Decentralised Trading Framework for Smart Manufacturing

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***Abstract*—The textile industry's supply chain management (SCM) is intricate, involving numerous stakeholders worldwide and grappling with issues like corruption, middlemen and counterfeiting. While SCM promises cost reduction, efficiency gains and sustainability, addressing these challenges demands strategic solutions. Traditional methods, including anti-corruption policies and technology integration, encounter enforcement, cost and complexity hurdles.**

Blockchain technology emerges as a promising solution, providing transparency, traceability and trustworthiness in supply chain transactions. By incorporating blockchain as an extension to existing systems, institutions can reduce risks, streamline legal documentation through smart contracts and achieve automation, leading to increased efficiency and cost reduction. The decentralized nature of blockchain facilitates global accessibility, breaking down geographical and institutional barriers.

This paper introduces a smart contract to unify different government entities related to authenticity of goods in the supply chain. The smart contract aims to generate a hash for every product in the supply chain, wherein the hash contains details of every intermediate government verification like Trade License, Importer Exporter Code (IEC) etc. that a product has undergone. This removes the hassle of independently carrying out every verification and provides a secure storage for all the validated entities.

***Index Terms*—Supply Chain Management, Textile Industry, Blockchain, Smart Contract, Government entity**

I. Introduction

Supply chain management (SCM) in the textile industry is the process of planning, coordinating and executing the flow of goods and services from the point of origin to the point of consumption. It is essential because the textile supply chain is long and complex, involving multiple suppliers, manufacturers and retailers in different countries. Effective SCM can help textile companies reduce costs, improve efficiency, increase customer satisfaction and enhance sustainability. However, textile supply chains are also vulnerable to challenges such as corruption, middlemen and counterfeit goods. Corruption in the form of bribery, extortion and fraud can occur at any level of the supply chain and lead to increased costs and reduced quality. About 75% of the integrity related cases are due to bribery [1]. Middlemen can increase the cost of textile products by adding an extra margin to the price and slow down the flow of goods through the supply chain. Counterfeit goods can damage the reputation of legitimate textile companies. Textile companies need to take a number of steps to address these challenges, including implementing strong anti-corruption policies, working with ethical suppliers and partners, using technology to improve visibility and traceability in the supply chain and investing in brand protection measures.

Conventional solutions to handle corruption, counterfeit goods and unethical middlemen in the textile supply chain [9] include -

1) Implementing strong anti-corruption policies and procedures, working with ethical suppliers and partners
2) Using technology to improve visibility and traceability in the supply chain and creating a culture of integrity and transparency within the company
3) Investing in brand protection measures, working with law enforcement to investigate and prosecute counterfeiters and educating consumers about counterfeit goods
4) Negotiating directly with suppliers to get the best possible prices and reduce involvement of multiple middlemen in the supply chain

Anti-corruption policies and procedures can be complex and difficult to implement effectively. They may be difficult to enforce in countries with weak legal systems. Textile companies may be reluctant to work directly with suppliers in countries with high levels of corruption. Using technology to improve visibility and traceability can be expensive to implement and maintain. It can be tedious to ensure that all suppliers are using the same technology and that the data is accurate and reliable. Creating a culture of integrity and transparency within a company takes time and effort. It also requires the commitment of senior management and all employees. Reducing corruption in SCM requires a detailed process of various checks and paperwork that prevent false goods and corrupt middlemen from ruining the process [2]. This process has several stages and can differ from one business to another. Implementing the entire process to automate the supply chain is tedious, time consuming and technology intensive.

Cryptography is a powerful tool that can be used to improve the security and efficiency of textile supply chain management by enhancing authentication and authorization. Digital signatures can be used to verify the identity of the sender

of a message or the authenticity of a document. This can help to prevent fraud and ensure that only authorized parties are able to access the supply chain. Hash functions can be used to create a unique digital fingerprint of a piece of data. This digital fingerprint can be used to verify the integrity of data or to detect unauthorized changes. This can be used to prevent counterfeiting and ensure that consumers are receiving the products that they have paid for. Cryptographic tags act as carriers which map the information with physical products [4]. One such tag can be made using QR code and PUC which is unique for every product and can be verified by scanning it using smart phones. On-the-tag public key cryptography allows for enhanced security and privacy in RFID applications [7]. FPGA-based implementation of the GPS public key identification on RFID tags shows that the complete tag authentication process takes 200ms and only requires 2600 GE for the cryptographic components. A demerit of cryptography is the cost of implementing and maintaining the solutions. It can be complex and expensive to implement, especially for small and medium-sized businesses. If cryptography solutions are not implemented and used correctly, they can be vulnerable to attack. Additionally, cryptography can also be used for malicious purposes. Criminals can use cryptography to encrypt illegal goods or to hide their communications. This can make it more difficult for law enforcement to investigate and prosecute crimes.

Blockchain has the potential to open outstanding values for the institutions by reducing supply chain risks, increase transparency, traceability and improves trustiness across the system. Blockchain technology can be added as an extension to existing systems. In the current supply chain management, transparency is one of the key concerns where one entity cannot look into other entities' transactions though being involved in the same set of transactions, whereas in case of blockchain a long chain records will be added as and when any entity performs any action which can be traced back by other entities involved. Tamper proof records will enable institutions to take better steps by carefully carrying out various analytics on these records towards the development of the institution. Various legal documentation involved in the process can be reduced to few digital documents i.e. smart contracts, where all the necessary agreements are clearly mentioned and all the required entities have their respective contributions. Smart contracts are programmable and self-executing, which means they will automatically enforce the terms and conditions agreed upon by the parties involved. This automation eliminates the need for intermediaries and manual processing, resulting in increased efficiency and reduced costs. They operate on a decentralized blockchain network, ensuring that all transactions and actions are recorded and verified. They can be accessed and executed by anyone with permission to interact with the blockchain network. This accessibility opens up opportunities for individuals and businesses to engage in transactions and agreements that were previously limited by geographical or institutional barriers. [13] [3]

A. Research Contributions

The research contributions of this paper are as follows -

1) Identify required goverment verifications for each product in the supply chain
2) Verify each government entity against a product using Govt. provided APIs
3) Unify the entire verification process into a smart contract and generate a hash for each product
4) Use the hash at any stage of the supply chain to verify the product integrity and get status of every Govt. entity associated with it

B. Organization

The rest of the paper is organized as follows. Section II contains Literature review of past advancements in the field. Section III talks about the problem statement in detail. Section IV presents the system model and problem formulation. Section V outlines the implementation of the solution. Section VI enlists the advantages of using Blockchain in Supply Chain Management. Results are discussed and the paper is concluded in Section VI.

II. Literature Review

Online shopping has emerged as a successful competitor to shopping from markets and showrooms. Customers now indulge in both seeing the vast variety of products available and cost-effectiveness. This bifurcates the supply chain into 2 - direct channel (online shopping directly from the manufacturer) and retail channel (from markets via retailers). Decentralized dual channel helps manufacturers and retailers maximize their own individual profits while still giving a rich experience to the customers [15]. This model is based on the Stackelberg game theory wherein the manufacturer (leader) decides the wholesale price and direct sale price. The retailer (follower) decides the retail price accordingly. Both decide their own leading time in line with their profit aspirations. The system remains profitable for both as long as both guarantee the Stackelberg equilibrium. This model gives insights on the relation between retail price and direct sale price in different conditions of demand in the market.

Traditional supply chain systems limit access of company's products via their hosted websites only, enabling a centralized source of data only. Any issues with the server and the entire access to the data is gone. Order details, customer details, sellers, manufacturers etc. should be stored in a decentralized manner for a more flexible and transparent system [10]. A blockchain network with nodes for each raw material supplier, manufacturer, assembler and product supplier can bridge the gap between any 2 of these entities. All data is stored in floating ledger and every entity has its own Smart Contract. A decentralized app can be used for viewing all activities done as a part of the supply chain management. This system provides for better transparency and improved watch over the data flow.

Internet of Things enabled supply chain management has introduced the concept of Smart Tags - RFID, NFC and QR codes that help track products throughout their lifecycle in

TABLE I: Literature Review of existing Blockchain systems for Supply Chain Management

Author	Year	Objective	Pros	Cons
Yin et al. [15]	2013	Develop a decentralized dual supply chain for manufacturers and retailers respectively such that both can earn better profits while still remaining an important face in the market	Gives mathematical equations based on game theory which help determine optimal retail price and direct sell price in different demand situations	
Naidu et al. [10]	2018	Bridge the gap between different nodes of the supply chain tree Automate the transport process between entities	Removes any discontinuity by using blockchain such that the entire supply chain tree is viewed as one system and every update is visible to anyone having the required authority	Requires every computer in the system to have an entry point into the Ethereum environment (eg - MetaMask)
Bencic et al. [6]	2019	Prevent tampering or duplication of Smart Tags and ambiguous chain where products paid for are not delivered and delivered products are not acknowledged	DL-Tags provides for a distributed and privacy preserving system for verifying authenticity of Smart Tags on products and identifying fake products in the chain	Might not always be cost effective. Max costs for using Ethereum blockchain was 128 USD in 2018 which is too high to accept
Haque et al. [8]	2020	Formulate a decentralized supply chain system that considers multiple objectives of every stakeholder and optimizes accordingly	Pareto graph analysis of the objective functions using Matlab helps obtain suitable values which are more realistic than a centralized system	
Pranesh et al. [12]	2020	Develop a blockchain system for supply chain management which calculates incentives for supply chain parties in a manner fair for the manufacturer and the parties involved	Uses game theory to calculate the incentive in a fair manner to prevent counterfeit products from entering the market as all parties are motivated to follow the protocol	Manufacturer has to spend some fixed amount of ethers to mine the transaction for rewarding incentives
Omar et al. [11]	2020	To increase the productivity, performance, transparency and trust among the entities of vendor-managed inventory systems.	Improved traceability, data integrity, data retrieval. Increased productivity, transparency and accessibility	Limitations of smart contracts, key management, learning curve, limited adoption, regulatory and legal considerations
Agrawal et al. [5]	2021	Improve traceability of goods for better visibility and transparency in the supply chain Provide easy access to product data for ease of customers	Distributed ledger stores all transactions which is validated by the smart contracts deployed Retailer can trace all transactions by accessing the shared ledger	
Wagner et al. [14]	2022	To meet privacy and scalability requirements in a permission less blockchain used for decentralized supply chain management systems for less complex products	Dynamic and fine granular data access policies. Scalable, flexible and incrementally deployment support	Can be used only for less complex products.

the chain. A consumer needs to know of the authenticity of these tags before trusting the product because corrupt middlemen can sell fake underpriced or branded over priced goods in place of the original product by tampering the tags. DL-Tags [6] is a decentralized and privacy-preserving way to manage Smart Tags. The stakeholders identified include - TagItSmart platform, producer and e-commerce store. All involved stakeholders and product consumers need to agree upon a consensus to verify the authenticity of the product while remaining anonymous themselves. This solution mitigates issues of duplicate tags, undelivered products, fake goods etc. and improves consumer experience.

Decentralized supply chain management is gaining more and more popularity over the years. In this, each supply chain member makes his own decisions. Every member in the chain might have a different objective - profit maximization, cost minimisation etc. Hence on a larger scale, multiple decisions with multiple objectives need to be tackled. A bilevel approach with a central authority for taking major decisions and flexibility to allow individual members to optimize their own objectives has been proposed [8]. It considers a central authority that can collect required information for overall synchronization of the chain while lower level decisions will be made in accordance with individual objectives of manufacturer, distributor and retailer. This mathematical model exhibits slightly higher sales and order quantities to meet the demand but fewer inventories compared to a centralized system.

Blockchain stands as one of the proven ways to integrate all supply chain parties. Attractive incentives have been proposed to ensure supply chain parties always follow the protocols to eliminate counterfeit products in the market [12]. An ethereum based fair incentive calculation policy has been devised which reduces the overhead on manufacturers to mine the transaction fee and supply chain parties to mine their transactions. The policy is based on game theory for fairness. The proposed algorithm infers that incentive is directly proportional to average transaction fee and that manufacturer is always aware of how much incentive needs to be paid to the supply chain parties.

It is important to trace products in the supply chain to prevent ambiguities in transactions, delivery of products, and product data. Textile industry is one such industry that requires product traceability for smooth functioning. A study of organic cotton supply chain [11] that uses blockchain and smart contracts reveals the trust that can be built among supply chain partners like - cotton producer, yarn manufacturer, fabric manufacturer, apparel manufacturer and retailer by using smart contracts and distributed ledger. Stakeholders can also use this information to trace back the supply chain network and create a sustainable supply chain.

Blockchain technology assures trust and privacy required for centralized information sharing but current decentralized

supply chain management systems either require a trusted consortium or it doesn't provide / meet privacy requirements. Storing all information locally gives companies/users complete sovereignty over who accesses their data and tamper protection of all the data via permissionless blockchain provides on-demand tracking, tracing of every kind of information for many, less complex products [5]. Every company / organization stores their data locally thus having complete control over the stored data and periodically publishing a cryptographic witness over all recent events to a public ledger maintains the integrity of the data. If an external entity requires some information then share that particular information only, hence both privacy and scalability is encountered. In the proposed system every action will have a unique identifier along with some details regarding the action, similarly products will also have a unique identifier along with some other details. Actions can reference product identifiers as input and product records will be its output depending on the action performed.

Traditional vendor managed inventory systems have problems such as data integrity, data accessibility, information delay, traceability and transparency. All these can be solved by integrating blockchain technology with vendor managed inventory management systems [14]. Blockchain synchronizes vendor managed inventory operations between all stages of the supply chain as planning and execution processes are made transparent and data retrieval is more effective due to permissioned access of the data. It also generates alerts when stakeholders violate predefined conditions for replenishment stated in the smart contracts.

III. Problem Statement

In the dynamic global market, the export of textile goods from India constitutes a complex web of interactions among various stakeholders, including manufacturers, transporters, customs departments, quality assurance (QA) departments, income tax authorities, the governments of both source and destination countries, and potentially, legal entities. Despite the intricate nature of these interactions, the current export process is susceptible to inherent flaws that may give rise to fraudulent activities, misrepresentations, and cheating by unscrupulous third parties as shown by the red-marked area in Fig 1.

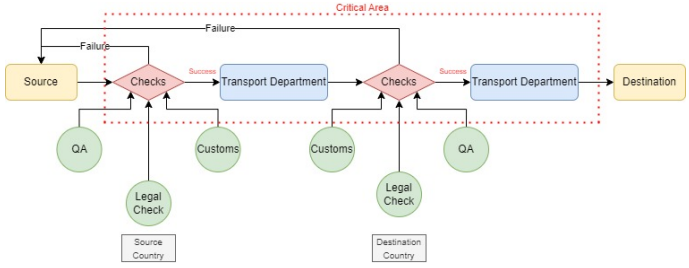

Fig. 1: Overview of traditional process

A. Flaws in current export process

1) Information Asymmetry: The export process involves a multitude of stakeholders, each with specific roles and responsibilities. However, information asymmetry is a critical flaw, as certain stakeholders may have incomplete or inaccurate information, leading to misunderstandings and potential exploitation by malicious entities.

2) Regulatory Compliance Challenges: Compliance with export regulations and standards is a multifaceted challenge. The involvement of multiple government departments and agencies, both in India and the destination country, creates a complex regulatory landscape. Non-compliance or manipulation of regulatory requirements poses a significant risk and may be exploited by unscrupulous third parties.

3) Document Verification and Authentication: The reliance on physical and electronic documentation for customs clearance, quality assurance, and taxation purposes introduces vulnerabilities in the form of document forgery, manipulation, or misrepresentation. Inefficiencies in the verification process may lead to the acceptance of fraudulent documents.

4) Inadequate Quality Assurance Protocols: The export of textile goods necessitates stringent quality assurance measures. However, flaws in the existing QA protocols, such as insufficient inspections, substandard testing procedures, or inadequate oversight, may enable the export of subpar or defective goods.

5) Lack of a Unified Information System: The absence of a centralized and integrated information system hampers real-time communication and data sharing among stakeholders. This lack of coordination can be exploited by third parties engaging in fraudulent activities, as they may capitalize on the gaps in information exchange.

B. Potential for Cheating and Misleading Activities

1) False Declarations and Undervaluation: Third parties may exploit the decentralized nature of the export process to make false declarations regarding the nature, quantity, or value of exported goods. Undervaluation of goods, for instance, can lead to reduced tax liabilities and increased profits for dishonest actors.

2) Bribery and Corruption: The involvement of multiple government agencies creates opportunities for bribery and corruption. Unethical practices, such as bribing customs officials or QA inspectors, may allow unscrupulous individuals to circumvent regulations and gain an unfair advantage in the export process.

3) Manipulation of Inspection Processes: The quality assurance phase is vulnerable to manipulation, with third parties potentially influencing or compromising inspection

procedures. This could result in the export of substandard goods, posing risks to the reputation of Indian textile exports.

4) Exploitation of Legal Loopholes: Complex legal frameworks may inadvertently create loopholes that can be exploited by third parties engaging in misleading activities. Ambiguities in laws and regulations may be manipulated to the advantage of those with an intent to cheat the system.

IV. System Model and Problem Formulation

A. Mathematical Problem formulation

Following is the description of a system which verifies each product present in the supply chain. Required Govt. verifications like Trade License, RCMC, IEC etc. are validated using Govt. API. Based on the result of the API call, a new transaction is created and a block is mined.

1) Input Parameters:

- V_{tl}: Verification status of Trade License
- V_{qa}: Verification status of Quality Assurance (QA)
- V_{iec}: Verification status of Importer Exporter Code (IEC)
- V_{rcmc}: Verification status of Registration-cum-Membership Certificate (RCMC)
- V_{gst}: Verification status of Goods and Service Tax (GST)
- V_{acc}: Verification status of International Bank Account Number
- V_{sc}: Verification status of Swift Code (SC)

2) Output Parameters:

- V_{status}: Combined verification status of all entities
- $Hash_{Tx}$: Transaction hash of current verified transaction

3) Mathematical Expressions:

$$V = \{V_{tl}, V_{qa}, V_{iec}, V_{rcmc}, V_{gst}, V_{acc}, V_{sc}\}$$

- Verification Function ($Verify$):

$$Verify(V) = \begin{cases} 1, & \text{if } \forall x \in V | x = 1 \\ 0, & \text{otherwise} \end{cases}$$

- Create Block Function ($CreateBlock$):

$$CreateBlock(V_{status}) = \begin{cases} 1, & \text{if } V_{status} = 1 \\ 0, & \text{otherwise} \end{cases}$$

- Main Function ($IEWayVerification$):

$$IEWayVerification(V) = CreateBlock(Verify(V))$$

B. System Model

Manufacturer uploads product details: Product specifications, quality parameters, and export documentation are recorded on the blockchain.

- Transporters update real-time location data: IoT devices on transportation vehicles upload location data at each stage of the journey.

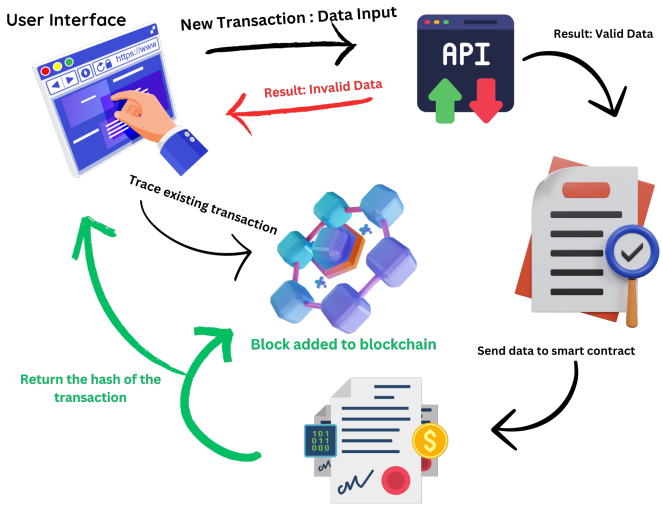

Fig. 2: System Model

- Customs officials validate documentation: Smart contracts automatically verify compliance with export regulations, and customs officials validate the documentation.
- Quality assurance inspections and tests: Decentralized network of inspectors conduct inspections, record results on the blockchain, and issue certificates.
- Government entities access relevant data: Regulatory oversight and taxation agencies access necessary information from the blockchain for auditing and monitoring purposes.
- Secure financial transactions: Cryptocurrency or digital tokens facilitate transparent and secure financial transactions, reducing the risk of fraudulent activities.

V. Implementation

A. Certificate Verification

Algorithm 1: Verify all the necessary documents

```
Input all the certificates
check = Call the government API (input)

if check == True then
    create a new transaction using the smart contract
end if

if check == False then
    entries are not valid, transaction not allowed
end if
```

B. Smart Contract

```
Contract Name: IEWay

variables:
    owner: address of the source
    tradeLicense: issued by DGFT
```

```
    IEC: issued by the Govt.
    RCMC: issued by the Govt.
    QCI: issued by the QA Agencies
    GST: GST number of the source
    SWIFT: source's bank account
    Account: source's bank account
    invoiceNumber: current invoice
    clientTradeLicense: dest. country

constructor(){
    set the source address
}

setTradeLicense(tradeLicense){
    set the tradeLicense
}

setClientTradeLicense(tradeLicense){
    set the clientTradeLicense
}

setIEC(IEC){
    set the IEC license
}

setRCMC(RCMC){
    set the RCMC license
}

setGST(){
    set the GST number
}

setBankDetails(account,SWIFT){
    set the account details and SWIFT code of the
    source
}

setData(all the parameters){
    call all the internal functions to set
    respective items
}
```

C. Integration

The UI-based application will be served to the user where they can access the services such as adding new transactions, tracing an existing transaction etc. Internally when the user adds all the required data and proceeds with the new transaction, this data is first validated via API provided by API Setu (API service for validating Indian Govt. data). If all the certificates and checks result into true then a new block is added to the blockchain as mentioned above.

VI. Results

A. Transparency and Immutability

The decentralized ledger inherent in blockchain technology has ushered in a new era of transparency within the export process. By providing a tamper-resistant record of all transactions and interactions, blockchain mitigates information asymmetry among stakeholders. The immutability of data recorded on the blockchain further ensures that once information is captured, it remains unalterable, thus preventing unauthorized changes and substantially reducing the risk of fraudulent activities.

B. Smart Contracts for Automated Compliance

The integration of smart contracts, characterized as self-executing agreements with predefined rules, has revolutionized the compliance aspect of the export process. By embedding regulatory requirements into smart contracts, the system has achieved inherent compliance, markedly reducing the likelihood of non-compliance and minimizing potential third-party manipulation. This automation has streamlined the compliance verification process, enhancing efficiency and reliability.

C. Enhanced Document Verification through Digital Signatures

The implementation of blockchain technology has introduced a robust system for document verification through digital signatures. The cryptographic security of digital signatures on the blockchain provides a reliable method for verifying the authenticity and integrity of documents throughout the export process. This has significantly diminished the risk of fraudulent document submissions and misrepresentations, establishing a more secure documentation framework.

D. Real-time Tracking and Traceability

Utilizing blockchain for supply chain management has brought about real-time tracking and traceability of textile goods from manufacturing to export. This feature has greatly enhanced the visibility of the entire supply chain, making it challenging for third parties to engage in deceptive practices such as undervaluation or misdirection of goods. Stakeholders now have access to real-time data, ensuring accountability and substantially reducing the potential for exploitation.

E. Decentralized Quality Assurance

Blockchain implementation in quality assurance processes has facilitated the creation of a decentralized network of inspectors and auditors. Each inspection and test result is securely recorded on the blockchain, providing an immutable record of the quality of exported goods. This has led to a significant reduction in the risk of substandard goods entering the market, thereby safeguarding the reputation of Indian textile exports.

F. Unified Information System for Stakeholder Collaboration

The integration of blockchain has paved the way for a unified and secure information system where all authorized stakeholders can access relevant data in real-time. This collaborative environment has drastically reduced delays in communication, fostering a more coordinated and secure export process. The shared blockchain ledger ensures that all stakeholders are on the same page, enhancing overall efficiency.

G. Protection Against Corruption with Cryptographic Security

The cryptographic nature of blockchain technology has become a formidable defense against corruption. Transactions on the blockchain are encrypted and secure, rendering the system more resistant to bribery and manipulation. This cryptographic

security has played a pivotal role in fortifying the overall integrity of the export process.

H. Streamlined Settlements and Reduced Fraud

Blockchain's ability to enable faster and more transparent financial transactions, particularly through the use of cryptocurrency or digital tokens, has streamlined settlements between stakeholders. This reduction in reliance on traditional banking systems has simultaneously minimized the risk of fraudulent financial activities, contributing to a more secure and efficient financial landscape within the export process.

REFERENCES

[1] Bribery and corruption due diligence in the apparel supply chain. https://mneguidelines.oecd.org/OECD-Garment-Forum-2019-session-note-Five-FAQs-on-Bribery-and-corruption.pdf.

[2] Preventing corruption in the supply chain. https://www.textilbuendnis.com/wp-content/uploads/2018/03/AfIn$_K orruption spr$

[3] Using blockchain to drive supply chain transparency. https://www2.deloitte.com/us/en/pages/operations/articles/blockchain-supply-chain-innovation.html.

[4] Tarun Kumar Agrawal, Ludovic Koehl, and Christine Campagne. Cryptographic tracking tags for traceability in textiles and clothing supply chain. In *Uncertainty Modelling in Knowledge Engineering and Decision Making: Proceedings of the 12th International FLINS Conference*, pages 800–805. World Scientific, 2016.

[5] Tarun Kumar Agrawal, Vijay Kumar, Rudrajeet Pal, Lichuan Wang, and Yan Chen. Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. *Computers & industrial engineering*, 154:107130, 2021.

[6] Federico Matteo Benčić, Pavle Skočir, and Ivana Podnar Žarko. Dl-tags: Dlt and smart tags for decentralized, privacy-preserving, and verifiable supply chain management. *IEEE access*, 7:46198–46209, 2019.

[7] Marc Girault, Loic Juniot, and Matt Robshaw. The feasibility of on-the-tag public key cryptography. In *conference on RFID security*, page 68. Citeseer, 2007.

[8] Marjia Haque, Sanjoy Kumar Paul, Ruhul Sarker, and Daryl Essam. Bi-objective multistage decentralized supply chain planning. In *2020 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pages 766–770. IEEE, 2020.

[9] Maryanne K Karanja. What you can do to reduce corruption in your supply chain. https://www.linkedin.com/pulse/what-you-can-do-reduce-corruption-your-supply-chain-maryanne/.

[10] Vishal Naidu, Kumaresan Mudliar, Abhishek Naik, and Prasenjit Bhavathankar. A fully observable supply chain management system using block chain and iot. In *2018 3rd International Conference for Convergence in Technology (I2CT)*, pages 1–4. IEEE, 2018.

[11] Ilhaam A Omar, Raja Jayaraman, Khaled Salah, Mazin Debe, and Mohammed Omar. Enhancing vendor managed inventory supply chain operations using blockchain smart contracts. *IEEE Access*, 8:182704–182719, 2020.

[12] SA Pranesh, N Viswanathan, M Vijayalakshmi, et al. Design and analysis of incentive mechanism for ethereum-based supply chain management systems. In *2020 11th International conference on computing, communication and networking technologies (ICCCNT)*, pages 1–6. IEEE, 2020.

[13] Vishal GaurAbhinav Gaiha. Building a transparent supply chain. https://hbr.org/2020/05/building-a-transparent-supply-chain.

[14] Eric Wagner, Roman Matzutt, Jan Pennekamp, Lennart Bader, Irakli Bajelidze, Klaus Wehrle, and Martin Henze. Scalable and privacy-focused company-centric supply chain management. In *2022 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*, pages 1–5. IEEE, 2022.

[15] Hong Li Yin and Yong Ming Wang. Optimization for decentralized-dual-channel supply chain based on game theory. In *2013 25th Chinese Control and Decision Conference (CCDC)*, pages 2750–2754. IEEE, 2013.