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The Adoption of Blockchain Technology in Green Supply Chain Networks

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Abstract

The demand for acting sustainable across companies has gained increasing importance. With the goal set by the European Commission to reach a climate neutral economy by 2050, the mission of acting green and lower the carbon footprint will become a significant challenge for firms across industries. In this paper, a blockchain-based theoretical framework will be proposed as an implementation guideline for companies to provide immutable and trusted data towards supply chain partners, customers and third parties. As a result, a systematic architecture is introduced reflecting a permission-based distributed ledger connected via four additional layers to optimize green supply chain designs and improve transparency.

Keywords: Green Supply Chain Management, Blockchain, Blockchain-based Supply Chain, Change Management

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Table of Content

List of Figures

1. Introduction

Acting in accordance to sustainable methodologies has become vital for companies' success. The rise of global warming, increased pressure from society, changing biodiversity, and the importance of reputation, have triggered the need for new sustainable business models (Long et al., 2018). Consequently, firms aimed at identifying strategies that reduce the impact on environment and societal pressure whilst simultaneously generating competitive business concepts (Bocken and Short, 2016). As a result, the definition of green supply chain management (GSCM) has become increasing attention and is leading to several new optimization approaches: for instance, low-carbon manufacturing is introduced to maximise material and energy efficiency and costs and benefits are being balanced through the selection of ethical suppliers (Boons and Lüdeke-Freund, 2013).

Within this paper, an analysis will be conducted to identify the innovation and optimization potential within such green supply chain networks through the introduction of a decentralized and trusted database, namely Blockchain (Nakamoto, 2008). To do so, a theoretical framework will be introduced and discussed. Blockchain has already set foot in the cryptocurrency market and although not yet fully introduced into a supply chain network, its characteristics can help to improve, track and trust sustainable practices across industries (Casino et al., 2018).

Consequently, the paper is structured as follows. Section 2 and 3 represent a literature review were current frameworks and definitions of GSCM and Blockchain are being discussed. Section 4 will elaborate the potential of introducing a decentralized system, such as Blockchain, into a current supply chain network, discuss its existing use cases and current experienced societal and regulatory pressures. Section 5 provides a theoretical framework and the needed pillars for implementing a Blockchain-based supply chain. Section 6 and 7 contains a discussion based on the given limitations and improvement areas respectively and Section 8 concludes.

2. Green Supply Chain Management

The term sustainable, green supply chain management (GSCM) is defined by Seuring and Müller (2008) as the "management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements" (p. 1700). However, it needs to be differentiated between the management of a green supply chain and the supply chain itself. Whilst the former one manages the network, the latter one is a set of firms connected via one or more downstream and upstream flows of services, products, etc. (Tseng et al., 2018).

Generally, research has concluded that firms adopt green supply chain methods in order to prevent noxious effects on the environment (Jia et al., 2018). A clear practice on how such GSCM is defined though, is not given as it varies across industries. Nevertheless, due to rapid urbanisation, increasing pollution and rising living standards, increasing literature can be found addressing the economic, social and environmental challenges that are tackled via green missions (Miemczyk et al., 2012). According to Tseng et al. (2018), firms across industries have started to kick-off collaboration projects with suppliers, logistic providers and customers to counter-attack the new wave of demand.

In particular, developing countries will be introduced as a dependent variable for the success of GSCM (Fahimnia et al., 2015). The high degree of globalization has consequently encountered a global supply chain set-up with production and manufacturing plants being often shifted due to cost purposes to less developed countries (Jia et al., 2018). Thus, the introduction of GSCM needs to be regarded as a global rather than a local matter of concern.

A consensus definition of green and sustainable supply chains is not given. Within this paper, the definition of integrating sustainable actions to prevent harmful effects on the environment will be defined as GSCM.

2.1 GSCM Drivers

To successfully integrate practices of GSCM, several internal and external drivers have been identified (Tseng et al., 2018).

To provide an overall framework of what companies' 'drive', the Institutional Theory will be introduced to identify and evaluate a company's willingness to change towards sustainable practices (Jia et al., 2018). Firstly, **regulatory drivers** such as law and regulation are motivating firms to adopt GSCM. More precisely, international regulations on sustainable production are high in some countries and need to be adhered in a global network in order to prevent any sanctions, etc. (Lo, 2010). Secondly, **normative drivers** such as codes of conduct, procurement policies, and adherence to international standards, e.g., ISO 14067 are playing a vital role in adopting sustainable practices (Jia et al., 2018). Moreover, sustainable engagement has also been observed as a mean to achieve a differentiation strategy to create superior brand reputation (McMurray et al., 2014). At last, **cultural-cognitive drivers** referring to internal beliefs and values are encouraging people to act and change current systems and behaviours (Jia et al., 2018). In particular, internal leadership is detected next to the variables of social responsibility and national culture as being the most significant driver when adopting sustainable practices (van Hoof and Thiell, 2015).

In addition, the elaborated driving forces of the Institutional Theory are strengthened by Huang et al. (2017) who argue that external regulatory pressure, customer awareness and competitive market are considered as main drivers to implement a sustainable supply chain such as GSCM.

2.2 GSCM Barriers

Next to drivers, barriers across industries have been identified. A high degree of barriers, results in a poor implementation level of GSCM (Dube and Gawande, 2016).

Generally, barriers can be divided into internal and external challenges (Tseng et al., 2018). On one hand, internal organizational barriers arise due to lack of legitimacy and arising costs that come along with the transformation towards sustainable practice implementation. On other hand, external barriers come along through poor supplier commitment, industry-specific constraints and regulation aspects.

Looking from a global perspective, firms' supply chain partners in developing countries are considered as the most frequently mentioned barrier when it comes to implementing GSCM (Clarke and Boersma, 2017). Due to the poor political support in those countries, the level and enforcement of regulations are low (Huq et al., 2014) and the incentives to increase sustainable practices are limited (Bouzon et al., 2015). Furthermore, suppliers and consumers in developing countries are not aware of the necessity to change their supply chain systems towards a more sustainable practice due to a general lack of awareness about the company's impact on the environment (Soda et al., 2015).

In addition, the individual companies within a supply chain are playing a vital role in GSCM as they are vulnerable for corruption and mock compliance (Silvestre, 2015). For example, supply chain partners may claim to be conducting GSCM practices although not fulfilling the needed criteria. More precisely, the presentation of fake documents during GSCM inspections (Huq et al., 2014) and the lack of transparency within the suppliers' operational model (Jia et al., 2018) remain unresolved key challenges and barriers when transforming and ensuring the right implementation into GSCM. Those barriers are consequently causing lack of trust, participation, credibility and transparency among the supply chain partners affecting the consistent success of GSCM.

2.3 GSCM Transformation

GSCM practices are according to Markman and Krause (2016) "a function of two inseparable principles: (1) they must enhance ecological health, follow ethical standards to further social justice and improve economic vitality; and (2) they must prioritize the environment first, society second, and economics third" (p. 4). Moreover, many studies consider a successful introduction of GSCM with the implementation of practices such as green initiatives in manufacturing, and purchasing procedures (Kusi-Sarpong et al., 2016). For example, Tseng et al. (2018) argued that in order to act green, companies are obliged to collaborate with their suppliers. Furthermore, previous research suggests that GSCM practices need to be pushed by (1) internal management, (2) the collaboration with customers and (3) suppliers and need to involve the introduction of eco-design and investment recovery (Zhu et al., 2018). Rao and Holt (2005) claim that GSCM practices are reflected through green purchasing and design, reverse logistics, collaboration with customers and suppliers as well as recycling initiatives.

Moreover, psychological aspects such as trust and confidence into third parties such as supply chain partners are playing a vital role when transforming current supply chain models (Tseng et al., 2018). For example, when adapting green purchasing into the company`s procurement strategy, the selected suppliers need to be trusted to act in compliance to the upon agreed on environmental standards (Miemczyk et al., 2012).

3. Blockchain

Blockchain is a distributed network technology (Chen et al., 2018). In 2008, Satoshi Nakamoto, introduced Blockchain technology as the solution for an immutable distributable ledger that can prevent the double-spending problem, i.e. the problem of committing fraud by spending repetitively the same digital currency (Nakamoto, 2008). Although nowadays Blockchain is most commonly known in relationship with cryptocurrencies such as Bitcoin, it has gained increasing importance across disciplines (Casino et al., 2018).

Each participant of the blockchain network, can be defined as a node (Buterin, 2015). In general, the Blockchain itself, is a sequence of blocks that reflects a complete list of transaction records (Lee Kuo Chuen, 2015). The first block of a Blockchain is a so-called *genesis block*. Every following block to that is defined as *parent block* (Zheng et al., 2018). Each block contains a header and a body and is composed of several characteristics such as the nonce and the hash function (Tschorsch and Scheuermann, 2016). The definition of nonce is abbreviated from 'number only used once' and is a randomly generated number linked to a hashed block. The hash is a function that contains a limited length and is derived from the given information contained in a block.

More recently, Swan (2015) claimed that Blockchain applications evolved into three versions. Blockchain 1.0 deploys the peer-to-peer cash payment system of cryptocurrencies. Blockchain 2.0 extends its features from simple transaction procedures towards the integration of smart contracts and several other applications. Blockchain 3.0 introduces its distributed network feature to the areas of government, science, and IoT. However, the feasibility of Blockchain implementation remains on Blockchain 1.0 and 2.0 (Chen et al., 2018).

3.1 Blockchain Architecture

In practice, the architecture of the Blockchain technology can be divided into the following sequential layers (Casino et al., 2018). Firstly, signed transactions can be introduced as the lowest level of the Blockchain infrastructure. Signed transactions represent a reached agreement between two parties and can involve the transfer of tangible or intangible assets such as a product or the completion of a task. In any case, one of the participants is obliged to sign the transaction (Christidis and Devetsikiotis, 2016).

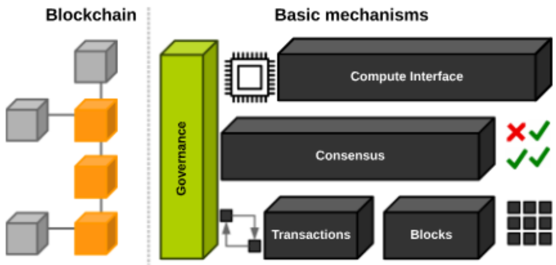

Figure 1: Blockchain Architecture (Casino et al., 2018)

Secondly, the consensus layer comes into place representing different consensus algorithms. Such algorithms are mechanisms that need to be created to validate transactions and be agreed upon the nodes of the network. More precisely, to counterattack the Blockchain's trust-less nature, the given consensus algorithms have been transformed from the Byzantine Generals (BG) Problem (Lamport et al., 1982). In BG problem, a group of generals possess each a fraction of Byzantine army and need to decide whether to attack the city. To reach to an agreement, the generals need to communicate with each other. However, if a traitor is between them, different decisions could be sent to different generals. Consequently, a trust less environment derives. This dilemma is also reflected in Blockchain networks because they are distributed (Zheng et al., 2018). Thus, protocols have been introduced that ensure that the ledgers across the nodes are consistent.

The original consensus algorithm to confirm transactions is the *Proof-of-Work* (PoW) (Antonopoulos, 2014). To reach consensus via PoW, transactions of a new block can only be validated when its hash value meets the given criteria (Zheng et al., 2018). More precisely, a computational process is required in which a hash value is being calculated by using different nonces. When a hash value is computed that matches the given thresholds e.g. a leading number of zeros, all other nodes need to unanimously agree upon the correctness of the hash value. As an alternative however, *Proof-of-Stake* (PoS) is being introduced as a fairer and more equilibrated mechanism to confirm transactions (Pilkington, 2016). More precisely, instead of dividing blocks according to the relative hash rates of miners, PoS allocates mining power to the proportion of the current wealth of miners. For private Blockchains, a vote-based consensus model has gained increasing popularity in which each node votes to accept or reject a block (Chen et al., 2018).

Thirdly, the compute interface layer extends the functionalities of a Blockchain (Casino et al., 2018). With the rise of computer programs, new applications such as smart contracts can be used throughout the Blockchain as a function for autonomous work process. For example, smart contracts can be added as a block on the Blockchain and be distributed across the nodes of the network. Hence, Blockchains can adopt to new states accordingly via flexible set-up (Buterin, 2015).

At last, the governance layer brings human interaction into play and is vital for the future development of the Blockchain (Casino et al., 2018). More precisely, it deals on how a variety of actors across the network come together to produce, maintain, or modify certain criteria in order to influence the methodology of the Blockchain. Although Blockchain rules and set-ups are pre-defined, new methods can be integrated in order to alter and optimize the current process (Zheng et al., 2018).

3.2 Blockchain Categorization

Blockchains can be categorized into permission-based and permission-less systems (Buterin, 2015). Firstly, permission-based systems are private systems that offer restricted access to the Blockchain network (Swanson, 2015). In such systems, a whitelist of users is usually defined before-hand. Due to its high level of security and transparency, the risk of Sybil attacks, i.e. the risk of a node committing fraud through creating several fake identities, is reduced and expensive PoW mechanisms can be avoided (Zheng et al, 2018). In terms of use cases, private Blockchains are increasingly applied within applications such as database management, auditing and performance demanding solutions.

Secondly, permission-less Blockchains are networks that can be implemented and accessed anonymously without restrictions, e.g. public. In this case, anyone can become a new user or node miner, i.e. a participant that has the right to confirm the authenticity of transactions and is allowed to conduct operations such as contracts and transactions (Buterin, 2015). The most common use cases of such networks include in general, most cryptocurrencies such as Bitcoin and Ethereum (Haferkorn and Quintana Diaz, 2015).

At last, the federated Blockchain reflects a combination of the before-mentioned types of Blockchains (Casino et al., 2018). Whilst scalability and privacy features are similar to a permission-based Blockchain, its set-up varies significantly. More precisely, in a federated Blockchain, a set of nodes namely leader nodes are selected to verify transactions (Kravchenko, 2016). This results in a partially decentralised form of network where the power shifts towards the leader nodes as they are responsible for the verification processes and are also granting permissions to other users (Buterin, 2015). One common project to emphasize in this relation is the Hyperledger project (Hyperledger Project, 2015), which works on permission-based, cross-industry Blockchain frameworks.

3.3 Blockchain Singularity

From a technical point of view, utilizing Blockchain technology leads to decentralization, immutability and traceability (Chen et al., 2018).

Decentralisation is ensured through eliminating the need for third parties (Zheng et al., 2018). More precisely, whilst in the traditional sense each transaction is being validated through a trusted intermediary, peers within a Blockchain network can make use of the distributed system structure to make transactions and substitute centralized organisations through mathematical consensus methods.

Moreover, immutability is assured via two ways. Firstly, through the calculation of hashes, stored data cannot be tampered. More precisely, each node holds a copy of every transaction that took place. If a transaction is altered, the hash function of a block changes and cannot be linked to the next block (Crosby et al., 2016). Hence, each node of the network that runs the same validation algorithm is being notified. Secondly, through its shareable public ledger feature and its consensus methodology. Only if consensus is reached, data can be stored in the Blockchain. Trying to commit fraud or tamper information would only be successful if more than 51% of the ledgers is being altered (Tschorsch and Scheuermann, 2016).

At last, traceability of each transaction is given due to the high degree of transparency that comes along with the implementation of Blockchain (Chen et al., 2018). All transactions are stored in a chronological order within blocks and connected via respective cryptographic hash functions. Each transaction can consequently be tracked and traced.

4. Blockchain and Its Potential Role in Green Supply Chain Management

The introduction of disruptive technologies such as Blockchain, re-designs trust and transparency (Saberi et al., 2018). Product and supply chain information can be immutably collected, stored, distributed and managed and consequently, ensure neutrality, openness, reliability, security and transparency for all members of a supply chain network and stakeholders (Abeyratne and Monfared, 2016). In terms of its application towards sustainable measures, an important focus has become the introduction of Blockchain as a mean to track potential social and environmental conditions (Adams, Kewell, and Parry, 2018).

Moreover, Blockchain-based green supply chains help companies to guarantee and adhere to fair work practices and human rights. Due to the transparent record of product history, customers can assure themselves that the purchased goods are supplied and produced from sources that are compliant with ethical sound. By using smart contracts, sustainable-driven rules for the interacting parties can be set and appropriate corrections can be enforced or governed (Saberi et al., 2018).

In addition, Blockchains detect non-sustainable suppliers and counterfeit products. For instance, the combined use of Radio Frequency Identification (RFID) systems and Blockchain technology ensures real-time traceability based on particular rules and frameworks. Each product can be equipped with a so-called RFID tag which transmits its data via radio frequencies to a RFID Reader into the Blockchain (Tian 2017). The stored and trusted data gives hence, the opportunity to reliably trace and track the right quality of the products based on rules that have been previously set.

According to Ward (2017), Blockchains can also lead to supply chain disintermediation. The resulting fewer tiers lead to reduced transaction costs and time. Data and information can be immediately shared across the network enabling rapid deployment of processes and products while reducing transaction times and human errors. Moreover, Blockchain technology can ensure authenticity and safety of the data due to its decentralised and immutable deployment. Thus, companies can increase business reliability and reduce their supply chain risks (Ivanov et al., 2018). However, blockchain is not limited to the mentioned disciplines as it still reflects an exploratory stage.

4.1 Green Blockchain-Based Use Cases

Depending on the industry, different Blockchain-based practices can be identified resolving different issues at hand such as the examples presented below.

Firstly, Blockchain technology can help to decrease both, resource consumption and greenhouse gas emissions. The start-ups ElectricChain and Suncontract have introduced power platforms based on Blockchain technologies with the aim to reduce supply chain waste (futurethinkers, 2017). In this model, intermediaries are being excluded and long-distance energy transmissions substituted through regional energy supply. Thus, energy waste can be optimized over long distance transmissions and the need for energy storage reduced.

Secondly, Blockchain technology can play a key role for companies that need to pay carbon tax. In the past, the Supply Chain Environmental Analysis Tool (SCEnAT) has been introduced to measure carbon emissions across any participant within a supply chain network and life-cycle of products (Koh et al., 2013). The most current version, SCEnAT 4.0 has introduced Industry 4.0 technologies such as Blockchain as a novel form of tracking the product’s carbon footprint across the supply chain (Saberi et al., 2018). In this way, the product journey can be framed in a carbon-friendly manner as companies can identify more sustainable approaches on how to apply low-carbon production, product design, and transportation means (de Sousa Jabbour et al., 2018).

At last, Khaqqi et al. (2018) claim that using Blockchain technology can improve the efficacy of the emission trading schemes (ETS). ETS has been introduced as a policy to combat climate change and acts as a key tool to reduce greenhouse gas emissions. Through introducing the application of Blockchain technology in this matter, the risk of fraud can be minimized, and participants are getting encouraged to work on a long-term solution to reduce the emission.

4.2 Companies Success' Factors

Blockchain has not yet been adopt widely into the corporate world. However, the need for change into a trusted and immutable system has gained further increasing pressure through the European Commission's announcement on the 29 of November 2019 to reach a climate-neutral economy in 2050 (European Commission, 2019). Consequently, research has concluded that in order to adapt to current circumstances and to keep competitive, companies need to adopt a culture driven by innovation and reflected by a sustainable driven environment (Asswad et al., 2016).

More precisely, the first pillar, namely innovation, has to be introduced as a tool to tackle new trends, keep competitive and adapt current needs and circumstances (de Medeiros et al., 2014). Although it is often considered radical, transformative and with profound implications, innovation is essential for a continual drive to improve sustainable and profitable performances. In particular, research has shown that the success of sustainable innovation is significantly related with the synergy between supply chain actors (de Medeiros et al., 2014).

The second pillar of success identifies the need of establishing a sustainable fundament within a company. Although technology, innovation and continuous learning is needed to detect best practices that meet the current customer demands and satisfy regulatory hurdles, the people within the company are crucial to adapt to current methodologies (Hargreaves and Fink, 2012). Consequently, an internal drive needs to be inherited which push sustainable actions.

4.3 Reasons for Change

Companies experience the change of consumer behaviour swapping from brand loyalty to increasing interest in specific performance and features of individual products and whether those are provided through sustainable practices (Sartori, 2018). Moreover, the pressure on climate-neutrality goals, sharpened ETS and the possible introduction of carbon taxes is a call-to-action across industries (Guarascio and Ekblom, 2019). According to the study of the *Journal* *of Industrial Ecology* up to 60% of global greenhouse emissions are produced through consumer products which puts further pressure on altering current processes (Jacobs, 2016).

As a result, researchers across several ranges of expertise, agree upon the necessity to fight environmental challenges at individual and social level (Penz et al., 2019). Although consumers are still to an extent unaware on how their consumer behaviour impacts the environment, a rising trend can be observed and has become an interesting economic niche. More precisely, Ward (2017) claims that pioneering companies have realized the competitive advantage of transparency within their product portfolio, which results in increased customer satisfaction and trust and trigger the consumer to purchase more frequently. For example, companies that are offering CO2 emission reduced product options have experienced a customer spill-over effect which led to a high, frequent purchase rate of sustainable products (Penz et al., 2019).

However, although environmental conditions and changing consumer behaviour appeal to the conduction of change management towards sustainable measures, the variable "customer trust" remains an unresolved issue. More precisely, the *In Brands We Trust?* study has proven that trusting companies to act green within their supply chain is the main driver for the consumers purchasing decision. The study revealed that consumers are aware of social and environmental issues (64% of participants), and a significant majority of 81% of participants stated that customers need to trust brands to engage in sustainable matters (Boost, 2019).

5. Methodology

This study aims at providing a theoretical framework to demonstrate the application of Blockchain technology within organisations.

Within this model, the green supply chain framework and its influence by sustainable drivers will be evaluated upon their potential and performance gaps which can be counter-attacked via Blockchain technology. To do so, the given premise is framed by a permission-based Blockchain which is private, closed and accessible only for a limited and known number of players. In order to approve transactions, a vote-based consensus method and smart contracts will be introduced and will help to bypass any discrepancies across parties (Kormiltsyn et al., 2018).

As a representative green supply chain model, reference will be made towards Saberi et al. (2018) who define six actors across the supply chain: (1) Raw Material Supplier; (2) Manufacturer; (3) Distributors; (4) Wholesalers; (5) Retailers and (6) End Users. To better scope the research, the study will focus on forward supply chain and will disregard reverse logistics and closed loops supply chains. Furthermore, Steiner and Baker (2015) claim that a Blockchain-based supply chain should be extended by two additional actors namely: Standard Organisations such as ISO and Certifiers. The latter one will be responsible to control and verify whether each player of the supply chain network stick to the given standards e.g. fair trade, no animal testing, biodynamic etc.

The data of the product journey along the supply chain partners, the rules defined by the Standard Organisation and the inspection controls of the Certifiers will be captured in the Blockchain via individual uploads, controlled machine tool systems and sensors (Chen et al., 2017) such as presented in Figure 2. Information tags such as RFID tags or bar codes will represent the link between the real, physical goods and their digital identity within the Blockchain. To prevent distortion of competition, each product will have - through the use of smart contracts - its own profile within the Blockchain network, with restricted access respectively.

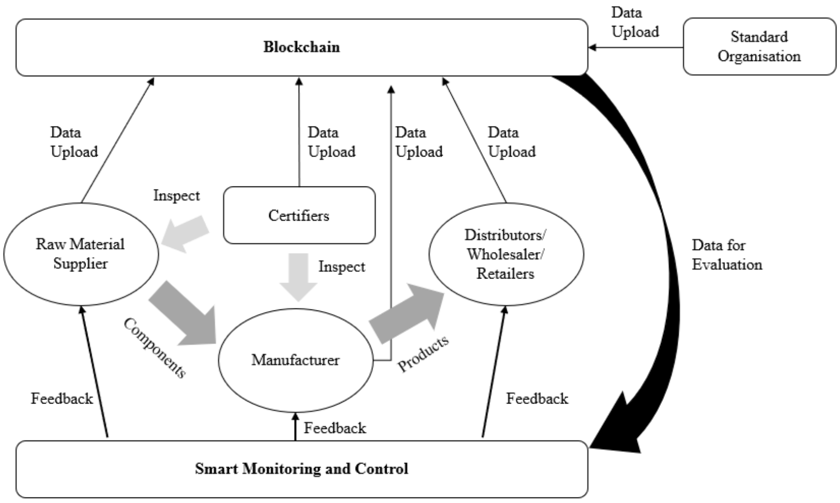

Figure 2: Blockchain-based Information Flow

Moreover, material and information flow will be transformed. Product data can only be modified once permission is granted (Saberi et al., 2018). More precisely, products change ownership across their lifecycle and hence, actors need to gain permission to alter information on a product's profile. For instance, to transfer the good from one party to another and to ensure that set standards such as FairTrade are met, both actors need to sign a digital contract or need to meet the requirements given within a smart contract. Once authorization of the transfer is given, the data within the Blockchain will be updated automatically and shared across the network (Abeyratne and Monfared, 2016).

At last, an improved financial transaction process will be observed (Hofmann, Strewe and Bosia, 2018). Financial agreements between supply chain actors will be set up via smart contracts. This ensures that each project has sufficient funds available and that financial debts between each participant are being paid in a timely manner.

5.1 Blockchain-based Supply Chain System

The framework presented in this section will be based on Blockchain, smart contracts and various sensors. Rather than transforming the whole IT infrastructure, the use of Blockchain technology shall be used as an add-on to the existing system and manage and store data that serves one specific business purpose such as tracking and embracing the product's carbon footprint. Therefore, this showcase will reference towards ISO 14067:2018, the standard setting for quantification and reporting of the carbon footprint of a product.

Blockchain will be taking on the role as the novel core element to provide an immutable distributed ledger with several information sources such as quality, assets, logistics and transactions data. Smart contracts will be set in accordance to the given requirements and guidelines of the standard ISO 14067:2018 and will be used to ensure standard adherence, privacy of the participants, automation and intelligence (Chen et al., 2017). At last, sensors such as GPS and RFID will be implemented as a supplement to gather real-time information on location and quality (Wu et al., 2014).

Thus, the illustrated framework of a Blockchain-based supply chain will be composed of five layers such as presented in Figure 3. Firstly, the Input layer will establish the ground layer and consists of different data components: data that is uploaded by the supply chain partners, data that provides real-time information, i.e. IoT technologies such as GPS and RFID mechanisms, data that is needed and demanded via the Green Standard Settings of Standard Organisations such as ISO 14067:2018, and data that verifies the implementation of those standards, i.e. Inspection Processes.

Secondly, the data layer will be introduced with the Blockchain at its core to secure trusted and immutable data storage. To do so, four kinds of data will be received and stored in the Blockchain: (1) Logistics Data; (2) Quality Data; (3) Assets Data and (4) Transactions Data. A copy of the data will be shared across the supply chain participants such as raw supplier, manufacturer, distributor, wholesaler, and retailer. The access to information, however, will vary across the parties (Swanson, 2015).

Thirdly, a contract layer will be implemented to set the rules on how to deal with the stored input data within the Blockchain. To do so, three contract pillars are defined:

1. **Digital Identity** - Privacy Issues – Digital Identities will be created for each participant and controlled through smart contracts. Thus, private information rules are set, degree of anonymity within the network obtained and product ownership regulated (Zheng et al., 2018).

2. **Real Time Monitoring** - Preventing Fraud and ensuring Quality – With the obtained real-time data on quality throughout the supply chain, smart contracts can be used to execute real time quality monitoring and track standard adherence (Wu et al., 2014).

3. **Customer Analysis** – Demand Forecasts - the customers' demands are analysed automatically and are enhanced by suggestions about further production and purchasing trends (Chen et al., 2017).

Fourthly, the Business Layer. Each enterprise in the Business Layer has access to the Blockchain and is allowed to control and manage the product (Tian, 2017). However, each enterprise of the supply chain has different authorities and access to information based on the digital identity.

At last, the customer layer will be presented. Aim of this layer is to provide the customer access towards data that can be trusted and provides prove on the product's provenance and its environmentally friendly production. According to Saberi et al. (2018) with the use of Blockchain, at least the following information can be presented: the nature (what it is), the quantity (how much of it exists), the quality (how it is), the location (where the product has been and is) and the ownership (who the owner of the product is).

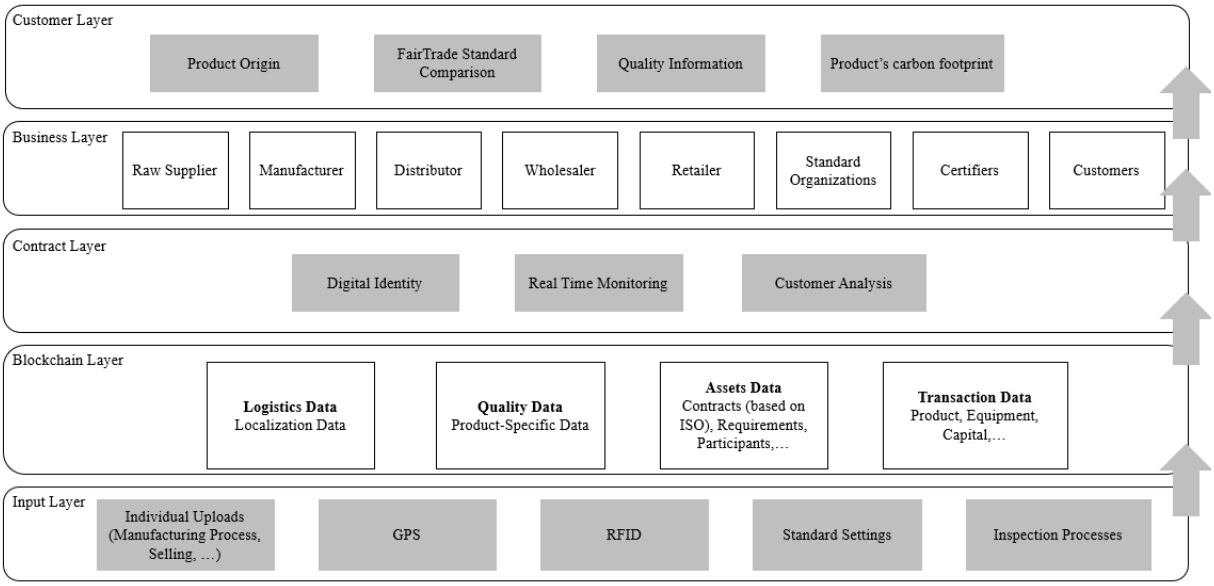

Figure 3: Blockchain-based Systematic Framework

6. Limitations

The proposed Blockchain-based framework reflects a theoretical basis and should encourage organizational re-thinking to provide trusted and transparent data to the customer. Whilst the main purpose of this paper is to deliver a new methodology to prove sustainable behaviour and green-acting, the use of Blockchain within a supply chain encounters several and not yet resolved restrictions which limits the current effectiveness of its implementation. In particular, the right of ownership, the restrictions of smart contracts, change management and non-existing legal framework are yet to be clarified.

More precisely, when introducing Blockchain into a supply chain network, a lack of responsibility-allocation is identified since there is no clear guidance or consensus stating who the responsible party will be that is responsible for maintenance of the distributed ledger and the consensus protocol (Jayachandran, 2017). The question of who and how a Blockchain-based supply chain will be governed is so far unclear (Crosby et al., 2016).

Moreover, the introduced automatic control-points, namely smart contracts, are not yet compatible to a full extent. Currently, this technology-based application finds its restriction in several ways. Firstly, the computing power is limited by the process and storage scalability of each node (Zheng et al., 2018). Consequently, the premise for an effective customer-based usage model of Blockchain across the supply chain is that each node has sufficient computing power. Secondly, the programming languages such as Solidity that are behind the smart contracts still lack testing and are currently only supported by a limited number of programming languages (Eskandari et al., 2017). Those programmes still encounter security issues and bugs in their design. One particular issue in this case is that smart contracts can only be verified once they are implemented within the Blockchain which leaves the network vulnerable to sybil attacks (Kormiltsyn et al., 2018).

Furthermore, the success of the Blockchain adoption also depends on the degree of employee's willingness to adapt to a novel system. People are not fully aware of the features and even less educated on the usability of new data management tools such as Blockchain. Consequently, first-time users will be facing new data storage methodologies and general Blockchain complexity and usability challenges (Yli-Huumo et al., 2016). With respect to the institutional theory, companies need to trigger cultural-cognitive drivers to ensure the success of Blockchain implementation into the supply chain network.

At last, there is no existing legal framework to address legal issues on Blockchain and smart contract applications (Fenwick et al., 2017). This could harm the participation quota of the firms of the supply chain network as they are not being protected by law in this matter. In case of global acting players, complexity and lack of governance is even further implied as industries should agree first upon best practices, standards and contract structures of Blockchain usage across borders (Casey and Wong, 2017).

7. Areas of Improvement

Although limitations already define a frame on the feasibility and spectrum that Blockchain technology implementation will face, several improvement areas within the presented model can already be discussed. More precisely, due to the immature stage of Blockchain in the area of supply chain networks its application on improving the status quo of sustainable performance is yet unknown (Francisco and Swanson, 2018). Consequently, this section aims at elaborating the areas of improvement within a Blockchain-based supply chain environment by presenting different propositions:

Proposition 1: Trust priorities within the supply chain network need to be identified. Although the measurement of sustainable practices across every node is vital, the importance on implementing such technology varies between the participants (Jahanbin et al., 2019). For example, tracking and implementing manufacturing data can be considered more valuable than implementing the data of the Retailer into the Blockchain when aiming at providing solid outcomes for carbon footprint measurements.

Proposition 2: Interoperability across the network needs to be improved through unanimous standard and governance settings. More precisely, clear standards and agreements are yet to be given with respect to Blockchain technology as the core of supply chain operations (Casey and Wong, 2017). Consequently, industries must agree on cross-border standards and best practices for technology usage and contract structures. For example, companies can adapt to the internet governance approaches of ICANN (Internet Corporation for Assigned Names and Numbers) to reach consensus in this matter.

Proposition 3: Blockchain should be used as a trigger to leverage sustainability across all its dimensions. The use of Blockchain to improve green supply chain networks has so far proven to boost environmental performances such as tracking greenhouse gas emissions or water usage (Varsei et al., 2014). However, sustainable development can also be achieved per definition of Seuring and Müller (2008) via economic and social dimensions. In particular, social dimensions are to be considered as a vital element, since sustainable practices are often incentivized through human interactions and practices and depend on how effectively they have been executed. Although social performances are difficult to measure, the Blockchain can be used to create a reward system based on cryptocurrencies tokens and reputations scores to ensure the successful implementation of sustainable practices (Pazaitis, De Filippi, and Kostakis, 2017).

Proposition 4: Supply Chain Analysis will need to be re-designed. The introduction of Blockchain into the supply chain network increases data visibility across the participants (Swan, 2015). More precisely, a new degree of data transparency will be exposed to the network. Consequently, companies are able to draw up on a novel order of data magnitude as a mean to analyse and improve operational performances (Zhu et al., 2018). Therefore, current processes around data analytics will need to be altered and adjusted to the new, transparent data environment given through Blockchain.

8. Conclusion

In this paper, a theoretical framework was proposed to develop an immutable, transparent and trusted blockchain-based green supply chain model. To prove sustainability, improve operations and detect deficiencies, Certifiers are suggested to act as separate agents to verify given standards (Steiner and Baker, 2015) and Smart Contracts to ensure privacy, automation and intelligence (Chen et al., 2017).

Due to the new arising challenges such as regulatory settings to reach a climate-neutral economy (European Commission, 2019), the experienced change in consumer behaviour towards higher curiosity of the product's provenance and the increasing demand for trust (Sartori, 2018), GSCM is becoming a core strategy for companies. Although the introduced framework is limited due to the current exploration stage of Blockchain technology usage in the industry which leads to outstanding issues such as the right of ownership and a missing legal framework (Fenwick et al., 2017), its features of immutability, traceability and decentralization are gaining increasing importance in order to prove and track sustainable measures. Whilst the current focus is reflected by current issues at hand, the implementation of Blockchain also demonstrates further benefits. The adoption of blockchain can be used as a strategy to improve social sustainability through incentivization programmes (Pazaitis, De Filippi, and Kostakis, 2017) and disrupts current data analysis approaches as it provides a new degree of data transparency across supply chain partners (Zhu et al., 2018).

In conclusion, the adoption of a blockchain-based supply chain will introduce an immutable, decentralized and trusted system into the supply chain network to prove and optimize current sustainable practices and counter-attack current regulatory and social pressures.

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