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Blockchain Driven Supply Chain Management: A Promising Tool

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***Abstract*— It is wide known that the use of Blockchain technology (BCT) has recently become widespread. It has emerged as an essential tool in various academic and industrial fields, such as healthcare, transportation, finance, cybersecurity, and supply chain management (SCM). This paper provides an overview of the characteristics, mode of operation, and applications of BCTs in SCM. The aim was to identify the key research themes addressed in existing studies within the field of SCM and suggest future research directions for this field.**

Keywords*— *Artificial Intelligence; Big data; Blockchain; Blockchain Technology*; *Industry 4.0; internet of things*; *Supply Chain Management.

I. INTRODUCTION

A Blockchain is a technology that chains several blocks of information together in ways that are decentralized, traceable, and unalterable. It was first introduced in 2008 to track transactions of the decentralized digital currency Bitcoin. Various transactions are verified in a distributed and decentralized database and can be updated on all nodes of the peer-to-peer (P2P) network. Each block formed is a collection of new information gathered whenever a transaction occurs, and it has a unique hash value based on complex computations [1]. Blockchain technologies (BTCs) are a form of distributed ledger technologies that allow multiple parties to engage in secure, trusted transactions without any intermediary [2]. BCT can be applied to some specific areas of supply chains such as smart contracts, asset tracking, secure and error-free order fulfillment, and cybersecurity. Smart contracts help companies to exchange money property, shares, or anything valuable in a reliable, transparent, and conflict-free way. Hence, the transaction time and costs will be minimized. One of the main functions of the BCT is to track and record all the supply chain activities of a particular asset from its origin to its final destination. This is called the asset tracking feature of Blockchain. This feature of the BCT hedges companies against fake transactions and make it easier to track goods throughout the supply chain. The asset tracking capability of BCT reduces the risk of loss and damage during transit. BCT can expedite the order fulfillment process with its merits such as rapid confirmation of customer credit history, quick inventory status analysis, order/shipping status notification, and offering transparency throughout the order fulfillment process. Growing cybercrime threats in recent years imposes a high risk on supply chain networks. BCT, with its visibility, privacy and, non-stop information verification features, is an outstanding technology that mitigates the cybercrime risks in supply chain networks chain networks.

As the today's business environment continues to become increasingly connected and transparent, the development of new emerging technologies such as internet of things, big data analytics, artificial intelligence, and Blockchain revolutionizes the way of existing business and industrial processes and it enables the creation of new business models. At the same time, organizations have to struggle with challenges such as limited asset management, empowered customers, high transaction fees, and the lack of end-to-end visibility. Moreover, today's record keeping systems in supply chain are centralized, trust based and require immediately third-party enforcements which can lead to bottlenecks, miscommunication and even slowdowns to optimal transaction time. Companies can greatly benefit and address these challenges notably by using Blockchain applications. Blockchain technology creates unprecedented visibility and accountability through peer-to-peer, distributed and time stamping transactions in the supply chain. In essence, Blockchain is a decentralized and distributed ledger technology to provide transparency, data security and integrity. Blockchain can record each sequence of transactions from raw material to finished product along the supply chain on a series of blocks or ledgers which are organized in chronological order and are linked through cryptographic proof. The records are accessible to all authorized participants involved, but cannot be modified or manipulated [3].

Blockchain is a decentralized digital ledger where data is stored in blocks secured using cryptographic principles. BCT's main components are node (server), transaction, block (set of transactions), ledger (where the transactions are recorded), and hash (algorithmic function). Blockchain is an internet-based technology that is valued for its ability to validate publicly, record, and distribute transactions in immutable, encrypted ledgers (see Fig. 1).

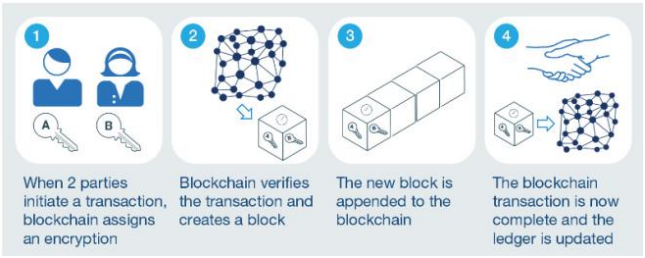

Fig. 1. How the transaction works with Blockchain [4].

Regardless of the growing effort into Blockchain implementation globally, the public seems confused between Bitcoin and Blockchain. The analysis of Google Search reveals a strong positive correlation 2 between "Blockchain" and "Bitcoin Price"(see Fig. 2), which implies that the Bitcoin price dominates the public attention on Blockchain. When the Bitcoin price rises, the public attention on Blockchain grows accordingly. This observation can be further justified by the change in Blockchain investment funding in 2018 and 2019. After a price peak in December 2017 to almost $20,000, Bitcoin declined by 83.5% to $3,214 in December 2018. Coincidentally, Blockchain investment dropped about 30% in 2019 compared to 2018.

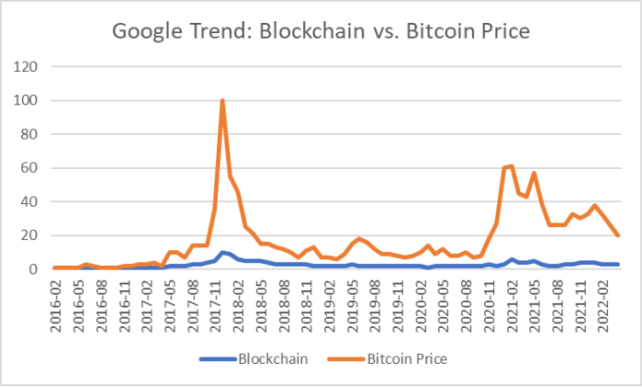

Fig. 2. Google Trend: "Blockchain" vs. "Bitcoin Price" [5].

II. BACKGROUND

A. Blockchain Overview and Architecture

Each block has a header and a body. The header contains a hash value and a hash reference that points to the hash of the previous block, and as each hash reference of each block points to the block generated before it, this sets up the chain between blocks. All transaction types of blocks are recorded in a ledger that is shared by all the connected nodes in the network. A transaction is confirmed by the nodes only when a block is added. A consensus protocol needs to be verified and maintained for each block. Because many nodes or computers are connected as a chain and each node has a copy of the main chain, the information cannot be easily accessed by hackers. If hackers want to break a block, they must break the hash reference that is pointing to the previous hash. Because of the protective processes embedded in Blockchain technology, breaking the chain is impossible at present. Participants manage the Blockchain using matching mechanisms such as Proof-of-Work (PoF), Proof-of-Elapsed Time (PoET), or Proof-of-Stake (PoS). Fig. 3 shows the Blockchain architecture, and Fig. 4 shows how transactions are managed in Blockchain.

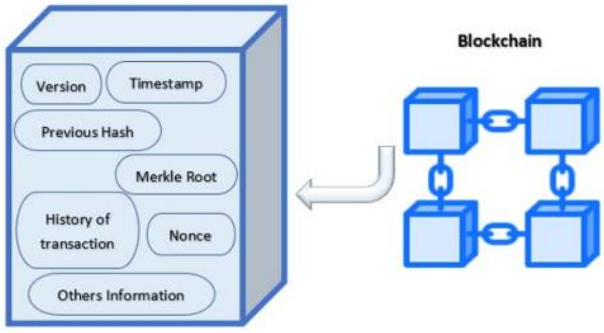

Fig. 3. Architecture of a block in blockchain. [1].

There are two types of blockchain technologies:
• **Public Blockchain:** It is decentralized. Users can put data into it and view the data, and it is open to all. No permission is needed to access the blocks.
• **Private Blockchain**: Only legal users can access the information in the blockchain, and they must maintain
their authentication and control of the access.

There are three phases in creating a Blockchain: Blockchain 1.0, Blockchain 2.0, and Blockchain 3.0 [6][7][8].
• Blockchain 1.0: Digital currency, such as Bitcoin, is the first production application of blockchain.
• Blockchain 2.0: Refers to economic and financial applications such as Ethereum.
• Blockchain 3.0: Refers to applications related to the digital society, such as education, healthcare, and government, where money is not involved.

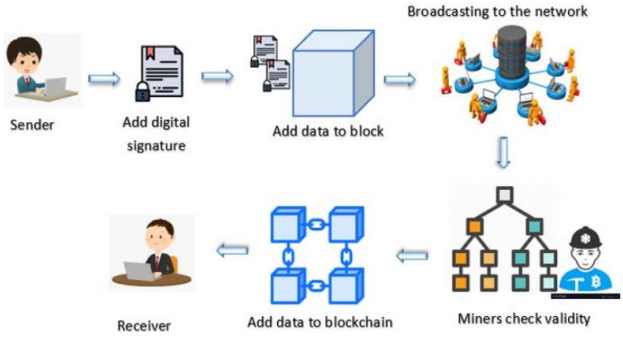

Fig. 4. Blockchain-based transaction process. [1].

From the perspective of the value factor and maturity, there are four different phases of Blockchain technologies, Blockchain 1.0, Blockchain 2.0, Blockchain 3.0, and Blockchain 4.0, as analyzed in [9]. The application area of Blockchain 1.0 is related to digital payment systems and currency transfer and remittance, which are mainly transaction oriented. Bitcoin is an example of Blockchain 1.0. A smart

contract is an example of Blockchain 2.0; it provides value in the area of privacy. An opensource software platform called a decentralized application (dApp) uses blockchain 3.0 and is a platform on which application developers can conduct their transactions. Blockchain 4.0 is considered an emerging technology that uses a decentralized artificial intelligence (AI) system driven by autonomous decision making.

B. Blockchain Driven Supply Chain Management

As a game-changer, Blockchain alone does not solve visibility and traceability challenges in supply chains, implementing emerging technologies with Blockchain effectively can facilitate connection and enhance efficiency, transparency and accountability from origin to completion among participated partners. Blockchain is clearly used with both Internet of Things (IoT), B2B and machine-to-machine (M2M) integrations. Notably, IoT and Blockchain technology have been rapidly approaching each other, in the very near future, blockchain systems will work with data generated from both near-edge or far-edge physical IoT devices (i.e., sensors, actuators, embedded devices) used in logistics and transport. Combining Blockchain's distributed ledger framework 150 Logistics 4.0: Digital Transformation of SCM with these applications and other emerging technologies such as smart mobile devices, artificial intelligence, augmented reality/virtual reality, cloud computing, edge computing, 5G, Radio Frequency IDentification (RFID), etc., can improve real-time process monitoring and tracking capability of (AR/VR) supply chain and logistics systems. In this area, industrial applications have begun to be seen even at the pilot stage. In particular, those with established Blockchain platforms—logistics companies and customers doing business in specific areas automate their commercial transactions during freight shipment by employing smart contracts based on Blockchain technology. Smart contracts improve traditional contracts by implementing rules that control the transfer of currencies or assets under certain [3].

Fig. 5. denotes asset tracking examples for Blockchain driven supply chain management using smart contracts and emerging technologies with supply chain ecosystem participants such as supplier, producer, transport provider, distributor, retailer and customer. Supplier A supplies the raw materials in bulk trucks, the transaction with information about raw materials, their origins and properties addressing environmental issues are recorded. Barcode and IoT applications can be used to generate data. After manufacturing factory B received the raw materials from supplier A, the quality and quantity of the materials are checked. Here, a smart contract is established and electronic entries are generated about this transaction. If the properties of raw materials are matched with the requirements of manufacturer B, then the goods are accepted, else sent back to suppliers. This rejection is also recorded to the blockchain ledger. Factory B produces goods which leave the factory in containers on wagons by rail transport and reach the shipping terminal C. Each product gets its own QR code and also containers are tracked by implementing RFID tags and IoT sensors. The containers are carried by sea transport in vessels from terminal C to terminal D. All road conditions are tracked by using Global Positioning System (GPS), General Packet Radio Service (GPRS) technologies, also the ambient temperature is tracked via time temperature sensors with sensor devices connected to a wireless sensor network (WSN). Then, containers are carried with trucks by road transport to warehouse/distribution center E. The transportation data is also recorded with temperature and localization sensors. The containers are handled at distribution center E, the quality and quantity of goods are checked and recorded by using indoor localization sensors, room temperature and humidity sensors and RFID tags. Smart contract is also established to check whether the products meet the requirement and then these are sent to retail point F by city logistics. Along the city distribution process, all temperature, humidity, localization data are recorded. After reaching the retail point F, room temperature, localization sensors are used to track the selling goods at the retail stores. Smart contract is used to check whether the goods are in required conditions. At the end, product item is bought from customer G by using Near-Field Communication (NFC) technology and its quality checked through the QR code or RFID on the packaging by using smart phone application. Cloud computing and edge computing to operate big data and instant data (advanced) analytics are also used as complementary technologies with Blockchain to increase security or quality of the data. Cloud computing operates on "bigdata" to identify risky transactions along supply chain which gives alerts and enables to make better decisions in the Blockchain platform, while edge computing operates on "instant data" that is on-site real-time data generated by sensors or users to assist instant decision making. For example, defective products are detected through big data analytics and returned to the factory before arrived at retail shelves which minimize recall costs of the defected product. Using emerging technologies with Blockchain help to connect the participants of the supply chain to each other, so that, all transactions throughout the supply chain system are recorded on the Blockchain platform.

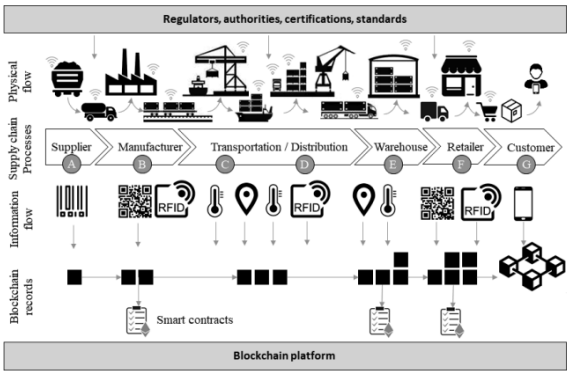

Fig. 5. Blockchain Driven Supply Chain Management [3].

Ecosystem participants access the Blockchain platform via open Application Programming Interfaces (APIs), which allow communication with protocols and smart contracts and their integration to Blockchain services. The Blockchain platforms in the supply chain industry are mostly established by using standard templates of BaaS based business models.

III. CURRENT STATUS OF BCTs IN SCM

A number of Blockchain-based solutions have been launched to facilitate international trade. In August 2018, Maersk and IBM announced that the two companies jointly developed a Blockchain-powered shipping solution TradeLens (https://www.tradelens.com/). The goals of TradeLens are to bring various parties involved in international trade together, support information sharing among them, and enhance transparency. As of March 2020, TradeLens network consisted of 150 members. That included five of the world's top six ocean carriersdAPM-Maersk, Mediterranean Shipping Company (MSC), China Ocean Shipping Company (COSCO), Hapag-Lloyd and Ocean Network Express (ONE). Together they represent over half the world's container cargo capacity. By March 2020, the platform had processed 15 million containers. There are a number of other similar initiatives. In November 2018, nine ocean carriers and terminal operatorsdCOSCO Shipping Lines (China), Compagnie Maritime d'Affrètement and Compagnie Générale Maritime (CMA CGM), Evergreen Marine, Hong Kong-based Orient Overseas Container Line (OOCL), Yang Ming, DP World, Hutchison Ports, PSA International and Shanghai International Port, and CargoSmartd announced that they would form a consortium to develop a blockchainbased platform, Global Shipping Business Network (GSBN). The Blockchain software will be created by CargoSmart, which is a software company funded by Hong Kong-based container shipping and logistics service company OOCL. OOCL is a founding member of GSBN. Likewise, in the early 2018, it was reported that AB InBev, Accenture, APL, Kuehne þ Nagel, and a European customs organization tested a Blockchain solution to exchange documents. While these companies are mainly based in developed countries, some of them have significant operations in the developing world. In addition, we discussed above some Blockchainbased solutions used in international trades in which most of the participants and beneficiaries are developing world-based [10].

BCT disruptively changes the way traditional SCM runs, while concludes that technology is one of the main critical and dominant barriers for Blockchain in SCM that would pose a threat specifically to industries with anxiety toward technology adoption. To illustrate the struggles of brick-and-mortar retailers (e.g., Macy's, J.C. Penny, Toys R US, etc.), cable T.V. service (e.g., Direct TV, Dish, etc.), traditional news media (e.g., local newspapers, etc.), and many others are creating a consensus of FOMO—fear of missing out— with technology adoption. Therefore, the advent of the Blockchain immediately drew public attention, and companies flocked to embrace the technology without hesitation. However, given the irrational pulse for technology adoption combined with the bewilderment of Bitcoin and Blockchain, many unsuccessful Blockchain projects emerged, and the failure rate is reported to be 92% [11].

Much of the available literature on Blockchain focuses on the technicalities of the technology with limited research investigating the organizational or business process complexities of its adoption and deployment. Due to the scarcity of literature on practice, studies based on literature reviews have tended to identify recurring themes. These largely discuss Blockchain technical aspects, including Blockchain maturity, design, scalability, block size, governance and interoperability. Although Blockchain has been strongly advocated for supply chain applications, only a small number of empirical studies have investigated its adoption in practice in a supply chain context. The main drivers identified included improved visibility, transparency and reduced costs, while the main barriers included lack of understanding of costs and limited perceived benefits of Blockchain [12].

The recent studies in the area of BCT depict its popularity beyond the realm of cryptocurriencies. SCM is one of the many leading areas discussing the applicability of BCT. Numerous works in the past have been published stating the use of BCT for managing food, agriculture, retail, hospitality, and pharmaceutical supply chains. SCM has always been a challenging task for organizations, and, specifically post pandemic, the complexity and challenges have increased manyfold. SCM holds the key to numerous economic activities of a country, and any disruption may lead to large fiscal deficits and job losses. Companies need to modernize SCM practices in order to stay relevant and possess a competitive advantage. Blockchain integration with SCM serves this purpose by providing viable methods of asset tracking while ensuring security and data integrity. Data being generated at every stage of the supply chain are recorded in the form of transactions. Blockchain enabled systems are transparent in nature and support the real-time data collection of a product across the entire supply chain. The entire lifecycle of a product can be managed using BCT while ensuring quality control. BCT has the potential to contribute to various aspects of SCM such as physical and digital asset tracking; tracking orders and payments; and managing invoices, licenses, and copyrights. The decentralized nature of Blockchain enables a continuous information flow and facilitates the seamless sharing of this information between suppliers, vendors, manufactures, and end-user customers across the entire supply chain. The absence of a central authority, the presence of a distributed ledger, and a trust-based ecosystems enable Blockchain to weave a network of complex assembly lines [13].

BCT is currently undergoing tremendous innovation. Innovation in Blockchain solutions, along with smart

contracts, internet of things (IoT) adoption, big data implementation, artificial intelligence (AI) and machine learning can result in tremendous potential for digital disruption. In Blockchain enabled supply chain practices, a smart contract ensures the automatic change of ownership of a product once the product moves across various supply chain actors such as manufacturer to distributor and helps in easier tracking and trust-building amongst stakeholders [14].

IV. CHALLENGES AND FUTURE DIRECTIONS

Despite a series of opportunities that the adoption of BCT brings to the industry, the shortcomings of Blockchain are still notable for discussion. In this section, we discuss the challenges that the industry is currently facing to whilst the integration of Blockchain into the existing SCM system. According to [15], the authors summarize 3 challenges that are urgently waiting for a solution to facilitate large scale adoption of Blockchain into industry, and moreover we also discuss the potential mitigation as the direction of future advance. These challenges are performance, scalability and privacy. Blockchain is an evolving technology with multiple innovations happening in this field. As part of the scope for future research, the applicability of smart contract and IOT can be studied. A smart contract, along with IoT, has more potential and usage in supply chain management for effective end-to-end product tracking. This area can be explored more as part of the scope of future research [16]. According to [17], BCTs global contribution to the supply chain industry is estimated to reach $424 million by 2023. In the near 5 to 10 years, SCM is likely to be among the most successful implementations of BCT, and BCT is likely to become the standard in SCM. Fig. 6. shows the SWOT study regarding adoption of BC in supply chain.

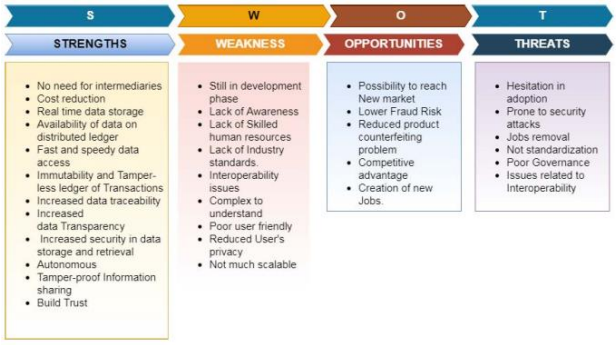

Fig. 6. SWOT study regarding adoption of BC in supply industry [17].

Because several obstacles and restrictions have already been recognized, acceptance of BCT into supply chain processes won't be as easy as anticipated. In a 2017 poll conducted by ABI Research, 93 percent of those making decisions across nine industrial areas stated they were unfamiliar with BCT, while 7% said they were conducting preliminary research on the technology. The most significant obstacle to BCT implementation in the supply chain is an image problem. Many people associate BCT with cryptocurrencies like Bitcoin, and cryptocurrency has a bad reputation owing to its usage in illicit activities. As a result, individuals are hesitant to embrace it. Many businesses have no idea what BCT is or what it can achieve. The second major issue is the lack of interoperability across several BCT networks. Interoperability refers to the capacity to share data, operate, and transact across several BCT platforms. Organizations are building their own BCs and apps to operate on top of them due to the lack of a common standard. Thousands of projects are now using various BC systems, the majority of which are standalone. They employ a variety of protocols, coding languages, consensus methods, and privacy protections. The issue is that the BCT sector is chaotic since there are so many different networks. Another major issue is a scarcity of qualified developers. As a result, companies cannot access the necessary pool of BCT capability to connect in BCT adoption. The widespread execution of BCT in worldwide supply chains faces significant regulatory and legal obstacles. Because each stakeholder in a BCT ledger might be in a different world, it's impossible to say which jurisdiction a BCT would fall under. Choosing which law(s) to follow and which courts have the authority to decide on certain issues may be a complex and sometimes contradictory process. A BC system has no one owner due to the nature of BCT [17].

V. CONCLUSION

BCT is employed in SCM in a variety of sectors. The present state of use of BCT and Smart Contracts in numerous major industrial domains is studied in this research working. The study delivers academically sound data on the overall state of BC deployment for various supply chains. The study's findings and conclusions show that research on BC-based supply chains is a growing topic garnering a lot of attention. The majority of the reviewed papers that were evaluated agreed on the prospective benefits that BCT may offer to the supply chain.

According to [16], effectiveness can be measured by establishing performance metrics. BCT is an enabler for smart logistics via easy product traceability, and a Blockchain-based logistics system results in better predictive maintenance. The usage of Blockchain Platform in supply chain ecosystem creates sustainability practices among stakeholders. Interoperability features of blockchain such as security, resilience, reliability, flexibility, and collaboration results into driving smart logistics for real time tracking of products through integrated platform. Blockchain establishes sustainable supply chain practices by building transparency among ecosystem stakeholders.

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