Blockchain adoption in the fashion sustainable supply chain: Pragmatically addressing barriers

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Abstract

Purpose – This paper aims to examine and overcome the barriers to the widespread adoption of blockchain technology, introducing a novel concept of sustainability in the fashion supply chain.

Design/methodology/approach – This work is an exploratory study of a well-known fashion company operating in the Veneto region (Italy). Data extracted from interviews and focus groups are coded using the (CAQDAS) software AQUAD. The outcome is then organized according to an adapted TOE view.

Findings – This exploration study's findings support the idea that the blockchain solution could be a valuable add-on in sustainable supply chains. However, a high understanding of technology and extensive communication with clients is required for successful integration.

Research limitations/implications – Being the outcome of qualitative analysis, the findings require further investigation to be inferable at a broader scale. As the project is still incomplete, some managerial choices are always subject to change.

Practical implications – Focused on a practitioner approach, this paper should guide managers in the process of successfully implementing blockchain technology. Arguably, similar companies may opt for similar choices.

Originality/value – To the best of the authors' knowledge, this is the first paper to contextualize and address the blockchain adoption barriers in the fashion supply chain. Furthermore, it offers an overview of how blockchain affects sustainable production.

Keywords Blockchain, Fashion, Supply chain, Sustainability

Paper type Research paper

Introduction

The fashion industry employs more than 60 million people globally, and its global turnover exceeds $2.5 trillion (Choi and Luo, 2019). Critical approaches describe this industry as characterized by producing a high quantity of pollutants and selling products in markets full of demand uncertainty (Guo *et al.*, 2020). With consistent operations in the emerging markets, the fashion industry is also characterized by scarcity or delay of data quality, which raises doubts about the supply chain (Rosenberg and Goodwin, 2016). As traditional supply chains have failed to meet customers' demand for a reasonable price and high quality, a new approach based on a sustainable supply chain is recommended (Yadav and Singh, 2020a). Cole and Fernando (2020) excellently explain that the challenges of this new configuration cannot be overcome without customers' help and the integration of new technologies in the system. Lately, much hype has been created by blockchain technology (Nakamoto, 2008), whose forecasted ability to reduce costs (Catalini and Gans, 2020) and enhance quality (Benton and Radziwill, 2017) would increase the robustness of supply chains. In a well-known article, Korpela *et al.* (2017) debate the importance of blockchain integration in supply chain management since it can improve the organization's performance and cost-effective

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production by securing the data and transaction. However, despite the rich promises, and the increasing number of projects involving blockchain adoption, the real implementation rate is still around ten percent of the total (Perego *et al.*, 2019).

A recent study by Kouhizadeh *et al.* (2021) addresses the motive behind the scarce adoption in the sustainable supply chain management building on the TOE view (Baker, 2012). The author states that despite the promises, barriers prevent widespread adoption of blockchain technology (Saberi *et al.*, 2019). Technology barriers involve speed and low scalability (Kaur and Gandhi, 2020), exposure to security threats (Conti *et al.*, 2018), heterogeneity (Tasca and Tessone, 2019), transparency, and immutability (Namasudra *et al.*, 2020). Organizational barriers comprehend, lack of ad hoc investments for maintenance and management, a scarce commitment by middle-management, insufficient understanding, and lack of standards. Environmental barriers are divided into internal and external. Internal limitations concern the commitment to sustainable production as a whole (Moggi *et al.*, 2020), while external constraints address government regulation/incentives and market uncertainty. To better understand the impact and importance of these barriers and hopefully proposing a way to manage them, this paper presents a case study of a well-known Italian fashion company operating in the Veneto region. In that specific region, blockchain has already proven useful in the food sustainable supply chain (Caldarelli *et al.*, 2020).

On the other hand, since the fashion supply chain has its peculiar characteristics, the present study's findings should be contextualized. Theoretical and axial coding was implemented on the collected qualitative data to understand which implications sustainability has in textile global supply chains. This study, in sum, aims to answer the following research questions:

RQ1. What does sustainability mean, and which implications does it have in the fashion supply chain?

RQ2. How can barriers to widespread adoption for the blockchain in the fashion industry be efficiently addressed?

The analysis supports the view that although the fashion and the food supply chain's sustainability concept are quite similar, the former needs a substantial client awareness to create value. Concerning the organization, the study shows that a specialized consultant is essential for the project's success. At the same time, an integrated supply chain is better manageable when implementing blockchain. The importance of this study is given by the lack of empirical researches in this area. Furthermore, going beyond the hype generated by the technology, the research aims to enlighten its real potential, and the constraints met in a real-world application. The results provided in this paper could help managers to understand whether a blockchain integration could be useful for their businesses. At the same time, academics could further build and improve the selected model. The paper proceeds as follows. Section two outlines the theoretical background to which this paper refers, and section three explains the methodology utilized and the data collected. Section four extensively discusses the findings, while section five concludes the article, providing hints for further researches.

Theoretical background

Despite being a thirty years old technology (Haber and Stornetta, 1991), blockchain owes its recent popularity to Nakamoto (2008), who exploited its potential for the Bitcoin cryptocurrency (Yermack, 2017). Although its disruptive potential was initially observed in the financial-oriented applications (Crosby *et al.*, 2016), enthusiast also sought potential for nonfinancial applications such as e-government (Navadkar *et al.*, 2018), healthcare (Plant, 2017), energy (Hu *et al.*, 2019) and supply chains (Treiblmaier, 2018). Applications involving real-world assets, better known as real-world blockchains (Sharma, 2019), are, however, often

criticized by experts due to the lack of trust in the communication channel (Oracles) between the real-world and blockchains (Antonopoulos and Woods, 2018; Egberts, 2017). Despite being the Oracle problem, still an unsolved issue in the blockchain literature (Caldarelli, 2020; Schaad *et al.*, 2019), expected benefit, especially in the supply chain field, is fueling literature production in this area (Venkatesh *et al.*, 2020; Yadav and Singh, 2020b). The features connecting blockchain in the supply chain field are usually identified in trust, technology, traceability and transparency (Pournader *et al.*, 2020). Recent papers also sought the potential to address global supply chain issues, to achieve United Nations Sustainable Development Goals, and to enhance product provenance, custody chain and authenticity (Chang *et al.*, 2020; Hughes *et al.*, 2019; Montecchi *et al.*, 2019). As Saberi *et al.* (2019) explain, blockchain's contribution to sustainable supply chain management lies in generating enhanced confidence over information supply chain flow. The idea is that blockchain would trace the product and data of the social and environmental conditions, which may generate concerns on the environment and safety of people involved (Adams *et al.*, 2018). Blockchain could also contribute to sustainable practices such as circular economy, reduced waste, and reduced emissions (Manupati *et al.*, 2020; Zhang, 2019). However, as Kouhizadeh *et al.* (2021) explain, few studies address blockchain adoption barriers. A well-known study by Saberi *et al.* (2019) managed to distinguish these barriers according to the TOE view (Baker, 2012). The TOE framework is a theoretical lens used to understand the aspects related to the adoption of technological innovation (Zhu *et al.*, 2002). The TOE framework explains that the successful implementation of technology is influenced by the technological (T), organizational (O) and Environmental (E) factors (Baker, 2012). While the first two are endogenous to the company, the environmental factors are exogenous to the company. As a technological innovation, the blockchain can then be analyzed following the TOE view (Kouhizadeh *et al.*, 2021; Saberi *et al.*, 2019). The technology barriers are related to the intrinsic characteristic of blockchains, which are slow and low scalable (Antonopoulos, 2017). Then, since using blockchain implies relying on a third party, it raises concerns about previous hack attempts (Thomson, 2016) and community "split" (Islam *et al.*, 2019). Also, there are issues with technology's heterogeneity (as we may have public, private, proof-of-work, proof-of-stake) and their adaptability to a specific project (Crosby *et al.*, 2016). Then there is the problem of transparency and immutability of data. Depending on the project and the sector, those characteristics may not be welcomed by the company (Ramachandran and Kantarcioglu, 2017). At the organization level, the lack of a recognized and the accepted standard is the main obstacle to a widespread adoption due to concerns about interoperability (Morkunas *et al.*, 2019). On the other hand, as an infancy state technology, the lack of a platform with an easy user interface makes it necessary for the company to rely on an expert consultant or be adequately skilled (Mougayar, 2016). The last group of barriers is the environmental ones, which, according to Kouhizadeh *et al.* (2021), can be split into internal and external. The internal barriers may be referred to as how practically implement the blockchain in the sustainable supply chain. As Venkatesh *et al.* (2020) explain, transparency over the supply chain is fundamental, and the management should not contrast blockchain disclosure. On the other hand, blockchain alone is insufficient to guarantee the sustainability of the supply chain, and acceptable practices should be efficiently implemented before by the company (Yadav and Singh, 2020a). As many supply chains are now global, there is also harmonization between supply chains if they belong to different areas and are managed according to different cultures (Choi and Luo, 2019). External barriers instead refer to how the government and market can affect the adoption of blockchain. Even if more and more countries are proposing plans to welcome the DLT and blockchains, at this stage, helps from the government is still **scarce** and uncertain. Furthermore, market uncertainty regarding the acceptance of the technology and the related products prevents the manager from taking this investment risk (Mangla *et al.*, 2017, 2018).

Organized with an adapted TOE view, a summary of those barriers can be observed in Table 1.

Concerning the content, the model has not been "altered" from the original one. The "adaptation" to which the author refers consists of polishing the table from related references and theoretical explanation. Then the entries were shortened and summarized to be more practitioner-friendly. The next section explains the methodology utilized and the data collection.

Methodology and data

Considering the lack of quantitative data, the authors opted for an exploration–case study (Mintzberg, 1979). The data will be analyzed using the TOE view adapted from Kouhizadeh *et al.* (2021). Data was collected by a team of 2 professors, one Ph.D. student, and two master students. The professors organized face to face interviews and focus groups with company members and the consultant company. In particular, the team interviewed the CEO of the Carrera group (4 times), the CEO assistant (1 time), the CEO of the consulting company (3 times), and a consultant (1 time). The professors also organized a focus group on zoom between CEO and consultants in March 2020 and another focus group with the CEO and managers in September 2020 during the semi-annual meeting. The interviews followed a semi-structured (SS) format and lasted 70 min in media, while the focus groups (FG) followed a flexible structure and lasted around 2 h each. The reason behind the choice of SS interviews over other types is because, as an exploration study, the interviewer wanted to keep a high degree of flexibility to gather as much information as possible. Questions were also different according to the people interviewed. Some ad hoc questions were made to the CEO of the Carrera group and the consultant company's CEO. Again, additional questions were made in the focus groups to better verify and outline the degree of alignment between the company, consultant, and employees. Table 2 summarizes the data collection process, while an abstract of the questionnaires can be found in Appendices 1 and 2.

The master students had the task to transcribe the interviews while the Ph.D. student executed the coding using the (CAQDAS) software AQUAD. Since interviews and focus groups were conducted in Italian, two team members analyzed the data separately, comparing data at the end of the analysis. The dataset was polished, removing redundant words or pauses, and then sent to a proof-editor. The translated text was then compared again with the original text to ensure that the meaning was retained. The implemented coding techniques were concept/*in vivo* coding for the first cycle and theoretical/axial for the second cycle (Saldaña, 2015). The methods were not exclusive of interviews or focus groups, although *in vivo* was preferred for the latter. On the other hand, intensive use of topic coding was used when analyzing the Company and Consultant CEOs' interview transcripts. Figure 1

Table 1. Adapted from Kouhizadeh *et al.* (2021): TOE view

Technological context	Organizational context	Environmental context (internal)	Environmental context (external)
Scalability and speed	Maintenance and Management	Adopt adequate, sustainable practices	Government regulations
Security	Participation of middle-management	Ensure Transparency over sustainability	Government incentives
Interoperability	Fully understanding of the technology	Blockchain role over sustainability	Market uncertainty
Immutability	Lack of standard	Harmonize sustainability practices	
User acceptance			

Data type	Participant	Purpose	Number	Duration*
SS interview	CEO Carrera	Understand his commitment to sustainability cause and his expectation from blockchain implementation	4	1 h 16 m
SS interview	CEO Assistant	Verify the effectiveness of company value sharing	1	57 m
SS interview	CEO Consultant company	Understand the technical limitations and delimitation of a blockchain implementation	3	1 h 02 m
SS interview	consultant	Understand the task executed by the consultant	1	49 m
Focus group	CEOs Carrera and consultant company	Check the alignment of intention between the Company and consultant	1	1 h 57 m
Focus group	CEO Carrera with managers	Verify the communication process between CEO and management	1	2 h 39 m

Note(s): *For multiple interviews, the mean duration is displayed

Table 2.
Data collection

Figure 1.
Word cloud

graphically shows the most redundant words extracted from the interview transcripts, while Tables 3 and 4 outlines the coding structure.

The coding outcome will be discussed in the finding section. However, it is interesting to report that the Employees and Environment Safeguard codes were mostly found in the transcript of Carrera CEO. On the other hand, extensive references to the standards and client awareness were found in the consultant CEO transcript. As expected, all the people interviewed made intensive use of the word "sustainability."

Code type	Code name	Occurrences
In Vivo	"Product"	46
	"Consumer"	21
	"Blockchain"	24
	"People"	14
	"Sustainability"	27
Concept	Blockchain awareness	12
	Interaction with external authorities	4
	Blockchain and Sustainability	21
	Data management	7
	Standards	5
	Consumer choices	14
	Employee management	9
	Company culture	13
	Products management	14
	Sustainability and fashion	18

Table 3.
First cycle coding*

Note(s): *Most Recurrent and significant codes

Code type	Code name	Code description	Occurrences
Theoretical	Sustainability = Normality	Comprehends all other coding related to the concept of sustainability perceived as a "must"	16
Axial	Employees safeguard	Comprehends coding related to employees management and sequential outcomes on production and costs	7
	Environment safeguard	Comprehends culture, organizational, and technological effort to lower impacts as well as their consequences on costs and production	9
	Market-oriented production	Regards all the choices oriented to limit the number of leftover products	4
	Client awareness	Counts coding related to blockchain awareness as well as sustainability awareness and their impact on the value perception	7

Table 4.
Second cycle coding

Case study

As a case study, we decided to analyze Carrera Group, a textile company in the Veneto region (Northern Italy). The company was founded in the mid-1960s in the periphery of Verona. It was born as a tailor and then, with the advent of the first sewing machines, began to make industrial productions dedicated to local wholesalers. Compared to other types of clothes, the Jeans allowed for a higher industrialization level so that the Carrera group was the first company in the world to produce jeans in less than 10 min. From the 1970s until the mid-1980s, production was mainly in Italy with various plants throughout the territory. However, with the increase in labor costs, the company made some internationalization tests in Malta, Morocco, and Tunisia, which proven to be inconvenient due to the instability of labor costs and product quality.

Towards the end of the 90s, the company decided to dismantle all the Italian industrial supply chains and move the plants to where the raw material was produced: Tajikistan. The company then reverse integrated the entire supply chain from the raw material to the finished product in a unique factory. Although the group always had an eye for sustainability, the integration of their supply chain gave the company complete control over production and traceability. Moving to Tajikistan and with an integrated supply chain, they followed the sustainability triple bottom line (Elkington, 2002). From an environmental point of view, the

Carrera group harvest raw material (cotton) without using chemicals and machinery. That takes months and employs many people but guarantees better quality and preserve the terrain from chemical pollution. Hiring people for harvesting also affects social sustainability. In Tajikistan, the Carrera group employs more than two thousand women. The wages are even higher than the country's media to guarantee staff loyalty, and working conditions are kept at the finest because they are thought of affecting the quality of products. Quality control also affects economic sustainability, since if the quality of production is high, the percentage of returns and waste is low. In 2019, the Carrera group CEO started a project involving the use of blockchain to trace the productions of their jeans. The project is articulated in three phases, which progressively add more data to the blockchain, from the company data to the lots on specific products. In the absence of recognized standards, framing the project in three phases leaves more flexibility and responsiveness to the company. The objective is to bring more visibility to their brand and their sustainable supply chain. By September 2020, they completed the first phase and added a Quick Response (QR) code to their products. Impacts on the clients, however, are yet to be analyzed. The authors are aware that part of the literature does not recommend blockchain implementation for integrated supply chains (Ivanitskiy, 2019; Kot, 2019; Qin *et al.*, 2019). However, since, in this case, the production centers in Tajikistan are semi-independent from the central administration, the blockchain adoption is positively perceived for internal purposes as a means to enhance transparency and trust among actors (Crosby *et al.*, 2016; Kasthala, 2019; Marr, 2020). This case study has been chosen because the authors had direct access to data. Secondly, this is one of the few active projects concerning blockchain in the sustainable supply chain of fashion products. Finally, because the company aims to be able to trace (thanks to the blockchain) the production from the cotton harvesting to the final consumer.

Findings

Before introducing the discussion on barriers and how the company planned to overcome them, it is interesting to analyze how they considered sustainability. Built with theoretical and axial coding (Charmaz, 2014; Corbin and Strauss, 2015), Figure 2 graphically shows how sustainable production affects product quality, the environment, and value creation. According to the Carrera Group CEO, sustainability is nothing extraordinary as he overlaps

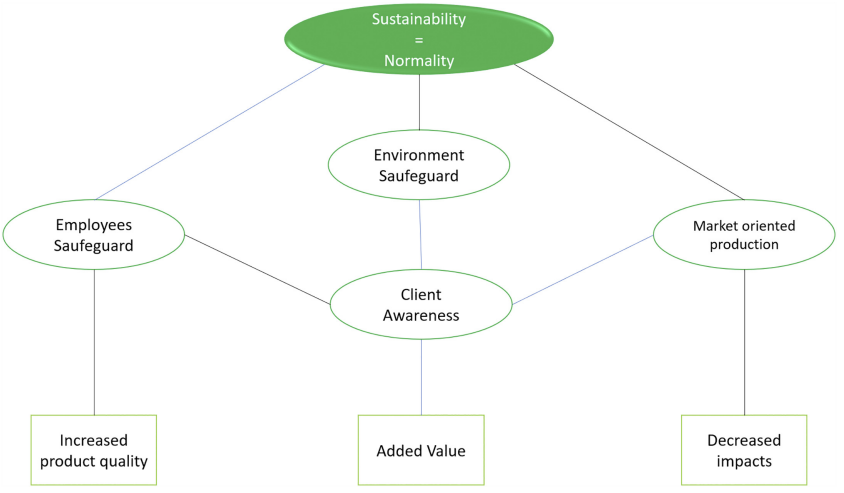

Figure 2.
Practical implications of a fashion sustainable supply chain

it with "normality." Drawing from an example that he made, "when the child is hungry, the mom feeds him, and that should not be considered an extraordinary act… so being sustainable should not be considered extraordinary but normal."

Normality excludes unsustainable choices such as unethical waste management, employee overexploitation, and irrational production. Providing the employee with a healthy environment, a fair wage, and a balanced hourly plan should be an everyday habit, and it may directly affect the quality of products. In one of the first interviews with the CEO, he said: "If we provide our women with a wisely illuminated and heated workspace, a rich meal at the cafeteria and a generous wage, we'll have better products and less waste." Maintaining a good reputation is vital for a company and adopting unsustainable practices for short-term gain is not a desirable option. As the CEO states, "*Losing a client is a process of a second while building his trust is a process of years*."

A critical aspect of sustainability concerning in particular textile supply chains regards production and leftover product policies. Those aspects involve, in particular, recycled or premium products. A recycled work is seen to the final consumer as a product that defends waste and protects nature from further exploiting natural resources. However, as the CEO explains, the process of dismantling and regenerating recycled products may be more unsustainable than the regular ones. During the first focus group, the CEO states: "To remove the color from jeans is necessary to use an aggressive chemical product not employed in the average production. Furthermore, the fabric recovered in this process is of shallow quality and should not be used again for clothing." A process that goes under a sophisticated production is usually more expensive than the regular one. As this will inevitably affect the price, it will lead to another critical drawback. Failing to provide a product at a price acceptable for the consumer will probably lead to the product to remain unsold and be left on the store shelf. Sustainable development is indeed subject to the same market rules as regular ones. Precisely as other products, it should be fashionable, comfortable, and affordable; otherwise, it will remain unsold. As the CEO declared: "I saw many good projects failing because the market laws were not followed… in the textile industry, the 'wallet' is still a major discriminating factor."

It may be argued that a company with a good reputation built through history is more inclined to have sustainable behavior. The final but main aspect of sustainable supply chains that can be observed in a practical case is the concept of "customer awareness." As emerged from the first and the second focus group, sustainability represents a "value" only if it is known to the customers. As shown in Nike, Nestlè, and Volkswagen cases (Greenhouse, 1997; Hotten, 2015; Nelsen, 2018), the companies had drawbacks for their unsustainable practices only after clients were aware of them. Before that, the companies enjoyed a privileged market position, probably pushing out of the market more sustainable competitors. At the same time, it is arguable that a company operating (sustainably) enjoys no positive outcomes until those practices are well known to the market and customers. Building on that assumption, blockchain technology in the sustainable supply chain field is also seen as a method to give transparency to virtuously managed companies. Furthermore, with the implementation of IoT and blockchain, those practices can be directly verified by customers. The following sections consider the methods to address the blockchain adoption barriers according to the sustainability construct outlined above.

Technological barriers

According to the literature, technological barriers involve scalability, security, interoperability, immutability and user acceptance (see Table 5). In our case study, the scalability problem has been widely addressed by the service provider. Since the first phase of the project involved the traceability of entire lots of production, the data uploaded on the blockchain and retrievable through the QR code regards the lot as a whole. Uploading data about the full lots, as the

Barrier	Company position	Quotation
Scalability and speed	Trace production lots instead of single products	The number of information we have to record, including the lot, should not have too much impact on the cost or time
Security	Rely on Ethereum Network	We chose Ethereum because it is the most reliable platform for production-related smart contracts
Interoperability	Adopt the right platform for the right task	We choose Ethereum because if the project is meant for the customers, we prefer a blockchain where access is free
Immutability	Accept the limitation as a strength	I perceive immutability in a very positive way; otherwise, I would not have done it!
User awareness	Rely on long term acceptance	I think the consumer can only take it as a positive add-on. . .if interested in discovering something more

Table 5.
Technology barriers

consultant declared, dramatically decreases the cost of the service and makes platforms delays irrelevant: "the number of information we have to record, including the lot, should not have too much impact on the cost or time" (Consultant). Converting a non-fungible product to a fungible one addresses cost/speed issues and the "*oracle problem*" (Antonopoulos, 2019).

However, customers' advantage that gives value to the specific product bought is lost with this choice. Regarding security, the consultant used Ethereum platforms. Although the long history of hacks and the known ETC hard-forks (Graham, 2016; Thomson, 2016), it is still the most secure platform to build smart contracts. Furthermore, as the consultant's head declared: "we choose Ethereum because if the project is meant for the customers, we prefer a blockchain where access is free." Due to scalability issues, open platforms may not prove to be reliable for internal use. Because of that, the consultant admitted: "if in the future the project will develop only on the internal supply chain. . . we will change platform."

Regarding the intrinsic characteristic of data immutability, this problem regards more the company type and its commitment to transparency. In the case of Carrera, they welcomed this limitation with enthusiasm. The CEO of the Carrera group proudly declared, "I perceive immutability in a very positive way; otherwise, I would not have done it!". The last technology barrier is also the most controversial because it is not related to blockchain characteristics but to customers' perceptions over it. By the consultant and the company are perceived as the most challenging barriers to break. Accordingly, it is also the most crucial factor for the project to succeed. The chief consultant declared that "*as long as it is not perceived as an added value by the client, its acceptance will be long in coming*." The Carrera group's CEO, although expressing some concerns, shared a more optimistic vision. He declared that: "I think the consumer can only take it as a positive add-on. . . if interested in discovering something more." He intends to offer an added service to the client but does not exploit it for a short-term marketing campaign. Aware that the technology is in his infancy, he will leave to customers the time to discover and appreciate the offered service. For a broad audience, it can be argued that although specific marketing campaigns can be rewarding in the short term, the social acceptance of the technology would create more benefits in the long run.

Organizational barriers

According to the latest research, the organizational barrier comprises maintenance and management, middle-management participation, fully understanding by company members, and lack of standards (Table 6). As a new technology, there are not user-friendly interfaces to manage its features. For that reason, the reliance on an expert consultant company may be a reasonable choice. In our case, the company completely delegated the process to a specialized consultant. The company will internally organize the data production among the different

Barrier	Company position	Quotation
Maintenance and Management	Complete delegation to a consultant	We have not done much. . ..it was more a work of graphics and topic organization
Participation of middle-management	Semi-annual meeting with managers	We usually do a semi-annual meeting in September. . . blockchain will be one of the agenda items
Fully understanding of the technology	Technology Enthusiast	I heard about blockchain, and I said, why not. . .we have everything to gain
Lack of standard	Consultant customized protocol	We apply our protocol, but we customize it according to the client

Table 6. Organizational barriers

offices and then deliver it to the consultant to autonomously manage the upload on the chain. The task in which the company was most involved was the creation of the content that could be retrievable through the QR code. As Carrera's CEO declared, "we have not done much. . . it was more a work of graphics and topic organization." Although fascinated by the technology, he admitted that he was not aware of how it worked precisely, but they always embraced innovative projects. This lack of skill constitutes the most critical aspect of the project. As Mougayar (2016) explained, having a strong understanding of how the blockchain work is fundamental for a project's successful outcome. Delegating a process without the ability and knowledge to supervise also exposes the company to a severe agency relationship. The service offered by the consultant may not be properly evaluated (Hart and Moore, 1990). The involvement of middle management is also fundamental for a project to be successful. Regardless of whom decided to integrate blockchain, all the parties should actively cooperate to contribute to data gathering. As the task was delegated to a consultant in our study, middle-management was not wholly involved in the process.

The CEO was the one who had the idea of implementing the blockchain. Considering the blockchain's implementation, not a core change of the business, he decided to discuss and present the blockchain to the managers in the semi-annual meeting. In the last interview we had with the CEO, he declared: "we usually do a semi-annual meeting in September. . .. blockchain will be one of the agenda items." The last organizational barrier regards the lack of standards. As there is still no universally accepted standard to implement blockchain, it is vital to rely on the few practical experiments in practitioner literature. The consultant company efficiently addressed this barrier since, with the experience, they managed to develop a standardized protocol to be implemented for traceability projects. As declared by the project manager: "we still have not a universal standard but. . .nobody does."

Environmental barriers (internal view)

Internal environmental barriers reflect the supply chain processes and are recognized in adequate, sustainable practices, transparency over sustainability, clarify blockchain role over sustainability, and harmonize sustainability practices (Table 7). For these kinds of barriers, the type and culture of the company play a determinant role. Companies like the Carrera group that developed an integrated supply chain to guarantee their products' quality bear an advantage when implementing blockchain. From the raw material to the finished products, all the data about the production phases are available to the company. Thus it can be easily uploaded on the blockchain. Having all the production phases under control gives the CEO absolute confidence about making promises about sustainability. As he proudly declares: "Although the World Bank is one of our auditors. . .. anyone can come to our factory and verify what we declare." With such a high level of transparency, the blockchain can easily

Barrier	Company position	Quotation
Adopt adequate, sustainable practices	The company completely integrated the supply chain to ensure sustainable practices	Only with a fully integrated supply chain, you can indelibly certify the provenance of a product
Ensure transparency over sustainability	Completely open for auditing	The first request to have the world bank as a partner is to be sustainable; furthermore, we ask everyone to take the plane and do their auditing!
Blockchain role over sustainability	Keep a record of production for the company. Data disclosure for clients	Blockchain will not certify our sustainability but the path that we follow
Harmonize sustainability practices	Implement blockchain only for ultimately traced and transparent production	Trousers will be traced with blockchain because we made them, but shirting will be not

Table 7. Environmental (internal) barriers

be implemented as data is publicly available. An integrated supply chain makes it also more comfortable for the consultant company to implement the blockchain. Accessing every production site data is guaranteed as they are all under the control of the same Group. The consultant declared that "The most difficult task is to gather all the necessary data to upload on the blockchain. . .however, all the plants belong to Carrera, so they shall cooperate."

Furthermore, the blockchain's role over sustainability is clear for the company, as it is seen as a way to ensure data to be always accessible for traceability and auditing purposes. The uncertainty regards customers since there is still no accurate perception of the technology implication over sustainability. Both the company and consultant agreed that the client's awareness of blockchain implications over sustainability would take time to develop. Although a critical and necessary step, the CEO of Carrera affirmed that "we cannot stress our clients with too much information, but if they request them, they will have blockchain." Despite being necessary for the client to be informed about the blockchain use, an effective information campaign should not divert the attention away from the core values of a product by focusing attention on the blockchain. The main aspects to focus on are sustainability and product core values, while blockchain should be perceived as a means to get guarantees over them (Saberi *et al.*, 2019). The last barrier involves the harmonization of sustainable supply chain practices among factories. For companies such as Carrera, where the supply chain is all in the same place, this is unnecessary; however, for outsourced products where sustainability practices cannot be guaranteed, the blockchain should not be implemented. The Carrera group's CEO specified that "we will only implement blockchain for products that are completely under our control. . .although we trust our shirts supplier, we will not attach them to the blockchain as we lack all the necessary data."

Environmental barriers (external view)

External barriers comprise government regulation, incentives, and market uncertainty (Table 8). At the moment, many governments are experimenting with regulations to

Barrier	Company position	Quotation
Government regulations	Embrace the risk	I see only positive outcomes; the real risk is to tell something untrue
Government incentives	Not entirely rely on incentives	Sometimes, the cost of the bonus is higher than the bonus itself
Market uncertainty	Keep product core values as market drivers	If the product is not perceived as valuable, no blockchain can convince customers to buy it

Table 8. Environmental (External) barriers

manage blockchains, decentralized ledgers, and fintech. The first area under regulation was fintech, as it was necessary for anti-money laundering. Blockchains and DLT, in general, were not the priority, but many states like China in Asia and Malta in Europe are regulating the environment also to incentive startups (Wolfson, 2018; Wu, 2020). In Italy, by June 2020, a proposal has been presented to implement the regulation in the sector of Blockchain and DLT, but at the moment, there is still not a widely accepted standard. The Carrera group used to embrace innovation and aims to be a pioneer for machines, computers, and blockchain. The absence of a regulation is not perceived as a limitation and the CEO, although welcoming any government guideline, is not afraid of taking some risks.

Being a risk seeker is a fundamental characteristic for a company undertaking blockchain projects as revenues in non-financial projects are hypothesized in literature but still not proven (Kumar *et al.*, 2020). The CEO chose to count blockchain implementation expenses as R & D not charging the cost directly on the product traced with the technology. As he said in an interview, "we are not charging costs on the products. . .since it does not impact supply chain directly." This advantageous condition is due to the choice of tracing lots instead of single products. It can be argued that charging a small mark-up on the product to have it traceable may be a reasonable choice as long as clients accept it (Steven, 2018). Government incentives are also expected when undertaking an innovative project. Italy has a complex and cumbersome system of incentives and often the "gain worth, not the pain." Due to the complexity and newness of blockchain projects, a reasonable choice would be to cooperate with a specialized consultant to manage government incentives. Although useful, however, incentives can be late or insufficient, so a successful project should not consider them as essential funds to rely on. In our case study, due to the system's complexity, the company cooperated with the consultant, as the CEO declared, "they are giving us a hand. . .sometimes the cost of the bonus is higher than the bonus itself".

The last external environmental barrier is market uncertainty. Relying on the blockchain to increase market share may not be a reasonable option for non-financial products. First, as already explained, clients are still mostly unaware of blockchain potentials and are still not sensitive to the blockchain implementation. The client prioritizes intrinsic product characteristics over sustainability-related or blockchain components. As the CEO declares, "if the product is not perceived as valuable, there is no blockchain that can convince customers to buy it."

Conclusions

Recent literature supports the advantages of implementing blockchain in sustainable supply chains (Kamath, 2018; Lucena *et al.*, 2018; Treiblmaier, 2018). Few, however, explains why although those positive expectations, the practical implementations are low and declining. Building on the studies of Saberi *et al.* (2019) and Kouhizadeh *et al.* (2021), this paper addresses the main barriers to blockchain adoption in SSC. This study provided possible solutions to the proposed barriers analyzing data obtained through an exploration – case study of a well-known Italian company. However, as the literature describes the barriers in general, the present study contextualizes the sustainability concept in the fashion supply chain exploiting theoretical and axial coding. This research shows that due to the novelty of the technology, blockchain projects require support from an expert consultant. At the same time, company members should also be well informed about the blockchain features to limit the agency problem. Oracle limitation can be addressed, turning non-fungible products into fungible ones, although restricting the precision of the information provided. This choice will also lower the costs and manage the scalability issues, ensuring the adoption of a public

blockchain such as Ethereum. It again emerges that blockchain is not seen as directly connected with sustainability itself, but the higher transparency feature may increase the trust over products. As detailed data is required for blockchain traceability, companies with a very fragmented supply chain will probably need more organizational efforts and sustain higher costs. For example, the Carrera group could only implement blockchain for trousers, as the shirts supply chain is partially outsourced. The environment could influence blockchain adoption with government incentives and also with informed clients who request its features. The adoption of a national standard could also contribute to ease of the process. Although this study is the first to address those barriers through a practical case, being a qualitative study makes it difficult to build robust inferences in other cases. Furthermore, as the project is still in its infancy, it needs longitudinal proof that confirms the solutions found. Managers could benefit from the results provided as similar choices may lead to similar outcomes. As a practitioner friendly model, the TOE view is readable and exploitable by a broad audience so that it may be easily implemented for multinationals and SMEs. Academic could also handily adapt the model for other sectors and blockchain applications at different development stages. Additional studies could quantitatively address barriers, matching the most successful practices according to the application sector.

References

Adams, R., Kewell, B. and Parry, G. (2018), "Blockchain for good? Digital ledger technology and sustainable development goals", in Leal Filho, W., Marans, R. and Callewaert, J. (Eds), *Handbook of Sustainability and Social Science Research. World Sustainability Series*, Springer, Cham, doi: 10.1007/978-3-319-67122-2_7.

Antonopoulos, A.M. (2017), *Mastering Bitcoin: Programming the Open Blockchain*, 2nd ed., O'Reilly Media, Inc., Sebastopol, CA.

Antonopoulos, A.M. (2019), "The killer app: bananas on the blockchain?", *Coinscrum Meetup on 13 June 2019 at Monzo Bank HQ*, London, UK, available at: https://aantonop.com/the-killer-app-bananas-on-theblockchain (accessed 3 March 2020).

Antonopoulos, A.M. and Woods, G. (2018), *Mastering Ethereum – Building Smart Contracts and DAPPS*, O'Reilly Media, Inc., Sebastopol, CA.

Baker, J. (2012), "The technology–organization–environment framework", in Dwivedi, Y., Wade, M. and Schneberger, S. (Eds), *Information Systems Theory. Integrated Series in Information Systems*, Vol. 28, New York, NY, doi: 10.1007/978-1-4419-6108-2_12.

Benton, M.C. and Radziwill, N.M. (2017), "Quality and innovation with Blockchain Technology", arXiv: 1710.04130.

Caldarelli, G. (2020), "Understanding the blockchain oracle Problem : a call for action", *Information*, Vol. 11 No. 11, doi: 10.3390/info11110509.

Caldarelli, G., Rossignoli, C. and Zardini, A. (2020), "Overcoming the blockchain oracle problem in the traceability of non-fungible products", *Sustainability*, Vol. 12 No. 6, doi: 10.3390/su12062391.

Catalini, C. and Gans, J.S. (2020), "Some simple economics of the blockchain", *Communications of the ACM*, Vol. 63 No. 7, pp. 80-90.

Chang, Y., Iakovou, E. and Shi, W. (2020), "Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2082-2099.

Charmaz, K. (2014), "Grounded theory in global perspective: reviews by international researchers", *Qualitative Inquiry*, Vol. 20 No. 9, pp. 1074-1084.

Choi, T.-M. and Luo, S. (2019), "Data quality challenges for sustainable fashion supply chain operations in emerging markets: roles of blockchain, government sponsors and environment taxes", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 131, pp. 139-152.

Cole, S.A. and Fernando, A.N. (2020), "'Mobile'izing agricultural advice: technology adoption, diffusion, and sustainability", *The Economic Journal*, ueaa084, doi: 10.1093/ej/ueaa084.

Conti, M., Sandeep Kumar, E., Lal, C. and Ruj, S. (2018), "A survey on security and privacy issues of bitcoin", *IEEE Communications Surveys and Tutorials*, Vol. 20 No. 4, pp. 3416-3452.

Corbin, J. and Strauss, A. (2015), *Basics of Qualitative Research*, 4th ed., Sage Publications, San Jose State University.

Crosby, M., Pattanayak, P., Verma, S. and Kalyanaraman, V. (2016), "Blockchain technology: beyond bitcoin", *Applied Innovation Review*, No. 2, available at: https://www.appliedinnovationinstitute.org/blockchain-technology-beyond-bitcoin/.

Egberts, A. (2017), "The oracle problem - an analysis of how blockchain oracles undermine the advantages of decentralized ledger systems", *SSRN Electronic Journal*. doi: 10.2139/ssrn.3382343 (accessed 12 December 2017).

Elkington, J. (2002), "Corporate strategy in the chrysalis economy", *Corporate Environmental Strategy*, Vol. 9 No. 1, pp. 5-12.

Graham, R. (2016), *Ethereum/TheDAO Hack Simplified*, Errata Security Blog, available at: https://blog.erratasec.com/2016/06/etheriumdao-hack-similfied.html (accessed 14 April 2020).

Greenhouse, S. (1997), "Nike shoe plant in Vietnam is called unsafe for workers", *New York Times*, available at: https://www.nytimes.com/1997/11/08/business/nike-shoe-plant-in-vietnam-is-called-unsafe-for-workers.html (accessed 14 April 2017).

Guo, S., Choi, T.M. and Shen, B. (2020), "Green product development under competition: a study of the fashion apparel industry", *European Journal of Operational Research*, Vol. 280 No. 2, pp. 523-538, Elsevier B.V.

Haber, S. and Stornetta, S. (1991), "How to timestamp a digital document - original blockchain paper 1991", *Journal of Cryptology*, Vol. 3 No. 2, pp. 99-111.

Hart, O. and Moore, J. (1990), "Property rights and the nature of the firm", *Journal of Political Economy*, Vol. 98 No. 6, pp. 1119-1158.

Hotten, R. (2015), "Volkswagen: the scandal explained", *BBC*, available at: https://www.bbc.com/news/business-34324772 (accessed 14 August 2020).

Hu, W., Hu, Y.W., Yao, W.H., Lu, W.Q., Li, H.H. and Lv, Z.W. (2019), "A blockchain-based smart contract trading mechanism for energy power supply and demand network", *Advances in Production Engineering And Management*, Vol. 14 No. 3, pp. 284-296.

Hughes, A., Park, A., Kietzmann, J. and Archer-Brown, C. (2019), "Beyond Bitcoin: what blockchain and distributed ledger technologies mean for firms", *Business Horizons*, Vol. 62 No. 3, pp. 273-281.

Islam, A.K.M.N.K.M.N., Mäntymäki, M. and Turunen, M. (2019), "Why do blockchains split? An actor-network perspective on Bitcoin splits", *Technological Forecasting and Social Change*, Vol. 148, No. December 2018, Elsevier, p. 119743.

Ivanitskiy, I. (2019), *You Do Not Need Blockchain: Eight Popular Use Cases and Why They Do Not Work*, SmartDec, available at: https://blog.smartdec.net/you-do-not-need-blockchain-eight-popular-use-cases-and-why-they-do-not-work-f2ecc6cc2129 (accessed 24 July 2020).

Kamath, R. (2018), "Food traceability on blockchain: Walmart's pork and mango pilots with IBM", *The Journal of the British Blockchain Association*, Vol. 1 No. 1, pp. 1-12.

Kasthala, V. (2019), *Blockchain Key Characteristics and the Conditions to Use it as a Solution*, Medium, available at: https://medium.com/swlh/blockchain-characteristics-and-its-suitability-as-a-technical-solution-bd65fc2c1ad1 (accessed 9 March 2020).

Kaur, G. and Gandhi, C. (2020), "Scalability in blockchain: challenges and solutions", *Handbook of Research on Blockchain Technology*, INC, doi: 10.1016/b978-0-12-819816-2.00015-0.

Korpela, K., Hallikas, J. and Dahlberg, T. (2017), "Digital supply chain transformation toward blockchain integration", *Proceedings of the 50th Hawaii International Conference on System Sciences (2017)*, No. January, doi: 10.24251/hicss.2017.506.

Kot, I. (2019), *Blockchain Limitations: When Your Company Doesn't Need Blockchain*, Itransition, available at: https://www.itransition.com/blog/blockchain-limitations (accessed 12 April 2020).

Kouhizadeh, M., Saberi, S. and Sarkis, J. (2021), "Blockchain technology and the sustainable supply chain: theoretically exploring adoption barriers", *International Journal of Production Economics*, Vol. 231, No. September 2019, Elsevier B.V., p. 107831.

Kumar, A., Liu, R. and Shan, Z. (2020), "Is blockchain a silver bullet for supply chain management? Technical challenges and research opportunities", *Decision Sciences*, Vol. 51 No. 1, pp. 8-37.

Lucena, P., Binotto, A.P.D., Momoda, F.S. and Kim, H. (2018), "A case study for grain quality assurance tracking based on a blockchain business network", ArXiv:1803.07877 [Cs], available at: http://arxiv.org/abs/1803.07877 (accessed 20 March 2020).

Mangla, S.K., Govindan, K. and Luthra, S. (2017), "Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy analytical hierarchy process", *Journal of Cleaner Production*, Vol. 151, pp. 509-525, Elsevier.

Mangla, S.K., Luthra, S., Mishra, N., Singh, A., Rana, N.P., Dora, M. and Dwivedi, Y. (2018), "Barriers to effective circular supply chain management in a developing country context", *Production Planning and Control*, Vol. 29 No. 6, pp. 551-569, Taylor & Francis.

Manupati, V.K., Schoenherr, T., Ramkumar, M., Wagner, S.M., Pabba, S.K. and Inder Raj Singh, R. (2020), "A blockchain-based approach for a multi-echelon sustainable supply chain", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2222-2241, Taylor & Francis.

Marr, B. (2020), *How Can Blockchain Technology Be Applied in Real Life?*, Bernardmarr, available at: https://bernardmarr.com/default.asp?contentID=1788 (accessed 21 August 2020).

Mintzberg, H. (1979), "The structuring of organizations", in Asch, D. and Bowman, C. (Eds), *Readings in Strategic Management*, Palgrave, London, doi: 10.1007/978-1-349-20317-8_23.

Moggi, S., Pagani, A. and Pierce, P. (2020), "The rise of sustainability in Italian wineries: key dimensions and practices", *Electronic Journal of Management*, Vol. 1, No. December 2019, pp. 1-20.

Montecchi, M., Plangger, K. and Etter, M. (2019), "It's real, trust me! Establishing supply chain provenance using blockchain", *Business Horizons*, Vol. 62 No. 3, pp. 283-293.

Morkunas, V.J., Paschen, J. and Boon, E. (2019), "How blockchain technologies impact your business model", *Business Horizons*, Vol. 62 No. 3, pp. 295-306.

Mougayar, W. (2016), *The Business Blockchain: Promise, Practice, and Application of the Next Internet Technology*, John Wiley & Sons, Wiley, Hoboken, New Jersey.

Nakamoto, S. (2008), *Bitcoin: A Peer-To-Peer Electronic Cash System*, p. 9.

Namasudra, S., Deka, G.C., Johri, P., Hosseinpour, M. and Gandomi, A.H. (2020), "The revolution of blockchain: state-of-the-art and research challenges", *Archives of Computational Methods in Engineering*, Springer, No. 0123456789, doi: 10.1007/s11831-020-09426-0.

Navadkar, V.H., Nighot, A. and Wantmure, R. (2018), "Overview of blockchain technology in government/public sectors", *International Research Journal of Engineering and Technology*, June, p. 2287.

Nelsen, A. (2018), "Nestlé under fire for marketing claims on baby milk formulas", *The Guardian*, available at: https://www.theguardian.com/business/2018/feb/01/nestle-under-fire-for-marketing-claims-on-baby-milk-formulas (accessed 21 June 2019).

Perego, A., Sciuto, D., Portale, V. and Bruschi, F. (2019), "Blockchain and distributed ledger", available at: https://www.osservatori.net/it/ricerche/osservatori-attivi/blockchain-distributed-ledger (accessed 12 November 2019).

Plant, L. (2017), "Implications of open source blockchain for increasing efficiency and transparency of the digital content supply chain in the australian telecommunications and media industry", *Australian Journal of Telecommunications and the Digital Economy*, Vol. 5 No. 3, pp. 15-29.

Pournader, M., Shi, Y., Seuring, S. and Koh, S.C.L. (2020), "Blockchain applications in supply chains, transport and logistics: a systematic review of the literature", *International Journal of Production Research*, Vol. 58 No. 7, pp. 2063-2081, Taylor & Francis.

Qin, K., Hadass, H., Gervais, A. and Reardon, J. (2019), "Applying private information retrieval to lightweight bitcoin clients", *Proceedings - 2019 Crypto Valley Conference on Blockchain Technology, CVCBT 2019*, pp. 60-72.

Ramachandran, A. and Kantarcioglu, D.M. (2017), "Using blockchain and smart contracts for secure data provenance management", ArXiv:1709.10000 [Cs], available at: http://arxiv.org/abs/1709.10000 (accessed 11 February 2020).

Rosenberg, A. and Goodwin, L. (2016), "The dos and don'ts of working with emerging-market data", *Harvard Business Review*, available at: https://hbr.org/2016/07/the-dos-and-donts-of-working-with-emerging-market-data.

Saberi, S., Kouhizadeh, M., Sarkis, J. and Shen, L. (2019), "Blockchain technology and its relationships to sustainable supply chain management", *International Journal of Production Research*, Vol. 57 No. 7, pp. 2117-2135.

Saldaña, J. (2015), *The Coding Manual for Qualitative Researchers*, 3rd ed., Sage Publications, London.

Schaad, A., Reski, T. and Winzenried, O. (2019), "Integration of a secure physical element as a trusted oracle in a hyperledger blockchain", *Proceedings of the 16th International Joint Conference on E-Business and Telecommunications*, SCITEPRESS - Science and Technology Publications, Prague, Czech Republic, pp. 498-503.

Sharma, T.K. (2019), *Top 10 Real-World Applications of Blockchain Technology*, Blockchain Council, available at: https://www.blockchain-council.org/blockchain/top-10-real-world-applications-of-blockchain-technology/ (accessed 2 April 2020).

Steven, G. (2018), *Diamonds and the Blockchain*, BABSON College, available at: https://www.babson.edu/academics/executive-education/babson-insight/technology-and-operations/diamonds-and-the-blockchain/ (accessed 19 August 2020).

Tasca, P. and Tessone, C.J. (2019), "A taxonomy of blockchain technologies: principles of identification and classification", *Ledger*, Vol. 4, doi: 10.5195/ledger.2019.140.

Thomson, C. (2016), *The DAO of ETHEREUM: Analyzing the DAO Hack, the Blockchain, Smart Contracts, and the Law*, Medium, available at: https://medium.com/blockchain-review/the-dao-of-ethereum-e228b93afc79 (accessed 3 April 2020).

Treiblmaier, H. (2018), "The impact of the blockchain on the supply chain: a theory-based research framework and a call for action", *Supply Chain Management: International Journal*, Vol. 23 No. 6, pp. 545-559.

Venkatesh, V.G., Kang, K., Wang, B., Zhong, R.Y. and Zhang, A. (2020), "System architecture for blockchain based transparency of supply chain social sustainability", *Robotics and Computer-Integrated Manufacturing*, Vol. 63, p. 101896.

Wolfson, R. (2018), "Maltese parliament passes laws that set regulatory framework for blockchain, cryptocurrency and DLT", *Forbes*, available at: https://www.forbes.com/sites/rachelwolfson/2018/07/05/maltese-parliament-passes-laws-that-set-regulatory-framework-for-blockchain-cryptocurrency-and-dlt/ (accessed 21 April 2019).

Wu, J. (2020), "Blockchain as an infrastructure: a deep dive into China's DLT strategy", *Cointelegraph*, available at: https://cointelegraph.com/news/blockchain-as-an-infrastructure-a-deep-dive-into-chinas-dlt-strategy (accessed 19 August 2020).

Yadav, S. and Singh, S.P. (2020a), "Blockchain critical success factors for sustainable supply chain", *Resources, Conservation and Recycling*, Vol. 152, doi: 10.1016/j.resconrec.2019.104505.

Yadav, S. and Singh, S.P. (2020b), "Resources , Conservation and Recycling Blockchain critical success factors for sustainable supply chain", *Resources, Conservation and Recycling*, Vol. 152, No. September 2019, Elsevier, p. 104505.

Yermack, D. (2017), "Corporate governance and blockchains", *Review of Finance*, Vol. 21 No. 1, pp. 7-31.

Zhang, D. (2019), "Application of blockchain technology in incentivizing efficient use of rural wastes: a case study on Yitong system", *Energy Procedia*, Vol. 158, pp. 6707-6714, Elsevier B.V.

Zhu, K., Kraemer, K.L. and Xu, S. (2002), "A cross-country study of electronic business adoption using the technology-organization-environment framework", *Proceedings of the International Conference on Information Systems (ICIS)*, No. 0085852, pp. 337-348.

Appendix 1

Table A1. Research questions enterprise

The second cycle of interviews
Business model
(1) What is the added value that customers enjoy thanks to Carrera products? What is the selection driver that makes the consumer choose Carrera instead of other equivalent price products?
(2) How should a company in your industry protect and/or improve its margin?
(3) Can the blockchain affect the perceived value and the margin of products?
Sustainability
(4) Why did you decide to undertake sustainable production?
(5) What are Carrera's objectives in sustainability? (corporate, social, environmental)
(6) How can a company's commitment to sustainability affect its margin?
(7) What consequences will the adoption of the blockchain have on the sustainable commitment of your company?
Digital transformation
(8) What was the biggest digitization in your company, when did it happen, and after what?
(9) How do you think digitization can improve your industry and producer margin?
(10) Have digital innovations made Carrera's commitment to sustainability easier? How?
(11) Have digital innovations changed the way you do business in any way? (e.g., relating to customers and suppliers?)
(12) Following the application of the blockchain, do you expect to change anything in your organizational structure?
The fourth cycle of interviews
Technical
(13) Why do you think, despite the hype, the blockchain finds only a few practical applications in the Sustainable Supply Chain?
(14) Who would benefit most from the application of the blockchain? The company or the consumer?
(15) Are you having some difficulties in starting the blockchain application procedure? If so, which ones?
(16) Are you aware that there are several types of blockchains? Did you choose one in particular, or did you rely on the consultant?
(17) When you decided to start this project, were you inspired by any existing cases?
(18) What kind of information will be on the blockchain? Will they be accessible to anyone?
(19) Do you perceive positively or negatively the immutability of the information uploaded on the blockchain?
(20) How do you think your customers will perceive the implementation of the blockchain?
Organizational
(21) Which are the main costs you expect to sustain by applying the blockchain?
(22) Beyond the possible advantages, the blockchain undoubtedly represents a cost. How are you going to allocate the expenses related to the new technology?
(23) Do you perceive the application of the blockchain difficult? Do you think you need the support of experts and/or external staff permanently?
(24) Do you plan to make changes from an organizational point of view?
(25) How do you perceive the absence of an application standard?

(*continued*)

The fourth cycle of interviews
Environmental (Internal)
(26) How are you going to communicate blockchain adoption to your customers and partners?
(27) Do you think your customers associate blockchain with sustainability? Are you planning to carry out marketing/awareness campaigns to explain how blockchain can contribute to sustainability?
(28) Do you think your company can quickly adapt to change?
(29) Are you planning to change something in your business processes or strategy?
Environmental (external)
(30) Have you ever received pressure from any institution to adopt sustainable procedures in Italy or abroad? If yes, of what kind?
(31) Is there a difference between the obligations for sustainability in the various countries in which you operate?
(32) Have you asked, or do you intend to request incentives from the government to implement the blockchain?
(33) Are you considering the environmental impact of "leftover" products? How do you try to predict market demand?
(34) Considering the technological, organizational, and environmental difficulties of applying the blockchain, which do you think are the most important/difficult to overcome?

Table A1.

Appendix 2

The third cycle of interviews
(1) Why do you think, despite the hype, the blockchain finds only a few practical applications in the Sustainable Supply Chain?
(2) Why would blockchain help sustainability? From what point of view? Who would benefit from it?
(3) Are you having difficulty implementing the blockchain for the entrepreneur? If so, which ones?
(4) What kind of blockchain did you choose for the Carrera case? Why?
(5) How is information entered into the blockchain?
(6) Will you make a project from scratch? Or do you have some standard that you will follow?
(7) According to traditional literature, only a limited number of operations can be performed on the blockchain. In light of this, what kind of operations will be done?
(8) How do you think Carrera's customers can react to the implementation of the blockchain?
(9) Do you have a different approach depending on the country in which you implement the blockchain? How does the external context influence or can influence the application?
(10) If you want to offer the same service but with a centralized database, which would be the main differences with blockchain?
(11) Why would blockchain help sustainability? From what point of view? Who would benefit from it?
(12) How was the project born? Above all, what are the objectives that the entrepreneur aims to achieve thanks to this project?
(13) Could you please tell us how the project is taking place?

Table A2.
Research questions consultants

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