



HAL
open science

Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector

Manal Hader, David Tchoffa, Abderrahman El Mhamedi, Parisa Ghodous, Alexandre Dolgui, Abdellah Abouabdellah

► To cite this version:

Manal Hader, David Tchoffa, Abderrahman El Mhamedi, Parisa Ghodous, Alexandre Dolgui, et al.. Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector. *Journal of Industrial Information Integration*, 2022, 28, pp.100345. 10.1016/j.jii.2022.100345 . hal-03834812

HAL Id: hal-03834812

<https://hal.science/hal-03834812v1>

Submitted on 22 Jul 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector

Manal Hader^a (manalhader94@gmail.com) , David Tchoffa^a, Abderrahman El Mhamedi^a,
Parisa Ghodous^b, Alexandre Dolgui^c, Abdellah Abouabdellah^d,

a- University Paris 8, 140 rue Nouvelle, 93100 Montreuil, France

b- LIRIS-CNRS, Université Lyon 1, France

c- IMT Atlantique, LS2N - UMR CNRS 6004 La Chantrerie, 4, rue Alfred Kastler

d- ENSA Kenitra ,Ibno Tofail University, MOSIL, Morocco

Applying integrated Blockchain and Big Data technologies to improve supply chain traceability and information sharing in the textile sector

Abstract:

Nowadays, the textile industry is strutting its stuff. On one hand, customers have a diverse choice of products available on personalized mobile apps, with immediate deliveries and returns. On the other hand, production is more effective and efficient than ever, thanks to increased automation and computerization in textile processes. However current supply chain management systems still face several serious problems such as tampering of products, poor traceability, delay, and lack of real-time information sharing. Today, a new technology called blockchain, which is a ground-breaking innovation in decentralized information technologies, can solve the above-mentioned challenges due to its important features, such as decentralization, transparency, and immutability. In this direction, this paper proposes a new framework for textile supply chain traceability based on blockchain which could offer an information platform, for all supply chain members with transparency and information sharing. Creating a traceable and transparent supply chain for textile industry would help customers to make informed choices about products they buy and the companies they support. For stakeholders in the textile supply chain, having traceability and real time information sharing builds better relationships, increases efficiency, and reduces the risk and cost of product recalls, counterfeit, and unethical labors. However, since blockchain technology is still in its early stages, it has some inherent defects, in which scalability becomes a primary and urgent one when we face the mass data in the real world. Hence, we present a new approach, consisting of the integration between two technologies which are blockchain and Big Data, to fill in the decentralized systems at scale. One of the primary research questions answered is how blockchain empowered by Big Data can be utilized and applied to manage traceability and information sharing more accurately through global supply chains. In this study we examine the necessity of traceability system concept and information sharing, followed by presentation of a blockchain integrated big data framework and its development processes. Finally, performance of this proposition is evaluated, and challenges of such a traceability system that can be addressed through further research are presented.

1- Introduction:

1.1. Background and motivations:

Considered as one of the oldest manufacturing sectors, the textile industry is one of the main contributors in the world wide economy, with a value of \$842.7 billion in 2015, which is expected to reach \$1004.6 billion, by 2020–2021 [1]. In fact, there are billions of garments being manufactured every day, through complex supply chains that can now cross several seas and continents, from the origin of raw materials to the final customer. Textile organisations have advanced and competitive technological tools to design, produce and deliver products to customers on time [2]. Despite these efficiencies, textile manufacturing processes pose significant environmental and reputational risks, which can potentially impact brands equity, profitability, and operational capabilities. Moreover, we know little information about how, when and where textile products were originated and knitted through their life cycle, especially that most of textile enterprises made the relocation of production facilities offshore by local apparel manufacturers in other developing countries [3]. Thus, typical supply chain of textile industry is becoming much more extended as manufacturing expands to Asia, Africa, and so forth. Even before reaching the end customer, clothes travel through a very vast network of retailers, distributors, transporters and storage facilities, that participate in designing,

spinning, knitting, delivery, sales and very often courses through opaque and distrustful networks. Indeed, even if databases that manage information exist, they are mostly fragmented and do not allow visibility on the origin of a product [68]. In response to those growing textile issues, many internet of things technologies, such as RFID and wireless sensor network-based architectures and hardware, are applied to supply chain traceability and visibility [5]. However, there is a very important issue, that has not been touched, is that whether the information shared by textile supply chain members in centralized systems can be trusted [5]. This kind of centralized systems become so powerful by possession of data that could result in information asymmetry between organizations and individuals [68]. It can also become a vulnerable target for bribery, and if, for example, the administrator can be bribed, valuable information can be tampered with, and then the whole system cannot be trusted anymore [68]. These limitations indicate several researches needs for methods of automated information sharing among different participants, to improve the efficiency of textile supply chain management and methods to enable the traceability of information pertaining to textile industry. As a promising technology, blockchain has drawn more and more attention from academic and industrial areas. Blockchain refers to a distributed ledger offering an unalterable record of digital transactions [4]. The decentralized and immutable nature of a blockchain network enables the creation of a non-refutable record of data and real-time information sharing among various networkers [4], these features could remove the reliance on a central entity. Instead of storing data in an opaque network system, with blockchain, all the information of the clothing products can be stored in a shared and transparent system for all the members along the supply chain. As an emerging technology, blockchain also has its inherent shortcomings, and with the increasing applications, scalability has become a primary and urgent concern which also will be treated in this work.

1.2. Contribution and paper's organization:

In this paper we will try to find solutions to the mentioned issues of textile supply chain traceability and information sharing using blockchain and distributed database technologies. All the separated processes in supply chain could be integrated into proposed model. In contrast, the primary focus of previous studies has been to introduce traceability and its advantages to counter the issues faced by the textile industry, without considering the mechanisms for information sharing and utilization. Thus, the scientific contribution of this study compared with existing relevant research lies in the application of blockchain technology to improve traceability in the textile industry which is new for such as industry. Further, it is among the first studies to use the novel blockchain technology empowered by Big Data to address the issue of textile traceability in the world, by avoiding the scalability issues that most of blockchains suffer from, which enables real-time automatic and scalable information sharing system for the supply chain. The present study fills the research gaps in the traceability and transparency management of textile sector and facilitates the reliability of information in the textile supply chain. The remainder of this study is organized as follows: Section 2 presents the literature review; section 3 is the typical textile supply chain and the major shortcoming of the existing supply chain management system. The textile supply chain management with blockchain technology and scalability issues of blockchain technology are detailed in Section 4. Section 5 presents Bigchaindb for textile supply chain and the proposed model. A case study is presented in section 6. And finally, conclusions and future research are discussed in Section 7.

2- Literature review:

2-1- Traceability and information sharing:

According to (ISO 9000:2015), traceability is the ability to identify and trace history, distribution, and location of products, materials, and services. Over the years, institutes have put in place guidelines for the protection and security of products, which require the implementation of traceability in certain sectors. Government regulation is a major factor for the implementation of traceability in certain sectors such as food industry and pharmacy sector [68]. However, when it comes to textile industry,

traceability does not have a long history, but lately, it has become one of the priorities of this sector [4,5]. Previous studies have focused on determining the influence of information sharing on inventory management [10,11], supply chain performance [12,13] and organizational efficiency [14], Lam and Poste in their work about information sharing and its impact on supply chain performance, confirmed that the lack of “information sharing “ could impact negatively the supply chain in textile and clothing industry in Hong Kong, due to the absence of standardization and frameworks to share information[4]. Regarding textile sector, it is not governed by any formal regulation requiring traceability, which negatively impacts the implementation of the latter [5]. Despite this, there are several voluntary initiatives in favor of traceability in the textile supply chains, like for example, the Italian union of chambers of commerce which encourages the adoption of traceability systems in supply chains for different sectors including the textile [17]. In addition to this, the actors in supply chain are increasingly aware of the importance of traceability [18], as for example the factor of the quality of finished products which depends on the origin and the authenticity of raw material and also the importance of traceability to deliver as quickly as possible to face the fierce competition in this sector.

2-2. Blockchain technology:

Blockchain became well known technology with the appearance of the cryptocurrency Bitcoin in 2009 [27] and since that time it has not stopped attracting the attention of researchers and practitioners [28]. In the textile domain, Kumar et al. suggested that blockchain could tackle the shortage of a trustworthy information resource in textile supply chain management [29], but limited studies have been conducted on the application of blockchain in the textile industry. Table 1 summarizes notable studies on the application of blockchain in the general supply chain domain. One notable benefit of blockchain is its ability to improve traceability and information sharing [30,31]. The validation methods of the peer to-peer public network have allowed the security and traceability of items across a supply chain [32,33,34]. Some of the studies listed in Table 1 have also indicated that blockchain can address the issues of asymmetric information, integration, transparency, and trust problems to enhance supply chain management. However, existing studies on blockchain applications primarily investigate these applications from a qualitative perspective to describe the potential benefits of adopting blockchain technology. Therefore, we aim to fill this gap in blockchain technology literature by building a framework for blockchain-based information management and illustrates the involved workflow to realize the traceability, transparency and real-time information sharing in the textile supply chain.

Authors	Research focus	Methods	Issues in supply chain
Dwivedi et al. [16]	Proposing a blockchain-based scheme for information sharing securely in the pharmaceutical supply chain system with smart contracts and consensus mechanism.	Qualitative analysis	Tampering of products, delay, and fraud
Kshetri [35]	Incorporating blockchain into IoT security	Qualitative analysis	Security problems
Agrawal et al. [29]	Enlisting the advantages of blockchain technology for implementing traceability. A case-based example has been used to explain blockchain application in implementing traceability in T&C supply chain	Qualitative analysis	Information asymmetry, visibility, and security
ElMessiry M. et al. [39]	Proposing a blockchain-based framework for textile quality improvement that enables in near real time and cross chain information sharing	Qualitative analysis	Lack of transparency
Fu B. et al. [40]	Proposing an environmentally sustainable solution for the fashion apparel manufacturing industry energized by blockchain to reduce carbon emissions for all key steps of clothing making.	Case study	Carbon emission of clothing manufacturing
Tieman and Darun [31]	Analyzing the application of blockchain in the halal supply chain to ensure its transparency	Qualitative analysis	Lack of transparency
Wang et al. [36]	Proposing three types of blockchain-enabled applications in construction	Qualitative	Challenges of trust,

	engineering management	analysis	automation, and information sharing
[72] Feng et al.	Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges	Qualitative analysis	Food Traceability
[73] Sunny et al.	Supply chain transparency through blockchain-based traceability: An overview with demonstration	Qualitative analysis	The visibility of various supply chain distribution network designs
[74] Wang et al.	Blockchain-enabled circular supply chain management: A system architecture for fast fashion	Qualitative analysis	Manage the complexities of circular supply chain management
[75] Pal et al.	Internet of Things and Blockchain Technology in Apparel Manufacturing Supply Chain Data Management	Qualitative analysis	The interoperability of information systems in apparel manufacturing supply chain management

Table 1: Summary of blockchain technology-based solution for supply chain

3- Textile supply chain management

3.1. Typical textile supply chain management – an overview:

In the manufacturing industries such as automotive, electronics and food, manufacturing have long product lifecycles, and require modern manufacturing practices to operate in a highly regulated environment. In the agri-food industry, applicable regulations, labelling standards, and audits make traceability a main goal [68]. In the pharmaceuticals supply chain, the rules must be strictly followed, and proper transparency along with trust are maintained among the different participants of the supply chain, as to deliver the product in due time, and proper condition [37]. The textile supply chain (TSC) operates very differently from other supply chain in which delivery of products are subjects to various kind of comprehensive regulations and rules [38]. The textile sector supply chain is generally known for being made up of a very long and complicated network, it deals with many players based in different parts of the world, and faces a great diversity of raw materials, a wide variety of processes through the links of the supply chain in addition to the various logistics intermediaries that provide transport and distribution [38]. Most of the textile supply chains are driven by retailers, who monitor the demand forecasts and make the orders for upstream suppliers [19]. In most of the time, a retailer does not have any manufacturing tools and acts as a reseller who buy the final products from the precedent vendors and sells them to the end customers [19] as shown in Figure 1 . Despite not owning any manufacturing tools, retailers act as the most dominating actors in the textile supply chain. At the macro-scale, each link takes the raw material as an input from the previous link, applies processes, and produces its final product. This process is repeated until it reaches the retailer. There are many processes performed by each actor. As a result, there is a significant amount of information and data created by each actor. Information is a critical component of supply chain; therefore, it is important that each supply chain actor controls the flow and protects important information [41]. Fig. 1. shows the different elements of the supply chain in the textile sector. The chain starts with the production of the raw material. It goes to the different steps of production processes until the product is finished. This product will run through different types of trade by reaching customer.

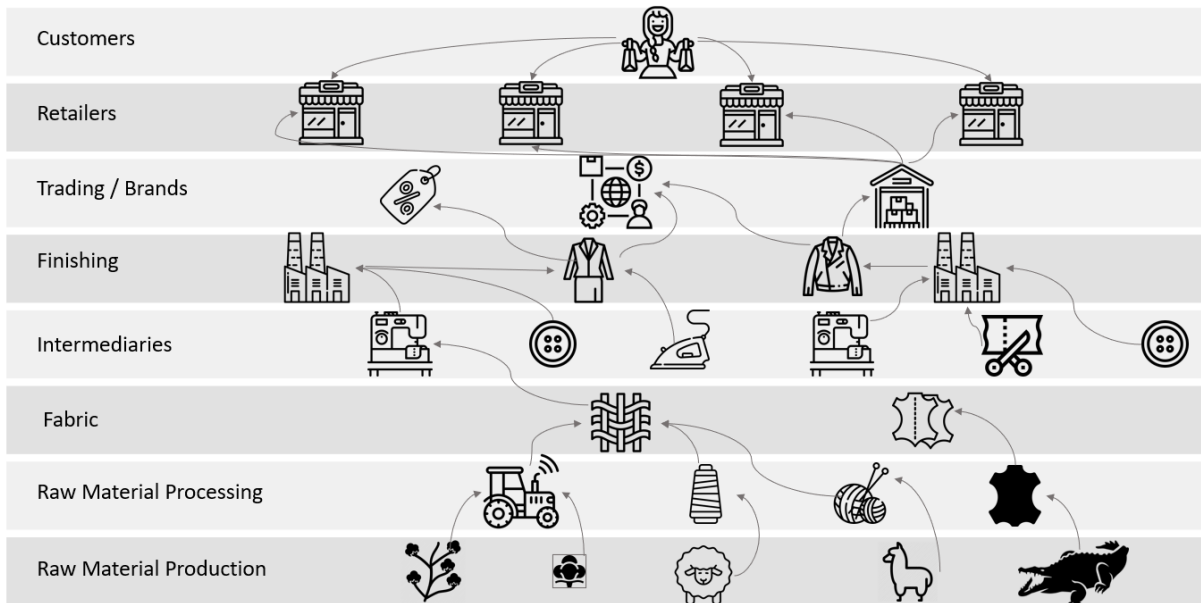


Fig. 1. Working mechanisms of typical textile supply chain without blockchain

3.2. Major Challenges & limitations of existing TSCM: why a fresh approach is needed?

With the rapid growth of internet technologies and centralized mechanism, a lot of emerging technologies have been applied in traceability systems of the textile industry supply chain for the confirmation and coordination of updated information regarding process status such as EDI, ERP and RFID systems [68]. However, to date, nearly all these systems are centralized which are monopolistic, asymmetric, and opaque that could result in the trust problem, such as fraud, corruption, tampering and falsifying information [68]. The partners and consumers must account on a single information point to store, transact, and broadcast the traceability information. As a result, it becomes difficult to customers and partners to acquire full transaction information and tracking the origins of products [6]. Customers and textile supply chain stakeholders need to be fully updated about the product life cycle to assure that products are high quality and authentic. Besides, centralized system is vulnerable to collapse since a single point of breakdown will lead the whole system to be crashed [68]. Moreover, enterprises with small resources still rely heavily on manual operations or f phone calls, e-mail correspondence, and web-based service to achieve minimum efficiency which remains ineffective to achieve synchronization among supply chain participants. Table 2 reports some famous incidents impacting the textile supply chain which are nothing but a result of complex supply chain structure with large geographical distance among actors which is making the textile sector one of the most opaque and vulnerable networks [41]. Although all textile supply chain partners are linked together as a network, yet, they do not have sufficient information about their supply chain.

	Issues	Incidents
Social	<ul style="list-style-type: none"> • Worker health and safety. • Human trafficking. • Below minimum wage. • Child labor. 	<ul style="list-style-type: none"> • Rana Plaza collapse — Bangladesh • Migrant worker exploitation — Turkey
Environmental	<ul style="list-style-type: none"> • Discharge of untreated toxic chemicals into the ground and water bodies. • High level of water consumption to produce cotton fabric. • Production of wood-based fibers leading to deforestation. 	<ul style="list-style-type: none"> • Independent analysis of water around viscose-producing factories in India, China and Indonesia, where severe water pollution was detected. • Desertification of the Aral Sea,
Quality	<ul style="list-style-type: none"> • Spurious or inferior raw materials. • Presence of harmful chemicals. 	<ul style="list-style-type: none"> • A large U.S. retailer where the use of Egyptian vs. Indian cotton was in question. • Significant levels of cadmium found in jewelry at major U.S. fashion retailers. • A large UK fast fashion retailer had to recall thousands of flip-flops after discovering a carcinogenic chemical used in the dye.

Table 2: Reported incidents impacting the fashion retail supply chain [54]

3.3. The impact of counterfeiting in the textile supply chain :

Technically the term “counterfeiting” is employed in specific cases of trademark transgression. However, in the field of fashion and textile industry, the term presents any producing of an item which imitates the appearance of an item of other producer as to dupe a customer that it is the authentic item. Counterfeiting in textile industry is very widespread in Europe [78]. The most relevant way to profit from the free movement of goods across borders is to import textile products and stick the labels in one European Member country and then buy the products in another Member country.

The international trading loses big amounts due to counterfeiting activities. As shown in table 3 these losses not only involve the owners of the original products, but they also influence social costs. It is true that the ultimate victims of that are the costumers because they buy poor-quality items at an expensive price which expose them to health and safety dangers too, but also governments are impacted by losing out on unpaid tax [79].

Costs to the right holder	Costs to countries where counterfeiting takes place	Costs to countries where counterfeits are sold	Social costs
<ul style="list-style-type: none"> - Industries which find themselves in direct competition with counterfeiters suffer a direct loss in sales. -Many counterfeit products today are of higher quality and compete directly with the genuine items - The budget for anti-counterfeiting is rarely well defined within an organization, but spans across several departments such as marketing, human resources, product development and legal departments 	<ul style="list-style-type: none"> - Foreign producers of reputable products become reluctant to manufacture their products in countries where counterfeiting is rife as they cannot rely on the enforcement of their intellectual property rights -Second, if many products from such countries, including genuine ones, gain a reputation of being of poor quality, this will cause export losses which in turn implies both job losses and loss of foreign exchange. - The prevalence of counterfeiters in a market discourages inventiveness in that country since it deters honest producers from investing resources in new products and market development. - Tax losses 	<ul style="list-style-type: none"> - The economic costs of counterfeiting for such "victim" countries include job losses, missed sales opportunities and lost tax revenues. -In the long run counterfeiting discourages investment in product development since a company will not get all the benefit from its investment. - The governments must expend increasing amounts of money in funding police and other investigation and enforcement operations. -The judicial authorities, including the courts and prison service, need to spend additional time and money in sentencing and dealing with counterfeiters 	<ul style="list-style-type: none"> - Many consumers believe they are getting a bargain when they buy counterfeits. - The inferior quality of many counterfeits, particularly those relating to health and safety. -Workers in factories where counterfeits are produced are frequently exploited.

Table 3: Types of lost costs to counterfeiting

Counterfeiting is perceived as a severe issue which is increasing recently. The amount of costs of counterfeiting in world-wide today are estimated to be 5-7 per cent of world trade [7]. There is no substantial aggregated data to support the high percentages, but the figures are now accepted and used to illustrate the extent of the counterfeiting problem.

As mentioned before there are lost costs associated to the job losses due to counterfeiting trade. Indeed, Estimates in US and Europe confirm that nearly 200 000 jobs are lost due to counterfeiting in their countries alone [79].

4- Blockchain technology in the textile supply chain

4-1. Potentials of blockchain in the textile supply chain

A Blockchain refers to a linked list of blocks, where each block contains transactions. Every block in the blockchain contains its own hash value and the one of the previous blocks and hence, each block is connected to its predecessor, which creates a "chain" if we consider all the previous blocks [64]. The blockchain is composed of a public, shared ledger containing details on each transaction made within a peer-to-peer system [55]. It is made up of a linked block, containing time stamped transactions that are encrypted by public-key and validated by the network participants.

Once a transaction is added to the blockchain, it cannot be edited, which make this technology immutable. Once the block is completed, nodes perform consensus algorithm like for example Proof-of-Work operations with mathematical calculations that are difficult to solve but simple to verify. Therefore, the first node that solves the Proof-of-Work problem appended the solution, along with the block of elements, to all other nodes.

A consensus algorithm is a method for all nodes in the network to agree on the current state of the distributed ledger. The main purpose of the consensus algorithm is to ensure that each new block added to the blockchain is the only version of the truth that all nodes in the network agree on. There are several consensus algorithms such as [18]:

- PoW (Proof of Work): Is a mechanism that requires a high computation calculation to solve a mathematical puzzle. Bitcoin and some other cryptocurrency used the PoW to process the transactions in a secure manner without the need for a third party. But one of the cons of PoW is that it requires a huge amount of energy.
- PoS (Proof of Stake): was created to be an alternative to PoW, since this mechanism doesn't require a huge amount of energy rather than PoW. PoS gives a mining power based on the percentage of coins held by a miner.
- PoA (Proof of Authority): Is a mechanism based on permitted blockchain. PoA is a consensus method that gives the ability of validation of transactions or interaction in the network to a limited number of actors. PoA doesn't require a huge amount of energy unlike PoW, but a limited number of validators.

Nodes can simply verify the transactions and solutions, and when 51% of the processing power of the network approve the block, nodes begin storing new transactions to a new block, adding them to all previous blocks [11]. The basic structure of the blockchain technology is shown in this figure 2.

Each participant in the network community owns a private key, and a public key is within all the community reach.

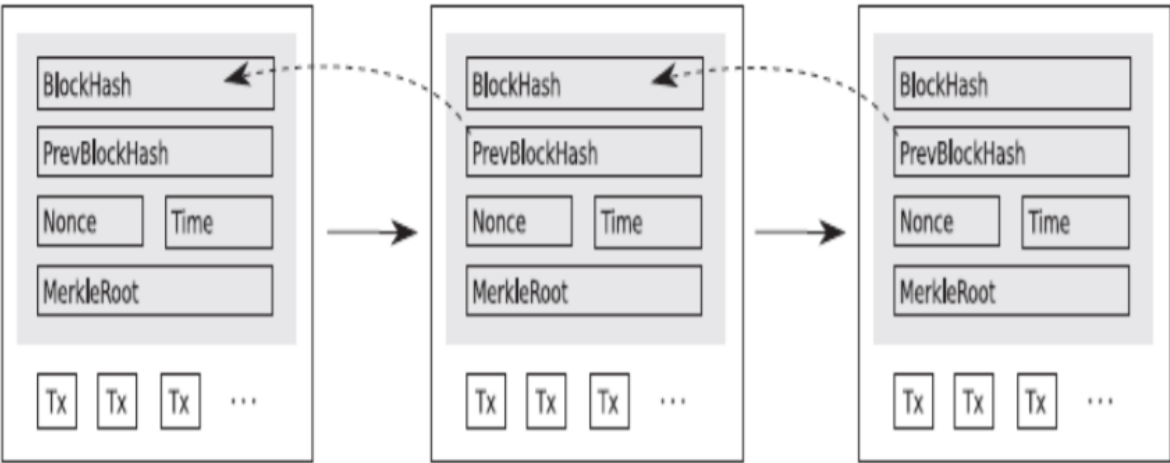


Figure 2. A basic block diagram of Blockchain [76]

Linked to the blockchain technology, the smart contract is defined as a computer program based on transaction protocol that executes the term of a contract by encoding the functional clauses and conditions in the required software. Smart contracts allow executing programs without the intervention

of any third party which make them self-verifying, self-executing, tamper-resistance against any malicious attack which allows the parties to carry out that whenever a given transaction takes place, other transactions also take place. For instance, in the case of a shipment in a supply chain where all data about vendors, consignees, goods and commercial conditions are shared in the supply chain databases. The sale of goods or services can be realized in the form of a transaction, cryptically signed by the seller and the purchaser, and joining a smart contract for sales transactions.

The completion of the fund transfer and the corresponding rights can be implemented when the sale occurs and all other agreed conditions, such as documentation, tax payment or quality checks, are completed; in other words, smart contracts can ensure the smooth execution of collaborative and business processes [81].

To sum up, In the case of Blockchain technology based smart contracts, they are nothing, but scripts appended on the blockchain, which can execute them, it takes any type of data as an input, executes the corresponding code, and triggers the output events. The basic structure of smart contracts is shown in this figure 3.

In terms of technical specification, a smart contract is a kind of code run on the blockchain which is executed mandatorily by the consensus protocol (e.g. PoW, PoS) that necessitates a structured language such as eSourcing Markup Language (eSML) to make the specification of possible interactions and contracts and to ensure that the agreements made are respected [81]. A smart contract can comprise a group of functions and rules written in dedicated programming language as solidity to handle the exchange of resources when certain events take place in a peer-to-peer network.

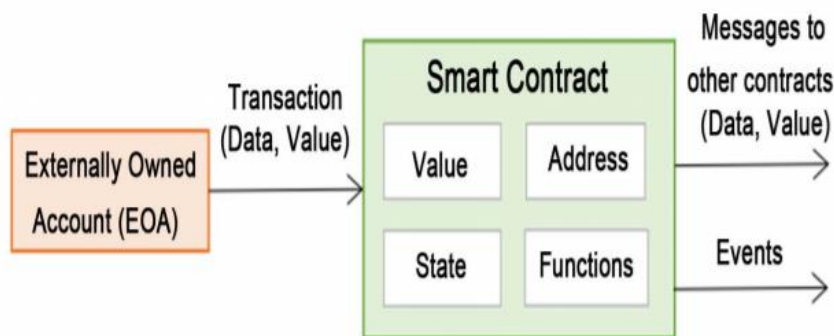


Figure 3. A basic structure of smart contract [77]

As mentioned earlier, blockchain offers several advantages when applied in the industry, including reliability [56], transparency [57], traceability [58], information sharing [59], and monitoring [59]. These advantages can also facilitate solving the issues in textile supply chain, as shown in Fig. 3. The textile supply chain is very complicated. This complexity often causes multiple problems as presented in the table 2. Furthermore, the close connection between the operations of suppliers, manufacturers, and retailers in a higher demand for real-time information sharing and information traceability. Blockchain technology can satisfy these demands to enhance the management of this complex supply chain. In this study, we build a framework to further explain how to realize real-time information sharing and traceability in a textile supply chain.

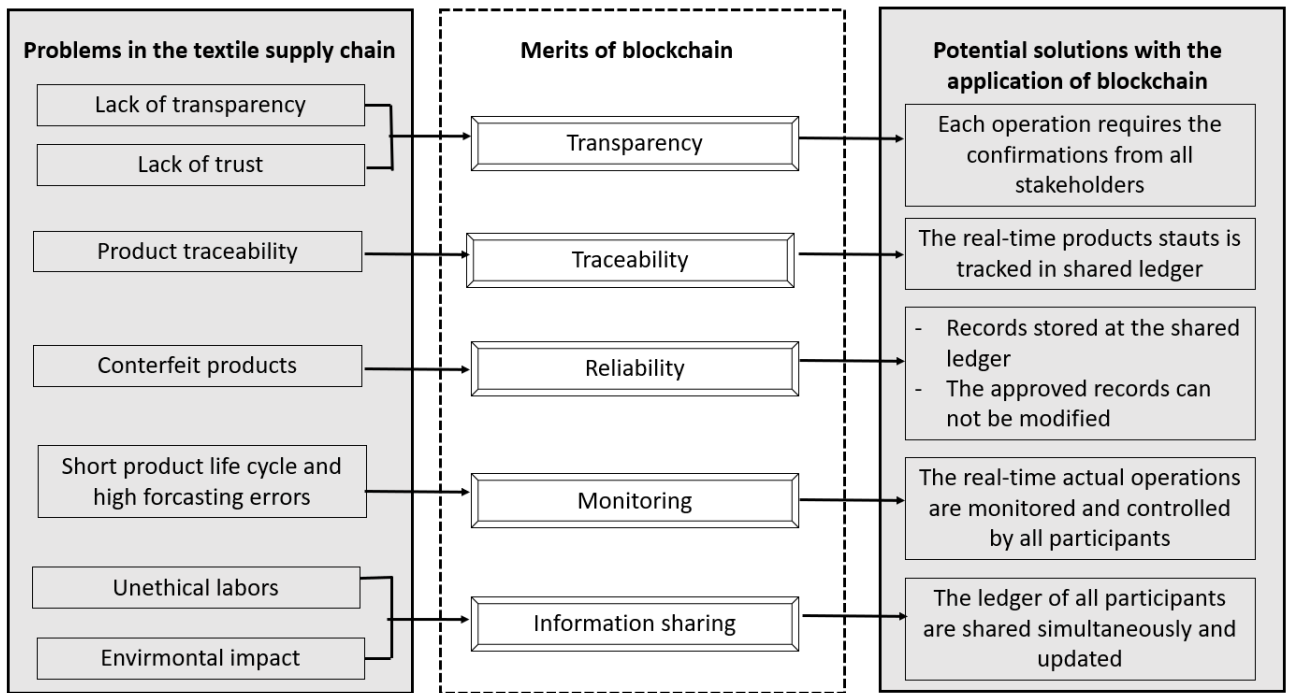


Figure 4: Selected merits of the application of blockchain technology in a textile supply

With the integration of blockchain technology all the phases of the supply chain could be recorded in a blockchain network. Every new transaction performed in the network is stored in an immutable block, and time-stamped to keep track of the specific product in the end-to-end chain [60] and assures that the details present in the block are not tampered [61,63]. All the entities of the network can log in to the network, and verify the authenticity, and history of any textile product. The general diagram of textile supply chain with blockchain is shown in Fig. 4.

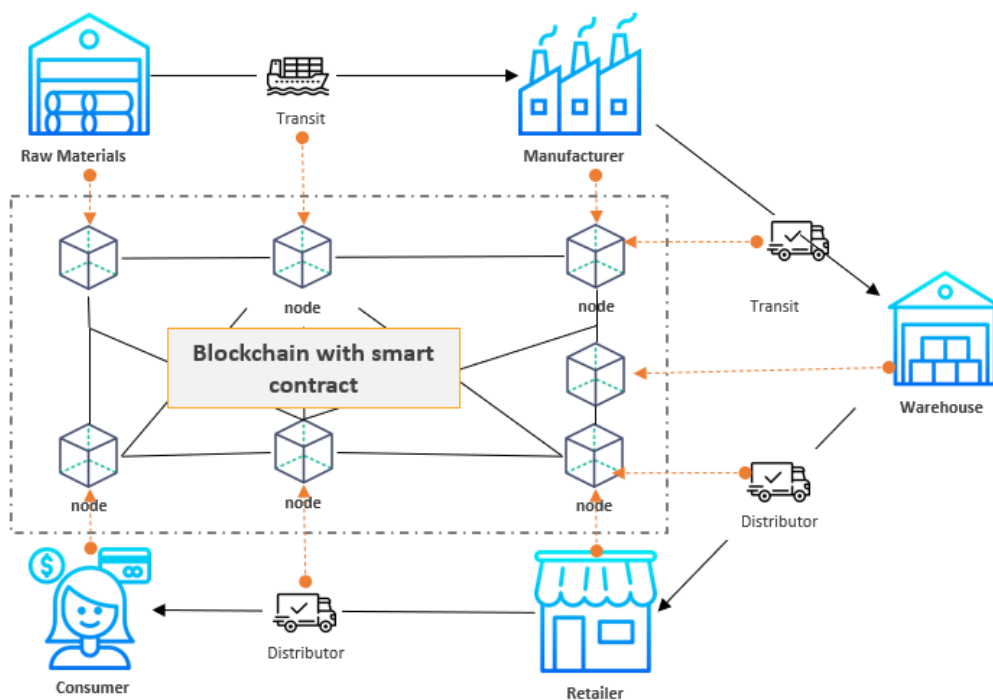


Fig. 5. Overview of textile supply chain management system with blockchain.

Fig. 5. illustrates that how the different entities of the TSCM system could interact and cooperate under the blockchain network. Each participating entity submits its transaction on the blockchain network. In the initial step, different suppliers deliver the raw materials to the manufacturer and submit their transactions on the blockchain network.

This transaction could include the raw material name, quantity, and quality of material and the location of the supplier. Once the manufacturer gets the raw materials, smart contracts are automatically executed, and suitable action (e.g. money is directly transferred from manufacturer to supplier) is executed. Every participating entity can verify the submitted transaction on the blockchain network whether the transaction is legitimate or not. Similarly, on the next stage manufacturer has an interaction with the network, and so on. Deployment of Blockchain network along with smart contracts or similar technologies would greatly help to keep proper track of the items, and triggers the payment process automatically, when necessary.

Smart contracts are simple programs, which specify the conditions for validation of a particular transaction [60,64], they represent specific rules and regulations that every participating entity must follow [63]. Moreover, as blockchain is immutable however, errors, human mistakes and wrong entries are unavoidable. The compromise to deal with that is s not related to the concept of working of the blockchain technology, but data should be designed it in such a way to be overwritten like in the case of accounting systems, in such systems if you need to correct an accounting error, you make an entry that removes the previous one (by subtracting the wrong value in some cases) and add the right value.

4.2. Scalability issues of blockchain technology and the integration of Bigdata as a solution:

Data decentralization, transparency, security, immutability, and privacy are the key driving principles of blockchain Technology.

However along with its different advantages. Users, investors, startups, and researchers involved in this technology are perceiving scalability as a serious issue [70]. Especially when you are dealing with a very heavy industry in terms of information and transaction such as the textile industry. With transaction data piling up, the current blockchain systems may bug.

In fact, with every operation, the blockchain adds one more block to its chain of operations, and every block increase with data as it carries the history of the blocks before it [64]. As more users join the network, the transaction histories of individual coins grow and consequently, the system risks to buckle [70].

Scalability can be categorized as throughput, cost and capacity and networking as follows [70] :

Cost and capacity: A large quantity of data is required to store in the Blockchain from recent block transaction to the genesis block. each node in the blockchain have limited storage capacity and resources.

Networking: Whenever any transaction is carried out, it is first broadcast to all nodes. when a block is mined it is again transmitted to all nodes which consume slot of network resources and it increases the propagation delay. So, there is a need to design more efficient data transmission mechanism.

Different applications are developed using the Blockchain, but the scalability is the major limitation.

Due to the growing number of transactions following things are observed [70]:

- 1) The average confirmation time for a transaction is increased.
- 2) Fee for the network transaction is increased
- 3) Difficulty to mine the block is also increased and hence computation power and resources is also increased.

Throughput: Blockchain storage requires a powerful database, and the traditional blockchain as a distributed database needs more scalability, as the throughput, latency is high, and low capacity.

Based on a modern distributed database “MongoDB”, the Bigchaindb adds blockchain characteristics. Hence BigchainDB is designed to merge the best of modern databases: linear scaling in throughput and capacity with the number of nodes, a fullfeatured NoSQL query language, efficient querying,

permissioning and also blockchain characteristics including decentralised control, immutability, and the creation and movement of digital assets.

As compared to traditional databases, a modern distributed database provides more throughput, High storage capacity, and low latency that is a fraction of a second, with no effect on throughput and latency when increasing the number of nodes. Table 4 summarizes the important performance metrics and presents the performance comparison between a traditional Blockchain, Traditional Distributed database, and the BigchainDB.

	Traditional Blockchain	Traditional Distributed DB	BigchainDB
High Throughput; increases with nodes↑	-	✓	✓
Low Latency	-	✓	✓
High Capacity; increases with nodes↑	-	✓	✓
Rich querying	-	✓	✓
Rich permissioning	-	✓	✓
Decentralized control	✓	-	✓
Immutability	✓	-	✓
Creation & movement of digital assets	✓	-	✓
Event chain structure	Merkle Tree	-	Hash Chain

Table 4: BigchainDB compared to traditional blockchains, and traditional distributed DBs [65]

As the number of transactions grow the system become slower, expensive, and unsustainable. Hence the scalability in blockchain become the focus area for researchers and academicians.

In the proposed research work, we have developed a framework called BigchainDB which integrates blockchain technology and bigdata technologies.

It has blockchain properties (e.g. decentralization, immutability, ...) and database properties (e.g. high transaction rate, low latency, indexing & querying of structured data) which supports scalability.

5- Blockchain-based Big data framework for textile supply chain (Bigchaindb-TSC):

5-1. Bigchaindb-TSC Principle:

The Bigchaindb-TSC model proposed in this study is shown in Fig. 4. It is composed by blockchain technology and MongoDB as big data system.

The different components composing the Bigchaindb-TSC are:

- **BigchainDB node:** which refers to a server or any device running the same software (bigchaindb in our case) and is connected to other nodes.
- **MongoDB:** which presents a document-oriented database engine, used to store asset, transactions and other information. Bigchaindb uses mongodb to ensure scalability and improves data types can be stored on the blockchain.

- **BigchainDB Server:** it is the main software piece which provides blockchain features and ensures orchestration with mongodb.

Tendermint: Is one of the most powerful software (open source) to ensure blockchain consensus, Tendermint is a software designed to ensure the distribution in the network. Tendermint can work even if up to 1/3 of the machines fail in an arbitrary way [82]. Tendermint is generally like two kinds of software. First consider it as a distributed key-value store, which uses a non-BFT (Byzantine fault tolerance) consensus algorithm. The second is known as Blockchain technology and consists of both cryptocurrencies like Bitcoin, and alternative distributed ledger such as Hyperledger [82].

Tendermint is a low-level protocol comprised two main pieces:

- A blockchain consensus engine and a generic application interface. The consensus engine, also known as tendermint core, ensures the distribution of the same transaction in all nodes.
- The application interface which represents the Application Blockchain Interface (ABCI), This allows any programming language to be used to process transactions, unlike other blockchain platforms or consensus solutions. Tendermint is designed to be easy to use, simple to understand, high performing and useful for a wide variety of distributed applications

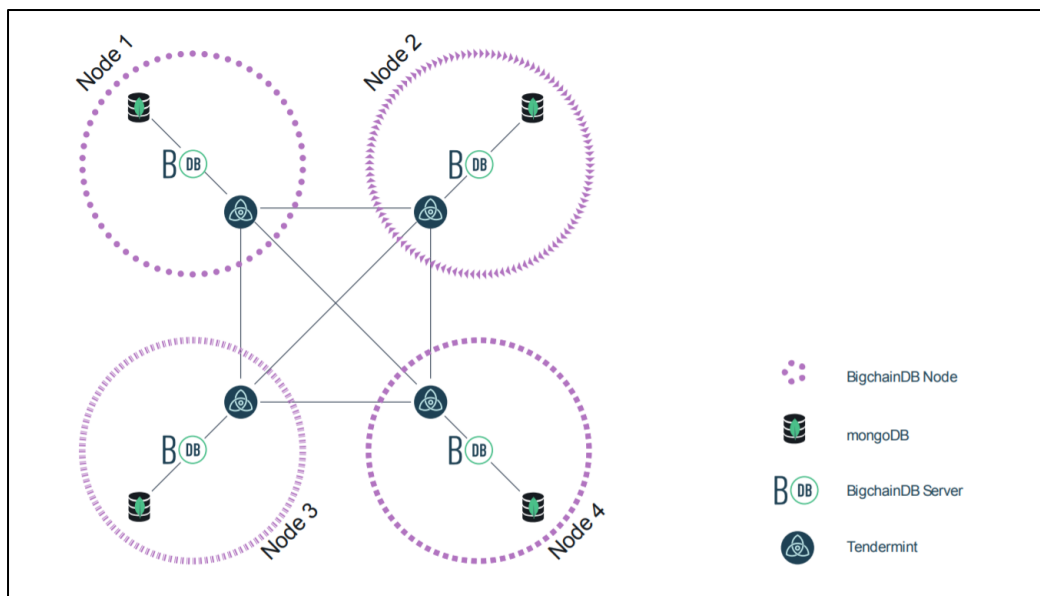


Figure 6: Deep view Inside bigchaindb [65]

In the following part, we present the architecture of our proposed model. Hence, as shown in figure 7 and as it is the case in the most of companies, enabling traceability in the supply chain requires the integration of Bigchaindb technology with many other technologies.

Therefore, we proposed a layer-based architectural model; each layer is structured by one or more components that include specific tasks such as customer interaction, application logic handling, transaction persistence, file persistence, and authentication management application. In Figure 7 we depict the architecture of the proposed model.

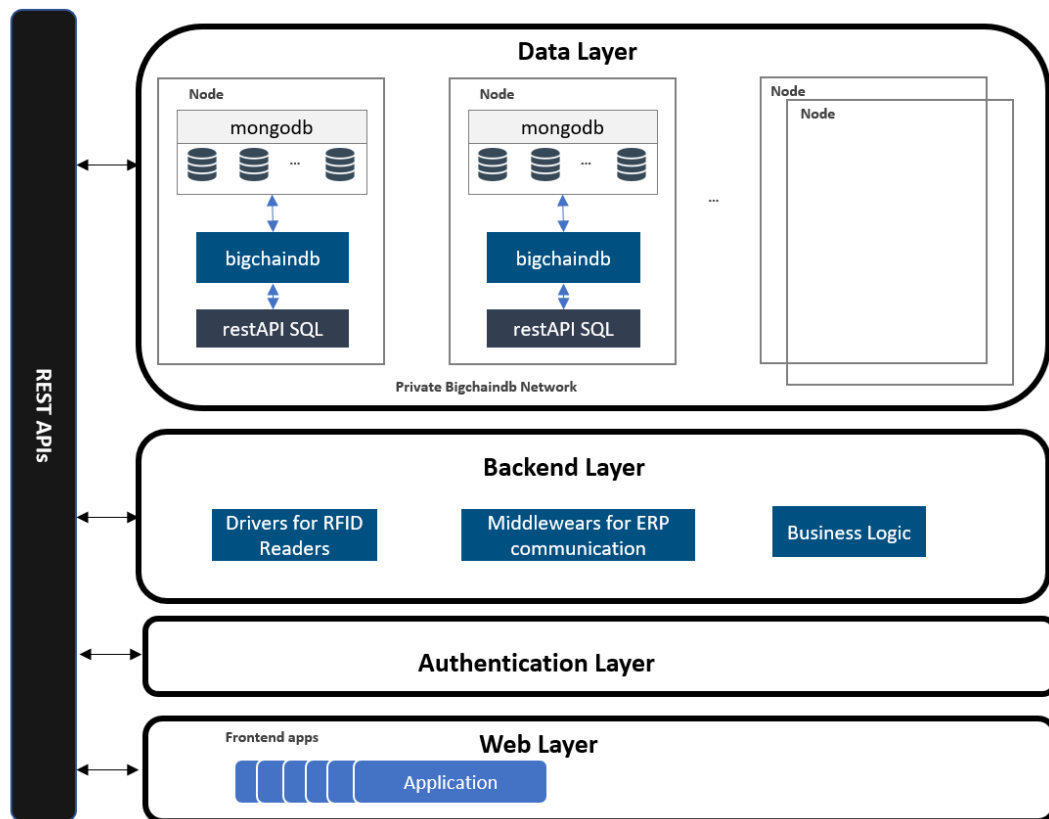


Figure 7: High level architecture Bigchaindb Decentralized application

Web layer: This layer refers to the platform that interact with the consumer, based on RESTful services this layer will interact with the intermediate layer which handles the business logic for storage

Backend layer: The layer will contain the logic of communicating with other information systems and applications like for example reading RFID tags, middleware for ERPs, ...

Storage layer - Database: This layer contains two databases. The first one is a NoSQL database that enable us to record the transactions stored in Blockchain, though the BigchainDB, the second is a SQL relational database that will consist of basic details for the transaction of the events

Authentication layer: This layer will enable the authentication system to secure the access to the platform through the Web layer.

Retailers first order the final products from the trading brands at the beginning, and the production of textile products (TPs) is scheduled according to their due time. Next, manufacturers need to contact suppliers and transporters to schedule transportation when the produced products achieve delivery strength. The final products are subsequently transported to retailers once a consensus is reached among the participants. The proposed framework could represent information on all operations in the textile supply chain, including raw materials information, final products information, production information, delivery information and check-in information.

The Bigchaindb-TSC framework, real time statuses and operation information are shared and accessible to all participants, and data are recorded and verified as happened. Once data are recorded, it cannot be changed which ensures traceability, and each entity can monitor whether the operation has been conducted according to the requirements set forth in the contracts.

Suppliers, Manufacturers, Trading brands, and Customers are connecting to various Nodes in the network, each node connected to the others through Tendermint to ensure security. In a private Blockchain there is no chance to access the details of any transaction, the access is available only for participants in a transaction who will have knowledge about it.[30].

The main element in the Bigchaindb-TSC is the asset, which can represent a physical or a digital item. The asset can be registered in the Bigchaindb-TSC by supply chain actors in two ways, during the creation of the transaction or during the transfer of the transaction. The flowchart in figure 6 represents how the supply chain actor user can interact with the Bigchaindb to create an asset.

The supply chain actor can create a new transaction which needs an asset. The asset could be already created in the bigchaindb but if not, the supply chain actor should create it.

In this case, the supply chain actor can do a “create” transaction in the system which allows him to create a new asset and self-attribute it to become the owner of this asset.

After that the user should define the transaction conditions to implement the processes (e.g the asset cannot be transferred if the contract is not signed by at least three users).

Transaction condition must be checked to change assets owner or any other operation in the asset, if not the transaction will be stored in a staging until all conditions are met. Whenever a new event is triggered, it will be stored in the temporary memory for review.

A Time to live (TTL) variable is defined to determine the time that the transaction stored in the Bigchaindb system will be released and cannot be updated anymore, a new transaction should be created if we want to complete the released one but the new transaction one will be independent from the released one, hence there will be no technical relationship between the two transactions.

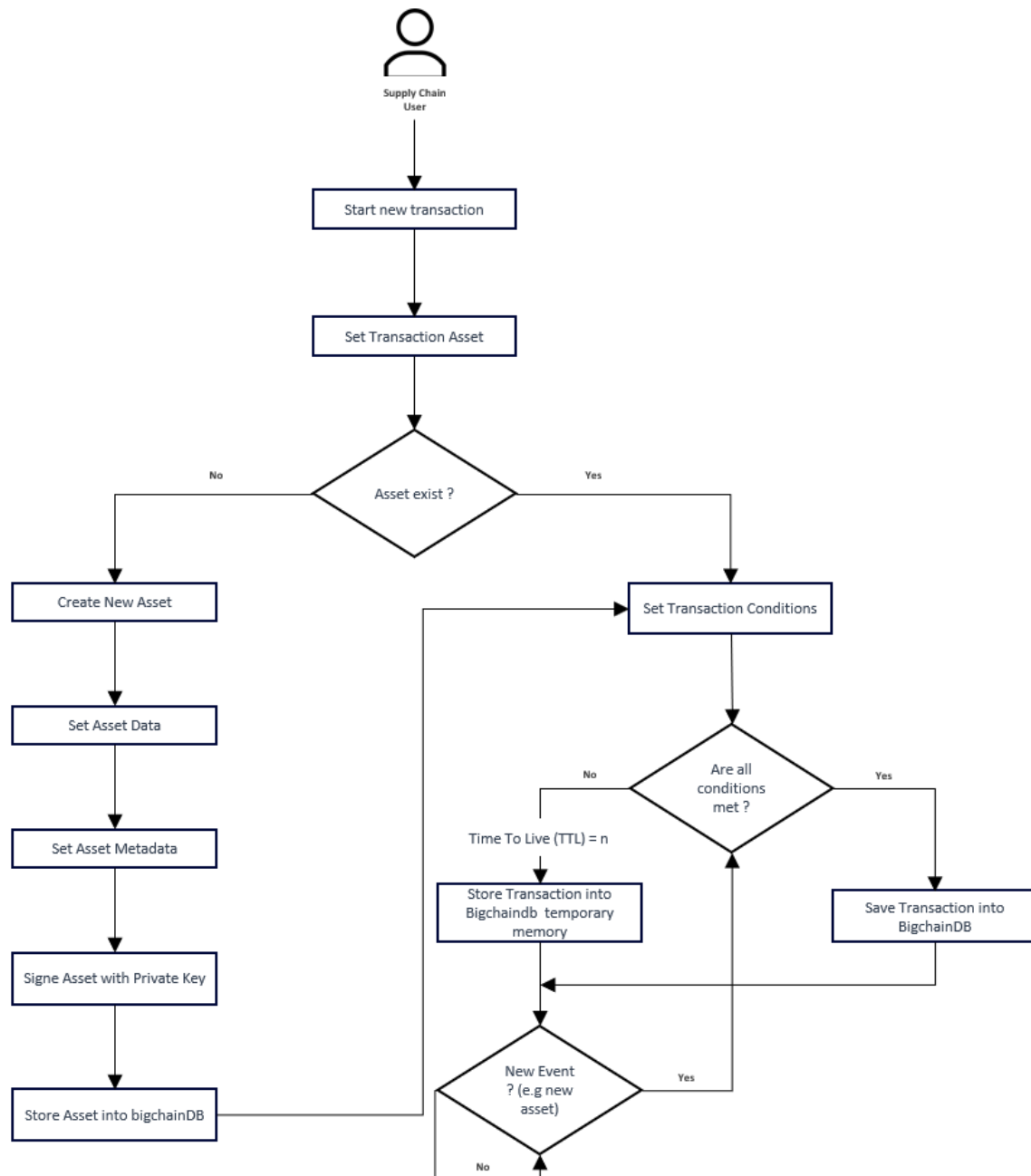


Fig. 7. Flow chart model of asset creation by a supply chain actor in the proposed model

5.2. Application of the proposed Bigchaindb-TSC:

The following example is an illustration of a digital asset used in the Bigchaindb-TSC, here a supplier adds a new asset. Once the asset is created in the BigchainDB system it cannot be modified or deleted anymore. However, there is a powerful feature of Bigchaindb-TSC which is the capacity to add metadata information about the asset. The metadata information enables the user to define key performance indicators (KPI) or to monitor any data that varies over time. This could be very helpful in the case of setting dynamic data. In this example we use the supplier's entity and its interaction with manufacturer entity. The supplier creates multiple assets to represent fabrics and needs to inform

manufacturer if the fabric (represented by the asset) is available or not, in our case we add a metadata called `stock_status` (available in the stock, available but limited quantity, not available).

For our specific case we need some data defined bellow, First, we defined some metadata that can be used in the process of traceability of a product, this data definition is not static and if need it, can be added more fields. This data can change in every transaction, for example, the status id changes in every step of the product chain because identifies the action that has been taken for the product itself.

Metadata :

```
{  
  
  "Location": "",  
  "Order_ID": "",  
  "Product_Description": "",  
  "Status_ID": "",  
  "Transaction_Date": "",  
  "Status_Description": "",  
  "Transport_Number": "",  
  
}
```

Asset :

```
{  
  
  "Product_ID": "",  
  "Product_name": "",  
  "Creation_Date": "",  
  "RFID_Tag_ID": "",  
  "Product_Type": "",  
  
}
```

As shown in fig.8 the proposed solution is applied on a simplified flow of procurement to pay process, indeed, the proposed model allows suppliers to create multiple assets. For this example, the supplier creates a digital asset representing the fabric with all required information.

The manufacturer user can query data stored in the Bigchaindb like any other database, he will receive the list of available fabrics created by all network suppliers (Figure 11).

If the manufacturer user decides to buy fabrics for the next production, based on the search query result, he can select a fabric digital asset and create a new transaction including the chosen asset (Figure 12).

Then the user defines the conditions for the transaction to be valid.

The transactions are stored in the Bigchaindb and wait for conditions to be verified to change status from a temporary transaction to a valid transaction (which mean recorded into the blockchain).

When all the conditions are met, the condition become valid and the supplier undertakes to deliver the fabrics to the manufacturer as mentioned in the order.

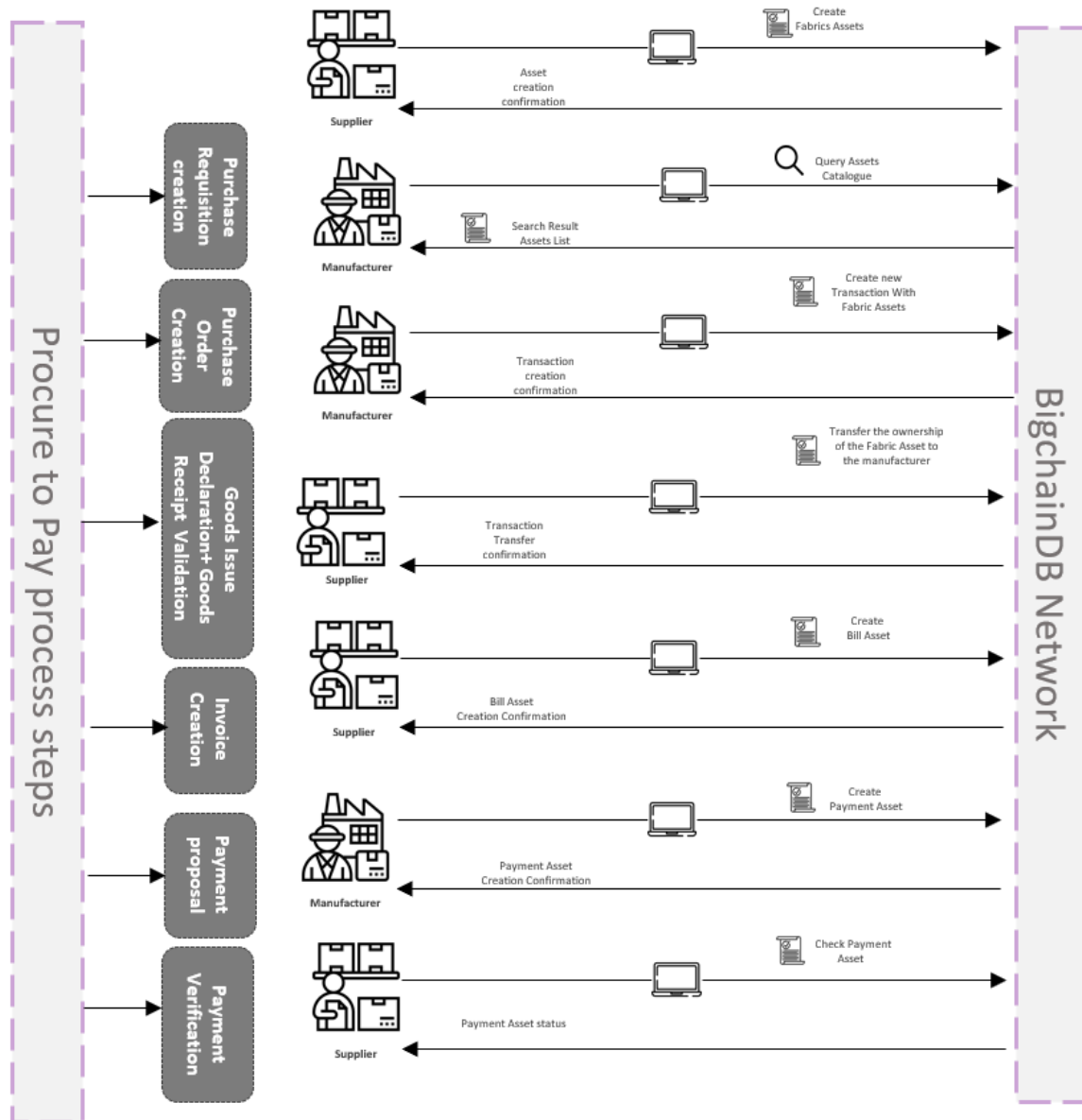


Figure 8: Transaction flow of the Bigchaindb-TSC model

Bigchaindb provides two types of operations to execute a transaction which are create and transfer, the first one is to create a new asset in the network (as presented in Figure 10), and the second is to transfer the ownership to the other address (Figure 11). The example blow demonstrates a transaction of creation a new asset.

Figure 9 shows how a transaction of creation could be defined in the Bigchaindb system while Figure 11 represents an application of that definition in the creation of an asset and metadata in the network. However, Figure 10 represents the payload that we sent to the server node to create a new asset and metadata in the network. This payload plays the role of a set of inputs of the Restful API used in the simulation of the proposed model. Figure 12 shows how a user “Customer” can interact with the BigchainDB platform to search an asset by its name. Figure 13 shows how the transferring of the ownership of the asset from the supplier to the manufacturer is done in the BigchainDB Platform. Figure 14: Example of creating an invoice in the Bigchaindb Platform. Figure 14 shows the transaction of creating the invoice in the Bigchaindb Platform. Figure 15: Example of sending the payment from the manufacturer to the Vendor. The Figure 16 shows that there is a way to verify is the payment is done or not as we get a message showing the status of the payment

The input of the transaction depends on the type of transaction if its CREATE then should have exactly one input. A TRANSFER transaction should have at least one input. The owner represents the Creator of the transaction. When it comes to the output, it specifies the crypto conditions that must be met in the order for that output to be spend/transfer. It also shows how many shares of the asset are linked to that output. The amount represents the Number of shares of the asset, The Fulfillment URI fulfilling the condition of the output being spent, the public key represents the id of user that CREATE/TRANSFER this transaction. In figure 16 we have created an endpoint to check if this transaction already exists, and depending on the existence of this transaction, we could check if the amount sent is equal to the price of the asset, because of this process the message appears on the screen.

```

"asset": {
  "data": {
    "creationDate": "2021-08-08 09:14:33",
    "idProduct": "28e41796-f215-11eb-9a03-0242ac130003",
    "idRfidTag": "638596aa-27d6-4861-83c7-5842cce05d16",
    "productName": "Cotton high quality",
    "productType": "Cotton"
  }
},
"id": "f523f9cddf34200e641d5a1f5aa07ea86dd9b519c412856f6c04cad6ed0e313",
"inputs": [
  {
    "fulfillment": "pGSAIFui_4iaf7cBSJaTXMdSkHC7EyswYAuF655m_Uzq5t5ogUDXGG7yTNo9FMdr19LS01bVZF87FbrT-zT-jPmUK0B1d91AH5MRyu9_NvuxkrJVn3H_vv7BimAvdZwq8Twb6yIG",
    "fulfills": null,
    "owners_before": [
      "7A1FuFV54qS3UfEgZ5k8pLdGa8BnbdFFKPSeqVTZfbsv"
    ]
  }
],
"metadata": {
  "location": null,
  "productDescription": "High quality from California",
  "productExpirationDate": "2022-01-07",
  "productTemperature": null
},
"operation": "CREATE",
"outputs": [
  {
    "amount": "1",
    "condition": {
      "details": {
        "public_key": "7A1FuFV54qS3UfEgZ5k8pLdGa8BnbdFFKPSeqVTZfbsv",
        "type": "ed25519-sha-256"
      },
      "uri": "ni:///sha-256;txPsw60939BVz8YddWTx12gYoIMCN2MbNbrOGF8_eHc?ftp=ed25519-sha-256&cost=131072"
    },
    "public_keys": [
      "7A1FuFV54qS3UfEgZ5k8pLdGa8BnbdFFKPSeqVTZfbsv"
    ]
  }
],
"version": "2.0"

```

Figure 9: Example of a transaction identified by a token and containing an asset and metadata.
Source: code own made.

Depending on the architecture that we proposed to communicate with the Bigchaindb network via Restful API, we ran several tests of our Restful API to verify interaction with the bigchaindb network. The examples below show the payload we used and the transaction we got.

```

1  [
2  -- "asset":
3  -----{
4  -----"data":-{
5  -----"idProduct": "28e41796-f215-11eb-9a83-0242ac130883",
6  -----"idRfidTag": "638596aa-27d6-4861-83c7-5842cce05d16",
7  -----"productName": "Cotton high quality",
8  -----"productType": "Cotton",
9  -----"creationDate": "2021-08-08 09:14:33"
10 -----}
11 -----},
12
13 -----"metadata":{
14 -----"location": null,
15 -----"productExpirationDate": "2022-01-07",
16 -----"productDescription": "High quality from California",
17 -----"productTemperature": null
18 -----},
19 -----
20 -----"private_key": "8u5fVRVd2KKCJ9EgN3jt0LKUUzawud9tTP8Zg5kF6htY",
21 -----"public_key": "7A1FuFV54qS3UfEgZ5kBpLdGa88nbdFFKPSegVTZfbsV"
22
23 ]

```

Figure 10: Example of payload that we sent to the server node to create a new asset and metadata in the network.
Source: code own made

```

9  }
10 }
11 "id": "f023f9cddfd34209e641d5a1f8aa07ea86dd9b519c412856f6c04cad6ed8e313",
12 "inputs": [
13   {
14     "fulfillment": "p6SAIFui_4iaf7CBSJaTXMcSkHC7EyswYAUf6S5m_Uzq5t5ogUDXGG7yTNo9FMdz19LS01bVZF87FbzT-zT-jPmUK081d91AH5MRyu9_MyuxkzJvN3H_vv78imAvd2wq8Twb6yIG",
15     "fulfills": null,
16     "owners_before": [
17       "7A1FuFV54qS3UfEgZ5kBpLdGa88nbdFFKPSegVTZfbsV"
18     ]
19   }
20 ],
21 "metadata": {
22   "location": null,
23   "productDescription": "High quality from California",
24   "productExpirationDate": "2022-01-07",
25   "productTemperature": null
26 },
27 "operation": "CREATE",
28 "outputs": [
29   {
30     "amount": "1",
31     "condition": {
32       "details": {
33         "public_key": "7A1FuFV54qS3UfEgZ5kBpLdGa88nbdFFKPSegVTZfbsV",
34         "type": "ed25519-sha-256"
35       },
36       "uri": "ni:///sha-256;txPaW60939BVz8YddwTx12gYoIwCN2Mbnx06F8_eHo?fmt=ed25519-sha-256&cost=131072"
37     },
38     "public_keys": [
39       "7A1FuFV54qS3UfEgZ5kBpLdGa88nbdFFKPSegVTZfbsV"
40     ]
41   }
42 ],
43 "version": "2.0"
44 ]

```

Figure 11: Example of a response of creating an asset and metadata as shown in the Figure 1. Source: code own made

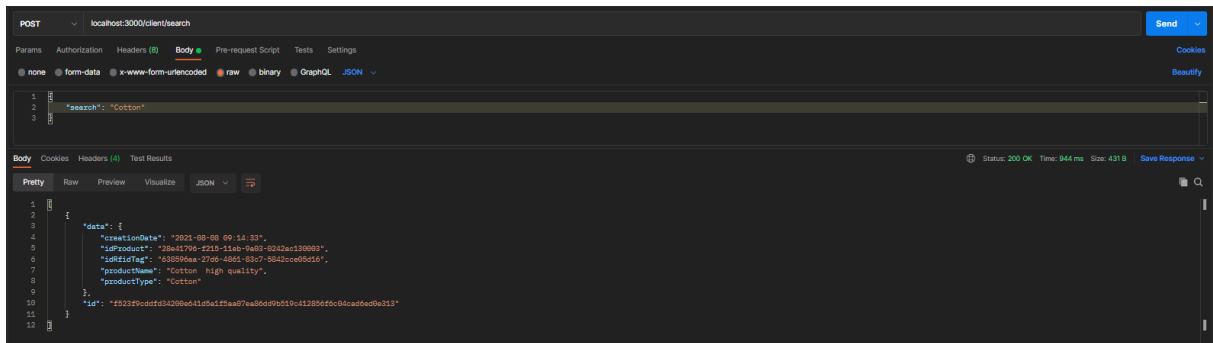


Figure 12: Example of looking for an asset by its name in the BigChainDB Platform. Source: code own made

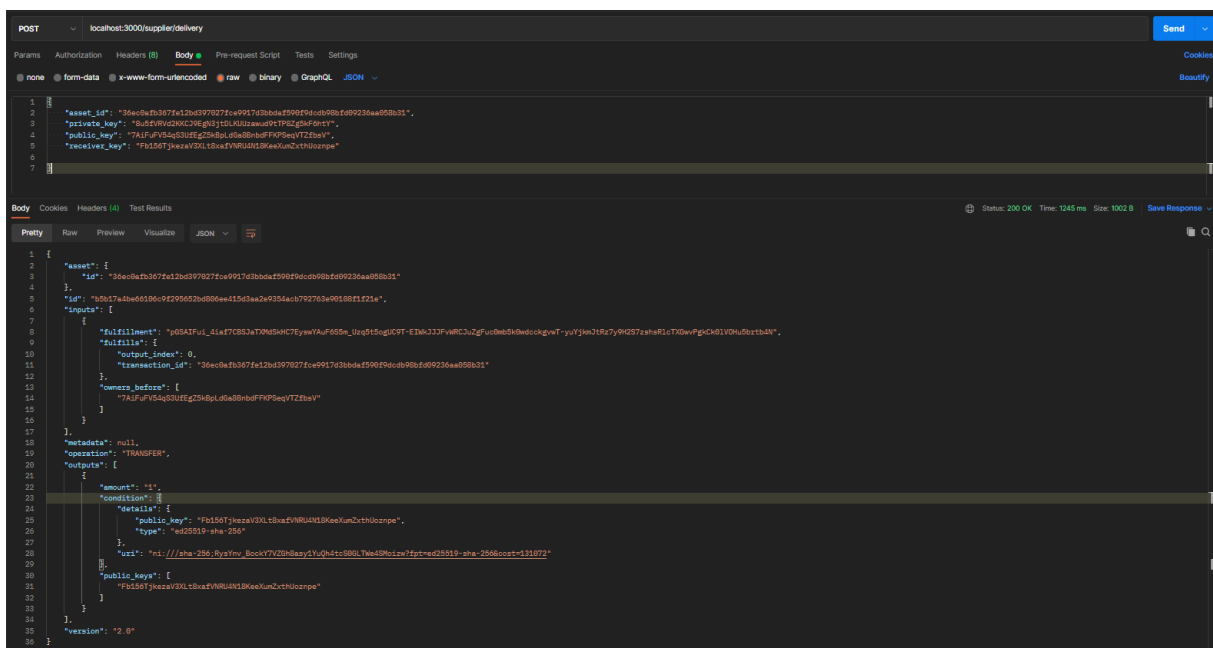


Figure 13: Example of transferring the ownership of an asset from the supplier to the manufacturer in the BigchainDB Platform. Source: code own made

```

POST localhost:3000/supplier/bill

{"asset": {"data": {"amount": "300"}, "assets": [{"id": "6fb31e6df51d9664467aaa228fd9585a0c7861c966c168f5579ba13ef07fe8"}]}, "id": "1e98929b36c44661e6b217992b49248382f2b356b745692e6219d9b6687a88", "inputs": {"fulfillment": "p6BAIFuJ_dix7C83J7Xh6SKIC7EysaYAf658m_Uzc8t5ogIABQ3k2o4z23qg0l_Vp6002VQuJhVBU-UuyA3jzEFB2WHSH6k01Vncz27VM4L_bwckezYbKCEBQe3gUeQH", "fulfill": null, "owarr_before": [{"public_key": "7A1FUFV8IqS3UEg2k8pLd6a8BnbFFKPSeqVTZfsv", "type": "ed25519-sha-256"}]}}, "metadata": {"currency": "dollar"}, "operation": "CREATE", "outputs": [{"amount": "1", "condition": {"detail": {"public_key": "7A1FUFV8IqS3UEg2k8pLd6a8BnbFFKPSeqVTZfsv", "type": "ed25519-sha-256"}, "url": "ni:///sha-256:tp34600938VzYoddyT12GfC1KCh26hbz0F8_anc7fpt=ed25519-sha-256:cost+131872"}, "public_key": "7A1FUFV8IqS3UEg2k8pLd6a8BnbFFKPSeqVTZfsv"}]}}, {"version": "2.0"}

```

Figure 14: Example of creating an invoice in the Bigchaindb Platform. Source: code own made

```

POST localhost:3000/client/payment

{"bill_id": "1e98929b36c44661e6b217992b49248382f2b356b745692e6219d9b6687a88", "amount": "300", "private_key": "8AapipQ089z0820xkVPacZYXLIe08vXTRkubvY", "public_key": "8RnaQw6GH0yKSwB3uAETHYevgn3agLc0Dz2uRXEH"}, {"asset": {"data": {"amount": "300", "bill_id": "1e98929b36c44661e6b217992b49248382f2b356b745692e6219d9b6687a88"}}, "id": "79f1d7b3032a338789edf39ed219db348d70ed1d0171b45646e22873e6e439", "inputs": {"fulfillment": "p6BAIDbnL_u4fD3F_630tr_K2zqRP_ID0jyyvQ40qzCZngUWP-LCLTVoC-ON_LvpACTB13ZDFfD6vLufnS6SECELCBEP14hPBoJfa0g401WVpMkch4DnjgIDW6d", "fulfill": null, "owarr_before": [{"public_key": "8RnaQw6GH0yKSwB3uAETHYevgn3agLc0Dz2uRXEH"}]}}, {"metadata": {"currency": "dollar"}, "operation": "CREATE", "outputs": [{"amount": "1", "condition": {"detail": {"public_key": "8RnaQw6GH0yKSwB3uAETHYevgn3agLc0Dz2uRXEH", "type": "ed25519-sha-256"}, "url": "ni:///sha-256:p195bnmE6k1TYL6c3PEpkczWtL5EA_w8Wzetz1U7fpt=ed25519-sha-256:cost+131872"}, "public_key": "8RnaQw6GH0yKSwB3uAETHYevgn3agLc0Dz2uRXEH"}]}}, {"version": "2.0"}

```

Figure 15: Example of sending the payment from the manufacturer to the Vendor. Source: code own made

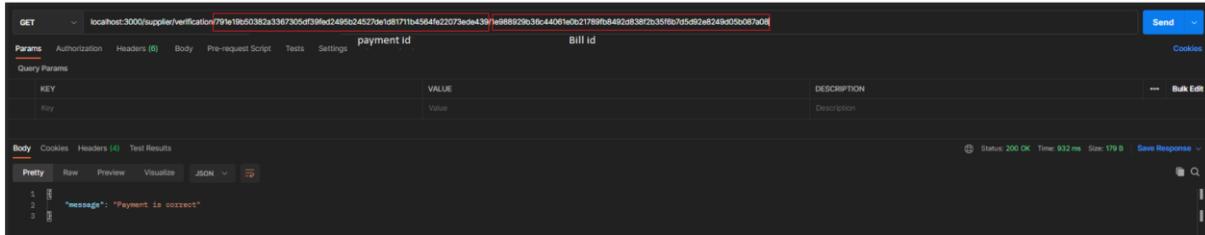


Figure 16: Verification of the status of the payment. Source: code own made

5.3. The Performance Test:

To demonstrate the performance of the proposed model, we used a scenario based on a random number of threads that present the actors in the process. Next, we conducted a performance test to determine the number of transactions that the platform could handle per second.

The node we used for testing is a Linux machine, the operating system is Ubuntu 20.04 LTS. The machine has 4 cores in CPU 8 logical processors, and 8Go of RAM, as well as we included the solid disk to increase the writing and reading operations.

We used Python 3.8 programming language to create the application, and simulation with multithreading, and our Restful API created with micro-framework Flask, we also utilized the plotly library to create our visualizations, to test our Restful API we used Postman tool, also we used bigchaindb_driver library v0.6.2 to connect with bigchaindb network.

We launched logistics actors of the procurement to pay process as a thread to simulate interaction with Bigchaindb Network as a real time application.

The following figure shows the evolution of the number of transactions per second generated by the actors.

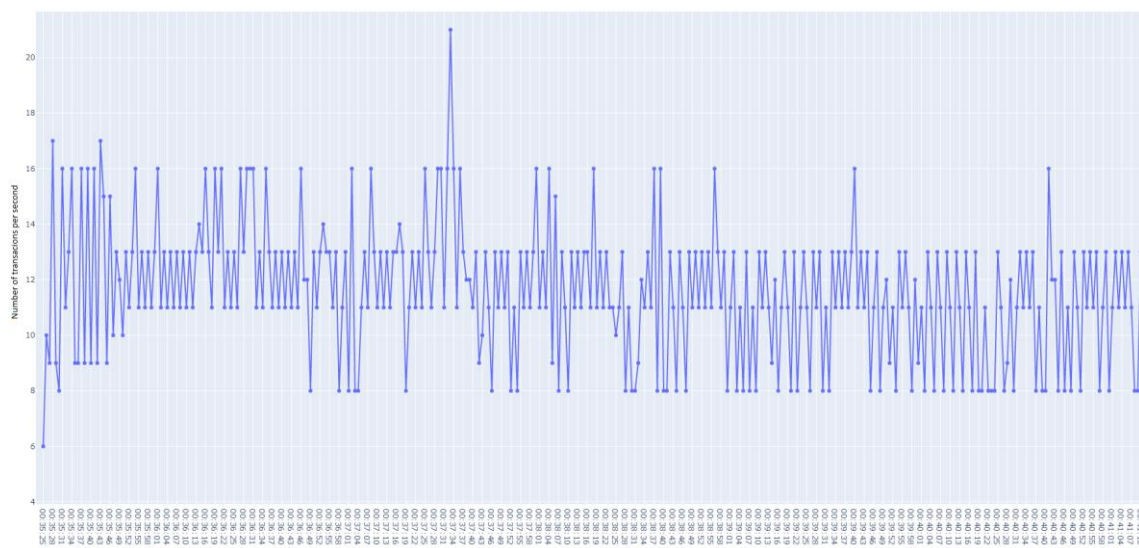


Figure 17: Transactions per second during the elapsed test time.

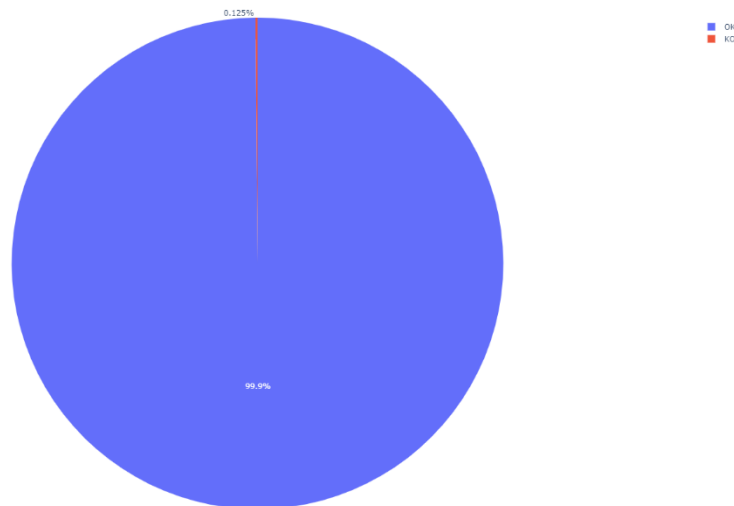


Figure 18: Pie graph with percentage of transaction correct and incorrect.

In our simulation we used a multithreading to represent the actors of the network (in our case the supplier and the manufacturer), each actor creates several transactions simultaneously, in our studies, we collect these transactions to outline the performance of Bigchaindb in the TSC, and this is by calculating the number of transactions that we could handle per second. In the following scenario we created 25,600 transactions in total, 25,568 transactions were successfully created in the network and only 32 of them failed.

Hence, BigchainDB API has an average throughput of 10.65 transactions per second (T/s).

Since blockchain technology based on a multiple node's server decentralized, we could avoid data alteration during the logistic processes, this is achieved by maintaining each operation as a transaction that is distributed on the decentralized network.

The biggest advantage about Bigchaindb is that it is more scalable than other blockchain platforms while creating transactions. However, there are some challenges and weaknesses of this technology, especially for creating multi-node servers, we had some difficulties in this case.

Algorithm of the presented model:

Algorithm for the Bigchaindb-TSC model

Input: Operations such as ManufacturerOrder,
 SupplierOrder,
 RetailerOrder,
 Delivery,
 NoAction,

Output: Information Messages, such as Ownership

of Asset, Error and Abort, No Action required

```
if (Operation == SupplierOrder) then
    If RawMaterials.Metadata.StockStatus is available then
        if Conditions are met then
            Start(Operation) = Delivery
            Message(Start delivery operation)
        else
            Message(Waiting for conditions to be met)
        end if
    else
        Message(Raw Materials is not available,
            Transaction cannot be done)
    end if
end if
if (Operation == Delivery) then
    if (Track.Metadata.Available == "Available") then
        if (Delivery_Date < Expiry_Date) then
            if Conditions are met then
                Message(Items are delivered in time)
            else
                Message(Waiting for conditions to be met)
            end if
        else
            Message(Items is not delivered)
        end if
    else
        Message(No track is available)
    end if
end if
If (Operation == ManufacturerOrder) then
    if Fabric.Metadata.StockStatus is available then
        if Conditions are met then
            Start(Operation) = Delivery
            Message(Start delivery operation)
        else
            Message(Waiting for conditions to be met)
        end if
    else
        Message(Fabric is not available, Transaction cannot be done)
    end if
end if
If (Operation == RetailerOrder) then
    if Product.Metadata.StockStatus is available then
        if Conditions are met then
            Start(Operation) = Delivery
            Message(Start delivery operation)
            Message(Product ownership changed to End User)
        else
            Message(Waiting for conditions to be met)
        end if
    else
        Message(Product is not available, Transaction cannot be done)
    end if
end if
if (Operation == No Action) then
```

```

        Message (Nothing to do, transaction remain in the same state)
    end if
-- "Conditions" fonction
all_condition_met = True
for each User in [Users_List] do:
    if User has not signed then
        all_condition_met = False
        Message (One or more user has not signed the transaction)
    end if
return all_condition_met

```

6. Evaluation

From a transparency perspective, the presented model offers features that do not exist in the actual information systems. To validate our proposed framework, we will use one of the most important factors in the textile industry which is quality. A case study has been conducted in company X, an international textile manufacturer. In this company, supplier evaluation and selection are made by quality assurance team and purchasing managers. In fact, this team receives a list of contracted and new suppliers, they review them and after that they suggest a list of potential suppliers. Then the decision is discussed at a meeting between purchasing managers and quality assurance team members. This process has always led to misunderstandings and inconsistencies in the decision taken because of subjective factors like for example the performance of the presenter and participants subjective feelings in the meeting which could affect the evaluation and the decision about suppliers. Moreover, the product quality criteria used by the quality team members to assess the products proposed by the suppliers were not explicitly known or shared with all the stakeholders which usually led to doubts about the decision taken regarding the overall product quality. In one of the previous studies that focuses on the impact of information sharing on product quality, the authors showed that in the textile sector, the quality of the finished product is impacted by several factors including how information and data are shared in the supply chain [69].

Based on this approach, we used an evaluation model which take into consideration product quality costs. In fact, we are going to demonstrate that the sharing of information between quality team during the assessment and the selection of suppliers with purchasing managers would impact the revenue attained by the manufacturer in the case of a company X operating in textile industry, the data is collected through a series of interviews with 5 representatives of quality assurance team and purchasing managers.

Notations:

- R_G is the net revenue attained by the manufacturer when he accepts the supplier's product and it is not defective.
- R_B is the revenue attained by the manufacturer when he accepts the supplier's product and it is defective.
- I_B is the net revenue received by the manufacturer rejects a product in the incoming inspection.
- R_M is profit of the manufacturer

The product quality related cost in this work represents the loss related to the detection of poor quality and correcting defective products. It can be external and internal failure cost [71]

External failure cost refers to the cost related to the defective products found after the delivery and internal failure cost is the cost for correction while the defect is detected before the delivery.

Moreover, we will consider the penalty W paid by the supplier to the manufacturer in the case of the internal failure and the penalty X in the case of external failure.

Thus, the external failure cost can be expressed as:

$$F_E = R_G - R_B = C_r - X \qquad R_B = R_G - C_r + X$$

Where C_r represents the Repair cost which includes the cost when the manufacturer needs to repair and replace the product if the customer returns the products.

The internal failure cost refers to the profit loss from production employed by the manufacturer to rework the product or sometimes to buy it from another supplier.

It can be expressed as below:

$$F_I = R_G - I_B = C_W - W + Z \qquad I_B = R_G - C_W + W - Z$$

Where C_W is the cost for ordering from backup production which means employing an extra process to rework the defective product from Supplier, and Z represents the penalty paid by the manufacturer to the store retailer when the defection is detected after delivery.

- The profit of the manufacturer is expressed as: $R_M = R_G + R_B + I_B$

The application of the BigchainDB- TSC model:

In this case the supplier screening and evaluation is assured with the implication of both purchasing managers and assurance quality team members who share the criteria to assess the quality of products. The use of BigchainDB will ensure the objectivity of the supplier's screening through its anonymity, in fact throughout its evaluation period it will be presented by a private key in the blockchain and it will only be selected if the criteria imposed by the two stakeholders are respected, this verification will be done in the blockchain using the defined conditions.

By using BigchainDB we will be able to ensure the objectivity of the decision, the verification of the criteria of all the stakeholders which will ensure the right choice of the supplier. If one of the participants would like to add criteria or change the priority of criteria, it will only be validated after the confirmation of all the participants. By this approach, the risks in upstream the supply chain would be minimized which going to minimize product quality costs. The quality team members inspect the received raw materials from suppliers, if the quality characteristics of received products meet with the requirements and the agreements in the contracts the process of production could be triggered, and the validated characteristics of the products will accompany the products during all the transformation process to ensure the traceability. In this case the manufacturer attains a net revenue of R_G . If the quality team members during the inspection detect defective products, they will share the information with all stakeholders including suppliers and purchasing managers to manage the rejection of those products which implies supplementary costs of ordering from backup suppliers C_W and the payment of a penalty W by the supplier. In this case the manufacturer attains a net revenue of I_B . But if the quality team members during the inspection do not detect the defective products or detect it and don't share it with stakeholders to take the right decision about it, those products will be accepted, and the late detection of the defection will imply costs C_r of reparation and maintenance and a penalty X paid by

the supplier. If the defection is detected by the final customer, this will imply cost incurred from selling a defective product which going to negatively impact the reputation of the manufacturer. This could be represented as reputational cost which represents the opportunity cost of lower sales related to the customer dissatisfaction. The reputational costs could not be calculated for this reason we are going to assume that when the defection is detected after the delivery the manufacturers pays a penalty Z to the store retailer.

Results:

Figure 19 shows the results of the application of both approaches on the different revenues and the manufacturer profit. The main idea of this calculations is the comparison and the analyze of the benefits if we apply the BigchainDB model rather than the traditional approach. For example, as presented the figure 1, if we compare R_G the net revenue attained by the manufacturer when he accepts the supplier’s product and it is not defective, we notice that the average revenue in the BigchainDB model is greater than the average revenue in the traditional approach, same for R_B and I_B . In this BigchainDB model, the evaluation and the screening of suppliers has been changed which led to the choice of another supplier who meets the selection criteria which led to the choice of another supplier who respects the selection criteria imposed by the quality team and purchasing managers. BigchainDB also ensured the objectivity of the results to establish the honesty and the subjectivity of the decision which reduced the defects detected during the quality inspection upon receipt of goods and the related costs it reduced the costs associated with a second order for the same product. BigchainDB has also contributed to the reduction of quality defects detected after the delivery of the product to the customer since sharing of information related to the quality of the products is done at each stage of the transformation of the product.

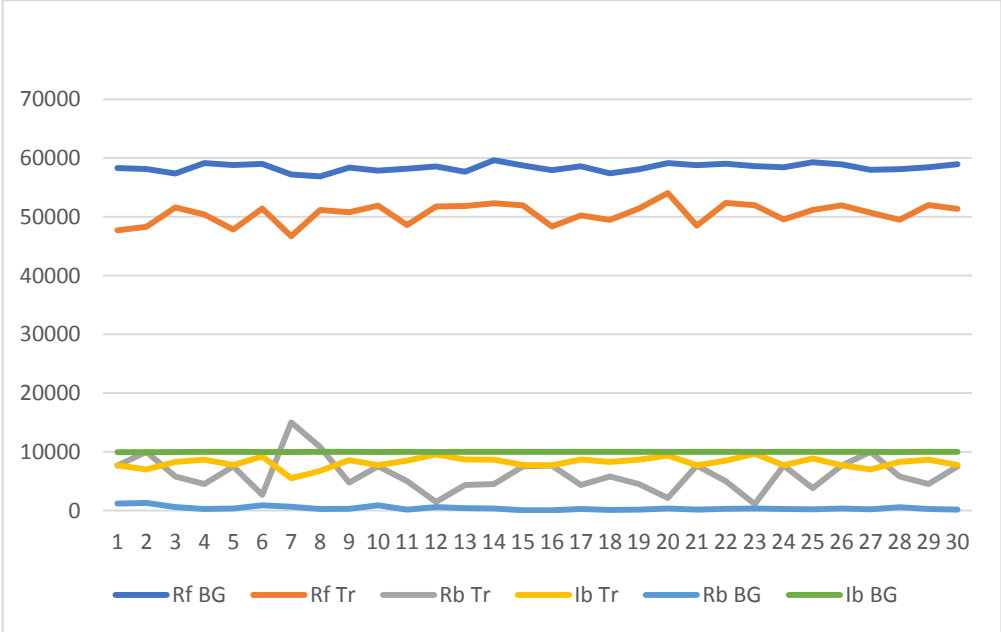


Figure 19: Revenue’s calculation results in the cases of traditional approach and BigchainDB model

7. Conclusion:

Nowadays, traceability has become a primordial subject in the context of complicated supply chains. A typical textile supply chain is made up of several actors who are scattered over the globe, and who have varied specialties with very different rules and standards governed by local systems [38]. As a result, it becomes more difficult to collaborate with the suppliers of the fabrics if the data are not well recorded in the system through all the links of the supply chain. In this context, this article presents Blockchain integrated Big data framework for improving supply chain traceability and information sharing in textile sector. In this work, we proposed a new approach which is a shared traceability system based on blockchain technology and big data and explored the challenges in scaling blockchains in general. Furthermore, a scenario was presented to show how it works in the textile supply chain with Bigchaindb. This system will deliver real-time information to all supply chain members on the status of textile products, which will extremely reduce the risks related to centralized information systems, and enable more secure, distributed, transparent, and collaborative system. Moreover, the evaluation of the proposed framework has demonstrated its positive impact on the manufacturer profit in the case of a textile industry. The proposed traceability framework shows also that brand owners can have better information about their supply chains. In the case of quality problems or a recall, this information can be efficiently utilized to track-back the involved actors to resolve the issue. Nonetheless, present article provides a framework to handle the situation related to traceability implementation in the textile supply chain. The next step would be to study the costs of BigchainDB implementation in an actual textile supply chain with real requirements, which would provide a better comprehension of the financial part and will contribute to the refinement of this framework. Subsequently, future research may further research about different aspects of this model like for example volume, velocity, and variety of exchanged information (the size, the type and time of transmitting and receiving information within the chain), outcome from sharing information (in the same chain the number of information shared Vs total information available), level of traceability (in one node of the chain, the capacity of access to strategic information available within the chain).

References:

- 1 Report M (2017) Marketline report store—global textile mills. Marketline, London, UK
2. Norton, T.; Beier, J.; Shields, L.; Househam, A.; Bombis, E.; Liew, D. A Guide to Traceability: A Practical Approach to Advance Sustainability in Global Supply Chains; United Nations Global Compact Office: New York, NY, USA, 2014.
3. Thakur, M.; Hurburgh, C.R. Framework for implementing traceability system in the bulk grain supply chain. *J. Food Eng.* 2009, 95, 617–626. [CrossRef]
4. Lam, J.K.; Postle, R. Textile and apparel supply chain management in Hong Kong. *Int. J. Cloth. Sci. Technol.* 2006, 18, 265–277
5. Goswami, S. Traceability to Farm & Factory, Country of Manufacturing, and Apparel Purchase Scenario. Master's Thesis, University of Missouri, Columbia, MO, USA, 2014.
6. United Nations Conference on Trade and Development (UNCTAD) (2005). UNCTAD Current Studies on FDI and Development: TNCs and the Removal of Textiles and Clothing Quotas.
- 6.b. Pigni F, Crave S, Ravaini A ((2007)) Traceability in the textile and clothing industry: issues and implications for RFID adoption. In: The 2nd Mediterranean Conference on Information Systems, MCIS. Venice, Italy, p 200

7. Kang Y-S, Lee Y-H (2013) Development of generic RFID traceability services. *Comput Ind* 64:609–623.
8. De Brito, M.P.; Carbone, V.; Blanquart, C.M. Towards a sustainable fashion retail supply chain in Europe: Organisation and performance. *Int. J. Prod. Econ.* 2008, 114, 534–553
9. Vachon, S.; Klassen, R.D. Extending green practices across the supply chain: The impact of upstream and downstream integration. *Int. J. Oper. Prod. Manag.* 2006, 26, 795–821.
10. Angulo, A.; Nachtmann, H.; Waller, M.A. Supply chain information sharing in a vendor managed inventory partnership. *J. Bus. Logist.* 2004, 25, 101–120
11. Cachon, G.P.; Fisher, M. Supply chain inventory management and the value of shared information. *Manag. Sci.* 2000, 46, 1032–1048
12. Hall, D.C.; Saygin, C. Impact of information sharing on supply chain performance. *Int. J. Adv. Manuf. Technol.* 2012, 58, 397–409
13. Zhao, Y. The Impact of Information Sharing on Supply Chain Performance. Ph.D. Thesis, Northwestern University, Evanston, IL, USA, 2002
14. Lotfi, Z.; Mukhtar, M.; Sahran, S.; Zadeh, A.T. Information sharing in supply chain management. *Procedia Technol.* 2013, 11, 298–304.
15. Nimbalkar, G.; Mawson, J.; Cremen, C. The Truth behind the Barcode: Australian Fashion Report; Baptist World Aid Australia: North Ryde, NSW, Australia, 2015
16. Dwivedi S. K., Amin R. , Vollala S. (2020) Blockchain based secured information sharing protocol in supply chain management system with key distribution mechanism. *Journal of Information Security and Applications* 102554
17. Gobbi, L.; Massa, I. Supply chain management in textile sector: The case of the Italian T-fashion traceability system. *Int. J. Environ. Health* 2015, 7, 359–370
18. Zhang, T.; Kraisintu, K. The Role of Traceability in Sustainable Supply Chain Management. Master's Thesis, Chalmers University of Technology, Göteborg, Sweden, 2011.
19. Thomassey, S. Sales forecasts in clothing industry: The key success factor of the supply chain management. *Int. J. Prod. Econ.* 2010, 128, 470–483
20. Alves, B.; Schumacher, M.; Cretton, F.; Le Calvé, A.; Cherix, G.; Werlen, D.; Gapany, C.; Baeryswil, B.; Gerber, D.; Cloux, P. Fairtrace: Applying Semantic Web Tools and Techniques to the Textile Traceability. In *Enterprise Information Systems*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 68–84.
21. Cheung HH, Choi SH (2011) Implementation issues in RFID-based anti-counterfeiting systems. *Comput Ind* 62:708–718. <https://doi.org/10.1016/j.compind.2011.04.001>
22. Burnotte L, Emmerecht E, Delaigle J-F et al (2006) Traceability rules against counterfeiting for international normalization groups. Belgium Science Policy. In: Brussels
23. Guercini, S.; Runfola, A. The integration between marketing and purchasing in the traceability process. *Ind. Mark. Manag.* 2009, 38, 883–891
24. Kumar V (2017) Exploring fully integrated textile tags and information systems for implementing traceability in textile supply

25. He W, Zhang N, Tan PS, et al. (2008) A secure RFID-based track and trace solution in supply chains. In: 2008 6th IEEE International Conference on Industrial Informatics. pp. 1364–1369
26. Richero R, Ferrigno S (2016) A background analysis on transparency and traceability in the garment value chain. Directorate General for International Cooperation and Development, European Commission, Brussels
27. S. Nakamoto, Bitcoin: A Peer-to-Peer Electronic Cash System, <http://bitcoin.org/bitcoin.pdf>, (2008).
28. J. Kang, R. Yu, X. Huang, S. Maharjan, Y. Zhang, E. Hossain, Enabling localized peer-to-peer electricity trading among plug-in hybrid electric vehicles using consortium blockchains, *IEEE Trans. Ind. Inf.* 13 (6) (2017) 3154–3164, <https://doi.org/10.1109/TII.2017.2709784>.
29. Agrawal T.K., Sharma A., Kumar V. (2018) Blockchain-Based Secured Traceability System for Textile and Clothing Supply Chain. In: Thomassey S., Zeng X. (eds) *Artificial Intelligence for Fashion Industry in the Big Data Era*. Springer Series in Fashion Business. Springer, Singapore
30. A. Badzar, Blockchain for Securing Sustainable Transport Contracts and Supply Chain Transparency-An Explorative Study of Blockchain Technology in Logistics, <http://lup.lub.lu.se/student-papers/record/8880383>, (2016).
31. M. Tieman, M.R. Darun, Leveraging blockchain technology for halal supply chains, *Islam Civilisational Renewal (ICR)* 8 (4) (2017) 547–550, <https://doi.org/10.12816/0045700>
32. F. Tian, An agri-food supply chain traceability system for China based on RFID & blockchain technology, *Proceedings of 2016 IEEE 13th International Conference on Service Systems and Service Management (ICSSSM)*, 2016, pp. 1–6, , <https://doi.org/10.1109/icsssm.2016.7538424>
33. K. Sadouskaya, Adoption of Blockchain Technology in Supply Chain and Logistics, <https://core.ac.uk/download/pdf/84794328.pdf>, (2017)
34. L. Xiong, L. Liu, Peertrust: supporting reputation-based trust for peer-to-peer electronic communities, *IEEE Trans. Knowl. Data Eng.* 16 (7) (2004) 843–857, <https://doi.org/10.1109/tkde.2004.1318566>
35. N. Kshetri, Can blockchain strengthen the internet of things? *IT Professional* 19 (4) (2017) 68–72, <https://doi.org/10.1109/mitp.2017.3051335>.
36. J. Wang, P. Wu, X. Wang, W. Shou, The outlook of blockchain technology for construction engineering management, *Front. Eng. Manag.* 4 (1) (2017) 67–75
37. Azzi R, Kilany R, Sokhn M. The power of a blockchain-based supply chain. *Comput Ind Eng* 2019;135:582–92.
38. Bruce, M.; Daly, L.; Towers, N. Lean or agile: A solution for supply chain management in the textiles and clothing industry? *Int. J. Oper. Prod. Manag.* 2004, 24, 151–170.
39. ElMessiry M., ElMessiry A. (2018) Blockchain Framework for Textile Supply Chain Management. In: Chen S., Wang H., Zhang LJ. (eds) *Blockchain – ICBC 2018*. ICBC 2018. Lecture Notes in Computer Science, vol 10974. Springer, Cham
40. Fu, B.; Shu, Z.; Liu, X. Blockchain Enhanced Emission Trading Framework in Fashion Apparel Manufacturing Industry. *Sustainability* 2018, 10, 1105.
41. Zhang, C.; Li, S. Secure information sharing in internet-based supply chain management systems. *J. Comput. Inf. Syst.* 2006, 46, 18–24.

- 41.. Kumar V, Koehl L, Zeng X (2016) A fully yarn integrated tag for tracking the international textile supply chain. *J Manuf Syst* 40:76– 86.
42. Lee S-Y (2008) Drivers for the participation of small and mediumsized suppliers in green supply chain initiatives. *Supply Chain Manag Int J* 13:185–198. <https://doi.org/10.1108/13598540810871235>
43. McMillen D, Alvarez M, Craig S (2016) Security trends in the manufacturing industry [White Paper]. IBM, New York, USA
44. Wajzman N, Burgos CA, Davies C (2015) The economic cost of IPR infringement in the clothing, footwear and accessories sector. Office for Harmonisation in the Internal Market, Alicante, Spain.
45. Corbellini S, Ferraris F, Parvis M (2006) A cryptographic system for brand authentication and material traceability in the textile industry. In: 2006 IEEE Instrumentation and Measurement Technology Conference Proceedings. pp. 1331–1335.
46. Ekwall D ((2009)) The risk for detection affects the logistics system setup for cargo smugglers. In: Nofoma. Jönköping, Sweden. Jönköping, Sweden, p 2009
47. Borjeson N, Boström M: Towards reflexive responsibility in a textile supply chain. *Bus Strateg Environ* 2018, 27:230–239
48. Madhav S, Ahamad A, Ahamad A, Singh P, Mishra PK: A review of textile industry: wet processing, environmental impacts, and effluent treatment methods. *Environ Qual Manag* 2018, 27: 31–41
49. He W, Zhang N, Tan PS, et al. (2008) A secure RFID-based track and trace solution in supply chains. In: 2008 6th IEEE International Conference on Industrial Informatics. pp. 1364–1369.
50. Azuara G, Luis Tornos J, Luis Salazar J (2012) Improving RFID traceability systems with verifiable quality. *Ind Manag Data Syst* 112:340–359.
51. Saak AE (2016) Traceability and reputation in supply chains. *Int J Prod Econ* 177:149–162.
52. Ilie-Zudor E, Kemény Z, Ekárt A et al (2014) A solution for information management in logistics operations of modern manufacturing chains. *Procedia CIRP* 25:337–344
53. Juels A (2006) RFID security and privacy: a research survey. *IEEE J Sel Areas Commun* 24:381–394. <https://doi.org/10.1109/JSAC.2005.861395>
54. <https://www.cognizant.com/whitepapers/a-blockchain-based-framework-for-apparel-and-footwear-supply-chain-traceability-codex4088.pdf>
55. J. Du, V. Sugumaran, B. Gao, RFID and multi-agent based architecture for information sharing in prefabricated component supply chain, *IEEE Access* 5 (2017) 4132–4139, <https://doi.org/10.1109/access.2017.2665778>.
56. H. Watanabe, S. Fujimura, A. Nakadaira, Y. Miyazaki, A. Akutsu, J.J. Kishigami, Blockchain contract: a complete consensus using blockchain, 2015 IEEE 4th Global Conference on Consumer Electronics (GCCE), IEEE, 2015, pp. 577–578, , <https://doi.org/10.1109/GCCE.2015.7398721> October
57. A. Badzar, Blockchain for Securing Sustainable Transport Contracts and Supply Chain Transparency-An Explorative Study of Blockchain Technology in Logistics, <http://lup.lub.lu.se/student-papers/record/8880383>, (2016).

58. F. Tian, An agri-food supply chain traceability system for China based on RFID & blockchain technology, Proceedings of 2016 IEEE 13th International Conference on Service Systems and Service Management (ICSSSM), 2016, pp. 1–6, <https://doi.org/10.1109/icsssm.2016.7538424>.
59. J. Wang, P. Wu, X. Wang, W. Shou, The outlook of blockchain technology for construction engineering management, *Front. Eng. Manag.* 4 (1) (2017) 67–75
60. Abeyratne SA, Monfared RP. Blockchain ready manufacturing supply chain using distributed ledger. *Int J Res Eng Technol* 2016;5:1–10.
61. Korpela K, Hallikas J, Dahlberg T. Digital supply chain transformation toward blockchain integration. In: Proceedings of the 50th Hawaii international conference on system sciences; 2017. p. 4182–91.
62. Ruta M, Scioscia F, Ieva S, Capurso G, Di Sciascio E. Supply chain object discovery with semantic-enhanced blockchain. In: Proceedings of the 15th ACM conference on embedded network sensor systems. ACM; 2017. p. 60.
63. Tönnissen S, Teuteberg F. Analysing the impact of blockchain-technology for operations and supply chain management: an explanatory model drawn from multiple case studies. *Int J Inf Manage* 2020;52(101953):1–10.
64. Bocek T, Rodrigues BB, Strasser T, Stiller B. Blockchains everywhere-a use-case of blockchains in the pharma supply-chain. In: 2017 IFIP/IEEE Symposium on integrated network and service management (IM). IEEE; 2017. p. 772–7.
65. <https://www.bigchaindb.com/whitepaper/bigchaindb-whitepaper.pdf>
66. Probst, L.; Frideres, L.; Pedersen, B. Traceability across the Value Chain: Advanced Tracking Systems; European Commission: Brussels, Belgium, 2015.
67. ElMessiry M., ElMessiry A. (2018) Blockchain Framework for Textile Supply Chain Management. In: Chen S., Wang H., Zhang LJ. (eds) Blockchain – ICBC 2018. ICBC 2018. Lecture Notes in Computer Science, vol 10974. Springer, Cham
68. Feng Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," 2016 13th International Conference on Service Systems and Service Management (ICSSSM), Kunming, 2016, pp. 1-6, doi: 10.1109/ICSSSM.2016.7538424.
69. Bartlett, P.A., Julien, D.M. and Baines, T.S. (2007), "Improving supply chain performance through improved visibility", *The International Journal of Logistics Management*, Vol. 18 No. 2, pp. 294-313
70. Hemlata Kohad, Sunil Kumar, Asha Ambhaikar (2020) "Scalability Issues of Blockchain Technology" *International Journal of Engineering and Advanced Technology (IJEAT)* ISSN: 2249 – 8958, Volume-9 Issue-3
71. Baiman, S., Fischer, P.E., Rajan, M.V., 2000. Information, contracting, and quality costs. *Management Science* 46 (6), 776–789.
72. Huanhuan Feng, Xiang Wang, Yanqing Duan, Jian Zhang, Xiaoshuan Zhang, Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges, *Journal of Cleaner Production*, Volume 260, 2020
73. Justin Sunny, Naveen Undralla, V. Madhusudanan Pillai, Supply chain transparency through blockchain-based traceability: An overview with demonstration, *Computers & Industrial Engineering*, Volume 150, 2020,

74. Bill Wang, Wen Luo, Abraham Zhang, Zonggui Tian, Z. Li, Blockchain-enabled circular supply chain management: A system architecture for fast fashion, *Computers in Industry*, Volume 123, 2020,
75. Kamalendu Pal, Ansar-Ul-Haque Yasar, Internet of Things and Blockchain Technology in Apparel Manufacturing Supply Chain Data Management, *Procedia Computer Science*, Volume 170, 2020, Pages 450-457,
76. Tschorsch, Florian, and Björn Scheuermann. "Bitcoin and beyond: A technical survey on decentralized digital currencies." *IEEE Communications Surveys Tutorials* 18.3 (2016): 2084-2123
77. Szabo, Nick. "Formalizing and securing relationships on public networks." *First Monday* 2.9 (1997)
78. S. Corbellini, F. Ferraris and M. Parvis, "A Cryptographic System for Brand Authentication and Material Traceability in the Textile Industry," *2006 IEEE Instrumentation and Measurement Technology Conference Proceedings*, 2006, pp. 1331-1335, doi: 10.1109/IMTC.2006.328556.
79. S. Sheng and X. Wu, "A new digital anti-counterfeiting scheme based on chaotic cryptography," *2012 International Conference on ICT Convergence (ICTC)*, 2012, pp. 687-691, doi: 10.1109/ICTC.2012.6387119
80. KAUR, Sivleen, CHATURVEDI, Sheetal, SHARMA, Aabha, et al. A Research Survey on Applications of Consensus Protocols in Blockchain. *Security and Communication Networks*, 2021, vol. 2021.
81. DAI, Patrick, MAHI, Neil, EARLS, Jordan, et al. Smart-contract value-transfer protocols on a distributed mobile application platform. 2017.
82. KWON, Jae. Tendermint: Consensus without mining. Draft v. 0.6, fall, 2014, vol. 1, no 11.