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Abstract. In this paper, we provide a preliminary investigation of the application of blockchain technology as a tool for decision-making with a sustainability focus on fashion supply chains.
In the fashion industry, information on various sustainability aspects has been the focus of business operations. The focus on these aspects can be traced back to the implementation and control of sustainability among suppliers. Through these implementation and control phases, selecting the finest suppliers suited to luxury production could be possible. In this spirit, the blockchain tool adopted for the textile supply chain could have some advantages, emphasizing transparency and traceability to benefit the various sustainability aspects. As commonly known, it is possible to study the potential utilization of blockchain technology as a decision-making tool for promoting sustainability within companies by following different methodological approaches. In this vein, in this work, we adopted a methodological approach that primarily entails the administration of a questionnaire to a targeted sample of professionals within companies in the fashion industry.

Keywords: sustainability, decision-making, blockchain technology, fashion industry

1 Introduction

In the present day, the fashion industry finds itself at a crossroads of challenges and opportunities never encountered before, where the pursuit of style and innovation intersects with pressing social and environmental concerns [1, 2].

Consumers' awareness regarding the implications of the fashion industry for our planet is on the rise [3]. Therefore, fashion companies face multiple pressures to address the environmental and social issues associated with the impact that their supply chains have [4].

In response to these challenges, there has been a surge of interest in integrating sustainability principles into various aspects of the fashion supply chain, from material sourcing to manufacturing and distribution [5, 6]. For this reason, the need to rethink traditional approaches to supplier selection and procurement is central, considering not only cost and quality but also the social and environmental performance of suppliers.

The main purpose of this study is to examine the social and environmental aspects of the supply chain in the fashion industry and consider how these factors can be integrated into the supplier selection process taking into consideration the perspective of corporate customers. Moreover, the study aims to investigate and try to verify how blockchain technology can serve as a tool to enhance transparency and traceability within the supply chain, thereby enabling informed decision-making in supplier selection.

The article begins with a theoretical background on the issues of the decision-making process, sustainability in the fashion system, and finally an introduction to blockchain and its possible use as a sustainability assessment tool along the fashion industry value chain. Next, the study methodology used for structuring the questionnaire and evaluating the results will be exposed.

2 Theoretical background

2.1 Decision-making

Decision-making can be synonymous with management, considering the final act of choice and the entire decision-making. As widely known, decision-making comprises three main steps: finding opportunities to decide, identifying possible courses of action, and choosing among different courses of action [7].

According to [8], especially in Economics, decision-making occurs through a continuous exchange of information and collection of data that allows information to be processed and transmitted. Accordingly, information is data that has been processed for a purpose, which is to support some decision. In recent years, information has become technology. At the basis of information systems research, we can observe an increasing interest in the study of Information Technology (IT)[9].

2.1.1 Information in the supply chain in the fashion system

Moral hazard is one of the most important serious issues in the supply chain [10]. It is therefore necessary for companies to invest in new technologies such as blockchain to solve the moral hazard problem and further improve supply chain performance. These undesirable behaviors represent a moral hazard and arise in the presence of information asymmetry. For this reason, there is a need for careful monitoring. By using blockchain technology, it is therefore possible to implement a storage system in full transparency, data are accessible to all those with permissions, security, with no possibility of tampering with the recorded data [11].

Blockchain technology makes it possible to overcome the problem of moral hazard; it has already been used in real practice in food supply chains [12].

Similarly, in recent years, in the fashion industry, information on various sustainability aspects has been the focus of business operations. Several studies have

shown by providing empirical evidence that the adaptation of an environmental management system has a positive impact on a company's financial performance.

Information along the fashion supply chain is gathered through audits carried out by brands or third-party companies directly at the companies concerned. The most relevant information mainly concerns three aspects [1]:

1. Environmental: use of toxic chemicals, water consumption, energy use and pollution control.
2. Social: child labor, long working hours, human rights, health and safety.
3. Those just listed are the criteria for selecting suppliers, of course the 'normal' criteria of cost, quality and time persist.

Table 1. Criteria for supplier classification

Criteria	**Definition**
Cost	Lowest product price without compromising the quality
Quality	Ensure high quality control on the products
On-time delivery	Level of delivery on-time as per the agreement with the customer
Rejection rate control	Control on rejection rate of material
Toxic chemical usage control	Control or avoid the usage of toxic chemicals in cultivation process and production process of textile
Water consumption control	Control the unwanted use of water in business operation
Energy usage control	Control the unwanted use of energy in business operation
Pollution control	Control the improper waste disposal, use of hazardous material in operation
Restriction on underage labor	Control the underage employment in business operation
Restriction on long working hours	Control of the forcing of workers to work more than determined hours (apart from overtime)
Human rights care	Basic facilities to labor, respect, etc.
Safeguard mechanism for workers	Monitor the workers' health and safety

As just said then, among the most complicated aspects of supply chain management, within the fashion system, is the implementation and control of sustainability among suppliers, in such a way as to select those best suited to luxury production.

Fashion brands are "manufacturers without factories" and the apparel industry is a good example of a buyer-driven supply chain. Fashion supply chains have many unmonitored aspects, the supply chain can't be defined as opaque [13].

2.2 Sustainability in the fashion system

The fashion industry is the second-largest polluting industry in the world (second only to the oil industry) [1]. Fashion therefore boasts of being one of the sectors where there is extensive literature on greenhouse gases and CO2 emissions of the fashion industry, water consumption, microfiber pollution, textile waste and management issues of waste, to this must be added the exponential increase in the consumption of low-energy products.

Yet, the industry shows little sign of slowing down its levels of production and so few brands are transparent about their climate impacts. The vast majority of brands fail to admit their clothing waste ends up in places like Ghana and Chile where local communities are managing mountains of waste. Industry injustice, however, is not an isolated incident. One positive development is that policy makers have recognized the need to regulate the actions of companies in global supply chains [14]. In recent years, structural changes are taking place in many industries, leading to the emergence of new markets and the need to renew established business models. It is possible to say that today sustainability is considered among the most important drivers for decision-making [15].

According to Kramer and Porter, in an article published by the Harvard Business Review in 2011, sustainability comes from an internal evolutionary process that reshapes the company's mission and strategy. It has now become strategic for companies to focus on the relationship between sustainability goals and corporate competitiveness goals. Indeed, these are two dimensions that are converging and, therefore, generating value the moment they complement each other. Addressing sustainability issues cannot be conceived merely as a mere compliance, but as a real business enabler.

Sustainability travels hand in hand with digital transformation.

Sustainable transformation involves an effort that depends on the ability to obtain adequate and correct data, and information technologies and systems enable the collection and categorization of large and complex data.

Sustainability measurement is a topic of discussion among researchers, policy makers, private individuals and other stakeholders [16].

These data come out of the normal flow of business information in the more classic budget cycle, other sources of information, very often intangibles that need to be transformed into data, must in fact be considered.

Digital makes it possible to manage this huge mass of information and trace it back to benchmarks. When it comes to ESG (an acronym for Environmental, Social and Governance), it is necessary to be able to measure the impact of everything intangible in terms of value creation for businesses.

The investments in digital technologies are expected to soon have a major impact on the textile and fashion companies 'sustainability and competitiveness. Investments in technology are about automating the entire value chain, from decision making to operations, such as efficient use of resources or customer and supplier relationship management [17].

According to stakeholder theory, engagement in ESG, can increase the company's profits and shareholder wealth in the long run because by considering the interests and

value maximization of stakeholders, and by valuing communication, the company can improve support for its activities (ESG).

It emerges that there can no longer be real competitiveness that is not sustainable. The literature highlights the relationship between sustainability and resilience: in a nutshell, companies with sustainability pathways in place show a more stable financial situation, a better propensity to deal with risk, and a greater ability to manage the supply chain.

In companies, digital transformation is enabling sustainability outcomes through the measurement and monitoring of ESG performance to support decision-making, including using enabling technologies for traceability and supply chain management.

2.3 Blockchain technology and its implementation in the fashion industry

In the early 2000s, a need developed in our society to create a digital currency with some specific characteristics: decentralized, not easily attacked, and with its own intrinsic value. Blockchain as a technology was first introduced in 1991 by Haber & Stornetta [18]. Even if in reality it's fairly old, blockchain gained traction only in recent years thanks to the contribution of Satoshi Nakamoto [18] who applied it to Bitcoin. Given the time Bitcoin was introduced, it can be noted that the need to have an electronic cash system was born because of the rise of commerce on the Internet and the lack of proof of the successful transaction. These motivations create the foundations for the concept and, consequently, the execution of an electronic payment system that allows "*any two willing parties to transact directly with each other without the need for a trusted third party*"[19].

Since its introduction in 2008 as the basis for mining and transacting Bitcoin and other cryptocurrencies, blockchain technology has transformed, expanding and adapting to multiple industries and functions, such as supply chain and logistics [20].

Blockchain can be defined as an immutable, distributed, and decentralized digital ledger designed to record and transmit information between parties. As it is characterized by a data structure containing a sequence of transactions grouped into concatenated blocks, it is an advanced database mechanism that enables the transparent sharing of information within an enterprise network.

Some key aspects that characterize blockchain are digitization, disintermediation, decentralization, immutability, security, traceability, and transparency [21].

Specifically, information is digitally recorded within the blockchain, which can be considered a permanent and unalterable network because all validated records are irreversible and immutable. In addition, the security of the network is ensured by the fact that every piece of information within the blockchain is encrypted, and every piece of data has a unique identity, or hash, within the network. With this technology, every movement of a product along the supply chain is recorded and transactions become traceable and immutable, allowing parties to trade with confidence and without intermediaries. Furthermore, it is possible to distinguish between Private, Public, and Permissioned Blockchain [21]. In the former, also called permissionless, each participant can observe and access the same sequence of data (the distributed ledger) as

the other blockchain members, leading to a situation of “almost total” transparency between the actors. Since this type of blockchain is entirely transparent and distributed, it means that it’s a network where people are free to join, participate and leave whenever they want [21].

In contrast, in private blockchains, users must be authorized to own, transmit and verify transactions and/or information and, more generally, to participate. In other words, in this type of blockchain for a node to be part of the system it needs to be initiated or validated because, in this way, nodes are “*responsible for maintaining consensus*”[21, 22]. The last type of blockchain, meaning the permissioned blockchain, can be considered an hybrid of the public and private blockchain, because they incorporate “*many parties and the main nodes are initially and strictly selected*” [21, 22]. While the first type of blockchain (i.e., public) is more popular for cryptocurrencies, the private blockchain is preferred by corporations (closed systems), as decentralization is replaced by exercising more control over access, whereas permissioned blockchain can be considered more “*suitable for semi-closed systems consisting of a few enterprises, often organized in the form of a consortium*” [21, 22].

Transparency and traceability are two of the main features of blockchain and foster a natural state of trust. In this way, blockchain enables greater control and helps limit waste in production and in the final part of a product's life cycle. It also promotes accountability throughout the supply chain, requiring greater consumer awareness.

Blockchain makes it possible to trace the product throughout its life cycle. Including social and environmental conditions could bring to light concerns about the environment and the safety of the people involved in the entire production process. In turn, these concerns could lead to the implementation of sustainable practices such as:

- the circular economy, which is defined by the European Union as " an economic model based inter alia on sharing, leasing, reuse, repair, refurbishment, and recycling, in an (almost) closed loop, which aims to retain the highest utility and value of products, components, and materials at all times [23].
- the reduction of waste can be considered the core of the circular economy model. It's possible to reduce waste to a minimum by extending a product's life, so when it reaches the end of its life, all of its components are recycled (wherever possible) and thus reused [23]
- the reduction of emissions, as by tracking the entire product journey, blockchain could enable the identification of the points in the supply chain where the most emissions are produced, thus prompting the company to optimize them by choosing a supplier closer to home.

The Blockchain tool used for the textile supply chain has many advantages, in particular to emphasize transparency and traceability for the benefit of the various sustainability aspects. Information on the life cycle of a product is thus possible, and the different actors in the supply chain can learn about its impacts [24].

This technology can also promote sustainability from a consumer perspective. It is difficult for customers to access product information that can support ethical purchasing habits. Consumers are more encouraged and more likely to rely on sustainable fashion suppliers when they have access to more reliable and clear information on the social

and environmental effects of clothing. The use of blockchain in supply chains can also help prevent the inappropriate use of labor, as all information is open and cannot be covered up, and consumers become aware of the working conditions workers are exposed to.

3 Methodology

The methodology adopted in this study to verify the potential utilization of blockchain technology, understood as a decision-making tool for promoting sustainability within companies, primarily entails the administration of a questionnaire to a targeted sample of professionals within companies in the fashion industry.

The questionnaire was sent via e-mail and consisted of 22 questions, both open-ended and closed-ended [25]. The focus of the questionnaire revolves around capturing perceptions rather than quantifying responses. The questions asked are of a purely qualitative nature, although some could be considered Likert-type scale style, as the following statements were used as possible answers to the questions so as to collect the opinions of professionals: not important, slightly important, moderately important, important, very important.

Strictly speaking, we administered a mixed questionnaire to collect as much information as possible on companies' perceptions of sustainability and using blockchain technology as a decision-making tool. Specifically, as we shall see, these perceptions derive from the preferences expressed by professionals in the questionnaire on these topics. These perceptions could capture the attitudes and abilities of professionals to operate sustainably from different perspectives.

For the selection of companies to send in the questionnaire, it was first assessed which of the most important brands had company or supply chain certifications such as SA8000, an international standard on social responsibility, or ISO14001 referring instead to environmental performance.

It turned out that just a few brands possess these certifications. However, these certifications are requested from sub-contractors during activation audits. A subsequent selection was made on the basis of the 'Fashion Transparency Index 2022' published by Fashion Revolution. The Fashion Transparency Index is an annual review of 250 of the world's largest fashion brands and retailers ranked according to their level of public disclosure on human rights and environmental policies, practices and impacts in their own operations and in their supply chains.

Table 2. Percentage of brands publishing suppliers list

Year	N. of brands	First-tier manufactures	Processing facilities	Raw material suppliers
2018	150	47%	27%	11%
2019	200	40%	24%	7%
2020	250	35%	19%	5%
2021	250	37%	18%	1%

2022	250	32%	14%	0%

It is easy to assume that many brands are 'jealous' of their value chain by not disclosing suppliers or sub-suppliers. Naturally, transparency should not be confused with sustainability, but without transparency, achieving a sustainable, responsible, and fair fashion industry will be impossible.

Brands already used for the Fashion Transparency Index 2022 were then selected.

3.1 The questionnaire

To comprehensively understand the extent to which professionals within the sector have associated blockchain technology with sustainability, as well as to explore their perspectives on its potential application as a tool for enhancing sustainable practices within their respective organizations, the main figures considered for the administration of the questionnaire are sustainability manager, account manager, compliance manager, and purchasing manager. The questionnaire was sent by e-mail to 25 companies in the luxury fashion sector, and 13 valid answers were received. The questionnaire was constructed on Office Form, through which the answers were then collected, and the statistics viewed.

The questionnaire – included in the Appendix – is aimed at obtaining information to understand how decisions within the supply chain of the fashion industry are organized what they are based on, and whether it is influenced by variables such as sustainability. Within the general picture of sustainability, we would like to understand whether and how a digital tool such as blockchain technology can fit in.

4 Results

The data collected thanks to the administration of the questionnaires made it possible to create the following figures.

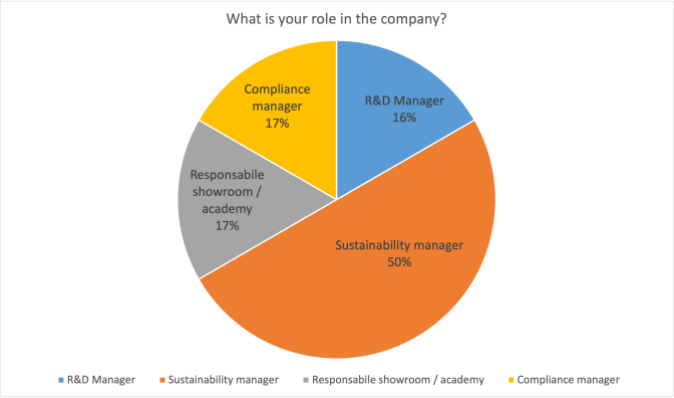

Fig. 1. Roles filled in the company by the individuals surveyed

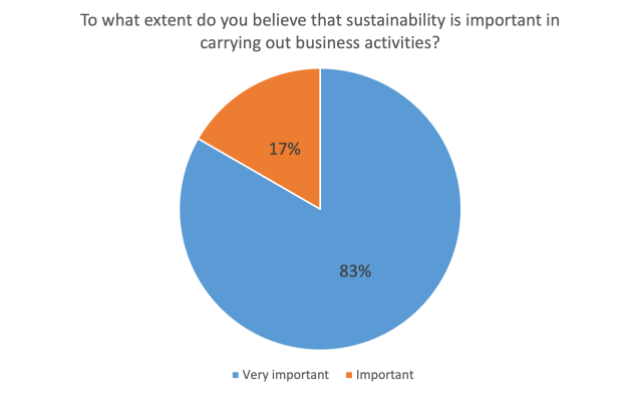

Fig. 2. Perceived importance of sustainability

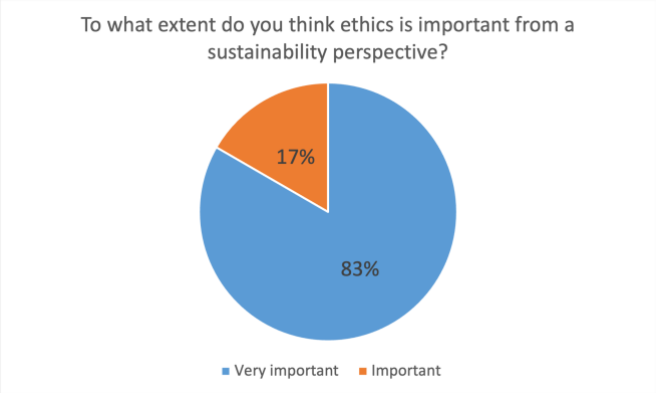

Fig. 3. Perceived importance of ethics

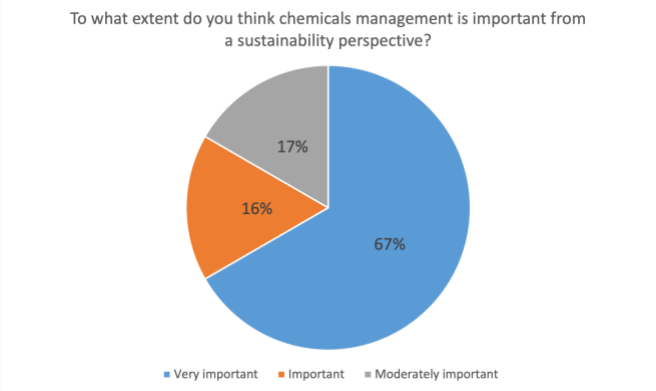

Fig. 4. Perceived importance of chemicals management

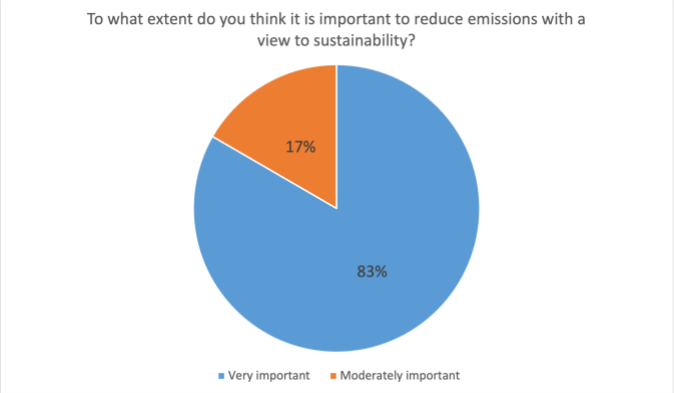

Fig. 5. Perceived importance of emissions reduction

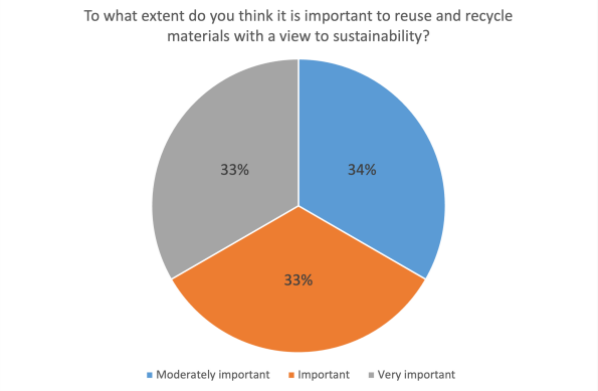

Fig. 6. Perceived importance of reuse and recycling materials

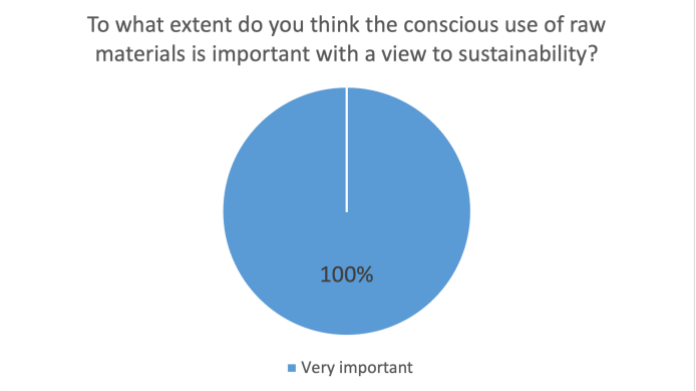

Fig. 7. Perceived importance of the conscious use of raw materials

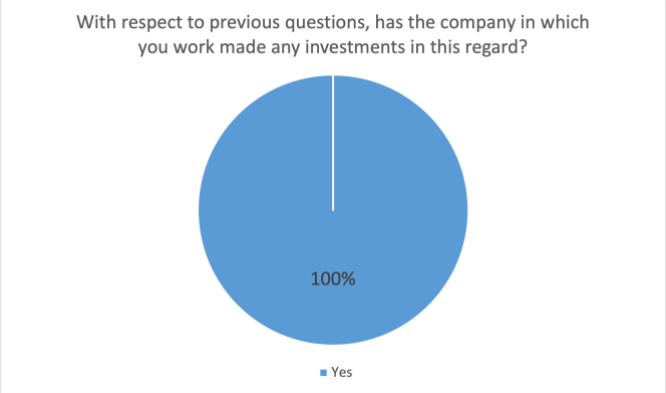

Fig. 8. Companies' investments in sustainability

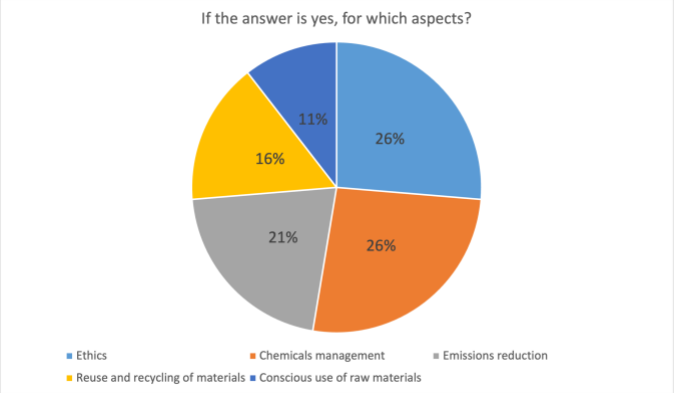

Fig. 9. Aspects in which companies have invested

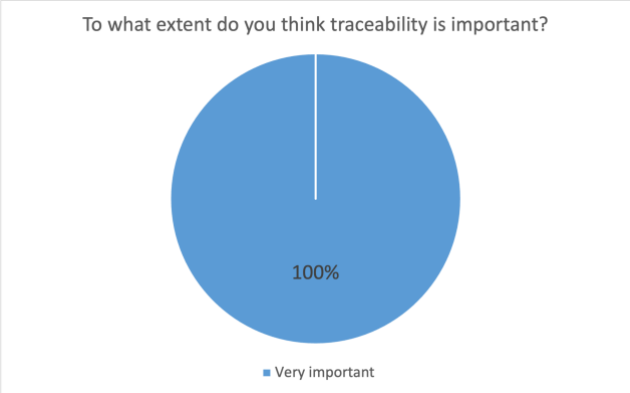

Fig. 10. Perceived importance of traceability

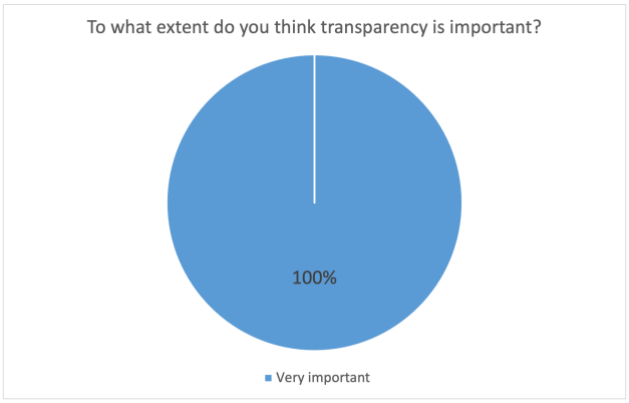

Fig. 11. Perceived importance of transparency

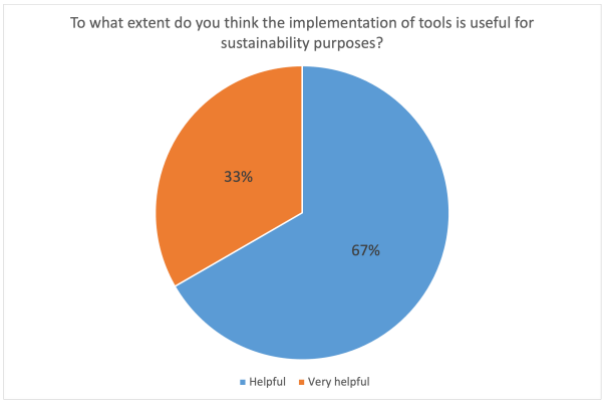

Fig. 12. Perceived usefulness of tools for sustainability

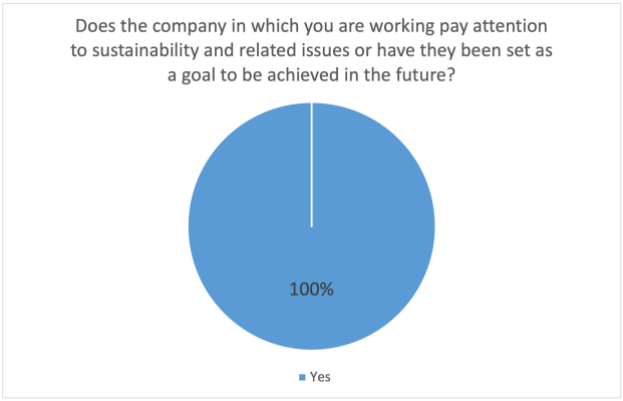

Fig. 13. Companies' attention to sustainability and related issues

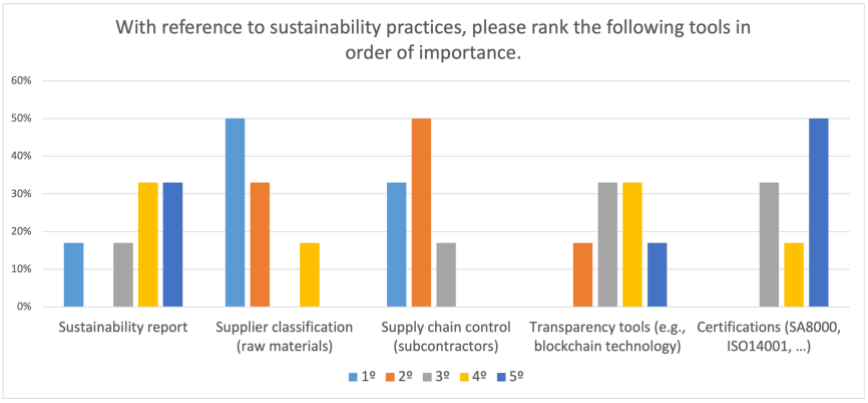

Fig. 10. Tools ranked in order of importance by respondents

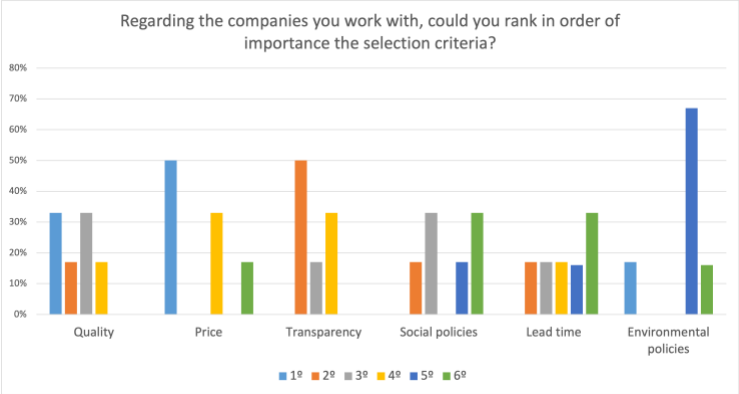

Fig. 11. Selection criteria ranked in order of importance by respondents

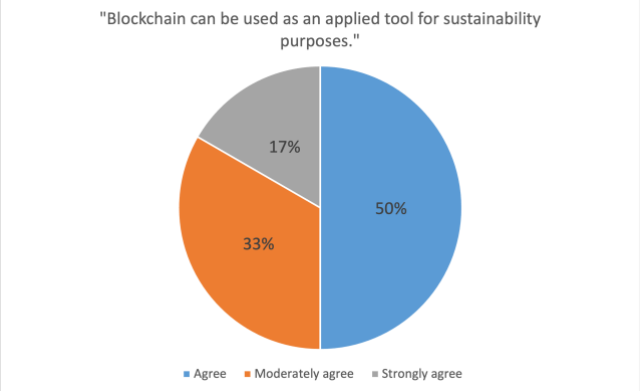

Fig. 16. Level of agreement with the statement on blockchain

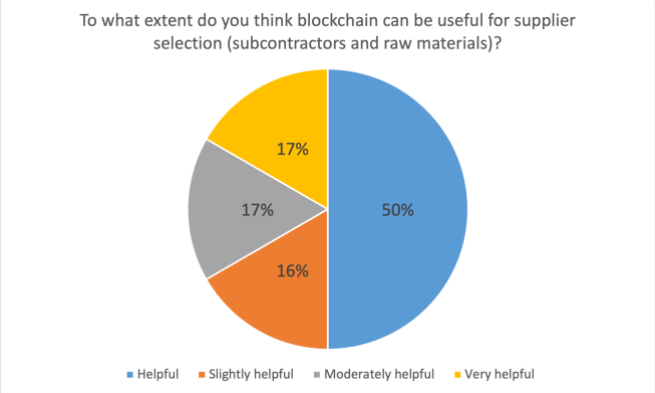

Fig. 17. Perceived usefulness of supplier selection

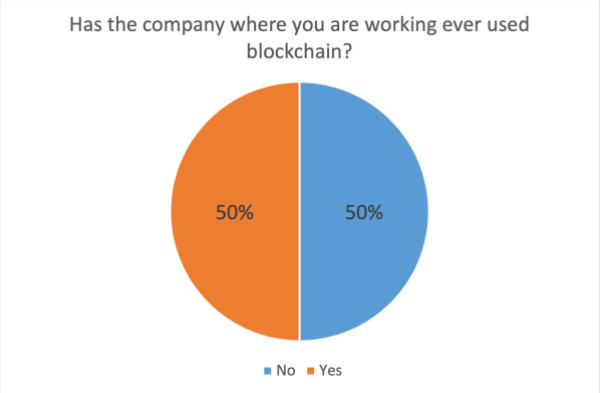

Fig. 18. Blockchain implementation in the companies

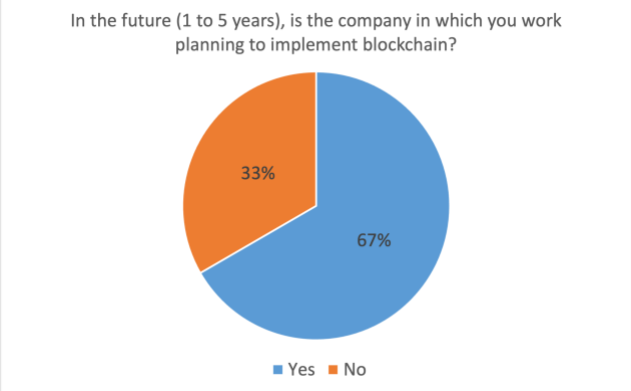

Fig. 20. Future blockchain implementation in the companies

5 Discussion and conclusion

An analysis of the responses showed that there are some obstacles to the acceptance and use of blockchain in the fashion sector, such as a bottleneck of digitization, a lack of industry knowledge, immutability, the network's poor scalability, interoperability, transaction speed, some security and privacy issues, block capacity, and power consumption. Companies with a highly fragmented supply chain will need greater organizational efforts and bear higher expenses since specific data is needed for blockchain traceability. Government incentives and knowledgeable customers who ask for its features might both have an impact on the environment and the adoption of blockchain.

Transparency is foundational to achieving systemic change in the global fashion industry. The brands continue to disclose information about their policies and commitments with respect to sustainability issues. There is, however, a lack of public disclosure by all big brands on issues such as social auditing of the supply chain, living wages for supply chain workers, purchasing practices, unionization, gender and racial equity, production and waste volumes, circularity, chemical use, deforestation circularity, chemical use, deforestation, and carbon emissions in the supply chain-all urgent and important issues that need faster progress. Blockchain is a transparency tool that, if overcome, can enable the fashion system to communicate and inform supply chain and customers, for an informed and responsible decision-making process.

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Appendix

Sustainability

In recent years, sustainability has become one of the most interesting, but also most used and "abused" topics in various sectors, particularly in the fashion industry. With incorporate realities, sustainability can be concretized with multiple actions that can range from the enhancement of social aspects (e.g., ethics), the management of chemicals used in the production process, and the control and reduction of atmospheric emissions to the circular management of raw materials.

1.1) To what extent do you believe that sustainability is important in the performance of business activities?
Not important
Slightly important
Moderately important
Important
Very important

1.2) To what extent do you think ethics is important from a sustainability perspective?
Not important
Slightly important
Moderately important
Important
Very important

1.3) To what extent do you think chemicals management is important from a sustainability perspective?
Not important
Slightly important
Moderately important
Important
Very important

1.4) To what extent do you think it is important to reduce emissions from a sustainability perspective?
Not important
Slightly important
Moderately important
Important
Very important

1.5) To what extent do you think reuse and recycling of materials are important from a sustainability perspective?
Not important
Slightly important
Moderately important
Important
Very important

1.6) To what extent do you think the conscious use of raw materials is important from a sustainability perspective?
Not important
Slightly important
Moderately important
Important
Very important

1.7) In relation to the previous questions, has the company you are part of made any investments in this regard?
Yes
No

1.8) If the answer is yes, for which aspects? More than one answer can be selected.
Ethics
Chemicals management
Emissions reduction
Reuse and recycling of materials
Conscious use of raw materials
No investments have been made

1.9) To what extent do you think traceability is important?
Not important
Slightly important
Moderately important
Important
Very important

1.10) To what extent do you think transparency is important?
Not important
Slightly important
Moderately important
Important
Very important

Sustainability tools
2.1) To what extent do you think the implementation of tools is helpful for sustainability purposes?
Not helpful
Slightly helpful
Moderately helpful
Helpful
Very helpful

2.2) With reference to sustainable practices, indicate the following tools in order of importance. Supply chain control (subcontractors)
Sustainability report
Supplier classification (raw materials)
Certification (SA8000, ISO14001)
Transparency tools (e.g. blockchain technology)

2.3) Does the company in which you operate pay attention to sustainability and related issues, or have they been set as a goal to be achieved in the future?
Yes
No

2.3.1) If the answer is yes, in what way? You may answer briefly or elaborate on the topic.

To date, companies have various tools at their disposal to report on the attention paid to sustainability issues and, at the same time, be aware of work in the same direction by other companies. Among these, we can find voluntary certification tools (e.g. SA8000 for ethical aspects, ISO14001 for environmental aspects, and ISO45001 for workers' health and safety), mandatory documentation to be produced such as sustainability reports and non-financial statements, and finally, supply chain control and enhancement tools such as supply chain audits and blockchain.

2.4) Regarding the companies you work with, could you rank the selection criteria in order of importance?
Price
Quality
Lead time
Environmental policies
Social policies
Transparency

Blockchain technology
Among the digital tools currently available, blockchain can be considered a technology in the service of sustainability. The geolocation of the work and production stages of a given raw material makes it possible to select and evaluate suppliers, subcontractors, and other companies based on geographic proximity, aimed at reducing emissions for transportation, but also on the direct connections these companies may have with others, with a perspective of promoting Made in Italy and certified supply chain.

3.1) How much do you agree with this statement?
"Blockchain technology can be used as an applied tool for sustainability purposes"
Strongly disagree
Disagree
Agree
Strongly agree
Extremely agree

3.2) To what extent do you think blockchain can be helpful for supplier selection (subcontractors and raw materials)?
Not helpful
Slightly helpful
Moderately helpful
Helpful
Very helpful

3.3) Has the company in which you work ever used blockchain?
Yes
No

3.3.1) If the answer is yes, in which way? You may answer briefly or elaborate on the topic.

3.4) In the future (1 to 5 years), is the company in which you work planning to implement blockchain?
Yes
No

3.4.1) If the answer is yes, how? (e.g., investment, publicly funded projects, etc.) You may answer briefly or elaborate on the topic.