Critical success factors for blockchain implementation in supply chain

Yingli Wang[ab]

[a]Logistics and Operations Management Section,
Cardiff Business School, Cardiff University, UK,
WangY14@cardiff.ac.uk
[b]Presenting author

Abstract

This research sets out to explore what key factors senior executives should consider when they look to implement blockchain for supply chain. A number of design thinking workshops were organised with 86 senior executives representing a range of diverse supply chain stakeholders, including manufacturers, construction firms, government agencies, port authorities, law firms, banks, technology service providers and consulting companies. Further interviews with senior executives who have led blockchain initiatives were conducted in order to gain more in-depth insights on why those factors matter. The main outputs are a range of key factors that are critical to the successful implementation of a blockchain solution in supply chains. Those factors were grouped into: business viability, ecosystem management, technical feasibility and user desirability. This research makes valuable contribution to both practice and academic literature by highlighting what factors should be considered that will drive the successful adoption of blockchain.

Keywords: blockchain, distributed ledger technology, design thinking, supply chain, critical success factors

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1. Introduction

Blockchain technology has gained increasing attentions in supply chains (Wang et al., 2019a; Saberi, et al., 2019). We start to witness some early implementations in practice ranging from product provenance, data validation, asset tokenisation, digital identity, trade finance and smart contract (Wang et al., 2019b). A recent global survey by Deloitte indicates that among many supply chain executives is now a shared recognition that blockchain has transformational impact to current supply chain ecosystems (Pawczuk et al. 2019). While 83 percent survey participants see compelling use cases for blockchain, most are not sure how to make blockchain work for their organisations. Therefore, this research sets out to explore what key factors senior executives should consider when they look to implement blockchain for supply chain.

A number of design thinking workshops were organised with 86 senior executives representing a range of diverse supply chain stakeholders, including manufacturers, construction firms, government agencies, port authorities, law firms, banks, technology service providers and consulting companies. The main outputs are a range of key factors that are critical to the successful implementation of a blockchain solution in supply chains. Given the embryotic nature of the blockchain technology and the majority of supply chain initiatives are still at proof of concept (POC) and pilot stages, this research makes valuable contribution to both practice and academic literature by highlighting what factors should be considered that will drive the successful adoption of blockchain.

The paper is organised as follows. Section 2 discusses the literature and our theoretical underpinnings. Following this, section 3 presents our research methodology detailing the design thinking approach as well as data analysis methods. Section 4 then presents our research findings, fulfilling the research objective laid out in Section 1. Section 5 discusses both our theoretical and practical contributions, acknowledges our research limitation and suggests future research directions.

2. Literature background

2.1. Blockchain and its relevance to supply chain

Blockchain is a shared, distributed electronic ledger technology that can record transactions as they occur between parties in a secure and tamper-resistant way. Transactions in a blockchain are typically confirmed by either by all participants (in a permissionless blockchain) or certain appointed participants (in a permissioned blockchain) via a consensus mechanism and are not subject to any form of central control (Wang, et al., 2019a). Once validated and recorded in a blockchain, a transaction becomes permanent and no single party is able to delete or change a transaction unilaterally. An identical copy of the ledger is thus held by all users (known as nodes) on the network. Any unauthorised change or malicious tampering as participants in a blockchain network will immediately become evident to the blockchain network nodes.

There is a much-debated classification of blockchain in practice, terms such as public/permissionless, private/permissioned or hybrid have emerged lately. According to IBM (2017) (one of the leading technology service providers in the blockchain space), the major distinction between public and private blockchain is related to who is allowed to participate in the network, execute the consensus protocol and maintain the shared ledger. A public blockchain network is completely open and anyone can join and participate in the network. The network typically has an incentivising mechanism to encourage more participants to join the network. Bitcoin is one of the largest public blockchain networks in production today. A private blockchain network requires an invitation and must be validated by either the network starter or by a set of rules put in place by the network starter. Participants need to obtain an invitation or permission to join. Once an entity has joined the network, it will play a role in maintaining the blockchain in a decentralized manner. The Linux Foundation's Hyperledger Fabric is an example of a permissioned blockchain framework implementation. A "hybrid" blockchain is one that combines benefits of both types. On the one hand, actual data can be stored on a private blockchain, where it is accessible to invited parties, and on the other a hash of the data can then be written to a public blockchain to ensure that no one central authority can alter or delete data.

In practice, most blockchain supply chain initiatives are permissioned. These supply chain use case applications are based on the following key attributes of blockchain (Wang et al. 2019b);

- Distributed: all (relevant) network participants have a full copy of the ledger for full transparency. This mitigates the risk of single point failure embedded in centralised internet-based platforms.
- Anonymous: The identity of participants is either pseudonymous or anonymous. In the context of supply chain, participants are largely known to each other. This attribute is more useful in a permissionless blockchain.
- Time-stamped: Transaction timestamp is recorded in a block, thus enabling perhaps the most popular usecase so far in supply chain – product provenance. A blockchain system records the digital footprint of a product/parts when it travels through the supply chain.
- Immutable: Any validated records are irreversible and cannot be changed. Subject to the data integrity prior to appending to a blockchain, this attribute ensures the legitimacy of data, therefore enabling use cases such as digitisation of important document such as Bill of Lading and Letter of Credit. In healthcare supply chains, patients' records can be shared securely via a blockchain to ensure both access control and data accuracy.
- Consensus: There are various consensus mechanisms being deployed and developed at the moment. For a public blockchain, Proof-of-Work and Proof-of-Stake are the most established so far and offer various degrees of security. For a private blockchain one can select the one that aligns with the nature of its setting. In both cases it is critical to rely on the right consensus mechanism to achieve the intended security goals.
- Secure: All records are individually encrypted using advanced cryptography techniques. This attributes is of critical importance as it offers additional protection to supply chains given the increasing cyber-attacks on digital supply chains in recent years. For instance, a malware known as NotPetya in 2017 has caused worldwide disruptions in businesses such as shipping company Maersk, pharmaceutical giant Merck, FedEx's European subsidiary TNT Express, French construction company Saint-Gobain, and food producer Mondelēz and paralyzing their operations.
- Programmable: Blockchains can be programmed to automate a large number of business processes across different entities (e.g. make a payment) once certain conditions are met. This gives birth to the concept of 'smart contract'. A smart contract is a computerised transaction protocol that automatically executes the terms of a contract upon a blockchain.

2.2. Critical success factors

The theory of critical success factors (CSFs) has its foundation within strategy research

(Grimm et al., 2014), and is well established in the operations, general management and technology management disciplines. CSFs are “those few things that must go well to ensure success for an organisation, and therefore must be given special and continual attention in order to bring about high performance” (Boynton and Zmud, 1984). CSFs have been explored in a variety of areas, e.g. ERP implementation (Holland and Light, 1999), TQM (Wali et al., 2003), emergency relief logistics (Pettit and Beresford, 2009), sustainability (Luthra et al., 2018) and business process management (Bai and Sarkis, 2013).

Despite the increasing efforts in exploring blockchain adoption in supply chains in recent years, there has been a lack of systematic efforts in understanding what factors organisations should pay critical attention to the success deployment of blockchain. Various issues on challenges (Queiroz and Wamba 2019) and opportunities have been discussed (Kshetri 2018; Wang et al. 2019b) but most are speculative, ad hoc or based on the review of literature. It is therefore hoped that by identifying CSFs in blockchain deployment via an empirical research, we can contribute to fill this void in the literature.

3. Research methodology

To extricate the key critical success factors for blockchain deployment in supply chain, we organised a number of design thinking workshops in September 2019, with 86 senior executives representing a range of diverse supply chain stakeholders, including manufacturers, construction firms, government agencies, port authorities, law firms, banks, technology service providers and consulting companies. Most of our participants are senior executives from their organisations and have in-depth domain knowledge in their fields and about 80% of then have also involved in one or more blockchain initiatives.

Though being widely used in practice, design thinking has not been fully utilised by academic scholars either as a data collection method or as an intervention-based research methodological approach. Yet it has proved to (as evidenced by this research) a powerful tool to go beyond the surface issues and explore deep insights when it comes to make sense of and adopt a disruptive technological innovation such as blockchain.

Design thinking is “a discipline that uses the designers’ sensibility and methods to match people’s needs with what is technologically feasibly and what a viable business strategy can convert into customer value and market opportunity (Tim Brown, 2008)”. It balances the quantitative focus of analytical thinking with its impulse to standardisation and preference for consistency, with the creativity and freedom of initiative thinking (Martin and Martin 2009). It encourages both the exploration and exploitation thinking in designing a new business/service or improving an existing one, or solving a specific problem experienced by an organisation for competitive advantages. In the context of problem solving, design thinking bears similarities to some well-established concepts in the OM and OR disciplines, e.g. problem structuring methods (Ackermann 2012) and business system engineering (Towill 1997) but with a more human-centred focus. A typical design thinking approach of insight-ideation-implementation-inspiration as depicted in figure 1.

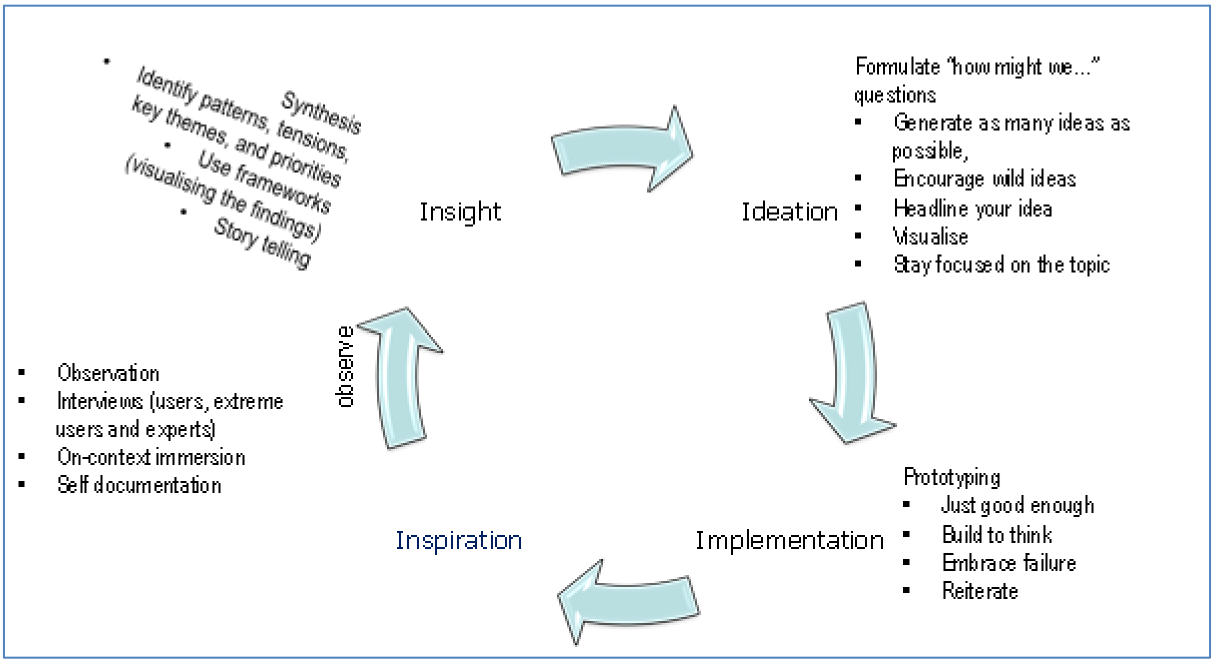

Figure 1: A generic design thinking process

Our rationale for using design thinking is that it provides us a structured and systematic way to engage with multiple stakeholders to go through the whole early adoption process cycle, from understanding the blockchain technology developments, identifying its potential use within supply chains, creating use case persona to developing a blockchain use case protocol for implementation. While methods such as survey may be able to identify what could be CSFs, it will not offer insights about why those factors are critical.

In the design thinking workshop, we grouped our participants together based on their mutual interests in the four use case persona we created, and we were able to 'assembly' a blockchain supply chain among the participants within each group that largely mirrors a 'real' supply chain in practice. We then asked them to articulate the value proposition, map out the business process, identify the critical success factors and then develop a business protocol. Following this, each group was asked to pitch their business use case to a panel of government, academic and business agencies (of which the author is one of the eight panel members) and the winning team was given the opportunity to work with a government innovation accelerator department to operationalise their use case. Methods such as focus group or individual interviews can hardly capture the behavioural dynamics and interactions between supply chain actors embedded in our design thinking workshops. The workshop took place in a sequence of five days and on the sixth day, we finish with a team presentation and wrap-up activity.

Data collected include group meeting records (e.g. post-it note exercises), process maps, email communications and presentations. Each team leader also wrote a group reflection at the end of each day. The researcher (author) as one of the four facilitators also wrote her own observations. Following the design thinking principles, we asked each use case group to build a blockchain platform that adds value to the case supply chain, is desired by all key supply chain stakeholders, and technologically feasible, economically viable & achievable for the ecosystem. Based on the same rationale, we conducted our data analysis, namely when we examine the factors, we would relate them to the principles we previously outlined. Within-use case analysis was conducted, followed by cross use cases analysis. Factors were identified and then grouped into clusters. Further follow-up conversations with participants were conducted when it was unclear why a specific factor is considered as a CSF.

4. Findings

A number of factors were identified. Some factors are context-specific, which although still important, are less useful for other use cases. These are phased out. Factors that are common across the use cases were grouped into the following categories: business viability, ecosystem management, technical feasibility and user desirability. In total we extricated 16 factors as CSFs. We will discuss each category accordingly in the following sections.

4.1. Business viability

Based on their own blockchain experience, our participants almost universally agreed that at the early stage of any blockchain initiative, there needs to be a clear definition of the entry point, i.e. what problem/opportunity is this blockchain supply chain initiative aims to address. Most participants commented that it took them a long time to 'figure out' where blockchain will bring most value to their organisations and their supply chain ecosystem. Therefore, they see a *clearly defined and shared vision and value proposition* as critical. As blockchain is a 'team work' (commented by one of the supply chain directors), the value proposition has to be for all the key supply chain stakeholders. Otherwise it will be difficult to bring together the required stakeholders. Following this, they also suggest that *educating and increasing awareness of relevant stakeholders* is essential for the project champion to recruit and form a supply chain consortia as well as to 'bring everyone to the same baseline level of understanding (a senior executive from a technology service provider)'. Once stakeholders are on board, there needs to be a *clearly defined scopes and expectations* for the project – which will then serve to form a *road map for deployment*. "Virtually all PoCs that did not define a clear roadmap, post-PoC stalled or failed" – a senior consultant who has involved more than 40 blockchain initiatives pointed out.

Effective collaboration is of utter importance. But participants also lamented that it is tricky to collaborate in a decentralised blockchain context. It is because that every organisation has to be on board but they all have different priorities, expectations and level of expertise and understanding of blockchain. Compared to a typical project with centralized deployment, blockchain projects require continuous engagement of multiple stakeholders across multiple organizations, which presents new technical and business challenges. "Not only does implementation have to be managed across many sites, every government and corporate has their own security policies and internal infrastructure team. Therefore, implementations had to address the requirements of every participant (a senior corporate executive)". Every participating organisation needs to collaborate and work towards the shared vision and objectives.

Ecosystem was a frequently mentioned phrase. The general sense from our participants is that individual organisations are no longer independent actors, and their success largely depends on collaboration (sometimes even co-petition) with other supply chain actors. A blockchain ecosystem signifies a number of issues that organisations have to deal with in order to create value - such as cost/benefits sharing, access control, methods of coordination. This led them to define that *a proper alignment of stakeholder incentives*, as well as *clearly defined role and responsibilities* within a blockchain ecosystem is another CSF. Participants proposed that a written version of a Memorandum of Understanding (MoU) type of agreement should be set out that delineates rights and responsibilities to allow for a fluid working arrangement among the parties.

4.2. Ecosystem management

This category consists some of the most complex issues discussed by participants. First, once the ecosystem participants were decided and a consortia formed, *maintaining continuous, close communication* with those stakeholders is seen critical to ensure an inclusive and timely approach towards deployments, as with blockchain "the project only moves as quickly as the slowest actor in the chain (commented by a senior government officer)". However, participants acknowledged that determining who is responsible for this can be a challenge. This led to another important factor identified as *meticulous orchestration* of stakeholder management. The role and importance of a blockchain ecosystem orchestrator was highlighted by all working groups. Depending on the nature of the initiative, participants felt that a government agency (if it is a government led initiative), a powerful entity in the supply chain (e.g. a large retailer, a shipping line, a port operator) or a technology service provider (as a neutral party) could act as the community lead and the orchestrator.

Establishing the right governance model should not be left at the later stage of a blockchain deployment. Some participants pointed out that many existing blockchain initiatives do not yet have a governance model and feel that things often 'become very chaotic and progress painfully slow'. It is worth noting that the term governance in here denotes both on-chain and off-chain governance, though most discussions centred around off-chain issues. According to Reijers et al. (2018), on-chain governance refers to rules and decision-making processes that have been encoded directly into the underlying infrastructure of a blockchain-based system. Off-chain governance comprises all other (i.e. non-on-chain) rules and decision-making processes that might affect the operations and the future development of blockchain-based systems. But what should be included in a governance model? There are varied opinions. Most agreed that it has to fair and inclusive. Regarding off-chain governance, our participants related it mostly to project governance, and issues being discussed include how to distribute liability, who owns the IP, how to set up memberships, who makes decisions regarding the product and the technology, and how to decide objectives and values, how to deal with new members and exits, etc.. On-chain governance discussions typically centred around who runs the nodes, what consensus protocol should be used, what are the permissions and how are they granted, and how new features should be decided upon and implemented.

4.3. Technical feasibility

Blockchain applications provide new ways of exchanging data in a secure manner and may change the way information is shared. Participants commented that given that different organisations and consortia groups are developing and deploying, different blockchain applications, there are different blockchain systems co-existing in practice, therefore *interoperability* is a critical factor that would enable different blockchains ‘speak’ to each other. *Standards* developments is seen of critical importance to enable the much-desired interoperability. *Modularity* is another enabler that will support agile and flexible blockchain developments. It helps to avoid reliance on a specific blockchain because currently blockchain standards continue to evolve and will only settle when the technology matures. When it comes to implementation, many favoured *staged incremental approach* rather than a ‘big bang’ roll out.

Date integrity was highlighted as critical, particularly before data gets appended to a blockchain system. Although data becomes almost immutable once entering blockchain, they can still be manipulated before that stage. Automatic data capturing using IoT devices or setting up a third party ensuring the legitimacy of data has been proposed as potential remedies. *Security* is perceived equally important. A number of potential vulnerabilities were identified, for instance, in a permissioned blockchain system, an attacker could rewrite the ledger by compromising a sufficient number of nodes, putting the community at serious risk. Some technical experts pointed out that security closely links with the concept of *risk management.* They argue that organisations should clearly define their security goals - which in turn determines how blockchain should be configured (e.g. which platform to choose, what consensus mechanism to use). A risk management framework should be in place and “security should be designed into the blockchain from the very beginning and treated as a continuous process, rather than as an after-thought (a chief information officer from a shipping company)”.

4.4. User desirability

Factors under this category are related to user experience of blockchain system. The rationale is that a more desirable a blockchain system will lead to higher level of adoption and more continuous usage. While the previous three sections mainly discuss factors at organisation or ecosystem level, this category of factors deal with individual issues. Many expressed the concerns of privacy and confidentiality. Personal data protection is perceived as a challenging issue in a blockchain system. European Union’s General Data Protection Regulation (GDPR) was the most frequently referred laws at the workshops. One law expert pointed out that satisfying data subject rights under the GDPR on a blockchain can be challenging, because GDPR grants individuals’ right to access their data, have it rectified and deleted upon request. While blockchain, on the other hand, in its very nature, is designed to offer immutability: i.e. once data is written to the chain, it cannot be deleted. At various points of a supply chain, there will inevitably be records of personal data, e.g. identities of authorizing/confirming individuals for transactions, beneficial cargo-owner information and customs information. These need to be handled with great care. Participants fear that if this issue is not addressed properly, people will be put off in using the blockchain system. Therefore *user-centric private data management* was proposed a CSF, though there was no consensus as to how this should be executed in a blockchain.

Another issue mostly discussed was digital identity. Participants argued that despite the rapid increase in digital transactions between businesses, individuals and public organisations, the existing identity verification system remains primarily paper based. The concept of *decentralised identity management or self-sovereign Identity management* was brough out and was agreed as a CSF for blockchain deployment, particularly in the cases of healthcare supply chains. Participants mentioned that there have been various government led initiatives on digital identity. One notable example raised was UAE Pass app, which is the first national digital identity and signature solution that enables users to identify themselves to government service providers in all emirates through a smartphone-based authentication. Others also argued that in a blockchain supply chain, in many cases, real time authoritative data is needed, e.g. by banks, hence and pseudonomity is key.

5. Discussion and conclusion

Our research aims to explore the critical success factors for blockchain deployment in a supply chain. We conducted a series of design thinking workshops with 86 senior executives from both private and public organisations. In total sixteen CSFs were identified and were categorised under business viability, ecosystem management, technical feasibility and user desirability. While research on blockchain has gained increasing popularity in the past two years, there has been limited attention on what factors would determine the ultimate success or failure of a blockchain supply chain initiative. Our research provides valuable insights to both academics and practitioners, not only by identifying what are those factors but also explaining why they are critical. Our second contribution is methodological - we demonstrated using design thinking to extract insights is an effective research tool when exploring an emerging and complex technological phenomenon such as blockchain.

As this research is exploratory, the list of factors identified may not be comprehensive or representative across different industries. Future research should extend to include more in-depth empirical studies to examine whether the factors identified are indeed critical and/or discover new factors. Longitudinal studies following an end-to-end blockchain project is particularly worthwhile. Survey instruments could also be used to empirically devise and validate CSFs at large scale and identify the casual relationships between the factors and organisation performance.

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Biography

Yingli Wang is a Reader in Logistics and Operations Management at Cardiff Business School, Cardiff University, UK. She specialises in logistics and supply chain digitisation. Her research started with examining technological innovation for organisations such as logistics service providers and manufacturers, and then recently extended to explore how technological innovations could benefit a wider society. One of her research priorities is blockchain/distributed ledger technology and its integrative use with other digital technologies such as artificial intelligence, internet of things and cloud computing.