Exploring blockchain implementation in the supply chain – Learning from pioneers and RFID research

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IJOPM - DOI 10.1108/IJOPM-01-2019-0022

Abstract

Purpose – There is great interest in blockchain in the supply chain yet there is little empirical research to support the consideration of the technology. Ferdows (2018) calls for research aimed at learning from pioneers in the field and Gartner points out that the interest in blockchain holds similarities to the interest surrounding RFID 15 years ago. As a result, there may be opportunities to leverage insights from RFID research to inform the consideration of blockchain. This paper aims to explore how the Reyes et al (2016) framework for the implementation of RFID may inform the consideration of blockchain in the supply chain.

Design/methodology/approach – A two-stage approach is used to (1) explore considerations of managers interested in blockchain using a focus group and a survey and (2) to more in depth explore three case companies pioneering blockchain.

Findings – Several factors from the Reyes et al (2016) can inform the consideration of blockchain but there are also differences in considering blockchain. A framework is developed that details considerations found to be relevant by implementation stage.

Originality/value – This paper adds to the limited amount of empirical research on blockchain in the supply chain and advances research beyond the consideration of use cases into the exploration of actual implementation of blockchain in the supply chain. The decision framework developed both leverages and nuances findings from RFID research and can inform managerial decision making. It also adds to research a multi-stage approach to implementation and uncovers rich opportunity to further learn from pioneers.

Keywords Blockchain, RFID, implementation

Paper type Research paper

1. Introduction

Blockchain is said to be a ground-breaking innovative platform (Abeyratne and Monfared, 2016) that is set to transform supply chain activities (Carter and Koh, 2019; Ksherti, 2018) and blockchain reached the top of Gartner's hype cycle a while ago (Bocek et al. 2017). Dobrovnik et al (2018) state that there is very little empirical research on blockchain in the supply chain. And Treiblmaier (2018) states that most publications are practitioner-oriented and that while publications predict a huge impact of the technology, these predictions are not grounded in existing theory and little is done to warn against unrealistic expectations. It is perhaps not surprising therefore that in a study of blockchain use cases Verhoeven et al (2018) found indications that there may be a lack in mindfulness of blockchain technology implementation and that there may be a degree of "a solution looking for a problem" surrounding blockchain use cases.

Given the limited amount of empirical research on blockchain in the supply chain and given the high expectations and interest in the technology it is relevant to empirically explore the consideration and implementation of blockchain in the supply chain. Ferdows (2018) in his most recent IJOPM paper called for more research into blockchain. Additionally, he encouraged more case study research stating that we can learn from pioneers in this area just like we did from Toyota on lean. In this paper we hope to respond to this call directly. However, because there may only be a few pioneers to date, it seems relevant to also explore what factors companies and managers that are interested in blockchain in the supply chain, but that are not necessarily yet pioneers, are using when considering blockchain in the supply chain.

In addition to learning from pioneers and interested companies, learning from research on existing technology is another way to add to the limited research. Dwight Klappich from Gartner in a recent interview with Supply Chain Quarterly points specifically at the parallel between blockchain and RFID technology and calls for effort to avoid relearning lessons of the past:

"There is hype around how blockchain is going to solve world hunger, create world peace. No technology can live up to all that hype. It relates to what we saw around RFID in 2004-2005. It was a technology with clear potential and opportunity but the hype became so overzealous. I remember being at an event where it was claimed that soon we would have refrigerators with RFID readers that would auto-replenish. I don't think we have that yet today, we did not replace the barcode, we still have work to do on RFID and there is still more potential for its roll out." (June 4, 2018)

Considering this parallel there may be valid lessons from research into RFID implementation that can inform the development of an understanding of blockchain implementation in the supply chain. Leveraging the rich body of research on RFID implementation may help accelerate and nuance the learning about blockchain in the supply chain and in this respect the Reyes et al (2016) framework for the implementation of RFID in the supply chain may be informative and helpful. In particular because recent studies point at similarity in supply chain functionality between RFID and blockchain. Both technologies support visibility and traceability throughout the supply chain (Saberi et al 2018, van Hoek et al 2019 I and II) making them more similar than other technologies such as ERP or robotics that offer distinctly different functionalities. Additionally, recent papers have indicated that RFID and blockchain could complement each other well when adopted in concert with blockchain (Biswas et al 2017, Chen et al 2017, Galvez et al 2018, Saberi et al 2018, Toyoda et al 2017). Tseng et al (2018) for example, suggest the use of RFID for data capture and blockchain for the authentication and dissemination of this data throughout the supply chain.

In summary, there is great interest in blockchain as a newer technology in the supply chain, in both research and industry. Given the lack of empirical exploration of blockchain implementation in the supply chain and because of the similarities with RFID technology, there may be opportunities to use the existing framework for the implementation of RFID from Reyes et al (2016) to inform consideration of blockchain in the supply chain. This may also help avoid needing to relearn lesson in research and industry. We therefore pose the following research question:

How can the Reyes et al (2016) framework for the implementation of RFID in the supply chain inform the consideration of blockchain in the supply chain?

The remainder of this paper is structured as follows: the next section will review literature on the blockchain implementation in the supply chain, further consider why RFID literature may be a relevant source of lessons learned and review RFID literature for implementation considerations. An overview of implementation drivers, barriers and benefits of RFID is generated and the comprehensive implementation framework from Reyes et al (2016) is used to frame lessons learned about implementation considerations. This provides the basis for a two-part empirical exploration of blockchain in the supply chain. The first part in a broad quantitative exploration of implementation considerations using a focus group and a survey. The second part is a more qualitative set of rare and rich multiple case studies of companies that are pioneering and actually implementing blockchain in the supply chain. Based upon the cross-method comparison of findings we adapt the Reyes et al (2016) RFID implementation framework to inform the consideration of blockchain in the supply chain and are able to develop a decision framework for considering blockchain in the supply chain that distinguished between different stages of implementation. In addition to implications for managers we reflect upon limitations of our research and offer suggestions for further research.

2. Literature review – blockchain in the supply chain and factors from RFID literature to consider

Given the wide interest in blockchain in the supply chain (Mena et al 2018; van Hoek et al 2019), Dobrovnik et al (2018) stress the relevance of more detailed consideration of blockchain in the supply chain:

"Despite the claim that blockchain will revolutionise business and redefine logistics, existing research so far is limited concerning frameworks that categorise blockchain application potentials and their implications. In particular, academic literature [...]to date has not sufficiently distinguished between blockchain adoption ("what to adopt") and the identification of the right business opportunity ("where to start")."

Regarding "where to start," companies may perceive barriers to the implementation of blockchain in the supply chain. Even if only perceived by managers interested in blockchain, these are still of relevance as perceived ease of use of blockchain in the supply chain has been found to influence intention to implement (Kamble et al. 2018). Based upon a conceptual exploration Saberi et al (2018) point at intra-organizational, inter-organization and system related barriers. Intra-organization barriers include financial constraints, lack of managerial commitment and lack of knowledge and expertise. Inter-organization barriers include challenges with information disclosure policy between supply chain partners and problems in collaborating, communicating and coordinating in the supply chain. Cole et al (2019) state that blockchain can impact the relationship between supply chain parties and, more specifically, Wang et al (2019) point at the need to build a blockchain ecosystem by involving the right supply chain partners and establishing a governance model. Finally, Saberi et al (2018) and Wang et al (2019) point at system related barriers including security concerns, system reliability issues and the need to integrate blockchain with existing supply chain technology.

In response to Dobrovnik et al's (2018) question "what to adopt," Ksherti (2018) and Verhoeven et al (2018) found a number of different use cases in the public domain ranging from sourcing applications upstream in the supply chain to shipping applications further downstream in the supply chain. A review of the literature indicated that blockchain can be applied in different sections of supply chains, varying from sourcing, manufacturing, warehousing, transportation and logistics (Conoscenti et al, 2016; van Hoek, 2019). These existing studies of high-level use cases and early pilots focus on early stages of implementation and Wang et al (2019) call for research into scaling implementation across the supply chain.

2.1 Parallels between RFID and blockchain

There are at least three reasons for specifically considering lessons learned from RFID research when considering blockchain in the supply chain. These are: (1) similarities in hype as pointed out by Gartner and focus in research, (2) similarity in functionality and use cases that is stronger than with other supply chain technologies and (3) a growing call for considering combined applications of RFID and blockchain in the supply chain making it relevant to consider lessons learned about RFID implementation.

2.1.1 Similarity in hype and research focus

In 2003, after the US Department of Defense (DOD) and several major retailers around the world announced plans for large scale RFID implementation throughout their supply chains, there was a lot of interest in the technology. Predictions of a RFID revolution in the supply chain were common (Srivastava, 2004) and a fair amount of myth about the potential of RFID was created (Reyes and Jaska, 2007). One of them was that RFID was going to replace barcodes (Thiesse et al, 2011). As Gartner pointed out, blockchain is receiving similar attention today as RFID did 15 years ago. Because RFID has been around longer, fortunately, a healthy body of research as been able to be developed, empirically investigating true implementation, benefits and challenges of implementing RFID in the supply chain (Vijayaraman and Osyk, 2006; Li et al, 2010).

With RFID technology we may have gone through precisely what Treiblmaier (2018) is warning for when pointing at the risk of unrealistic expectations for blockchain. Treiblmaier's research also reveals a similarity with RFID research when it comes to questions asked. He explores how economic theories such as the resource based view of the firm and transaction cost economics could inform blockchain decision making. This is a question that Cannon et al (2008) already answered for RFID, considering the same theories.

2.1.2 Similarity in functionality and usecase

Recent studies point at similarity in supply chain functionality between RFID and blockchain. Both technologies support visibility and traceability throughout the supply chain (Saberi et al 2018, van Hoek et al 2019) making them more similar than other technologies such as ERP or robotics that offer distinctly different functionalities. Additionally, unlike other widely studied supply chain technologies such as ERP or robotics, RFID and blockchain are also used primarily in a cross company supply chain setting, across supply chain tiers, instead of inside a company and in one segment of the supply chain.

2.1.3 Combined implementation reinforcing relevance of RFID lessons learned

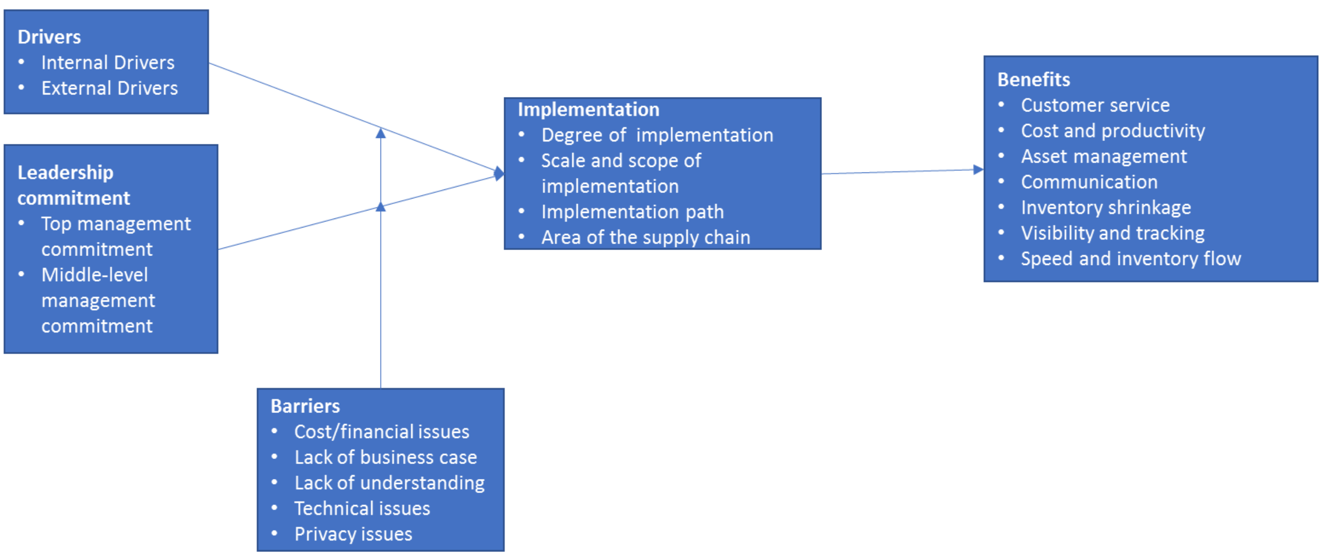
Recent papers have indicated that RFID and blockchain could complement each other well when adopted in concert in a joint supply chain implementation (Biswas et al 2017, Chen et al 2017, Galvez et al 2018, Saberi et al 2018, Toyoda et al 2017). In the study and development of numerous different supply chains, from food to fishing to wine production to governance of the drugs supply chain authors have pointed at the value of combining RFID and blockchain. Tseng et al (2018) for example, suggest the use of RFID for data capture and blockchain for the authentication and dissemination of this data throughout the supply chain. In making this connection, blockchain can enable faster dissemination of RFID data across multiple tiers in the supply chain simultaneously. This is functionality that RFID technology can do not achieve by itself.

2.2 Lessons learned about the implementation of RFID in the supply chain

In one of the more recent studies of the implementation of RFID in the supply chain Reyes et al (2016) offer both a critical review of RFID implementation and develop a framework for understanding implementation. The framework is shown in figure 1 and it may provide a framework that can be used for the study of blockchain in the supply chain. Reyes et al (2016) build upon a rich body of research on RFID in the supply chain and several solid literature reviews (Lim et al, 2013; Ngai et al, 2008; Sarac et al, 2010).

The Reyes et al (2016) framework for the empirical study of RFID implementation in the supply chain is comprehensive and considers implementation dynamics and degrees of implementation over time, without assuming overnight implementation. Nor does it imply that RFID makes existing technologies obsolete. The framework realistically considers barriers as well as performance and economic benefits and provides a clear overview of key considerations and their interrelations. Thus, the framework can be used to realistically, without hype, inform senior management about implementation considerations. The framework as displayed in figure 1 includes a few added considerations within the main constructs based upon our review of existing literature as shown in annex 1.

Figure 1 Model for implementing RFID in the supply chain



Source: Revised from Reyes et al (2016)

Reyes et al (2016) break drivers for RFID implementation into internal and external drivers. Internal drivers that are commonly referenced in literature include operating costs reductions, improved visibility and tracking, and reductions in out of stocks. The most commonly referenced external driver is customer pressure. A third driver of RFID implementation in the Reyes et al (2016) framework is leadership commitment. This area is broken into top management and middle-level management commitment. But only top management commitment was found to be a significant driver of implementation (Reyes et al, 2016). The importance of top management commitment is obvious (van Hoek et al, 2010), particularly in emerging technologies. It can drive focus, investment, and resourcing. But middle management is key for the implementation of new technology, process, and capability (van Hoek et al, 2014). Reyes and Jaska (2007) specify several types of managers who should be involved in the effective implementation of RFID. Perhaps this reflects middle-management engagement more than just commitment.

There are four barriers to RFID implementation included in the Reyes et al (2016) framework – cost issues, lack of understanding, technical issues, and privacy issues. Based upon the review of literature, we reframed the cost barrier to "cost and financial issues." Items that were missing from the cost issue factor in Reyes et al (2016) are that the cost of maintaining the system may be high (Li et al, 2010) and that there may be a lack of funds (Vijayaraman and Osyk, 2006). Frequently referenced cost issues are the costs of tags and readers and the ROI on the investment being too low and uncertain (Smart et al, 2010).

Within lack of understanding, the item "lack of understanding about RFID technology and its implementation in the supply chain" is frequently referenced, followed by "resistance from employees." The latter is argued to be driven by a fear of jobs being automated away (Hou and Huang, 2006; Bhattacharya, 2012). Technical issues most frequently referenced are system reliability issues and lack of standards (Chuang and Shaw, 2007) The lack of a business case to benchmark against and to justify costs vs benefits is referenced as a barrier in several studies (Prater et al, 2005, Chuang and Shaw, 2007).

Implementation of RFID was measured with a qualitative scale ranging from not considering, to considering, piloting and implementing (Vijayaraman and Osyk, 2006; Reyes et al, 2016). Additional measures used include implementation paths (Lee et al, 2008), scale and scope of implementation (Roh et al, 2009), and areas of supply chain implementation (Zelbst, 2012). Benefits of RFID studied include costs and productivity improvements (Shin and Eksioglu, 2014), customer service (Sarac et al, 2010), improved asset management (Tzeng et al, 2008) and communication between channel partners (Lim et al, 2013), improved inventory efficiency (Shin and Eksioglu, 2014), reduced inventory shrinkage (Rekik et al, 2008), improved visibility and tracking (Prater et al, 2005), and speed and inventory flow (Ferrer et al, 2010).

3. Method

We use multiple methods that can complement each other and build upon each other towards a richer empirical exploration. This study is structured into two stages, initial exploration using a focus group and a survey and further exploration using a multiple case study method. Initially, implementation considerations were explored in a focus group with managers interested in blockchain in the supply chain. This served the purpose of beginning to identify relevant implementation considerations suggested in RFID research for considering blockchain in the supply chain. Next, the exploration is continued using a high level survey of 99 managers. The survey serves the purpose of beginning to evaluate the relevance of considerations statistically. The use of this initial exploration using a survey is in line with Goldsby and Zinn's (2018) call for more multi-method research, combining qualitative and quantitative research when studying complex phenomena. They suggest that survey research can be used to frame, rather than to statistically generalize a problem, perhaps counter to common uses of multi-method and survey research, in that way returning to its descriptive roots. The use of a survey in this stage of research and with this objective is obviously different from the more conventional survey research focused on robust statistical generalization. However, our research explores a terrain where there is very little empirical research and industry experience and practice in existence today. As a result, we feel that it is more appropriate to use the survey to broadly explore and provide input to the deeper exploration in case studies. Put differently, the current state of research may not yet make robust statistical generalization appropriate, nor may there be the sample of companies that are implementing blockchain available to survey at this point.

The next stage in our research involved conducting multiple case studies of companies that are actually piloting and pioneering blockchain in their supply chains. The case studies provide an opportunity to learn from innovators such as called for by Ferdows (2018). Table I further outlines how the methods and research stages complement and supplement each other in our research design.

	Focus group	Survey	Case studies
Primary contribution to the goal of:	Simplicity	Initial generalization about key consideration	Accuracy
Secondary contribution to the goal of:	Accuracy	Accuracy	Simplicity
Least performing on:	Generalization	Simplicity	Generalization
Set up	Discussion amongst interested executives facilitated by author	Survey of interested executives using items generated in focus group	Deep dive study of case companies
Objective-contribution	Learning from interested companies	Learning from interested companies	Learning from pioneers
	Exploring considerations at high level	Exploring engagement specifically (found key in focus group) with early statistical analysis	Exploring considerations and implementation factors holistically
	Identify relevant considerations descriptively	Begin to evaluate relevant considerations identified in focus group descriptively	Dive deeper into relevant considerations identified in focus group and survey
Geographical scope	USA	Europe and USA	Companies in Europe and USA

Table I. Overview of research methods used

3.1 Initial exploration using focus group and survey

A focus group was organized with EMBA alumni, bringing together executives for a highly interactive worksession on blockchain in the supply chain. In order to provide a basis for the discussion participants were asked to complete a questionnaire in advance of the meeting and aggregated findings were used during the session to drive discussion. The questionnaire used items from RFID literature (see annex 1). Across the 58 participants a number of industries were represented. There was a concentration of retailers (14 participants) and consumer products companies (12 participants). Additionally, professional and financial services (12 participants) and logistics services (4 participants) were prominently represented. Participant experience ranged from manager to vice president.

In order to further the exploration of implementation considerations and the validity of items from RFID literature for blockchain, we conducted a survey among supply chain professionals in both the USA and Europe. Data was collected online from 330 conference attendees during a supply chain conference in Finland, 20 university research center participants in the USA, and 220 supply chain executive contacts in the professional network of the author. Because we set out to study considerations of interested companies specifically, not a random sample of companies we intentionally used a convenience sample. Additionally, because blockchain is a newer technology there may not yet be that many companies with interest and experience to make it possible to survey a random sample.

A total of 99 responses were received in a six weeks period, leading to a response rate of 17.37 percent. This represents a response rate higher than that in most papers referenced in the literature review and well above, for example, Li et al (2010), who received 49 respondents from an unspecified sample size of several hundred. Non-response bias was assessed by comparing responses for the first 20 percent of respondents to the last 20 percent of respondents. No statistically significant differences were found in these tests. Table II provides demographic information of the survey respondents. There are a wide variety of industries represented in the sample, which enhances the generalizability of the findings. In addition, the size of the firms is fairly evenly distributed across the brackets listed.

Industry	Logistics and transportation – 20%	Other manufacturing – 15%
	Energy, Oil & Gas – 11%	CPG & FMCG– 11%
	Healthcare and medical technology – 10%	Construction – 8%
	Technology and high tech – 6%	Media and entertainment – 4%
	Financial services and insurance – 4%	Retail – 3%
	Wholesale – 2%	Hospitality – 2%
Revenue size	<$500 million – 18%	>$500 million – $1 billion – 22%
	>$1 billion – $20 billion – 39%	>$20 billion – 21%

Table II. Respondents demographics

3.2 Further exploration using case studies

Three case studies of companies piloting blockchain in the supply chain were found and studied. Table III offers details on these companies. The companies represent different industries and positions in the supply chain (e,g, logistics providers, consumer product manufacturers and retailers), geographies (North America and Europe), and blockchain applications (international shipping and tracking, tracing of ingredients and creating transparency of the environmental footprint of supplies used). This serves as a basis for broader exploration, which is appropriate at this early stage of knowledge development.

While the inclusion of three case studies may represent a smaller number of companies than in some other blockchain studies, it should be taken into consideration that these are case studies that go beyond the use case stage and publicly available data used in existing research. They study pioneers well into their implementation process and this represent empirical scope beyond existing research. We should acknowledge also that there are not that many pioneers that are this far along into the implementation process.

	Case study 1	Case study 2	Case study 3
Industry	Logistics services	Food and beverage products	Retail
Location	North America	Europe	USA
Focus of pilot	International shipping lanes	Tracking and tracing of ingredients and environmental footprint upstream in the supply chain	Tracing product upstream in the supply chain
Number of informants	4 (multiple calls with each)	2 (multiple meetings with each)	3 (multiple meetings with each)
Level of informants	Senior supply chain and IT executives and project team members	Senior (global supply chain leadership team) and project team member	Senior (supply chain CIO) functional (product safety leader) and IT middle manager
Function of informants	Supply chain, commerce, IT and external consultant	IT and supply chain	Supply chain, IT, product safety
Additional sources	Project documentation, consultant documents and templates used	Project documentation and internal video of project team online work meetings testing the blockchain, also used to communicate internally	Video, external presentations

Table III. Case study details

The case studies were conducted through multiple interviews with multiple informants representing different levels in the company (executive and manager), as well as different functional domains (IT and supply chain). Additionally, we interviewed informants at different levels and forms of involvement in the pilots, including project team members and sponsoring executives. We also included an external consultant involved in case companies 1 and 3 to get an outside perspective from an expert who is involved in the pilots. Internal company reports and videos were also used as sources. Table IV offers further detail on the case study process used leveraging screens for rigorous case study research from Barratt et al (2011) and Beverland and Lindgreen (2010).

Screens for rigorous case studies	This study
Number of cases	Case studies from different continents and industries to enable both broad explorations, as well as to be able to reflect upon findings across different operating environments
Explicit justification of case method	Justified based upon the limited amount of research and practice in place today; there are very few known applications to be studied and this study aims to begin to explore blockchain applications in the supply chain in this infancy stage
Data sources	Observation, files, documents and video, in depth discussion
Reliability	Multiple informants and multiple interviews and data sources help reduce risk of bias
Interview and coding process	Author populated the case study item table and cross-referenced findings from one conversation to the next. Drafted findings were also shared back with the case companies for verification, correction, addition, and validation
Number of coders	Author in multiple steps, from in-company documents to discussing and testing findings with company representatives to reviewing drafted cases study reports
Internal validity	Pattern matching through cross-case comparison
External validity	Multiple case studies in different continents and industries
Unit of analysis	The blockchain pilot of the case companies
Theory vs phenomenon focus	Study is grounded in existing RFID literature aiming explicitly to leverage learning from prior research into this new technology domain
Data analysis	Within and cross-case analysis

Table IV. Screens for rigorous case study research and how they are covered in this research

4. Findings from the initial exploration

In order to explore the relevance of considerations from RFID literature for blockchain implementation, participants in the focus group were first asked to rate relevance of items from RFID research using a 7-point Likert scale, ranging from 1 "not at all" to 7 "to a very large degree". Figures 2 and 3 show average scores ranked from high to low, and these tables were used to drive discussion during the focus group.

Regarding drivers, pressure from customers ranks low. This may indicate a difference from RFID, which initially had pressure from customers surrounding its implementation. The top ranking drivers surround transparency and visibility drivers and a substantial portion of the workshop discussion surrounded this theme. One participant indicated how blockchain can build upon RFID capability;

"With blockchain you can make RFID data available throughout the supply chain and this accelerates its impact and grows the transparency that it helps create."

The drive to fix processes is also an interesting item. In the words of one participant:

"If we can have greater transparency throughout the supply chain faster, we can begin to identify processes that need improving – such as in case of responding to food safety issues."

The importance of this driver may indicate that managers are turning their attention beyond initial use case considerations to what improved transparency can help them achieve. In the words of one participant:

"Blockchain can offer new functionality and supply chain capability, and this is interesting."

While blockchain consideration may be less driven by customer demand or mandate, interested companies and managers do explicitly consider supply chain objectives, just as Ksherti (2018) suggested they should.

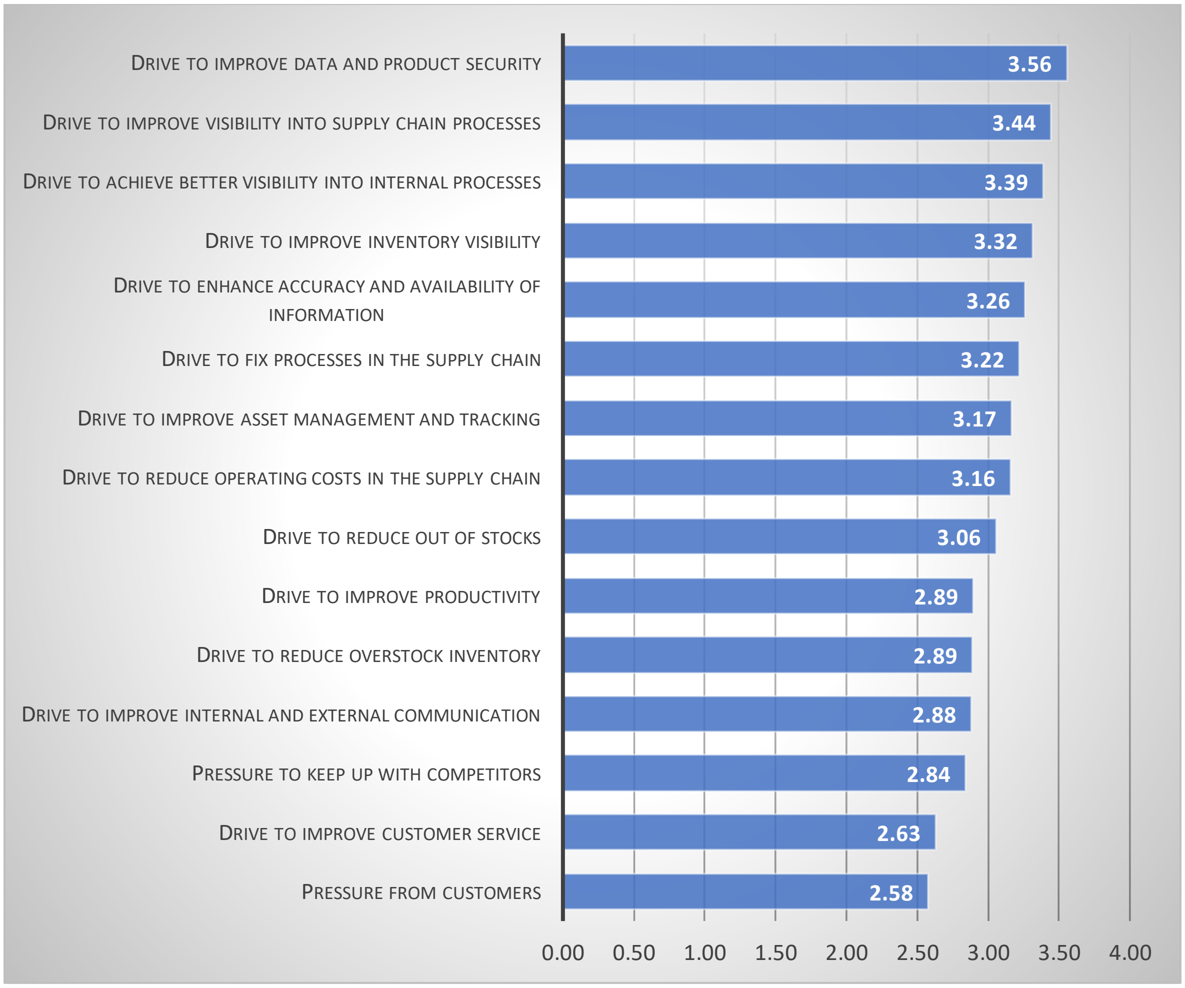


Figure 2. Drivers for blockchain implementation in the supply chain

Regarding barriers, interestingly enough, security, data integrity and technical issues with hardware and software rank towards the bottom of the list. Participants had lots of questions and recognized a need to develop greater understanding of how to integrate blockchain into their supply chain processes, as well as the benefits, the costs, and the ROI of doing so. In the words of one participant:

"It is not hard or expensive to start a blockchain pilot. But, beyond the initial technical proof of concept and the initial pilot, the question becomes how to scale throughout the supply chain and what will the cost and the ROI of that be – we don't know enough about that yet."

This limited understanding today reinforces the relevance of including the focus group exploration; pioneers may not have this lack of understanding, yet many interested managers and companies are asking lots of questions. The consideration being given is positive because it reinforces the relevance of our research and the value of aiming to learn from pioneers.

It was clear from the discussions during the workshop that the concerns are far less about the technology and a lot more about how to adopt and roll the technology out well. This is positive because in their study of use cases Verhoeven et al (2018) found that the technology is sometimes picked first, and the problem is applied to a blockchain solution afterwards. This risk may be decreasing.

Participants did indicate that engagement and leadership commitment in blockchain is a key consideration for them today:

"There is so much interest in blockchain today around the company and this is really driving a willingness to get started and pilot."

"Executives are interested in blockchain and are asking their teams what we are doing with blockchain in our supply chain – this is driving consideration and focus on pilots and use cases. It makes it easier to make the business case, set up a team and include blockchain on the technology roadmap."

These considerations where not included in the focus group discussion document and it seemed relevant therefore to use the high level survey to further study engagement as a consideration identified to be of great relevance.

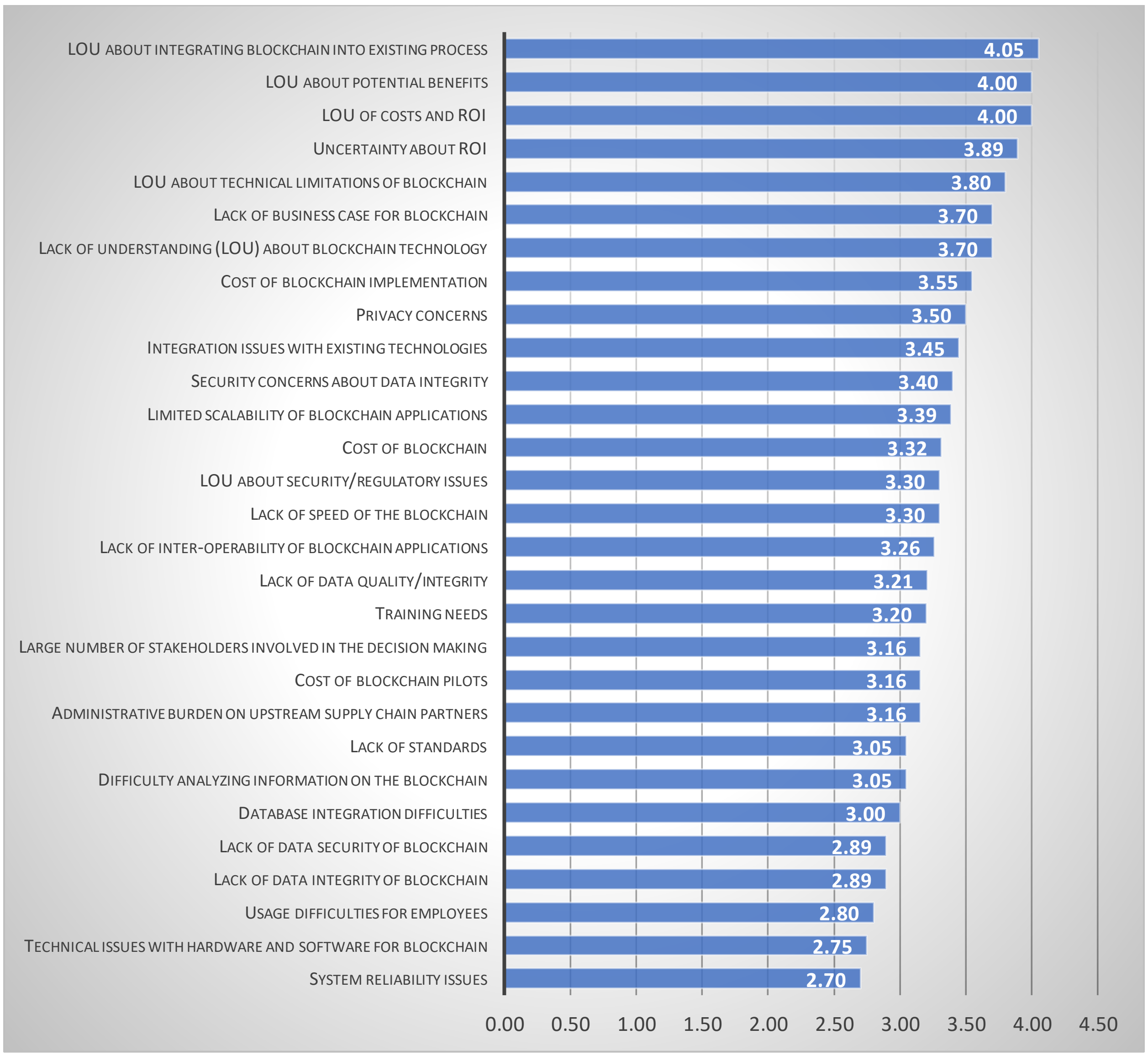


Figure 3. Barriers to blockchain implementation

Whereas the focus group explored drivers and barriers of blockchain implementation, we used the survey to explore the other key factors impacting implementation; leadership commitment and engagement as also identified as a key consideration in the focus groups. Because of the lack of supply chain-wide implementation of blockchain, we chose to ask respondents to indicate if they were piloting blockchain in their supply chain or not. Next, we asked respondents to indicate the degree of engagement in blockchain using a 7-point Likert scale ranging from -3 (not at all) to +3 (very much so).

Table V shows one-way anova analysis comparing average scores for respondents that are piloting vs respondents that are not piloting blockchain in their supply chain. All of the differences between those averages were found to be significant ($p<.01$). As a result, our exploration indicates that executive engagement does matter for the implementation of blockchain in the supply chain, as was the case with the implementation of RFID in the supply chain. This engagement breaks out into both executive and operational management engagement. Additionally, this engagement should be leveraged to develop a strategy for the implementation of blockchain, a business case, a roadmap and a programmatic approach that is staffed with a team. Table VI presents correlation coefficients between these items. The large coefficients imply that there may be opportunities for multi-item scale development in the future as research progresses beyond initial exploration stages. We will revisit this in the future research suggestions.

	Respondents that are not piloting blockchain in the supply chain	Respondents that are piloting blockchain in the supply chain	Significance?
To what degree is there recognition in your company for the potential of blockchain in the supply chain?	-.94	1.47	.000
To what degree is there executive engagement in your company in blockchain in the supply chain?	-1.16	1.09	.000
To what degree is there operational management engagement in your company in blockchain in the supply chain?	-1.49	.97	.000
To what degree does your company have a strategy in place for blockchain in the supply chain?	-1.81	.38	.000
To what degree does your company have an accepted business case in place for blockchain in the supply chain?	-1.64	1.12	.000
To what degree does your company have a program in place for blockchain in the supply chain?	-2.02	.53	.000
To what degree does your company have a roadmap in place for blockchain in the supply chain?	-1.92	.41	.000
To what degree does your company have a dedicated team in place for blockchain in the supply chain?	-1,95	.35	.000

Table V. Comparison of engagement scores between companies that are and that are not piloting blockchain in the supply chain, one-way Anova

	Recognition of potential	Executive engagement	Operational engagement	Strategy in place	Accepted business case	Program in place	Roadmap in place
Executive engagement	.776						
Operational engagement	.738	.812					
Strategy in place	.653	.741	.745				
Accepted business case	.698	.709	.741	.736			
Program in place	.692	.728	.787	.903	.822		
Roadmap n place	.717	.760	.773	.880	.807	.915	
Dedicated team in place	.645	.701	.744	.857	.765	.929	.849

Table VI. Pearson correlation coefficients between engagement items all significant at 0.01 level, two tailed

The findings from the focus group and the survey indicate that implementation factors and considerations suggested in RFID literature are relevant for the consideration of blockchain in the supply chain. In the next section, case study findings will be presented to further explore implementation factors and considerations.

5. Findings from case studies

5.1 Case study 1

Case company 1 is a logistics service provider that is piloting blockchain in an international shipping lane. The international flow of goods involves hundreds of documents – customs forms, shipping logs, and other records. The company hoped that blockchain could make these documents available sooner and easier. The blockchain pilot is customer-facing and tracks shipments through an international shipping lane. The small scale and scope were very intentional. As a consultant involved in the pilot described:

"If you keep a use case focused, you can move fast and learn fast. What is key during the process is that you keep watching for scope creep and the natural tendency of project team members to start solving more and more things during the process. You need to keep a long backlog of issues for phase 2, otherwise you can quickly get bogged down in complexity."

The pilot started when both chief executive officer (CEO) and the chief commercial officer expressed an interest in blockchain and inquired internally as to what was being done with blockchain. This led to the commercial team volunteering for a pilot. Counter to common practice, the company did not go through a business case development process. The interest of the CEO and anticipation from the commercial leadership team that innovating in blockchain could provide meaningful attention and potential differentiation in the marketplace was sufficient bases for launching a pilot. As the supply chain team member on the project team described:

"It was pretty simple to get going. Leadership was interested, the pilot was inexpensive, and we saw real potential to stand out in the marketplace with blockchain innovation and drive revenue based upon that."

Furthermore, the chief information officer (CIO) stated:

"There were also other benefits we anticipated including improved transparency of the flow of goods, reduced administrative burdens, resulting in increased speed in the flow of goods."

Regarding barriers and obstacles, some differences with RFID implementation were found, at least at this pilot stage. Costs concerns are lower because no major investments in hardware were needed and coding requirements were limited. Leveraging insights from an external consultant also made the pilot faster and more doable. A lack of understanding about blockchain was more of a driver behind the pilot and less of a barrier:

"We were really hoping to learn fast and experiment to develop lessons learned." (CIO)

Technical issues were fewer than with RFID, at least in the pilot stage. Beyond the pilot stage however, the blockchain needs to be scaled across more parties and computing powers need to increase. Additionally, data entry is manual and results in possible integrity and accuracy issues. So, unlike RFID, there is less of a system reliability and privacy issue with blockchain pilots, but interoperability between different systems and blockchains and integrity of data may create barriers.

It is too early in the pilot project to fully evaluate the benefits achieved from the pilot. However, similar to RFID not replacing the barcode, blockchain is also not replacing existing technology. In fact, it uses existing EDI links and RFID data as inputs to its dataset:

"We are not replacing technology. We are getting more out of it and creating a neutral platform where we can pull data together to get a more visibility." (Supply Chain manager involved in the pilot)

Integrating systems creates more information availability earlier in the process so that documentation can be handled with fewer errors. The benefits are faster flow through, fewer hold ups for the shipper, and improved asset utilization.

5.2 Case study 2

Case company 2 is food and beverage company. Its pilot centered around tracking the environmental impact of ingredients from upstream suppliers through the supply chain. Linking energy and water consumption information from suppliers to shipments, consumer can scan the barcode on a product on the shelve and see the environmental impact of the ingredients used in that product.

The pilot started after the IT team had communicated about blockchain technology to company leadership in a standing brief about new technologies. This was followed by an internal session with leadership from various functions exploring potential use cases for blockchain. As an outcome of this session, there were requests to the IT team to start pilots. The chief procurement officer (CPO) and the procurement team were among the first and most engaged, and its use case was selected for a pilot.

"It really helped that both the CIO and the CPO wanted to do this pilot, and it helped that there was a procurement manager who was also really willing to commit." (IT manager on the project team)

The limited investment needed in the pilot was provided by the CIO and the CPO, and an external consultant also absorbed some of the costs for the development work. The consultant provided external expertise and resources, as well as some investment.

Case company 2 also found that the use case and teaming are key:

"It is not about the technology. That is the easy part. It is about finding a relevant process and a group of stakeholders internally and externally who are willing to engage. We had great engagement from the procurement leadership and from procurement management on the project team. We had an external partner willing to invest, and we found a supplier that was willing to pilot – that is what it took to get going." (IT project team member)

Case company 2 also leveraged existing technologies, such as barcodes, in its pilot. The scale and scope of the pilot was kept very focused on one type of ingredient and a limited set of the supply line, in order to be able to develop the pilot fast.

The benefits achieved in the pilot are new levels of visibility into the energy and water consumption throughout the supply chain. Consumers can scan the barcode on a product and see its upstream environmental impact. The focus for case company 2 is less on speed, cost and inventory reduction and more about developing new capabilities to achieve the company's sustainability objectives and respond to consumer demands.

5.3 Case study 3

Case company 3 is piloting blockchain as a technology that can track product from the retail shelf back to the producer. What is different from the focus on RFID is that the use case is less focused on on-shelf availability and product inventory. Instead, the focus is on the ability to track product quality or safety issues upstream to the producer. The benefit is the ability to address issues at the source quickly without needing to shut down the entire supply chain. Traditionally, when there is an incident of salmonella in lettuce, for example, the entire supply chain is shut down. All lettuce is removed from the shelves and it takes days if not weeks to find the source of the problem before the supply line can be reopened. In the traditional process there is significant waste, all producers are impacted by the shut down (not just the producer that caused the issue) and consumers are faced with product unavailability and fear.

The intended use of case company 3's blockchain pilot is to not have to shut down the entire supply chain for days or weeks. Instead, they can address the concern with the producer right away by tracing the product back to the producer within seconds, not days or weeks. This has tremendous customer service benefits, financial benefits, and sustainability benefits; less waste, minimal supply chain disruption and limited impact on product availability and on non-troublesome suppliers. As a supply chain manager describes:

"The ability to target product issues without needing to shut down the entire supply chain holds big consumer value; better product on the shelve in an economical manner."

The pilot focused on establishing proof of concept. By working with one farmer and one product group, across several pilot efforts proof of concept was established. The company was able to start piloting quickly by keeping the pilot scope small and by engaging just a few interested supply chain partners. Obviously, this means that scaling beyond the pilot may require more work and a greater effort. As the CIO puts it:

"If the technology works that is great but if you have proof of concept you have not yet rolled it out to the supply chain – that will require a lot more than a working technology."

6.4 Cross-case comparison and interpretation of findings

Table VII summarizes findings using the factors from the Reyes et al (2016) framework.

Items from literature	Case study 1	Case study 2	Case study 3
Drivers			
Internal drivers	Improving transparency and reducing administrative burdens enabling the speeding up of the supply chain. Fewer drivers than suggested in literature for RFID and external drivers were more important.	Commitment to sustainability and an interest in learning and experimenting with technology as part of larger supply chain digitization ambitions.	Improving ability to trace sources of product safety issues upstream much faster and effectively.
External drivers	Key factors: Interest in using blockchain to be seen as innovative and to	While tracking and tracing and supply chain transparency also is a driver	Potential consumer benefit critical driver behind pilot.

	differentiate the company in the market. This is different from drivers found in RFID; it is less driven by big customer pull and more by supplier push.	in RFID, the use of that is different here. The focus is on creating environmental impact visibility throughout the supply chain.	
Top management leadership	CEO and Chief Commercial Officer interest drove early efforts and made it easy to drive engagement, establish funding and resourcing.	CIO and CPO engagement made funding and staffing easy.	Supply chain and IT leadership driving but pilot was also featured in investor day presentation and citizenship report.
Middle level management leadership	Leaders in IT, operations and commerce keenly jumped on the opportunity to pilot and learn.	Engagement at the management level and the supplier level were key drivers.	In addition to internal project team, supported by consultants, supplier engagement was key.
Barriers/Obstacles			
Cost/financial issues	The pilot was inexpensive and, different from RFID, did not require major investment in coding or hardware. It did require resourcing across the stakeholders involved and consultant support. But because of the scope and the desire of the consultant to learn with the client, these costs were relatively low.	Investment was raised between CPO and CIO, as well as the consultant. The targeted scoping and scaling enabled a very affordable pilot budget.	Pilot scoped with focus to enable small budget and rapid ramp to pilot.
Lack of understanding	The pilot was highly driven by a desire to develop understanding and provide a basis for future larger scale roll out. Most of the RFID unknowns mentioned in literature apply to blockchain.	The pilot was driving by a desire to learn and experiment and consider future scaling potential.	Pilot centered around developing proof of concept of the technology.
Technical issues – internal and external	In the pilot, there were few technological concerns; the technology is relatively straight forward and coding only took a few weeks. Beyond the pilot, the lack of standards, possible interoperability between blockchains along the supply chain, as well as the need for computing power and correct data entry by staff can become issues. System reliability issues (a concern in RFID) is less of a concern than data accuracy and integrity issues.	Technology was not seen as a key bottleneck in the development of the pilot. Scaling beyond the pilot might lead to standardization issues and computing power concerns. The fact that manual data entry is required might limit the ability to scale and limit supplier acceptance, in particular if they get multiple requests for blockchain participation from multiple customers.	Proof of concept was established but to move from pilot to larger scale implementation requires many more supply chain partners to join the blockchain and this may require more time and effort than getting the pilot scope up and running. Put simply, with proof of concept you do not have a supply chain implementation yet.
Privacy issues	Less of a concern given the focus on transportation movements.	Less of a concern due to the focus on the upstream supply chain, but there are concerns	Less of a concern because the pilot is focused

		about protecting supplier data and confidentiality, and these run counter to the desire to drive transparency with blockchain.	upstream and does not include consumer data.
Lack of business case	Less of a concern. Leadership interest and relatively inexpensive piloting disposed of the need to develop a full business case, at least for the pilot.	Less of a concern, at least for the pilot; senior executive, supply chain, and management interest, coupled with limited investment requirements in the pilot, made it unnecessary to develop a full business case.	Less of a concern; focus on piloting use case to evaluate if there is proof of concept.
Implementation	Pilot that is customer facing in a small scale and scope (one route only) and is centered on international shipping.	Pilot that is supplier facing in a small scale and scope (a few ingredient suppliers only) and centered on the inbound supply line of ingredients.	Pilot is supplier facing and relatively small in scale and scope (a few suppliers only) but does cover multiple tiers in the supply chain.
Benefits			
Customer service	Too early to tell given the stage of the pilot, but automation and information benefits are in scope, and, as with RFID, transformational benefits may be limited.	Ultimately, this leads to a consumer benefit; creating visibility into energy and water consumption involved in the production of an individual product.	Most critical benefit – improved product quality in the store without quality concerns and quality driven product outages
Costs and productivity, asset management and inventory shrinkage	While there is some costs potential from improved asset utilization in transport, the effectiveness and speed of the flow of goods are bigger improvements. Reduced staff costs may not be fully achieved, unlike in RFID, because there is still data entry required. However, data feeds from existing technologies such as EDI and RFID tracking can be fed into the blockchain.	Not really a target and outside of the scope; this is more about creating new capability than driving down costs and inventory.	Not the main focus of the pilot but a side benefit of the faster response to safety issues is that there is less product waste.
Communication	The supply chain improvement is based on improved communication between supply chain parties, enabling faster and earlier processing of information (customs clearance etc.).	Creates more data sharing upstream in the supply chain leading to new levels of visibility.	Key – ability to address safety issues upstream with suppliers.
Visibility and tracking	Main effectiveness improvement in the supply chain.	Main enabler of the benefit.	Main added value of blockchain over existing technology.
Speed and inventory flow	Main consequence of the effectiveness improvement in the supply chain.	No impact.	Speed of response to issues key.

Table VII. Case Study Findings

Drivers - In all three case companies, the consideration of blockchain in the supply chain is driven by customer and market considerations. Whether being innovative in the eyes of customers for case company 1, creating new customer visibility for case company 2 or greater product safety for consumers in case company 3 all use cases prominently feature the customer. The customer however, is featured in a different way than in many RFID implementations. Customer-mandated implementation drove more RFID implementation than it does with blockchain. And internal consideration of blockchain represents more critical drivers. Whether it be the desire to improve sustainability in case company 2, reduce administrative burdens in case company or improve traceability in case company 3, all case companies have clear internal interests that are driving them to consider blockchain in the supply chain. This does not, however, mean that implementation is only driven by internal considerations. As is the case with RFID, blockchain is very much considered across supply chain tiers and multiple companies.

Leadership commitment – Case companies indicate that blockchain implementation can begin quickly with selected senior and middle/operational management engagement. This is in contrast to RFID implementation, which requires greater upfront technology and equipment investment. The case companies intentionally scoped their pilots narrowly to allow for a quick start and rapid learning. In addition to the engagement of a few senior executive sponsors and operational management peers, engagement of a few supply chain players (supplier, farmer, shipper) is also key to start a pilot.

Barriers – With the narrow and targeted scoping of blockchain pilots, case companies are able to begin implementation quickly. It also reduces the need for a business case because funding requirements are limited, and a pilot can provide a rich opportunity to learn and reduce lack of understanding about the technology. Interestingly, in all three case companies, technical and privacy issues were not perceived as a barrier in the pilot stage. Additionally, like with RFID technology, blockchain technology does not typically replace existing technology (despite popular claims about this). Instead, case companies use datafeeds from existing technologies (RFID in case company 1 and bar codes in case company 2 and 3).

Implementation - All three case companies were still uncertain of their ability to scale the implementation across the supply chain. Case company 1 noted a lack of standards, case company 2 cited limits on supplier acceptance if multiple forms of data entry are required for blockchain, and case company 3 stressed that moving beyond proof of concept may require more time and effort.

Benefits – While case companies have achieved proof of concept in their pilots, the benefits considered as part of the use case are not fully experienced in the pilot setting. However, it is clear that there is substantial overlap with RFID benefits in areas such as visibility, tracking, and improved communication throughout the supply chain. This may lead to cost reductions, productivity, and inventory benefits, but the case companies are more focused on improving service and disseminating data more quickly.

6. Discussion of cross-method findings

Our findings indicate that the factors from the Reyes et al (2016) framework are relevant for considering blockchain in the supply chain. For example, a number of internal and external drivers were found to be relevant considerations for blockchain in the supply chain. While RFID implementation was driven more by customer demands than blockchain is today, customer impact is still a key consideration. Leadership engagement in blockchain at both executive and operational levels is also relevant. This engagement, however, does not have to be universal; case companies engaged a few sponsors and participants for the initial implementation of blockchain in the supply chain. Engagement of 2-4 interested supply chain partners appears to be sufficient to start a pilot. Barriers to implementation may include a lack of understanding of blockchain, and implementation can vary by supply chain and use case. The benefits targeted with blockchain in the supply chain range from transparency and visibility to speed in the supply chain. And our findings do reinforce overlapping functionality between RFID and blockchain technologies in the transparency, visibility and traceability domain. Obviously, it remains key to ensure that use cases address specific supply chain benefits upfront in order to avoid a "solution looking for a problem" but we are encouraged to have found amply consideration being given to these by companies participating in our research.

As was the case with RFID, blockchain should not be approached as a new technology that is going to solve all supply chain challenges overnight. In particular, scaling to supply chain wide implementation of blockchain will require time, investment, and ongoing engagement of management. Blockchain is also not a technology that is going to make existing technology obsolete. In fact, it may leverage inputs from RFID and other existing supply chain technologies, which is in line with recent research from Saberi et al (2018) pointing to the value of combined consideration of RFID and blockchain in the supply chain. Blockchain may, indeed, be a complement to the existing technology roadmap and technology infrastructure.

Beyond the relevance of the factors from the Reyes et al (2016) framework, our findings indicate that there are some key differences between the implementation of RFID and blockchain technology in the supply chain. These differences can be used to adapt the Reyes et al (2016) framework for blockchain implementation, as shown in figure 4. Beginning with drivers, blockchain pilots appear to be driven more by executive interest and internal drivers, whereas customers often mandated RFID implementation. While the use cases in our case studies center around creating new customer value, they are not driven by customer mandates or requirements. The focus group findings indicated that customer pressures are low on the list of drivers behind blockchain. Consideration of blockchain in the supply chain includes customer and market benefits but tends to be initiated by internal factors.

	Similar to RFID implementation	Unique to blockchain implementation	Interpretation and discussion
Drivers	• Customer considerations are important…	• …but less of a customer requirement, more of a market potential perspective • …but internal drivers are more prominent	• Risk of technology driven consideration • Potential challenge to engage supply chain partners if drive is internal, not customer centric
Leadership commitment	• Top and middle management support enables implementation of blockchain like it does of RFID…	• …but executive engagement can greatly accelerate pilots • …and 2-4 engaged partner may suffice initially	• This implies great potential to start a pilot and do so fairly quickly, however this may be a temporal advantage • And this advantage may be partial; for further roll out wider supply chain engagement will be needed
Barriers	• Relevant to consider barriers upfront • Lack of understanding is equally prominent in blockchain consideration	• For a pilot a formal business case is less needed and • There is less upfront investment needed for blockchain	• A pilot can support the development of improved understanding and privacy issues can be controlled in a pilot setting • Possibility of loose economical foundation puts roll out and link to RFID at risk
Implementation	• Implementation levels can vary from supply chain to supply chain…	• …but actual blockchain implementation levels are limited to date • …making it unclear of blockchain will be as scalable as RFID	• Implementation directions can be both upstream and downstream oriented in the supply chain • If implementation can be supply chain-wide is worthy subject of further research
Benefits	• Visibility and traceability stand out as similar benefits/functionalities, confirming the overlapping functionality and potential to complement RFID with blockchain…	• …less of an inventory tracking and recording focus, more of a dissemination benefit • …benefits may be more narrowly defined	• Proof of concept does not represent supply chain wide adoption, for this more consideration will be needed

Figure 4 Similarities and differences between RFID and blockchain implementation, discussion of findings

Regarding leadership commitment, the interest in blockchain is helping drive use case and pilot development. The case study findings indicate that focusing on 2-4 interested supply chain partners will enable a fast start of a pilot. This may be somewhat different from RFID, as starting a pilot involves more hardware investment and physical infrastructure development. In that respect, barriers play a different role when it comes to blockchain. A business case is relevant, as indicated by both the survey and the focus group's interest in understanding the benefits and returns of blockchain. However, our case studies indicate that with the right executive engagement and a focus on 2-4 supply chain partners, the investment may be limited and a business case may not be needed.

Lack of understanding was an important consideration for focus group participants, and the case study findings suggest that starting a pilot for the sake of learning and evaluating technical issues and establishing proof of concept is a meaningful solution. Privacy issues were of lesser concern for the case companies, but this may partially be due to the controlled pilot environment with few participants. Both focus group findings and case study findings indicate that the consideration of blockchain in the supply chain centers far less on the technology than it does on supply chain improvement opportunities and potential customer value impact. This is encouraging given Verhoeven et al's (2018) warning against technology-centricity and a "solution looking for a problem". Our findings indicate that supply chain objectives are considered and that the companies currently piloting are centering their pioneering around supply chain objectives rather than just technology interest.

The case study findings regarding leadership commitment refine the findings from the survey. The survey findings indicated that engagement of executive and operational management is relevant for blockchain implementation in the supply chain. The exploration of survey data using correlation analysis further indicated that the is a strong relation between this engagement and the availability of a business case, roadmap, and a strategy for blockchain in the supply chain. Case study findings indicate, however, that while this may be true and valid for larger scale implementation, a business case and strategy is not needed for the initial pilot stages, nor is complete executive and operational management engagement. The commitment of only a few leaders and supply chain partners may suffice for the pilot. Additionally, case companies engaged in the blockchain pilots to learn and inform further consideration of blockchain in the supply chain, not yet having fully developed a roadmap or a strategy.

Implementation of blockchain across the supply chain is limited, so learnings from those at the frontier are limited when it comes to full scale implementation. The case study findings indicate that scaling the implementation beyond the pilot and beyond the initial 2-4 supply chain players may lead to scalability concerns and higher implementation costs.

Regarding benefits, while focus group participants see many potential benefits of blockchain in the supply chain, the case companies are more centered on visibility and communication throughout the supply chain. This is perhaps a bit of a narrower set of benefits than those considered for RFID.

Figure 5 offers a framework for considerations during the different stages of the implementation process. This figure summarizes how these considerations may evolve and change as pioneers move from pilot to roll out. Internal drivers, while found to be most important initially, may not suffice for roll out. And while executive engagement make use case development easier and 2-4 engaged partners may make it possible to start a pilot, this will not suffice for a larger scale roll out. Lack of understanding is a key barrier considered and a business case and security are less of a concern initially. For a larger scale roll out further economic evaluation will likely be necessary, in particular if blockchain adoption is scoped beyond a narrow section of the supply chain, which is the typical scope of pilot adoption. Finally, visibility and traceability are key benefits considered in use cases and experienced in pilots. The implementation of blockchain can complement that of RFID, in stead of replace it, but further proof of concept of these benefits is being sought by case companies. This figure expands upon the Reyes et al (2016) framework by offering blockchain specific considerations and insight into how these evolve and how priorities may change over time. The figure may also support managerial decision making and point at further research opportunities.

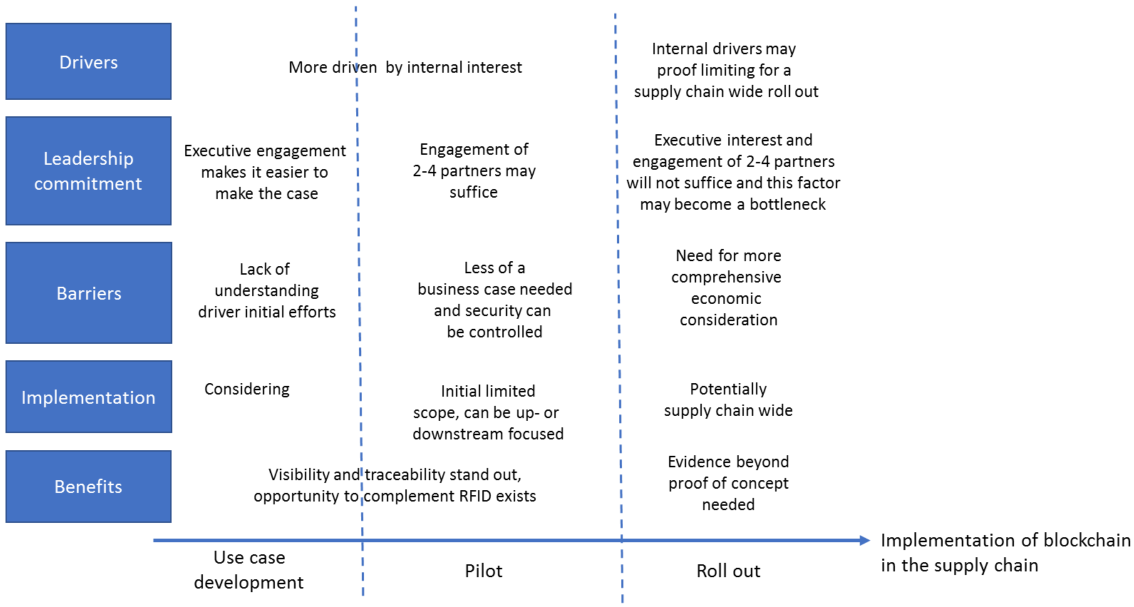


Figure 5 Importance and development of implementation considerations during blockchain implementation stages

6.3 Contributions and limitations

Beyond the contributions of our research to the advancement of the practice of operations management as outlined in the form of managerial implications in the next section, our research also makes multiple contributions to the advancement of operations theory and research. First of all, our research contributes a wider and deeper exploration of blockchain in the supply chain, advancing research beyond the many conceptual or literature studies and the studies that consider (publicly available) high level use case descriptions only. Our research more widely explores perspectives of interested managers through focus group and survey and explores lessons that the few pioneers in this field are learning by studying case companies. Additionally, our case studies advance further into the implementation process than most existing blockchain research and consider lessons from the start of the actual implementation and proof of concept stage.

Our findings reinforce the relevance of Ferdows (2018) call to learn from pioneers. Not only does it add to limited amount of empirical data available. It also reveals that pioneers pilot to reduce the lack of understanding so widely reported by interested managers. And our findings indicate that they not only generate lots of learnings but also that their decision making considerations evolve and change during the implementation process. Clearly indicating that there is a lot to learn and research beyond the use case stage.

Our research actively leverages research on the implementation of RFID in the supply chain to accelerate the learning process and to reduce the risk of "reinventing the wheel". RFID research was selected because of the similarity in hype and functionality, its joined explicit focus on cross company implementation in the supply chain and the calls for complementary implementations. Our findings do indicate that there is indeed overlapping functionality between RFID and blockchain in the supply chain. Both technologies can contribute to greater visibility, transparency and traceability, but RFID may also be used for additional reasons such as inventory shrinkage. Our case study findings indicated that blockchain can indeed complement RFID technology by disseminating data captured by RFID more quickly throughout the supply chain. And while case study findings indicated that blockchain can drive upstream and downstream benefits in the supply chain, at the current stage of implementation blockchain is not yet implemented supply chain wide.

More specifically, our research approach focused on leveraging lessons learned from research into RFID research enabled the identification of high level implementation factors such as internal and external drivers and leadership commitment. It also proved beneficial for identifying several specific considerations that are relevant for blockchain implementation, just as they are for RFID implementation. With many other newer technologies entering the supply chain, our research approach may be valid for wider use.

A specific contribution to the understanding of blockchain in the supply chain is captured in figure 4 – the specific considerations and their interpretation for blockchain implementation. This figure not only leverages RFID insights and lessons from pioneers, it contributes to a more detailed understanding of implementation considerations and creates a framework for decision making. Further to that, figure 5 makes additional contributions by capturing how considerations evolve and change from one implementation stage to the next. This finding reinforces the relevance of moving beyond the study of use cases as widely done in existing research. It also advances beyond the Reyes et al (2016) framework as this framework did not distinguish between implementation stages.

As our research contributes nuance to the consideration of blockchain in the supply chain and grounds findings in empirical study, as opposed to theoretical consideration of technologic possibility, it can contribute to a more grounded, less hyped, discussion of blockchain in the supply chain, in industry and research. And while a lot is learned from the contributing managers and pioneers, it is also fair to say that we did not yet find supply chain-wide and full-scale implementations of blockchain. Clearly this represents fruitful area for further learning from pioneers.

While of value, our contributions are not without limitations. Many areas for further research remain in this dynamic and rapidly evolving terrain. First of all, our focus group and survey where highly descriptive and used a convenience sample. As knowledge about blockchain and interest in blockchain spreads, it will become possible to survey a random sample of companies. This may allow for a more rigorous statistical analysis and potential generalization of findings. Furthermore, our survey findings indicate correlations between items surveyed; perhaps a more comprehensive survey would allow for multi-item scale development of an engagement measure and also for other factors from the framework. This can support progression from exploration and description into initial statistical generalization of findings.

While we were able to study pioneers at the frontier of the implementation of blockchain in the supply chain, it is not fully adopted by any of the case companies in our research. As a result, benefits, barriers, and implementation paths need to be explored more fully. There is opportunity to learn more as our case companies advance their implementation process into larger scale implementation. We recommend not only continued study of the pioneers and interested companies included in our research, but also more companies as they begin to consider and adopt blockchain in their supply chain. It will thus become possible to expand the number of cases studied and further explore blockchain implementation in different operating and supply chain environments, segments, and geographies.

Our research indicated that the consideration of blockchain in the supply chain can benefit from lessons learned in RFID research. Our research also indicated that there are specific reasons for considering lessons learned about RFID implementation including: (1) similarity in use cases, (2) a similar focus on cross company supply chain settings as opposed to in-company implementation such as is more common with ERP, (3) a similar amount of interest in blockchain as there was in RFID 15 years ago and (4) a call for considering blockchain as a complement to RFID implementations. However, there are several other existing technologies in the supply chain that could also inform blockchain implementation. For example, AI and big data may benefit from blockchain, or they may enable blockchain. Further to that, our findings indicated that blockchain in the supply chain may indeed complement and use existing technologies such as bar coding and RFID (instead of replace them). There are early use cases that combine blockchain with other new technologies. Walmart for example has reportedly filed for a patent on a robot delivery system that uses blockchain to record deliveries. Given that the benefits of RFID are still being studied and are not fully understood today (Shin and Eksioglu, 2015), another fruitful avenue for further research would be the impact of blockchain on existing technologies. Can blockchain make RFID applications better by communicating data on the blockchain? How does this change the investment in RFID and the return achievable?

7. Implications for managers

Our exploratory research offers several implications for managers considering blockchain in the supply chain. The first implication is that fueled by the hype around blockchain there is a wide interest in blockchain in the supply chain and it is recommended that managers that are not yet considering blockchain for their supply chain do so, using the findings from this paper. Those companies and managers that are already considering blockchain and that are piloting are advised to ensure they have a use case that identifies relevant supply chain objectives and consider drivers, engagement and barriers identified. Based upon our exploration and study of pioneers in the field figure 4 offers relevant factors to consider and specific blockchain considerations within that. Our findings can help managers move beyond discussions about the theoretical potential of blockchain to a better understanding of what to consider.

Figure 5 provides a decision support framework for managers considering blockchain from use case development, to pilot, to larger-scale roll out. It clarifies how factors such as barriers and benefits vary in importance from one stage to another, and it clarifies how specific considerations evolve during the implementation process. This framework can support managerial decision making beyond the Reyes et al (2016) framework because it includes blockchain-specific considerations and captures nuances in decision making by implementation stage.

Our case studies findings indicate that it can be relatively easy and inexpensive to start piloting blockchain in the supply chain when there are 2-4 interested parties and senior executive engagement and (modest) funding. In that respect, blockchain may be different from RFID, which requires larger upfront investments. For interested managers, the implication of this finding is that to get started engagement of a few sponsoring executives, operational managers and supply chain partners may suffice. It is key however is to ensure that a use case and pilot is focused and narrowly scoped to enable a faster start.

The case study findings indicate that blockchain may be approached as a complement to existing technologies rather than a replacement. In fact, it may use inputs from existing technologies. RFID and bar coding data, for example, are often used as data input in the blockchain implementation. As a result, managers should approach blockchain with nuanced consideration and not view it as the new panacea that will make all existing technology obsolete or irrelevant.

8. Conclusion

While there is great interest in blockchain in the supply chain, there is little empirical research and experience in industry to consider. As a result, it is relevant to consider lessons learned from RFID and to explore innovation at the frontier of practice as recommended by Ferdows (2018). While our research adds empirical findings beyond the scope of existing research on blockchain in the supply chain, while our research can help inform realistic expectations and develops a framework for considering blockchain in the supply chain, the exploration is far from over.

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Annex 1. Overview of items from literature on RFID implementation in the supply chain

Drivers	
Internal drivers	
Improve customer service	Reyes et al (2016)
Improve productivity	Reyes et al (2016)
Reduce operating costs in the supply chain	Vijayaraman and Osyk (2006); Li et al (2010); Reyes et al (2016)
Enhance accuracy and availability of information	Chuang and Shaw (2007); Reyes et al (2016)
Better inventory visibility	Vijayaraman and Osyk (2006); Reyes et al (2016)
Better visibility into supply chain processes	Vijayaraman and Osyk (2006); Li et al (2010); Reyes et al (2016)
Reduce overstock inventory	Reyes et al (2016)
Improve reconciliation of perpetual inventory	Reyes et al (2016)

Reduction of out of stock	Karkkainen (2003); Vijayaraman and Osyk (2006); Li et al (2010); Reyes et al (2016)
Improve asset management and tracking	Vijayaraman and Osyk (2006); Li et al (2010); Reyes et al (2016)
Improve internal and external communication	Reyes et al (2016)
Better inventory tracking and tracing	Li et al (2010)
Increased automation	Chuang and Shaw (2007)
Inventory reduction	Vijayaraman and Osyk (2006); Li et al (2010)
Lead time reduction	Li et al (2010)
Improved efficiency in operations	Hou and Huang (2006); Li et al (2010)
Improved labor efficiency	Vijayaraman and Osyk (2006); Li et al (2010)
Improve quality control	Li et al (2010)
Better ability to trace defects	Li et al (2010)
Improved accuracy in shipping and receiving	Li et al (2010)
Claims reduction	Vijayaraman and Osyk (2006); Li et al (2010)
Minimize inventory losses	Li et al (2010)
Reduced costs of labor for material handling	Chuang and Shaw (2007); Li et al (2010)
Strategic initiative	Li et al (2010)
Competitive advantage	Li et al (2010)
Security	Vijayaraman and Osyk (2006)
External drivers	
Pressure from customer(s) to improve efficiencies, reduce lead time and track and trace	Hou and Huang (2006); Vijayaraman and Osyk (2006); Li et al (2010); Bhattacharya (2012); Reyes et al (2016)
Keep up with competitors	Reyes et al (2016)
Improved store sales	Vijayaraman and Osyk (2006); Li et al (2010)
Improved store shelf inventory	Vijayaraman and Osyk (2006); Li et al (2010)
Improved customer service	Li et al (2010)
Improved response time to customer inquiries	Li et al (2010)
Increased collaboration and planning	Li et al (2010)
Improved supply chain information sharing	Li et al (2010)
Leadership Commitment	
Top management leadership	
Lack of top management buy in	Attaran (2007); Li et al (2010)
Top management develops and communicates the RFID implementation plan	Reyes et al (2016)
Top management sets priorities for RFID implementation	Thiesse et al (2011); Reyes et al (2016)
Top management participates in developing and implementing the policies and methods of RFID implementation	Reyes et al (2016)
Top management fosters communication among different departments concerning the RFID implementation	Reyes et al (2016)
Top management assures the organization’s staff is trained to implement RFID	Reyes et al (2016)
Middle level management leadership	
Department heads integrate the department’s RFID implementation plan with the organization’s RFID implementation plan	Reyes et al (2016)
Department heads coordinate interdepartmental and intradepartmental RFID implementation decisions and activities	Reyes et al (2016)
Department heads recommend resources needed to facilitate the RFID implementation plan	Reyes et al (2016)
Barriers/Obstacles	
Cost/Financial issues	

Cost including costs of tags and readers	Hou and Huang (2006); Vijayaraman and Osyk (2006); Chuang and Shaw (2007); Bottani and Rizzi (2008); Bhattacharya (2012); Fan et al (2015); Reyes et al (2016)
Initial cost of implementation	Li et al (2010); Fan et al (2015); Reyes et al (2016)
Return on investment too low/uncertain	Hou and Huang (2006); Attaran (2007); Miragliotta et al (2009); Li et al (2010); Bhattacharya (2012); Lim et al (2013); Reyes et al (2016)
Costs of maintaining the system are high	Li et al (2010)
Lack of funds	Vijayaraman and Osyk (2006); Li et al (2010)
Lack of understanding	
LOU about RFID technology and its implementation in the supply chain	Hou and Huang (2006); Bendoly et al (2007); Ngai et al (2007); Vijayaraman and Osyk (2006); Reyes et al (2016)
LOU about potential benefits	Li et al (2010); Reyes et al (2016)
LOU about developing/integrating new process	Reyes et al (2016)
LOU about determining potential costs and ROI	Miragliotta et al (2009); Li et al (2010); Reyes et al (2016)
LOU about technical limitations of RFID	Bendoly et al (2007)
Training problems	Reyes et al (2016)
LOU about security/regulation issues	Reyes et al (2016)
Large number of stakeholders involved in the decision making	Reyes et al (2016)
Payback period unclear	Li et al (2010)
Lack of top management understanding of RFID	Li et al (2010); Bhattacharya (2012)
Resistance from employees	Hou and Huang (2006); Ngai et al (2007); Thiesse et al (2011); Bhattacharya (2012)
Technical Issues – internal and external	
Technical issues with hardware and software	Attaran (2007); Bhattacharya (2012); Reyes et al (2016)
Analysis and utilization of information generated from the RFID system	Reyes et al (2016)
Usage difficulties for employees	Reyes et al (2016)
Database integration difficulties	Bhattacharya (2012); Reyes et al (2016)
Technology is too new	Li et al (2010)
System reliability issues	Chuang and Shaw (2007); Delen et al (2007); Ngai et al (2007); Li et al (2010); Lim et al (2013)
Lack of standards	Srivastava (2004); Hou and Huang (2006); Vijayaraman and Osyk (2006); Chuang and Shaw (2007); Ngai et al (2007); Li et al (2010); Bhattacharya (2012); Lim et al (2013)
Integration issues with existing technology	Attaran (2007); Niederman (2007); Li et al (2010); Lim et al (2013)
Privacy Issues	
Privacy concerns	Ngai et al (2007); Li et al (2010); Bhattacharya (2012); Lim et al (2013); Reyes et al (2016)
Educating customers and employees about RFID and how the data will be used	Reyes et al (2016)
Security concerns about data integrity	Ngai et al (2007); Reyes et al (2016)
Lack of business case	
Lack of business case to benchmark against/cost and benefit justification	Prater et al (2005); Chuang and Shaw (2007); Li et al (2010)
Expected benefits are not enough	Vijayaraman and Osyk (2006); Li et al (2010)
Implementation	
Not considering, considering, piloting, implementing	Vijayaraman and Osyk (2006); Reyes et al (2016)
Implementation path; supplier facing diffusion or customer facing diffusion	Lee at al (2008)
Scale of implementation (high – low) and scope of implementation (narrow – broad)	Roh et al. (2009)

Area of supply chain implementation (raw material flow, work in progress, finished goods	Zelbst (2012)
Without understanding data, more data does not add value	Delen et al (2007)
Innovation process: generation, acceptance, implementation	Smart et al (2010)
Benefits	
Automation benefits, information benefits, transformational benefits	Visich et al (2009)
Benefits may not be balanced in the supply chain; retailer may benefit more	Bottani and Rizzi (2008)
Do not over focus on costs vs supply chain effectiveness	Zelbst et al (2012)
Customer Service	
Improved service quality, service levels and on time delivery	Sarac et al (2010); Thiesse et al (2011); Bhattacharya (2012); Zelbst et al (2012)
Delivery performance/Improving customer satisfaction with delivery fulfilment processes	Lim et al (2013); Zelbst et al (2012); Reyes et al (2016)
Improving customer order tracking and visibility into customer needs	Attaran (2007); Reyes et al (2016)
Improving customer satisfaction by mainstreaming administrative processes and reducing dwell time	Kim et al (2008); Reyes et al (2016)
Improved order forecasts	Attaran (2007)
Reduced stock outs/fill rate/on shelf availability	Prater et al (2005); Bottani and Rizzi (2008); Thiesse et al (2011); Bhattacharya (2012); Zelbst et al (2012); Lim et al (2013)
Faster exception management and responsiveness	Zelbst et al (2012); Lim et al (2013)
Better expiry date management	Lim et al (2013)
Improved quality control	Lim et al (2013)
Improved returns/recall management	Attaran (2007); Bhattacharya (2012)
Gaining favor with retailers to better position products on shelves	Attaran (2007)
Revenue growth	Attaran (2007); Bottani and Rizzi (2008); Sarac et al (2010); Bhattacharya (2012)
Costs and Productivity	
Reduced supply chain costs	Attaran (2007); Sarac et al (2010); Bhattacharya (2012); Zelbst et al (2012); Lim et al (2013)
Improve support employees' productivity/less direct labor required for routine tasks such as inventory control and update entries	Kim et al (2008); Veronneau and Roy (2009); Ferrer et al (2010); Bhattacharya (2012); Lim et al (2013); Shin and Eksioglu (2015); Reyes et al (2016)
Lower inventory and safety stock	Attaran (2007); Bottani and Rizzi (2008); Thiesse et al (2011); Zelbst et al (2012); Lim et al (2013); Shin and Eksioglu (2014)
Improve material handling	Lim et al (2013); Reyes et al (2016)
Reduce fulfilment errors	Reyes et al (2016)
Increasing productivity/throughput of service facilities/improved space utilization	Poon et al (2009); Ferrer et al (2010); Thiesse et al (2011); Lim et al (2013)
Accelerate the cash to cash cycle time	Zelbst et al (2012)
Inventory days of supply reduction	Zelbst et al (2012)
Asset Management	
Improve the tracking, utilization and management of assets and equipment	Attaran (2007); Tzeng et al (2008); Lim et al (2013); Reyes et al (2016)
Improve the preventive maintenance of equipment	Reyes et al (2016)
Improve the utilization of reusable assets (totes for parts)	Reyes et al (2016)
Communication	

Improved/Ease of communication and data sharing between firm, customer and supply chain partners	Tzeng et al (2008); Sarac et al (2010); Lim et al (2013); Reyes et al (2016)
Improve internal communication among employees	Reyes et al (2016)
Better determining of arrival and dispatch times	Lim et al (2013)
Inventory shrinkage	
Reduced inventory shrinkage due to greater visibility and improved prevention	Rekik et al (2008); De Kok et al (2008); Bhattacharya (2012); Dai and Tseng (2012); Lim et al (2013); Fan et al (2014); Fan et al (2015)
Minimize inventory loses	Roh et al (2009); Sarac et al (2010); Ferrer et al (2010); Li et al (2010)
Reduced counterfeiting	Attaran (2007); Bhattacharya (2012)
Visibility and tracking	
Improve the tracking of supply and product throughout the supply chain	Attaran (2007); Lee and Ozer (2007); Sarac et al (2010); Lim et al (2013); Reyes et al (2016)
Increased inventory visibility	Prater et al (2005)
Accurate and timely asset tracking	Attaran (2007)
Greater data accuracy	Poon et al (2009); Sarac et al (2010); Bhattacharya (2012); Zelbst et al (2012); Lim et al (2013)
Enhanced visibility in the supply chain	Veronneau and Roy (2009); Sarac et al (2010)
More real time information/time reduction in storing and retrieving information	Prater et al (2005); Poon et al (2009); Sarac et al (2010); Bhattacharya (2012)
Reduction in bullwhip effect	Bottani and Rizzi (2008); Sarac et al (2010)
Speed and inventory flow	
Cycle time reduction	Roh et al (2009); Ferrer et al (2010)
Speed up operational processes such as tracking, shipping, checkout and counting	Sarac et al (2010)
Improved inventory flow	Sarac et al (2010)
Speed of delivery relative to competitors	Zelbst et al (2012)
Improved velocity by responding to demand signal faster	Attaran (2007)