Blockchain-based Traceability Platforms as a Tool for Sustainability

António Miguel Rosado da Cruz[1,2][a] and Estrela Ferreira Cruz[1,2][b]
[1]*Instituto Politécnico de Viana do Castelo, 4900-347, Viana do Castelo, Portugal*
[2]*Centro ALGORITMI, Escola de Engenharia, Universidade do Minho, Guimarães, Portugal*

Keywords: Social Sustainability, Environmental Sustainability, Supply-chain Traceability, Blockchain.

Abstract: Among the three pillars of sustainability (environmental, social and economic), modern society begins to give greater attention to the environmental and social ones at the expense of the economic. Consumers are beginning to be prepared to pay more for products that are socially and environmentally responsible, but, for taking that decision, they need to be sure that the products they choose are really socially and environmentally friendly. For that, it is necessary to have transparency about what happens in each stage of the products' supply chain and this information must be available to the consumer. Thus, it is necessary to know the entire supply chain, from the creation of raw materials to the arrival of the final products at the consumer. Storing information (where, who, how, when, etc.) on each of the steps of the supply chain is essential, enabling the traceability of products to become more transparent and even allowing them to be withdrawn from the market if necessary, for health reasons (for example: use of a toxic paint in a clothes' factory). This position paper proposes the use of the blockchain technology to implement traceability in the supply chain.

1 INTRODUCTION

Sustainability can be defined as the way "natural systems function, remain diverse and produce everything they need for the ecology to remain in balance" (James, 2015; Krajníková et al., 2019). A sustainable development is formed by a set of strategies and ideas ecologically correct, economically viable, socially just in order to preserve that balance.

Modern society is mainly driven by businesses and technology. Businesses provide people with jobs, goods and services, and it is the governments' job to define the rules by which those businesses are bound. Despite this, some businesses work while neglecting social or environmental issues. We can find several examples of this neglect in areas such as:

- **Fashion:** in recent years, and with the appearance of the so-called fast fashion, the fashion industry has become one of the most polluting industries. This industry encourages the (unnecessary) consumption, increases the carbon footprint (more raw materials, more energy spent on production, more production and transport from far away sites) and greater waste (more material to recycle or to be treated as waste), many times with no social neither environmental responsibility. Most of the fashion brands have moved their production to developing countries, without worrying about who works in those factories, or under what conditions. The fashion industry is a source of exploitation for millions (Sanders et al., 2019), sometimes using forced and child labor.
- **Agriculture, Forestry and Fisheries:** where resources are over exploited, leading to the reduction of wood forests, desertification of arable land and endangering some animal species;
- **Mining and Mineral Exploration:** the resources needed to sustain our modern society are, many times, extracted in developing countries with risks of using underpaid workers or even forced or child labor and, at the same time, damaging the environment modifying the landscape, most of the times with a poor treatment of chemical residues and contributing to water and soil pollution.

In developed countries, labor laws exist, prohibiting forced and child labor and protecting workers from being exploited. These countries also have environmental protection laws, which make possible to protect the environment. However, a large part of the industries transferred all or part of their production

[a] https://orcid.org/0000-0003-3883-1160
[b] https://orcid.org/0000-0001-6426-9939

Rosado da Cruz, A. and Cruz, E.
Blockchain-based Traceability Platforms as a Tool for Sustainability.
DOI: 10.5220/0009463803300337
In *Proceedings of the 22nd International Conference on Enterprise Information Systems (ICEIS 2020) - Volume 2*, pages 330-337
ISBN: 978-989-758-423-7

to countries where these laws do not exist (or are not enforced) and where labor is cheaper. In this way, the non-exploitation of workers is not guaranteed, nor the protection of the environment, and in addition, the products are transported over a much larger number of kilometers, increasing their carbon footprint.

Some brands (or companies), operating in developed countries, are concerned with treating their employees fairly, protecting the environment and being socially aware, but work with suppliers who do not have the same concerns. If companies don't know who their suppliers are, then they can't be totally sure that the workers who make their products are not being exploited (Sanders et al., 2019).

Ideally, when we buy (or consume) a product we should be able to know its constitution (raw materials), its origins, if workers are not exploited in any part of the supply chain, if companies involved in the supply chain are environmentally friendly, etc. If consumers cannot find information about products 'environmental impact and ethically and socially correctness, they cannot include this information in their decisions when they need to decide which product to buy. For that, it is necessary to know the entire supply chain of a product, meaning knowing its origins (since raw materials), how, when, where and in what conditions the product is produced, transformed, transported and stored.

At the same time, we have sustainable traditional regional products with Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) whose origins must be assured to avoid forgeries (Cruz and da Cruz, 2019).

This position paper defends that, in the name of sustainability, it is mandatory to know each step in the supply chain of the products, allowing traceability as a way to reinforcing transparency.

According to Ciccio *et al.* (2018) "traceability of information plays a pivotal role particularly in those supply chains where multiple parties are involved and rigorous criteria must be fulfilled to lead to a successful outcome" (Di Ciccio et al., 2018).

In the context of a supply chain, blockchain technology is being seen as one of the technologies that better fits traceability needs (Di Ciccio et al., 2018). The blockchain is a distributed technology that allows for registering and sharing information between those companies and the final consumers.

This position paper defends that, *traceability platforms are the key for tracing a set of social and environmental parameters, promoting sustainability improvement. And, public blockchains are the technological answer for registering this traceability information, enabling public scrutiny and helping backing consumers choices, by allowing them to take informed decisions on the selection of products with lower carbon footprint or products which help improving people's lives, either because they were produced by ethical and fair paying businesses or because they are based on better long-lasting products with lower carbon emissions.*

The remainder of the paper is structured as follows: The next section presents assertions and objections on the above stated position. Section 3 summarizes the best presented arguments and backs and further explains the position defended, despite the strength of some objections. And, after restating the defended position, concludes the paper.

2 ASSERTIONS AND OBJECTIONS ON THE STATED POSITION

In this section we present some arguments for and against the above stated position.

2.1 On Balancing the 3 Dimensions of Sustainability

The 1987 report of the World Commission on Environment and Development (WCED), aka Brundtland Commission report, defines sustainable development as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Scamans, 2016; Brundtland, 1987). The report brought into attention the need of working towards economic development without exhausting natural resources or harming the environment.

Although, at the beginning of its emergence, "sustainable development has been interpreted as an ecological vision" (Åhman, 2013), in recent years it has become a multifocal agenda involving social, environmental and economic aspects, pondering and harmonizing their conflicts (Rasouli and Kumarasuriyar, 2016).

Sustainable development is then based on three dimensions: social, environmental and economical (Adams, 2006; Scamans, 2016) (see Fig. 1).

Social sustainability aims at providing future generations the same or greater access to healthcare, nutrition, shelter, and education, in addition to cultural resources then today's generation. It is about allowing the society to function continually at a good level of social wellbeing. Issues as war, poverty, injustice, and

low level of education are signs of a socially unstable system (Adams, 2006; Basiago, 1999; McKenzie, 2004; Scamans, 2016).

Environmental sustainability aims at supporting a defined level of environmental quality and keeping the natural resource capital intact. For this, the consumption of renewable resources should not surpass the level at which they are renewed. Also, the production and management of pollution and waste must be kept at a sustainable level (Adams, 2006; Basiago, 1999; McKenzie, 2004; Scamans, 2016).

Economic sustainability is about ensuring a company's financial performance, whilst managing its intangible assets, considering its influence on the economy, and how it deals with social and environmental aspects (Adams, 2006; Scamans, 2016). Economic sustainability occurs when development is financially feasible, whilst socially and environmentally sustainable (Gilbert et al., 1996; Scamans, 2016).

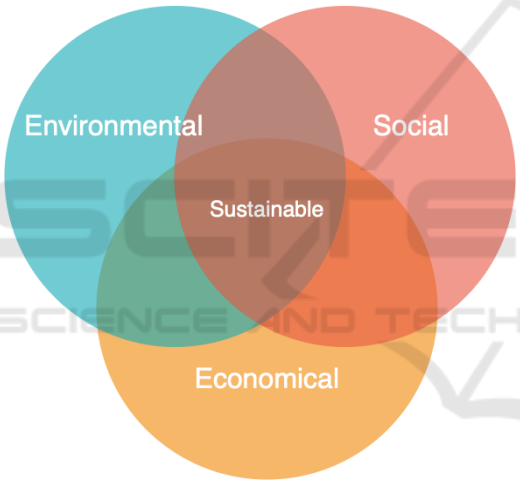

Figure 1: Sustainability overlapping circles (Adapted from (Adams, 2006; McKenzie, 2004; Scamans, 2016)).

2.2 Traceability Platforms as Promoters of Sustainability

Louis Roy defines Traceability as the capacity to verify the history, location or status of an item by means of documented identification (Roy, 2019). Putting together the ability to uniquely identifying a product or product lot, by assigning unique identifiers to them, with traceability, enables an end-to-end visibility over supply chains. Traceability allows to assess the efficiency of the entire supply chain process with data management and analytics, right up to the point of sale, the consumer, and beyond (Roy, 2019). But, most importantly, traceability allows to track information about social and environmental sustainability, which consumers can use to inform better decisions (Roy, 2019).

Traceability can be adapted to any industry. Some sectors, such as the pharmaceutical industry, are even subject to legislation requiring it (Roy, 2019).

Within all economy sectors, traceability systems may be applied to create a more sustainable world.

2.2.1 Traceability and Sustainability in the Fashion Industry

The Fashion industry is responsible for about 10% of humanity's carbon emissions (Sanders et al., 2019). That's more than all international flights and maritime shipping combined (McFall-Johnsen, 2019).

The study presented in (Sanders et al., 2019) concludes that, globally, humans are consuming 400% more new pieces of clothing per year, than we consumed two decades ago. Additionally, about 85% of all textiles go to waste each year.

The fashion industry is also the second-largest consumer of water worldwide. Fashion industry also causes water-pollution problems, being responsible for 20% of all industrial water pollution worldwide (McFall-Johnsen, 2019). Textile dyeing is, for instance, the world's second-largest polluter of water. Globally, only 12% of companies are monitoring the wastewater from all wet-processing facilities to ensure it is not environmentally hazardous (Sanders et al., 2019).

Additionally, fast fashion aggravates these problems by adopting a business model that uses cheap materials, and many times underpaid labor, to yield clothing collections at low cost. These creates a pattern where products are manufactured, consumed and disposed of - literally - fast.

According to McKinsey and Co., consumers are purchasing 60% more cloths, but keeping each garment for half as long, when comparing data from years 2014 and 2000 (McFall-Johnsen, 2019). The explanation varies between clothes being worn or deformed sooner, due to the use of weak materials, or just because they are out of fashion. Fast fashion is also based on poor working conditions, child labor and environmental abuse (McFall-Johnsen, 2019). And, being based on offshoring work to developing countries, it has created longer supply chains, increasing its carbon footprint. (Scamans, 2016)

Traceability platforms for the fashion industry have been developed for disparate reasons, ranging from tracking back products' process paths or monitoring the quality level from the point of sale back to the production of raw materials (Gobbi and Massa, 2016; Shen and Li, 2015; Choi and Luo, 2019; Kumar et al., 2017) to monitoring supply chains' carbon

emissions and environmental sustainability (Fu et al., 2018; Caniato et al., 2012).

Traceability systems are thus seen as an efficient tool for supporting sustainable supply chain management in the Fashion industry.

2.2.2 Traceability and Sustainability in the Agriculture, Forestry and Fisheries

Authorities, such as the European Union are proposing directives requiring the registering of the origin of certain products improving product traceability and faster recalls when necessary.

Traceability systems can effectively trace food quality, help maintain the population of wild fish at sea and manage livestock production in farms and aquaculture explorations, keep track of usage of water, pesticides and the land itself, and reduce food safety issues. Several examples exist of traceability systems in this sector. In (Donnelly and PetterOlsen, 2012; da Cruz et al., 2019; Cruz et al., 2019) reports are made about traceability platforms for registering and retrieving information about fish capture, both in the wild and in aquaculture explorations, and the subsequent transport, processing and sales activities.

All the supply chain events that change the state of the captured fish lots, from its capture (or breeding) until a final sale of the fish or a derived product, are recorded in a traceability platform along the supply chain, for providing consumers with better product information about the fish they purchase.

Currently about half of the humans-consumed fish comes from aquaculture farms. As it happens with other food products, the traceability of fish or fishery products is very important, either to inform the consumer about the path of the fish through the value chain or to recall fish lots in case of threats to the public health (da Cruz et al., 2019; Cruz et al., 2019).

Incidents of food scares, adulteration, fraudulence and foodborne disease outbreaks have put the consumer more alert about the food they consume (Montet and Ray, 2018). These incidents have lead some Food Supply Chain partners to implement a traceability system in their supply chains (Haleem et al., 2019) to help increase the consumer confidence.

In (Haleem et al., 2019) twelve drivers (major factors) playing a role in the successful implementation of the traceability system in food supply chains are identified. The most influential identified driver is the "food safety and quality" (Haleem et al., 2019).

In (Cruz and da Cruz, 2019), integrated pattern business-process and domain models for food product lots traceability in the inter-organizational space inside a food value chain are proposed. A supply-chain wide traceability system allows organizations to exchange information about the quality and location of product lots, from their production and first sale until the sale to the final customer.

The implementation of food traceability systems in big markets, such as China, faces challenges due to the scale, diversity, and complexity of food supply chains. In (Duan et al., 2017) critical success factors specific to these implementations are identified.

In (Xiaoshuan et al., 2010), four criteria are proposed to analyze strengths and limitations of the operating mechanisms of traceability systems in agribusiness. The paper concludes that an integrated mechanism is needed to implement traceability system in agribusiness (Xiaoshuan et al., 2010).

In (Thakur et al., 2009), efforts are made to understand and improve bulk grain traceability. Food safety events, such as aflatoxin in grains, salmonella in spinach and tomatoes, and melamine in feed and food, combined with the slow identification of the suspect products and with demand for high-quality food and feed products have increased interest in food traceability systems. Food safety and traceability laws exist in several countries, but traceability is important for several reasons other than just a legal obligation (Thakur et al., 2009), including efficient response to food safety threats, monitoring the chain of events (production, transportation, sales, etc.), meeting regulatory compliance, analyzing logistics costs and its carbon footprint, among other reasons.

In (Zhao, 2015) a discussion of the role of traceability systems in improving food safety is put into place, and legislations and regulatory practices between EU and China are analyzed.

Agricultural traceability systems have an important role to play in improving our food safety. In (Cheng et al., 2013), an analysis of existing agricultural traceability systems is made, and a common agricultural traceability method is proposed, describing the traceability information of different products with different processes of circulation by quoting the concepts: traceable resource unit, information granule, and supply chain, which can be applied to all agricultural traceability (Cheng et al., 2013).

2.2.3 Traceability and Sustainability in the Minerals and Mining Sector

Also, in the minerals and mining sector traceability systems can play an important role towards social and environmental sustainability, while assuring economical sustainability.

Western societies are increasingly concerned with environmental and social sustainability in the supply

of (primary) metals (Alvarenga et al., 2019). Environmental sustainability can be managed from different perspectives, including a site-oriented one (typically used by the mining sector) and a product-oriented one (along the product life cycle). In (Alvarenga et al., 2019) the differences in these perspectives are analyzed and discussed, supporting the idea that the metal/mining sector would have potential benefits if also adopted the product-oriented perspective.

The ability to track and trace products in a production process and in the transportation chain from supplier to customers is important for quality control and process improvements (Bergquist, 2012), improving economical sustainability. However, when product lots intermix, it is often difficult to achieve good traceability. In (Bergquist, 2012), guidelines for improving traceability and setting up a traceability system in the iron ore production process are presented.

'Responsible sourcing' is an important topic in the mining sector. The expression is used to address sustainability risks in globalized mineral supply chains, and refers to a wide range of sustainability objectives pursued by a variety of approaches (van den Brinka et al., 2019). In (van den Brinka et al., 2019) a review has been performed, on the existing literature and company policies about 'responsible sourcing' of minerals. The paper develops a framework for responsible sourcing, defined as "the management of social, environmental and/or economic sustainability in the supply chain through production data". The authors propose the use of the term 'responsible sourcing' as an umbrella encompassing all sourcing designed to be 'socially responsible', 'green' or 'sustainable' (van den Brinka et al., 2019).

Hofmann *et al.* addresses the management of conflict minerals in mineral products' value chains. Conflict minerals are those whose exploration and trade contribute to human right violations in the country of extraction and surrounding areas (Hofmann et al., 2018). Supply chain managers in the West are challenged to take steps to identify and prevent risks associated with conflict minerals, due to the globally dispersed nature of supply chains and the opacity of the origin of commodities (Hofmann et al., 2018).

2.2.4 Traceability and Sustainability in the Supply Chain Management

Some of the previously cited references address traceability along the entire products' supply chain, from their harvesting, extraction or production and first sale, until the sale to the final customer, passing through the transportation, storage, transformation and sale of each product or product lot. Bjarne Bergquist addresses this problem for the iron ore value chain (Bergquist, 2012). Da Cruz *et al.* address the same problem for the fisheries and aquaculture value chain (Cruz et al., 2019; da Cruz et al., 2019). And, other examples exist.

In (Saberi et al., 2019), the authors examine how blockchain technology can overcome potential barriers, such as inter-/intra-organisational, technical, and external barriers, and then propose future research directions to overcome such barriers and to adopt blockchain technology for supply chain management.

Traceability is a demand from customers and other value chain operators, driven by increasing product quality demands and customers awareness. In Pharmaceutical and in Food products value chains, the interest in traceability also includes safety aspects, demanding, for instance, the continuous measurement of products' transport and storage conditions.

In some value chains, product geographical origin and location of products is also important, either because of environmental sustainability issues or because of origin certification reasons.

Sundarakani *et al.* write on the importance of green supply chain in modern business environment, examining the heat flux and carbon wastages across the supply chain. The paper identifies some of the heat and carbon influencing drivers, such as Mode of Transport, Inventory Policy, Network Structure, etc., and proposes a model to measure the carbon footprint across the supply chain (Sundarakani et al., 2008).

In (Foogooa and Dookhitram, 2014), the authors present a self-green ICT maturity assessment tool, which, in their words, is simple, efficient and accessible. Some business benefits arising from the proposed green ICT maturity self-assessment tool are also illustrated (Foogooa and Dookhitram, 2014).

In (da Cruz et al., 2020), the authors are using a distributed App based on a smart contract on the Ethereum blockchain to trace the carbon footprint of products and organizations.

2.2.5 Traceability and Sustainability in the Traditional/Regional Products Industry

Traditional products try, most times, to preserve the origin of production and the manufacturing process, in order to preserve traditional characteristics such as quality, flavor, texture, etc. The processes can, however, be slightly altered to improve hygiene or working conditions. These products usually are more expensive, and so they are often subject to forgery.

Products' traceability is typically related to the product's geographical origin and location, and their transport and storage conditions. While properties such as temperature of transport or storage have mainly to do with quality control and food safety,

other properties such as the geographical origin of raw materials (e.g. bulk grains, fruit, milk, meat) or of finished traditional products (e.g. cheese, smoked or charcuterie products, traditional wool blankets or cloaks), may be linked to reasons of certification of origin and certification of the production process.

In (Regattieri et al., 2007) a platform is proposed to support the traceability of the famous Italian cheese Parmigiano Reggiano from the bovine farm to the final consumer. The framework supports the identification of the characteristics of the product in its different aspects along the value chain: bovine farm, dairy, seasoning warehouse and packaging factory.

Biswas *et al.* propose a blockchain-based traceability system for the wine supply chain to record detailed information in order to trace the origin, production and purchase history of the wine. The implemented blockchain system incorporates the transactions of all primary entities in the chain (grape growers, wine producers, bulk distributors, transit cellars, fillers/packers, finished goods distributors, wholesalers, and retailer entities) (Biswas et al., 2017).

2.2.6 Traceability Platforms Should Enable Public Scrutiny

The lack of transparency and traceability in supply chains leads to critical issues, some specific to particular business sectors. As argued in the previous sections, products traceability increases the confidence of all stakeholders in the supply chains. Public scrutiny of the traceability platforms increases the confidence of all those involved in the traceability information captured and registered.

According to Kirsi Niinimaki finding ethical information from the consumer point of view is "problematic", but the need for that information is strong (Niinimaki, 2009). Consumers need to be informed to take better, or more conscious, decisions when it comes to select a product to buy or consume. Consumers want to know the origin of the products they are buying or eating, and where, how and in what conditions products are produced, transported and stored (Cruz and da Cruz, 2019).

2.2.7 Traceability Platforms Are Difficult to Put into Massive Practice

Traceability platforms need all operators in the supply chain to be involved in providing true and reliable information about the origin and conditions of harvest/ production/ manufacture, transport, storage or other. When implementing a traceability platform, information must start to be registered in the beginning of the chain, and it may take some time to have all information about the supply chain collected in the platform. This must not demote consumers and other involved stakeholders in demanding full traceability information for all products.

2.2.8 Blockchain-based Traceability Platforms Are Expensive to Operate

Motivated by the advantages of blockchain technology, including decentralization, transparency, automation, and immutability characteristics, a growing number of businesses are thinking of it as the basis for redefining their existing operational systems (Fu et al., 2018) and automating their supply chain processes.

Blockchain has emerged as a reliable solution that can enable and ensure secure information sharing over the network. Blockchain technology is being applied in multiple fields including implementing traceability in the supply chain. Agrawal *et al.* explores blockchain's potential in implementing a blockchain-based traceability system for the textile and clothing supply chain (Agrawal et al., 2018). Fu *et al.* also study an environmentally sustainable solution for the fashion apparel manufacturing industry, which is based on the blockchain. Incorporating an Emission Trading Scheme, the proposed framework exposes carbon emission to the public and establishes a feature to reduce the emissions for all key steps of clothing making (Fu et al., 2018).

Several other examples of blockchain use in traceability platforms could be presented.

Despite their known benefits, blockchains have also several disadvantages, being their inefficiency the most annoying one. This inefficiency is linked to the protocol used to distribute data and reach consensus between the miners. Since mining is a competitive task, and there is just one winner in every transaction, the work of every other miner is wasted. The "proof of work" protocol (used in the Blockchain) is the most inefficient one, not only because it is slow to reach consensus, but also because the competition between miners wastes a lot of energy. For example, in 2019, bitcoin consumed approximately 66.7 terawatt-hours per year, according to the bitcoin energy consumption tracker at Digiconomist[1]. This is about the same total energy consumption of the Czech Republic[2].

There are other forms of consensus protocols more energy efficient, such as Proof of Stake (PoS), Proof of Elapsed Time (PoET), Proof of Existence

[1]https://digiconomist.net/bitcoin-energy-consumption
[2]https://www.vox.com/2019/6/18/18642645/bitcoin-energy-price-renewable-china

(PoE), Delegated Proof of Stake (DPoS), Proof of Activity (hybrid of proof of work and proof of stake), among others. But, a public blockchain with an efficient protocol that ensures committing several transaction blocks per minute is yet to appear.

3 CONCLUSIONS

Economic development has been traditionally based in purely financial performance of companies and states, without regarding how those companies and states deal with social and environmental aspects. Currently, consumers tend to be more alert to the social and environmental aspects, forcing companies, brands and governments to care about those aspects as well. This is motivating stakeholders from several economic branches and industries to make their supply chains more transparent. The report presented in (Sanders et al., 2019) for the fashion industry, concludes that, since 2013, "there has been 32% increase in companies who are tracing their inputs suppliers and 31% increase in companies who are tracing their raw materials suppliers". The same study also concludes that, despite these improvements, "traceability remains a significant challenge across the industry".

This position paper has presented arguments defending that traceability platforms are the key for tracing social and environmental parameters, besides the economic ones. And that blockchain technology is the answer for registering this traceability information. Although the arguments for traceability towards sustainability, presented in section 2, are focused on the Fashion, Food and Forestry, and mining industries, several similar arguments could be obtained from industries such as automotive, technological, pharmaceutical, and other industries.

Currently, the global opaque set up of some supply chains raises challenges when providing trust to customers and other supply chain operators. It is often impossible to trace products back to their origins, disabling the possibility of measuring their social and environmental impact (Montet and Ray, 2018).

For making transparent supply chains possible, which enable product traceability from production of raw materials to selling the final product to the final consumer, information at each stage of a supply chain has to be collected, stored and made available for consultation by the public in general. Thus, consumers will have the possibility to decide according to their conscience, when selecting and buying their products. The collected information must serve the three sustainability dimensions (social, environmental and economic).

For this purpose, the blockchain technology seems to be the most suitable. The blockchain technology offers a reliable solution for traceability platforms, several of which have been referenced in this paper. The main blockchain's drawback is its efficiency in terms of transactions per second. New blockchains are being developed with efficiency in mind (e.g. Cardano, Eris), which makes us believe that blockchains will be in the future of traceability platforms for sustainability.

REFERENCES

Adams, W. (2006). The future of sustainability: Rethinking environment and development in the twenty-first century. *Report of the IUCN Renowned Thinkers Meeting, 29 - 31 January 2006*.

Agrawal, T. K., Sharma, A., and Kumar, V. (2018). *Artificial Intelligence for Fashion Industry in the Big Data Era*, chapter Blockchain-Based Secured Traceability System for Textile and Clothing Supply Chain, pages 197–208. Springer.

Åhman, H. (2013). Social sustainability - society at the intersection of development and maintenance. *Local Environment*, 18(10):1153–1166.

Alvarenga, R. A., Dewulf, J., Guinée, J., Schulze, R., Weihed, P., Bark, G., and Drielsma, J. (2019). Towards product-oriented sustainability in the (primary) metal supply sector. *Resources, Conservation & Recycling*, 145:40–48.

Basiago, A. D. (1999). Economic, social, and environmental sustainability in development theory and urban planning practice. *The Environmentalist.*

Bergquist, B. (2012). Traceability in iron ore processing and transports. *Minerals Engineering*, 30:44–51.

Biswas, K., Muthukkumarasamy, V., and Tan, W. L. (2017). Blockchain based wine supply chain traceability system. In *Future Technologies Conference (FTC)*.

Brundtland, G. H. (1987). Report of the world commission on environment and development: Our common future. Technical report, World Commission on Environment and Development.

Caniato, F., Caridi, M., Crippa, L., and Moretto, A. (2012). Environmental sustainability in fashion supply chains: An exploratory case based research. *International Journal of Production Economics*, 135(2):659–670.

Cheng, C., Jiang, P., and Liu2, J. (2013). A common traceability method for agricultural products based on data center. *Sensor Letters*, 11.

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*, 131:139–152.

Cruz, E. F. and da Cruz, A. M. R. (2019). A food value chain integrated business process and domain mod-

els for product traceability and quality monitoring. In *21st Int'l Conf. on Enterprise Information Systems (ICEIS)*, Heraklion, Crete, Greece. INSTICC.

Cruz, E. F., da Cruz, A. M. R., and Gomes, R. (2019). Analysis of a traceability and quality monitoring platform for the fishery and aquaculture value chain. In *14th Iberian Conference on Information Systems and Technologies (CISTI 2019)*.

da Cruz, A. M. R., Cruz, E. F., Moreira, P. M., Carreira, R., ao Gomes, J., Oliveira, J., and Gomes, R. (2019). On the design of a platform for traceability in the fishery and aquaculture value chain. In *14th Iberian Conf. on Information Systems and Technologies (CISTI 2019)*.

da Cruz, A. M. R., Santos, F., Mendes, P., and Cruz, E. F. (2020). Blockchain-based traceability of carbon footprint a solidity smart contract for ethereum. In *22st International Conference on Enterprise Information Systems (ICEIS)*.

Di Ciccio, C., Cecconi, A., Mendling, J., Felix, D., Haas, D., Lilek, D., Riel, F., Rumpl, A., and Uhlig, P. (2018). Blockchain-based traceability of inter-organisational business processes. In *Business Modeling and Software Design*, pages 56–68. Springer Int'l Publishing.

Donnelly, K. A.-M. and PetterOlsen (2012). Catch to landing traceability and the effects of implementation – a case study from the norwegian white fish sector. *Food Control*, 27(1):228–233.

Duan, Y., Mao, M., Wang, R., Fu, Z., and Xu, M. (2017). A framework for the successful implementation of food traceability systems in china. *The Information Society - An International Journal*, 33(4):226–242.

Foogooa, R. and Dookhitram, K. (2014). A self green ict maturity assessment tool for smes. In *Proceedings of the IST-Africa 2014, Mauritius*.

Fu, B., Shu, Z., and Liu, X. (2018). Blockchain enhanced emission trading framework in fashion apparel manufacturing industry. *Sustainability*.

Gilbert, R., Stevenson, D., Girardet, H., and Stren, R. (1996). *Making Cities Work: The role of authrorities in the urban environment*. Earthscan Publications, Ltd., London.

Gobbi, L. and Massa, I. (2016). Supply chain management in textile sector: the case of the italian t-fashion traceability system. *Int'l Journal of Environment and Health*.

Haleem, A., Khan, S., and Khan, M. I. (2019). Traceability implementation in food supply chain: A grey-dematel approach. *Journal of Information Processing in Agriculture*, 6:335–348.

Hofmann, H., Schleper, M. C., and Blome, C. (2018). Conflict minerals and supply chain due diligence: An exploratory study of multi-tier supply chains. *Journal of Business Ethics*, 147(1):115–141.

James, P. (2015). *Urban Sustainability in Theory and Practice*. Routledge.

Krajníková, K., Smetanková, J., and Behúnová, A. (2019). Building sustainability and building information modelling. *Int'l Scientific Journal about Technologies*.

Kumar, V., Hallqvist, C., and Ekwall, D. (2017). Developing a framework for traceability implementation in the textile supply chain. *MDPI*.

McFall-Johnsen, M. (2019). The fashion industry emits more carbon than international flights and maritime shipping combined. *Business Insider*.

McKenzie, S. (2004). Social sustainability: Towards some definitions. Technical report, Hawke Research Institute Univ. South Australia Magill, South Australia. Hawke Research Inst. Working Paper Series, No 27.

Montet, D. and Ray, R. C., editors (2018). *Food Traceability and Authenticity: Analytical Techniques*, chapter History of food traceability. CRC Press, Taylor & Francis Group.

Niinimaki, K. (2009). Consumer values and eco-fashion in the future. In *Future of the Consumer Society*.

Rasouli, A. H. and Kumarasuriyar, A. (2016). The social dimention of sustainability: Towards some definitions and analysis. *Journal of Social Science for Policy Implications*, 4(2):23–34.

Regattieri, A., Gamberi, M., and Manzini, R. (2007). Traceability of food products: General framework and experimental evidence. *Journal of Food Engineering*, 81(2):347–356.

Roy, L. (2019). 5 ways traceability technologies can lead to a safer, more sustainable world. *Part of the Sustainable Dev. Impact Summit. World Economic Forum.*

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*, 57(7):2117–2135.

Sanders, L., Mawson, J., Tatzenko, J., Hart, C., and Hollister-Jones, A. (2019). The 2019 ethical fashion report: The truth behind the barcode. Technical report, Baptist World Aid Australia.

Scamans, S. (2016). Fast fashion and sustainability. *Helsinki Met. Univ. of Applied Sciences. MSc thesis*.

Shen, B. and Li, Q. (2015). Impacts of returning unsold products in retail outsourcing fashion supply chain: A sustainability analysis. *Sustainability*.

Sundarakani, B., Goh, M., de Souza, R., and Shun, C. (2008). Measuring carbon footprints across the supply chain. In *Proceeding of the 13th International Symposium on Logistics (ISL2008): Integrating the Global Supply Chain*, pages 555–562, Nottingham University Business School, UK.

Thakur, M., Mosher, G. A., Brown, B. R., Bennet, G. S., and Shepherd, H. E. (2009). Food safety series—traceability in the bulk grain supply chain. *Agricultural and Biosystems Engineering Publications*. Iowa State University Digital Repository.

van den Brinka, S., Kleijna, R., Tukkera, A., and Huisman, J. (2019). Approaches to responsible sourcing in mineral supply chains. *Resources, Conservation & Recycling*, 145:389–398.

Xiaoshuan, Z., Jian, Z., Feng, L., Zetian, F., and Weisong, M. (2010). Strengths and limitations on the operating mechanisms of traceability system in agro food, china. *Food Control*, 21(6):825–829.

Zhao, B. (2015). Food safety in china: application of traceability along the supply chain.