only with suitable partners. Not all information is shared, and so the security of this layer is quite critical. The second purpose is B2C information propagation, i.e. scan QR code on the package to check food origins. Most experts agree that data sharing in the blockchain environment is more secured than the prior data sharing options.

4.1.2 System quality

Interoperability: It can be difficult to share data between different blockchain platforms and networks (e.g. between Ethereum and Hyperledger). Only a small proportion of consortiums interconnect blockchains, particularly large organisations with strong financial and human resources (such as IBM collaborating with some start-ups) (I9).

Scalability: Most experts highlighted technical issues related to the scalability of blockchains, regarding the ability to store data for more participants. A digital FSC environment creates a lot of data, and blockchain application companies design and tailor the governance rules to handle this data. Another perspective was that there is a lack of leadership ability to enact a scalable industry solution (I5).

Adaptability: Blockchain platforms build up new functions to satisfy unmet needs and build competitive advantage or keep pace with competitors (I14). Application companies keep pace with ongoing blockchain platform developments. Although working with a blockchain platform can be a popular approach to robust and mature solutions, application firms also indicate the potential of changing to a better blockchain environment if needed.

> *'We believe we've got a good product, but we also believe there's going to be pretty good products out there. So we ... learn to coexist with various different solutions' (I1).*

Transaction speed: This concept was not widely discussed by the interviewees. Regarding posting speed, private blockchain is deemed better than the public blockchain. One solution is to combine Ethereum and InterPlanetary File System (IPFS) to create a private environment, so posting is not an issue (I4).

Innovation: FSC operations require technical facilities to capture, process and analyse data during the flow of products through the supply chain. It is essential for a blockchain solution to integrate different data formats with IoT, AI, DNA test kits, GPS and temperature records (I11), which enables better traceability and product recalls. Proof of certification evidence and counterfeit-proof QR codes are designed as part of the innovative traceability solutions (I7).

Blockchain maturity: Some of the interviewees were satisfied with the blockchain infrastructure they have. Interviewee 10 considered the capability to use different blockchain networks, as the pros and cons of each blockchain network are suitable for different business problems. Some other experts believe that in the future, they will have to switch to the best blockchain (I4, I7). Popular blockchain platforms such as Ethereum and Hyperledger are seen as more mature, with more guidelines and lessons available (I6).

4.1.3 Service quality

Technical support: Most blockchains have guideline documents to support developers. Developer teams of application firms also get help from the blockchain platform firms to develop their solution. Also, a national strategic blockchain project was helped by an internet company to build internet and IT infrastructure for the region, as they aimed to use blockchain to upgrade national food brands (I9).

Usability: The user interface is an important factor in the applications. The developed application software needs to work on a wide range of devices, smartphones, and potentially different languages and different countries. Regional accessibility is also important. Farmers' technology literacy, business models, farming sizes and farming practices must be taken into consideration when designing solutions.

4.2 Cost-benefit aspects

Return on investment: Some use cases just need tracking, but others want to upgrade the entire industry and build new branding (I9). The control required can be different depending on the value of food products, i.e. commodity (fruits) vs. premium (wagyu beef). A static QR code on the package is cheaper and less functional than a unique QR code. The latter enables the tracking of the smallest units, while the former only allows tracking products at batch or pallet level (I7).

Adoption cost: The initial investment required for blockchain implementations can be expensive as some require major investment in IT infrastructure, particularly with farmers. Such costs can be reduced over time when blockchain and IoT become more mainstream adoptions (I11).

Operating cost: Recording a large volume of FSC transactions may be too costly for large-scale blockchain adoption. Hence, considering the effectiveness of recording data in the blockchain is important for real-world adoption. Most of the transactional data for food products do not require a long lifetime of records (I10). In this case, using a private blockchain to record data for a short time span can be more affordable. However, certificates of organic practice or provenance, which can help to prevent counterfeits, need to be stored permanently on a public blockchain.

4.3 Management and operational aspects

Blockchain suitability: There were two important areas of discussion: decentralised databases (blockchain) vs centralised databases (i.e. EDI to exchange data) and, public vs private blockchains. The level of trust in the FSC environment and what business problem should be solved, will determine the selection. The blockchain-enabled FSC platform enables transparent information sharing, minimising frauds and errors and building trust in the data. When stakeholders in a FSC have a close relationship and trust is high, and EDI supports information sharing smoothly, blockchain is not necessary (I14).

Operational scope: To build up an agreement for a pilot use case, some stakeholders may agree on what should be shared, and data-level accessibility is granted by persona type (I2). Stakeholders in FSC can also have specific strategies and highlight requirements to narrow down the scope (I9). Another approach is that the food supply chain organisations themselves decide which data to put on the public or private layers (I3). They also opt who can see their data.

Efficiency in the operation: How blockchain helps to improve FSC operation is a major consideration of FSC users. Existing FSC applications significantly demonstrate the usefulness of blockchains to control food quality, traceability, provenance proving and anti-counterfeit. These benefits also help to upgrade the reputation of brands and FSC have a chance to expand their markets, i.e. a small brand in a developing country to export to a stringent market (I7,I9).

Governance: To build a blockchain solution in FSC, stakeholders must pay considerable consideration to governance and business models. FSC stakeholders discuss and agree on such a governance model. Use cases should be built on a small consortium when the governance rules are established and well matured before expanding the scope of participants (I14). The value distribution for all actors in the FSC is a primary motivation. Some examples given by the participants were farmers having a free subscription to the platform and selling farming data to other stakeholders.

Participation onboarding: From the findings, there is a myriad of blockchain-FSC consortiums, where small farmers with less technology abilities can also join the consortium. Small farmers can buy cheap smart phones that can also scan QR codes and enter data, or use digital bank cards and fingerprints for identity management and payments (I3,I8).

Policy adaptability: Experts building the blockchain solutions must follow FSC industry standards such as HACCP and GlobalGAP. Challenges also occur in some cases. For instance, due to a sovereign reason, a government decided not to join a blockchain platform (I14). Data transparency is not popular with the governments of some countries.

Change management: Businesses cannot necessarily keep their current operational practices or business models because the blockchain solution may help to streamline and cut through steps in the processes. It requires businesses to change and adapt.

> *'People are going to be changing their business models to make them more relevant…' (I4).*

4.4 End-user Issues

Level of expertise: Most of the blockchain application companies join different forums to have discussions with counterparts regarding the roadmap and standardisation for blockchain adoption in FSC. There is a common concern regarding the general public confusion between blockchain applications in FSC vs. cryptocurrencies (I6,I7,I8). Building developer capability can be a difficult task. When blockchain knowledge is accumulated, application firms do not want to switch to another blockchain platform, as it requires the developer teams to re-develop everything again (I5).

Blockchain platform's popularity in the market: The experts interviewed mostly use Ethereum and Hyperledger - *'Ethereum was on the market and was a leader'* (I14). FSC consortiums tend to work with start-ups to develop prototypes. They work with large firms with a high reputation as a way to increase the success of the project. Some organisations do not care much about which blockchain platform they use because they think it is just a storage foundation.

Trustworthiness: Blockchain application firms have to determine which blockchain network is reliable for them to invest their resources to build an application on top of that foundation. Interviewee 10 had a concern about the integrity of a blockchain network, resulting in using another blockchain platform. Regarding the reliability for FSC stakeholders, a blockchain application is considered more reliable than an e-commerce platform (I11).

4.5 Societal aspects

Energy consumption: Interviewee 8 and 12 mentioned that transactions on the public Ethereum blockchain are expensive both in terms of transaction fees (gas fees) and energy consumption.

Social responsibility concern: Supporting farmers is seen as one potential benefit of FSC blockchains (I8). While there is potential to track environmental data, many do not focus on implementing this functionality at this stage. They focus more on business operations and human support.

Employment: While blockchains have been promoted as having the potential to remove intermediaries, this is not a focus of the experts interviewed. Brokers were seen to have value, especially in some regions where farmers are living remotely from the manufacturer and cannot directly sell harvested materials (I9). Disintermediation can cause job losses and poverty, leading to economic impacts (I5).

5 Discussion and Conclusion

This paper makes a contribution to the deeper understanding of the issues involved in implementing blockchain solution in food supply chain contexts. It found that blockchain development experts in food supply chain solutions are primarily concerned with five main themes of issues: Technical aspects, cost-benefit aspects, management and operational aspects, end-user issues and societal aspects. These issues are described in more depth than previous studies. Some interesting insights in this paper include:

- To ensure information accuracy, experts introduce analytical methods to detect anomalies, or use IoT and sensors for automation and to minimise human errors.
- Data transparency is not popular with the governments of some countries.
- Transactional data for food products does not require a long lifetime of records or immutability.

- Supporting farmers is seen as one potential benefit of FSC blockchains.
- While blockchains have been promoted as having the potential to remove intermediaries, this is not a focus of the experts interviewed.

The findings will enrich research on what influences blockchain application developments and how blockchain applications are standardised to get acceptance from end-users. The findings can provide practitioners a more cohesive picture of blockchain application development, contributing to successful blockchain application developments and accelerating blockchain adoption and beneficial gains in FSC.

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