CHAPTER THREE

Blockchain Technology: Supply Chain Insights from ERP

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Contents

Abstract

The chapter provides a high level understanding of how ERP system alongside Blockchain technology will be a powerful tool to improve supply chain operations. The chapter details out how the two technologies will complement each other in every aspect of supply chain functions bringing in transparency, efficiency, and cost reduction. The chapter considers every aspects of supply chain for an ERP enabled organizations and details out use cases for master data, engineering design, sales process, procurement process, demand and supply planning process, manufacturing process, and logistics management processes. The chapter provides use case details and high level

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understanding of technology for product provenance and how it can bring in supply chain transparency using blockchain. The chapter illustrates theoretical and conceptual model for use of open and permissioned blockchain in different supply chain applications with real life practical use cases as is being developed and deployed in various industries and business functions. The chapter also emphasizes the use of blockchain in distribution industry and how it can solve pertinent problems as it exists today in the distribution supply chain. The chapter ends with an outlook of blockchain how it will shape the future to come and challenges which lies there within.

1. A BRIEF INTRODUCTION TO SUPPLY CHAIN, ERP, AND IMPLICATION OF ERP ON THE SUPPLY CHAIN

Supply chain management (SCM) is an established and essential business process in every organization today. SCM uses specific processes to connect a customer's requirement with a supplier through a channel. Supply chain practices involve numerous subprocesses. Over the years, technology developments have effected significant change and improvement in these practices across demand, operations, supply, and distribution. There has been tremendous development in technology to rationalize and improve supply chain processes. For instance, in the last four decades, supply chain technology has evolved from material requirement planning (MRP) to manufacturing resource planning (MRP II), to enterprise resource planning (ERP), and, finally, to advanced supply chain planning and optimization (APS/APO). All these systems depend heavily on technology. Of all the technologies, ERP is having the most noticeable impact on the supply chain improving its operations and maturing its practitioners. There has been numerous research findings which supports that ERP has positively impacted a firms supply chain performance [1–3]. Today, almost all leading companies run computerized ERP and supply chain management software (Brody, 2017).

Over the past two decades, ERP has had the most significant impact on supply chain business processes. However, despite employing large-scale digital infrastructure, most companies struggle with visibility into demand, orders, and supply. Further, they lack insights into where their products are at any given moment outside their organizations network. Li et al. [4] and Ince et al. [1] acknowledge that ERP improves supply chain effectiveness and increases its performance and competitive advantage. Koh et al. [35] highlighted the need of ERP II to share information across different ERPs

in supply chain. The concept of ERP II clearly states that there is gap existing between the ERP systems (across organizations) resulting in fragmented information. The research of Koh el al. [36], Addo-Tenkorang and Helo [37] highlights the need for an open system to make information available to supply chain trading partners. The reason for this gap is ERP primarily improves internal organization operations but hardly impacts anything outside the organizations. Thus, as a software product, ERP continues to evolve, particularly with cloud technologies and analytics but still lacks connectivity across its stakeholder outside the organizations.

ERP can be described as a system that integrates an organization and its resources to maximize resource utilization and improve planning. ERP transforms how the organization interacts internally as well as externally. It provides a common platform for different organizational departments like production planning, material planning, operations, inventory, warehousing, design, sales, distribution, accounting, and customer service to act as a unified entity. This enhances the customer experience, operating efficiency, delivery execution, and help track and improve supplier performance. ERP seamlessly marries information flow to material flow creating a homogeneous environment for computerized business processes. It removes physical boundaries, strengthens centralized processes, and globalizes IT architecture.

ERP systems are generally sold as packaged software by companies like Oracle, SAP, Infor, etc. ERP systems can be standard or bespoke. An important point to note is that while ERP transforms an organization's internal operations and the way it interacts with stakeholders, it does not connect one organization to another or create a network among partners/stakeholders. Even today, most companies rely on point-to-point messaging systems like XML or EDI to exchange data and in more recent years SOA architecture. So what is missing in today's IT supply chain world is a network that can connect ERP systems irrespective of their original developers and underlying technology. This is where blockchain can play a pivotal role.

With blockchain, ERP systems can come together to form an integrated platform across partners/stakeholders, providing data that cannot be manipulated (true record) and an audit trail for transactions that happen within the extended ERP network. This is the key tenet of this chapter. The focus of this chapter is to connect the supply chain processes in ERP system across industries and domains with blockchain in order to help practitioners achieve greater efficiency and cost benefit in final delivery of product.

2. ERP TRANSACTIONS, INDUSTRY USE CASES, AND GENERIC USE CASES WITH BLOCKCHAIN

As mentioned earlier, ERP transforms internal supply chain operations and processes from order booking to order fulfillment. Supply chain interacts across partners like suppliers, manufacturers, service providers, customers and so does their ERP systems. All these processes, subprocesses, and ERP systems can be integrated with a centralized blockchain for further improvement beyond what is possible with ERP. But first, companies must develop key integration capabilities so that blockchain can integrate with enterprise systems. The underlying principle is to connect all the partner ERP systems to a blockchain network. This can be an open network or a private permissioned network. This combined entity of ERP and Blockchain can complement each other's capability and provide a seamless supply chain transaction across partners.

In open architecture, all partners (ERP systems) can join/connect to the network. Here, miners play a significant role. Transactions as passed by members to the system and are verified and authenticated by miners before they are posted as a block. Organizations can use product, industry, or business-specific blockchains that are permission controlled and leverage a private permissioned blockchain network. In a private blockchain network, the ERP systems are connected to the blockchain. Smart contracts play a vital role in permissioned blockchains. Here, member entry can be decided either by existing members or by the network owners. Smart contracts determine the underlying rules of processes, validations, and interactions.

In either case, Blockchain with its distributed ledger will act as the central backbone for all its partner ERP systems or as a centralized repository across all partners. The data originating from ERP transactions can be channelized to blockchain as per the need, design, or smart contract of the use case. This extended enterprise platform can also drive multiple use cases by deriving value from all the connections across the partner ERP systems. These connections will help commercial operations/transactions, compliance, service operations efficiency, extended supply chain planning capabilities, and data consistency across enterprises, product provenance, and data sharing abilities, thereby enabling informed decision-making.

There are many industry-specific consortiums that bring together data, suppliers, customers, governments, supply chains, and even individuals onto a single platform to achieve a common goal. Most of them are privately

owned like Trade Service, OceanConnect, Exostar, and SiliconExpert. Companies subscribe to these consortium for data feeds. These industry consortium get the feed from manufacturers, etc. and enrich those data and feed it to their customers. The customers who are also a member of the consortium have their own transactional system. As the feeds are from multiple manufacturer or partners and that data is fed into many member systems the data lacks standardization. This also leads to lack of trust and independence. But, with Blockchain technology, industry-specific blockchain consortiums can maintain standardization, transparency, objectivity, and neutrality. Blockchain can bridge gaps in technology, transparency, and concurrency among various ERP systems so they can integrate effectively. This improves supplier relations, customer management, and margins while delivering cost savings and value generation on end products savings for all members.

The future sections of the chapter covers the various functions of ERP for supply chain and how it can work with blockchain as an integrated system.

3. MASTER DATA MANAGEMENT ENABLED BY BLOCKCHAIN

ERP systems (or any information system) transacts, processes, and makes decision based on data. The performance of enterprise systems depends heavily on the quality of data [5]. Thus, quality of the master data information should be up-to-date, accurate, and complete. Analyst firm Intelligent Business Strategies estimates that poor quality customer data costs US businesses around US $611 billion a year [6]. In reality, most data resides in private silos within a company and is not widely available. Even governmental data, which everyone has a right to view and use, is not easily available. While there have been attempts to release governmental data to consumers like citizens, businesses, and other organizations so they can make informed decisions [7], most of the data is not open. Similar is the case in business scenario and only some data is shared across consortiums like Trade Service, Industry Data Warehouse, Silicon Experts for distributors from manufacturer.

From a supply chain perspective, all enterprise systems have three sets of master data. The first set is the item (product) information as stored in the enterprise. These items also has the customer item name cross reference and

the supplier item cross reference maintained. The customer item means in the customer enterprise system the same item is known by a different item name/designator and supplier item means in the supplier enterprise system the same item is known by a different item name/designator. The second set contains the customer name (business entity name) with whom the enterprise does the transactions with, stored in the enterprise as the customer master data. The third set is the supplier name (business entity name) with whom the enterprise does the transactions with, stored in the enterprise as the supplier master data.

Say a distributor or retailer sells a product to its customer. In the distributor enterprise system, the product is known as product X; in the customer's enterprise system, it is called product Y; and in the supplier's enterprise system, it is called product Z. All these names/item designator refer to the same product. Every supply chain transaction that happens across enterprises must carry these cross references. Currently, all leading ERP systems (Oracle, JD Edwards, SAP) have the functionality to maintain customer item and supplier item cross references with its own enterprise's naming convention. So, the data exists independently in every ERP system of the enterprise. This approach has several challenges in the areas of:

1. Data setup: The data must be set up as cross references. Further, since access to data is privileged and is not openly available, it must be provided by the business entity for setup. This is a time-consuming and effort-laden process.
2. Data maintenance: The data must be maintained well in the enterprise system. Changes must be updated regularly to prevent asynchrony as out-of-sync data can negatively impact business transactions.
3. Data standardization: Since data is independently set up in every enterprise, it lacks standardization. This leads to maintenance issues, process slowdown and transaction failure. Unstructured and inconsistent data can negatively impact business transactions.
4. Multisystem architecture: The data depends on enterprise systems and this architecture must be integrated across multiple systems (satellite systems), which is challenging and tedious.

These challenges highlight the need for centralized system which can act as the universal data repository. Blockchain with its capability to interact with multiple enterprises can act as centralized repository. Blockchain will master and govern the data which will be accessible to all its nodes. This will enable the centralized availability of truth (data) with all its details like characteristics, description, technical attributes, business names, etc. Blockchain being

the unbreakable and impenetrable single source of truth the data will be securely available to all its nodes and any changes will be reflecting almost real time. There will be no scope of counterfeiting and other malicious attempts to jeopardize the data which is centrally available for all its members. When manufacturers, distributors, and retailers become part of the blockchain network, it will be the nodes and can streamline data management and transfer. For instance, the manufacturer can create, name, and characterize an item using a part number ID. This information is passed into the Blockchain and becomes the Blockchain part number ID. In this way, blockchain serves as the central information repository of the item along with all its technical information, and all the partners will have access to this information.

Now, when all partner ERP systems are connected to the centralized blockchain, the unique blockchain part number ID can be easily accessed by all the partners and converted to suit their systems. Any partner intending to do business can transfer the data from the blockchain and convert it for their ERP system. Thus, the blockchain also serves as a product marketplace whereby any partner wanting access to item data can refer to the blockchain and reach the partner/source. In this way, every unique part generated by the manufacturer can be associated with every partner, eliminating the need for separate customer and supplier part numbers. This will facilitate smoother transactions, lower transaction failure rates, and provide highly standardized data across all supply chain partners. This will also reduce the burden of generating Point Of Sale reports as the items designator will be same. This will also smoothen the claims and returns because of same item. This will also reduce time for product recall.

Another important type of master data is customer and supplier data also known as trading partner data. There is no standardization of customer data (name, address) and supplier data (name, address). This means that every system and company has a different way of storing this data. Currently, most companies use the Data Universal Numbering System (DUNS) to standardize and identify businesses. DUNS is a proprietary system developed and regulated by Dun & Bradstreet, Inc. (D&B) that assigns a unique numeric identifier, called the "DUNS number," to a single business entity or its legal address.

When it comes to customer and supplier data, the DUNS number can uniquely identify the entities with an address. The information is limited to the DUNS number. D&B is currently testing a project that allows its customers to verify the identity of a potential business partner through a unique

Blockchain identifying number that corresponds to the traditional D&B DUNS number [8].

Here is how DUNS will use blockchain. Say Company A in the United States wants to buy a product from Company B in Singapore. As these two firms have never done business before, A wants to verify the authenticity of B. Since A is part of the D&B blockchain consortium, it can download a node from the cloud where this blockchain instance resides. Typically, each node in the blockchain will be automatically updated with all the data contained as the blocks (from various companies, like B) are validated and updated with transactions. In this way, company A can search through its node and verify that B has a corresponding DUNS number and is a bona fide company. It is to be noted this feature is only available for D&B blockchain consortium customers.

The value of such a blockchain can be extended by connecting the ERP system of company A with the D&B blockchain consortium. This enables automatic verification whenever a new customer or supplier needs to be on-boarded. The D&B blockchain consortium is built on the open source Ethereum blockchain platform. This allows trading partners to confirm their identities and the terms of contracts through secure and immutable digital records that are stored on D&B's blockchain. The blockchain system matches the inquiry of the partner using DUNS numbers to a unique blockchain identifier code that is created for each company. It is to be noted that existing feature of D&B authentication through the API will still be available. The intent of moving to blockchain based authentication is to reduce the cost of authentication. Connecting it to ERP may provide further cost advantage.

Clearly, blockchain technology can help companies standardize data, connect ERPs, and create transparent consortiums with better security and authentication procedures. Blockchain will revolutionize how companies operate and maintain master data of items, supplier names, and customer names. In blockchain, every node is up-to-date, and the data is immutable. This drives data standardization, transparency, synchronization, and security across business entities and eliminates the risk of data duplication.

4. BLOCKCHAIN-DRIVEN ENGINEERING DESIGN

Engineering design is about using tools, techniques, and scientific knowledge to solve technical problems. Today, there are specialized firms that provide engineering design solutions in their areas of expertise. While

these institutions store high volumes of propriety information, data is often tightly controlled and communicated only through people or technology interfaces. This process involves a lot of bureaucracy. To combat this, the engineering design sector has developed design software that integrates with ERP systems to transfer data for business transactions.

A typical example is the CAD/CAM system that integrates with the ERP system and transfers bills of material and routing data to ERP. Other examples include quality monitoring system, 3D printing, technical product evaluation system, etc., that also integrate with ERP systems. As these systems operate independently, integrating them with blockchain as well as ERP systems will provide significant advantages. One example of such integration is SAP Leonardo that provides customers and partners with access to standard SAP products that are enhanced and augmented with blockchain functionalities.

Here is how blockchain can be used for engineering design:

- Single platform: In engineering design, blockchain can unify customers and partners across the globe onto a single platform, thereby cutting across ERPs. This simplifies identity ownership, verification, authenticity, data provenance, sourcing, and reconciliation processes. Besides accelerating design and prototyping processes, it will also encourage joint manufacturing.
- Certifying agents: In the manufacturing sector, there are third party agencies, or certifying agents, that provide verification services, benchmarking services, certificates, and material identification services. One example is the National Center for Manufacturing Sciences that matches companies with complimentary abilities. These certifying authorities/agencies share data as physical or even digital copies, which makes auditing cumbersome and time-consuming. In cases where quality issues arise, the timely availability of these certificates and their authenticity become extremely critical. When ERP systems of the certifying agencies are connected through blockchain, it greatly simplifies such transaction processes by enabling transparency.

French automaker Renault [9] is already using a Blockchain solution based on Microsoft Azure to manage car ownership and maintenance details, track its products in the market, and simplify the release of new designs. Typically, maintenance records of an automobile usually reside with various repair shops, insurers, or dealers. This makes it difficult for original equipment manufacturer (OEMs) to push new changes or designs to existing models or sold cars. In case of product recall, the manufacturer is forced to depend

on dealers as they have no direct access to customer information. Blockchain not only solves these issues but allows manufacturers to push newer designs and track products in the market.

5. BLOCKCHAIN-DRIVEN ORDERING AND PROCUREMENT

5.1 Procurement

Procure-to-pay or source-to-settle is a core procurement process involving sourcing decisions, supplier selection, supplier on-boarding, purchasing, receiving, supplier invoices, and payments. This process extends beyond the procurement division to include the finance, warehousing, and legal departments. Typically, all these processes occur in an ERP system involving data transfer and interaction across trading partners.

Today, blockchain can significantly change how these transactions take place. For instance, legal and procurement teams negotiate with trading partners to establish standards, terms, and conditions, transferring data through the system. Such data is stored either electronically or on paper. By enabling smart contracts between trading partners, blockchain can provide a digital and automated record that is constantly updated with the status of sold and delivered goods. It can establish rules and enable authentication, all of which will be stored on the blockchain. Thus, blockchain can also serve as a single repository for data exchange and invoicing.

Here is how blockchain can address common procurement challenges:

- People, places, and processes: These are the three major gaps in procurement. When a product arrives at the customer's location, the customer has no clear information about where all the product has been through, who has handled it and what kind of processes were involved in manufacturing it. Blockchain can store product information across the procurement lifecycle such as how it was made, who made it, where it was made, and product provenance. This provides customers with track-and-trace capabilities, enabling better visibility, greater control, lower risk, and improved regulatory compliance. This is detailed out further in the product provenance section.
- Standardizing terms: Most payment terms, freight, and discounting terms are not standardized across trading partners. This means that organizations must juggle several terms for different partners in various geographies, categories, and business lines. Blockchain can streamline this task by maintaining smart contracts. This will eliminate the need for multiple

data maintenance and there will be one authentic centralized data repository of terms and conditions accessible to all partners.

- Seamless integration: Disputes on supplier invoices for delivered goods are very common and key concern across enterprises. Gartner and J.P. Morgan estimate that, on an average, 10%–40% of all supplier invoices are disputed [10]. IBM Global Finances [11] survey shows that over US $100 million in invoices are in dispute between the buyer and supplier at any moment, requiring an average of 44 days for resolution. Blockchain can eliminate such causes for dispute by nearly 90%–95% [12–14]. Smart contracts allow details like proof of origin and delivery to be hosted in the immutable blockchain ledger, thereby authenticating demand, transfers, and transactions and reducing disputes. Also in case of disputes the data from blockchain (which is immutable) acts as the ultimate truth of evidence to easily settle the differences.
- Messaging system between partners: Typically, trading partners interact through email, EDI messaging, or B2B messaging systems. Blockchain can replace all these three systems by providing a unified business messaging system. While Margo [15] believes that blockchain is the new type of B2B standard messaging system, its success depends on widespread adoption. Through secure, auditable, and transparent information, blockchain can overcome the limitations of one-way, point-to-point, and batch approaches of existing messaging systems.
- Supplier benchmarking: Blockchain can help form consortiums in business-specific scenarios and share among themselves information like supplier performance, credibility, and quality aspects. This allows organizations to benchmark suppliers in the consortiums, enabling blockchain partners to make informed decisions about potential suppliers and future sourcing decisions.

Thus, blockchain can function as a supplementary layer between trading partners and their ERPs. Users can continue to use the ERP system even as the data is continuously transmitted to the blockchain digital ledger. The blockchain layer will improve trust and agility in the transaction and minimize disputes. Consortium-based supplier benchmarking is thus possible only through blockchain.

5.2 Ordering

Customer purchasing behavior is undergoing tremendous change thanks to internet and mobility. Customers, whether individuals or businesses, prefer

to buy products online, on their mobiles or in-store as is accessible at the time of need. The challenge for an enterprise today is to make the product available to customer at his point of need in his desired location irrespective of how it was ordered. This is called omnichannel distribution. The customer experience has to be same irrespective of how it was ordered and how it was received like through shipments, in-store pickup, lockers, etc. For most organizations, managing and tracking orders is a full-time job for sales representatives. Without real-time inventory visibility, it becomes challenging to ensure accurate and timely order transmissions, acknowledgements, etc.

While a blockchain-driven ordering system may appear too futuristic, it can transform order management. The critical elements of an order, particularly cost, are driven by trust and assumed in real time, which leads to disputes. Similarly, order quantity is often sensitive. Blockchain can address these challenges by changing the mechanism of interaction. For instance, ordering processes can use private (permissioned) blockchains. Here, a new customer is evaluated by assessing their history, transactional and payment performance, DUNS verification, etc. He must be on-boarded onto the blockchain network before he can place orders.

In a permissioned blockchain, once a customer is on-boarded, he gains full visibility and real-time updates for price, product catalog, price breaks, etc., as this information comes directly from the blockchain network. Once the order is booked and confirmed by the customer, it is copied to all the nodes. Sensitive transaction details will not be available for other customers to see and can be veiled under metadata. This eliminates the need for EDI transactions and customer contacts, minimizing order transmission delays. Smart contracts between the customer and blockchain network initiator or even other members will drive the mechanism for ordering, order change, order promising, fulfillment logistics, and other aspects of order management.

6. BLOCKCHAIN-DRIVEN DEMAND AND SUPPLY MANAGEMENT

6.1 Demand Management

With the advent of collaborative planning, forecasting, and replenishment, the supply chains echelons today are integrated and interdependent. In an integrated supply chain, the forecast is shared across partners to improve

supply planning. Most standard ERP products provide supplier scheduling/scheduling agreements that are widely used across organizations to share demand across partners. Such sharing is enabled through methods such as:

1. EDI transactions: Customers either use the planning schedule transaction, (EDI code 830) or the shipping schedule transaction (EDI code 862). Planning schedule transactions are like forecasts, while shipping schedules are the same as confirmed orders.
2. Excel sharing: Many companies use a predetermined Excel format to share demands among partners. These Excel files are generally uploaded into the transaction system to improve supply chain or MRP.
3. Direct maintenance in the source system as per customer forecast (ERP feature): Many ERP systems provide customers with a specific login to access the ERP system to upload, maintain, change, and confirm demands. These demands are subsequently used to drive supply chain or MRP.

As sharing data is limited to these three options, there is no real-time integration. Data must be exchanged several times before it is finally approved for use in supply planning. This creates confusion regarding the final data to be used, resulting in the need for additional processes like forecast approval. Further, this approach does not offer demand visibility to supply chain partners within a company and across companies. Companies that want to adopt lean SCM philosophies must synchronize data, production schedules, and demand requirements among all partners so that they can respond to demand changes and surges. However, this requires real-time data visibility, trust, rules of engagement, and above all, the right technology to support these interactions.

In this scenario, blockchain can deliver true transformation by improving how these transactions are executed. Here, open blockchain is unsuitable as data is shared among a limited number of trusted partners. So, a permissioned blockchain is a better choice. Partners and their relationships must be verified before they are on-boarded to the permissioned blockchain. Smart contracts can be used to set up the rules of engagement and share trusted data in real time. Such real-time data sharing across partners enables a robust consensus-driven causal forecast apart from statistical forecasts, thereby improving forecast accuracy. This eliminates the need for forecast approvals and reconciliations, enabling organizations to respond intuitively and faster to dynamic supply chain demands.

6.2 Supply Management

Today, the process of supply involves multitiered suppliers, manufacturing sites, contract manufacturers, distributor warehouses, regional, national and local distribution centers, and scattered inventory across third-party logistics providers (3PLs). The cost of inventory is a concern for all industries [16]. With the advent of omnichannel distribution, the marketing, sales, and distribution of products become extremely complex and involve higher number of business partners and associates. This results in poor supply visibility.

To adopt lean philosophies such as zero inventory, just-in-time (JIT) manufacturing, and single piece flow, inventory must always be available in the required quantity. This mandates deep trust among partners and the assurance of product availability at the right time and in the correct quantity. Failing to meet these demands can result in tough penalties. By ensuring supply commitments and supply visibility across manufacturing sites and contract manufacturers, companies can drive supply chain transparency, thereby reducing administrative effort, cost, and counterfeit products.

Open and permissioned blockchains can enable these high level of supply visibility. As there are limited stakeholders to share the supply data, a permissioned blockchain is more suitable. In a permissioned blockchain, all stakeholders can be part of the node that shares information when needed. Such data sharing can be set up and managed through smart contracts where the required node shares relevant information in adequate frequency. The best way of sharing information is by connecting the transactional ERP system to the blockchain. Adopting blockchain for supply visibility through the connected ERP system delivers significant benefits such as:

(a) Reduced counterfeiting: Providing product provenance details helps partners trace the origin of the product, its ingredients, ownership, and storage details, thereby eliminating counterfeit products.

(b) Enabling digital: Product details and its lifecycle are stored within the system in a digital format, eliminating product ambiguity.

(c) Improved sourcing: While implementing blockchain among all partners will be challenging, particularly for multiple and multilayer suppliers, it will drive long-term benefits of transparency, sustained growth, and accountable and responsible sourcing.

(d) Faster operations: Transparent auditing improves compliance with governmental regulations and accelerates customs clearance. Blockchain will eliminate the need to file for country of origin reports and other customs/border clearance papers. All these information will be readily

available in blockchain for instant access by governmental agencies. An example here is the Port of Rotterdam Authority in Netherlands that has launched a field lab to explore blockchain technology. The idea is to use blockchain for customs scanning to reduce vessel turnaround time in the port.

(e) Higher growth: Transparency among all stakeholders and partners will drive sustained growth with immutable, secure, and mutual data exchange.

(f) Faster supply availability: As higher number of enterprise and supply generating systems like ERP, MES, etc., get connected to blockchain, data availability becomes more real time and transparent.

Thus, blockchain can provide macro- as well as microvisibility across multiple suppliers from agri produce goods to high-tech manufacturing. It can also integrate with ERP to provide seamless data exchange and stakeholder interactions.

7. BLOCKCHAIN-DRIVEN MANUFACTURING AND LOGISTICS MANAGEMENT

7.1 Manufacturing Management

The Blockchain Research Institute states that blockchain is an Industry 4.0 technology [17]. In the news article, Neil [17] explains that Foxconn is using blockchain to simplify integration with its partners and streamline the movement of money and goods. With the proliferation of contract manufacturing, particularly in high-tech manufacturing, blockchain will play a crucial role by reducing the dependency on EDI transactions and enabling real-time updates on demand, supply, manufacturing status, and availability information.

To explore the application of blockchain in manufacturing, let us first understand the key pain points of the manufacturing industry today. Duvall [18], Carr [19], and Handfield and Steininger [20] list that the key challenges faced by manufacturing organizations with an existing ERP system are final product quality, counterfeit components, meeting governmental regulations, staying competitive with better products at lower cost, ensuring supply chain transparency, controlling cost, dealing with fragmented supply chains, managing multifacility and duplicate data/records, enabling data visualization and intelligence across entities, and driving collaboration among suppliers or contract manufacturers. A closer look at these challenges

shows that the inherent capabilities of blockchain can be used to deliver significant benefits. The main question is: how can blockchain address these challenges for manufacturers? The subsequent section provides an answer to this pertinent problem.

In manufacturing, a permissioned blockchain is more suitable than an open blockchain. A permissioned blockchain will be more acceptable and beneficial to the manufacturer as it gives control to on-board only specific supply chain partners as a node. The blockchain can act as a centralized distributed ledger that is owned and initiated by a manufacturer. It will have the capability to seamlessly collate data from multiple ERPs belonging to customers, suppliers, distributors, and contract manufacturers. This data can then be used by the original manufacturer for decision-making, transparency, and status updates. For example, an OEM may want to on-board only its top 10 suppliers and all contract manufacturers onto the blockchain. This will give him better control and in-depth visibility into material movement and manufacturing, which comprises the bulk of his business. In this way, blockchain addresses the challenge of fragmented supply chains.

In order to be audit-compliant, manufacturers need certificates that are usually obtained after a lot of paperwork, emails, phone calls, site visits, surprise checks, followups, etc. This gives rise to third-party certifying agencies like the International Organization for Standardization and BIS Hallmark, a jewelry certifying agency in India. However, manufacturers often lack visibility into the status and operations of a contract manufacturer and are mostly blind to its sourcing. Blockchain can help manufacturers gain better control over governmental regulations as all legal transactions are cryptographically stored in the blockchain. Any auditor or government body can access the blockchain node on the distributed database and use it for the intended purpose. Immutable data stored on the blockchain simplifies auditing, thereby reducing cost. Blockchain can also leverage smart contract rules to reduce nonapproved suppliers, products (ingredients), country of origin and transactions in ERP.

Additionally, blockchain can help manufacturers innovate their product lines faster and at lower cost, control counterfeit components, and combat supply chain transparency issues. This is possible because blockchain supports secure sharing of design documents across partners (suppliers, contract manufacturers, and OEMs), thereby enabling visibility into status of prototyping and sourcing and allowing frequent review of sourced costs. Blockchain can also track the cost of products from multiple sources to

control cost of the end-product. This will promote trust and secured sharing leading to accelerated innovation unconstrained by geographical boundaries. It will also drive economic development in emerging markets. Faster product development will improve the speed of material flow and reduce localized inventories, thus creating newer markets and opportunities.

7.2 Logistics Management

The logistics industry is currently undergoing a transformative change. Consider how Uber now delivers food, electric cars are replacing fuel-based vehicles, and flying cars are almost a reality. Technology is also transforming the logistics industry by enabling drone delivery. These futuristic solutions primarily benefit end customers and individuals. However, corporate logistics functions still struggle with transparency issues, high cost, manual effort, lack of trust, and challenged by real-time data availability. Most logistics executives focus on dealing with crises, disruption, and technology rather than collaborating with the freightliners.

According to research and articles published by Kavas [21], World Economic Forum [22], Morales [23], and Brosch [24], the logistics industry is plagued by challenges of risk, variability, volatility, and disruption. The reasons for these are natural disasters, violence, noncompliance with government regulations, poor accountability, delayed information sharing for logistics, poor communication among partners, limited shared logistics capability and capacity utilization opportunities among service providers, managing inventory visibility across various logistics providers, theft and pilferages, and the need for segmented and customized services as demanded by customers. As per Kralingen [25] the information flow in logistics industry is highly inefficient, error-prone, manual, nondigital, and heavily dependent on complex paper-based systems.

Today, the logistics industry needs better technology, efficient route planning, and stronger integration with ERP systems. While blockchain cannot provide these capabilities, it can ensure more transparency, reduce or remove dependencies on intermediaries, enable inventory visibility across the supply chain, and drive effective tracking and communication. These capabilities can significantly improve the functioning of the logistics industry.

To improve transparency and remove dependencies on intermediaries, Maersk and IBM have jointly developed a global trade digitization platform

based on blockchain. Port Houston, Rotterdam Port Community System, the Customs Administration of the Netherlands, and the US Customs and Border Protection will be part of this blockchain network [26]. Any company using this blockchain will enjoy paperless and seamless transfer of goods from one location to another. This is possible because the customs organizations are a node on this network and can identify what, when, where, and how much is being transferred. Similarly, in 2017, Samsung launched a blockchain consortium comprising the Korea Customs Service and Korea's Ministry of Oceans and Fisheries. Another example is the Port of Antwerp in Belgium that is testing the use of blockchain to automate and streamline container logistics operations in its terminal.

Thus, in the last few years, there has been a rise in logistics-specific blockchain solutions. For instance, the Blockchain in Transport Alliance (BiTA) [27] provides a platform to standardize and develop transport-related blockchain solutions. Some of its members include UPS, Fedex, SAP, BNSF, Salesforce, Schneider, JD.com, and Penske. Fedex was one of the first companies to join the forum and help develop blockchain technology standards and education for the freight industry. As more logistics giants join the blockchain platform, it will enrich the platform and enable smaller players to use these platforms for higher benefits.

The logistics industry can derive greatest value from blockchain when it connects logistics partners and manufacturers' ERP systems to the blockchain network. This will enable seamless information flow from one system to the centralized distributed ledgers, which can then be shared with any of the partners who are a node in the network. These blockchain-connected ERP systems of logistics service providers can improve supply chain functioning across the whole industry, bringing in transparency for customers and simplified product provenance tracking. Further, the digitization of logistics-connected ERP will replace paper-based information transfer through digital capabilities and help track and reduce pilferages and theft.

Blockchain will smoothen and accelerate the process of customs clearance, vessel turnaround time, and auditing. It will also improve visibility across supply chain partners, enabling near real-time tracking, and updates in case of supply chain disruption. When natural disasters occur, blockchain can check for alternate routes, suppliers, products within the network to make inventory/material available. Further, it provides a platform to share

container capacity, port capacity, route capacity, warehouse capacity, and other assets. Finally, coupling blockchain with digital transaction will reduce paper usage, driving green initiatives to protect the planet.

8. PRODUCT PROVENANCE USING BLOCKCHAIN

In 2015, diners at a US-based fast food restaurant contracted an *E. coli* infection. Despite independent reviews by state and federal regulatory officers as well as detailed independent investigation by various investigating agencies the company filed to stock exchange that there was no single food or ingredient that caused the infection. It is speculated that products like beef and agri produce like cilantro caused the outbreak, but sources are still unknown. In another example, Apple came under pressure from various organizations to audit its entire supply chain and confirm that chemicals used in manufacturing such as tantalum, cobalt, gold, tin, and tungsten were conflict-free and not sourced from companies that funded armed groups or violated human rights [28]. Steve jobs admitted this was challenge stating, "Until someone invents a way to chemically trace minerals from the source mine, it is a very difficult problem" [28]. These examples highlight the pressing need to know the origins of a product and trace its lifecycle from source to consumer, a process known as product provenance. The importance of this is significant when one considers how Mattel, the maker of Barbie dolls and Hot Wheels cars, had to recall around 1 million toys that had lead paint. From tracing non-GMO ingredients in the food supply chain to knowing whether leading apparel brands source from manufacturers who abuse human rights, product provenance is critical to supply chains and extremely challenging.

Companies must trace their ingredients or components to protect their reputation, ensure component quality, and inform the customers about the quality and authenticity of their finished products. However, supply chain or ERP software cannot provide such information as ERP is confined to a specific company or enterprise. The modern supply chain has become increasingly complex involving multiple parties/stakeholders across the world. Thus, companies need a centralized software platform that leverages a decentralized approach to connect disparate systems across the globe, irrespective of location or technology used.

Blockchain offers this very functionality. Product provenance can be used for a variety of products like packaged food, produce goods, seafood, diamond jewelry, precious metals, garments, rare earth elements, and fashion products to name a few. The use of blockchain to enable product provenance is seeing rapid adoption through two main types of solutions:

(1) Independent tracking via blockchain: Companies such as Provenance, Sourcemap, and Owlchain provide independent product tracking right from raw materials/origin to the end product that is delivered to the consumer. Provenance works on Bitcoin as well as Ethereum platforms and is a complete blockchain solution. Sourcemap is an interactive mapping platform that uses a global map to show users where the various elements came from. Now, Provenance and Sourcemap have linked their digital platforms to benefit customers, which is a breakthrough.

(2) Custom-built provenance solutions: Software service providers can use the blockchain framework to build provenance solutions for its customers (permissioned blockchain). For instance, Infosys has developed a product provenance solution using Oracle Blockchain Cloud services that is based on Hyperledger fabric [12–14]. Infosys has also developed a coffee bean tracking provenance solution for its customers. These examples prove that there is a need for custom built provenance solution which can be developed with product or industry specific validations.

It is important to note that the idea of provenance can only work when all the supply chain stakeholders are a part of the blockchain network. The architecture of blockchain inherently traces products as they pass from one supply chain entity to another. These transactions are stored as blocks and are chronologically linked according to the physical movement of the goods.

A fitting example of supply chain provenance and visibility is the ethical seafood traceability solution provided by Hyperledger. The Hyperledger Sawtooth framework records the journey of seafood from its origin, i.e., where it is caught till the end consumer. Consumers can view all this information on their smartphone using a mobile application. When seafood is caught, it is attached with IoT sensors that track its movement during transportation. The tracking mechanism monitors ownership, possession, location, temperature, humidity, motion, and shock among other things. Another example of product provenance is the Everledger Blockchain that provides provenance for diamonds. With more than 1.6 million diamonds

on its blockchain network, it creates a digital record of a physical diamond by capturing attributes like color, carat, and certificate number, which is etched on the diamond through lasers [29]. The goal of such solutions is to provide consumers with instant information about the source of products and their physical movement.

With growing customer demand to know the source and path of products, it will be imperative for manufacturers to enable supply chain transparency and product provenance. Several multinational companies and large retailers are already planning to adopt provenance solutions. Soon, this will become the new norm in modern supply chains, and blockchain is a promising and acceptable technology to achieve this. The connected ERP's to the centralized blockchain system will definitely ease the information flow and provenance.

9. BLOCKCHAIN USE CASES IN THE DISTRIBUTION INDUSTRY

So far, this chapter has dealt mostly with how blockchain can impact the operations of contract and OEMs. Another key area that deserves mention is the distribution industry. This industry is witnessing tremendous transformation because of newer technologies, and blockchain has a significant role to play. Blockchain is particularly important for this industry as its very dynamic with multiple stakeholders in the form of customer, supplier, manufacturer and 3rd party service providers. Blockchain provides capabilities that are set to improve operations, communications, transparency, visibility, and the bottom line of the distribution industry.

Before delving into the benefits of blockchain, let us evaluate the challenges in the global distribution industry. Research and analyses by Mulky [30], Yu et al. [31], Arnold [32], and Bolduc [33] show that the main challenges of distribution industry are:

- Synchronizing customer demand and supplier inventory: Distributors often struggle to effectively service the needs of customers and communicate with them seamlessly and transparently. To serve customers, the distributor needs to source, communicate, and receive materials from the suppliers. Here, the challenge for a distributor is in meeting customer demand for faster service and cheaper products, and sourcing it in this way from the supplier. Customers want to see the best price with discounts from the right source at the very beginning. They want information on shipment, transit time, lead time, acknowledgment, and a

proforma invoice as soon as they place an order along with the option of changing their order anytime. Similarly, distributors expect to receive inventory from their suppliers on time with the option to change their order anytime. Thus, customers, suppliers, and distributors want real-time information on order status, transit visibility, and pricing visibility.

- Transparency of sale from supplier, distributor to end customer: Distributors are legally bound to provide information of sale to their suppliers source of material information to their customers. This information is also needed to enable, manage, and check the ship and debit claims. Such information enables visibility and profitability analysis of distributor channels and price management in the market. In a multilevel distribution channel, this information exchange can become extremely complex with limited visibility. While ERP systems provide some visibility, it is not in real time and is not across all stakeholders. The main reason for this is that ERP systems are not connected with each other and confined to an enterprise. There are a number of reports shared today across suppliers, manufacturer and distributor like Point of Sale (POS) report, Product Transfer and Resale Report, Availability report, Planning and Shipping schedules, etc. which are time consuming and asynchronized.
- Counterfeit products: Counterfeit products invariably create revenue loss for distributors because of higher instances of product returns. Further, in some cases, customers transfer the financial liability caused by faulty products to its distributors. Without proper insurance, this can have significant negative impact on a distributor's reputation and credibility in sourcing the right product.
- Item information and its attributes (for informed buying/sourcing): Google has created a breed of tech-savvy customers who can instantly access information on-the-go. Such customers want exact information on the product being sold. According to Banerjee [12–14], companies are expending significant effort in providing customers with granular information from nutrition facts to carbon labels. However, this requires product provenance and detailed product information.
- Moving to an omnichannel distribution supply chain model: Today, most retailers and distributors are shifting to an omnichannel distribution supply chain model. The intent of the distributor is to use existing stock to fulfill orders from retailers and customers across various channels like stores, franchises, online, and mobile. This helps distributors control price and stock, improve margins, increase their customer base, and boost revenue. However, it also increases supply chain complexity.

The challenge here is to ensure minimum turnaround time while seamlessly connecting customer demands and supplier purchase orders irrespective of location.

Blockchain can help solve most of the above problems. The blockchain can be centrally owned and managed by distributors. Using several methods, suppliers and customers can be a node in the blockchain network, thereby promoting transparency. Alternatively, the distributor can be a node in the manufacturer/supplier or customer-owned and managed blockchain network. In both these cases, the blockchain can be either open or permissioned networks.

We have already discussed several capabilities that are possible in blockchain. Based on these, product provenance and supply/demand visibility will resolve the challenge of counterfeit products, item attribute information, and synchronizing customer demand/supplier supply. A blockchain that is synchronized and integrated with the ERP systems of distributors, suppliers, and customers can provide visibility into order and inventory status and help with ship and debit claim management. ERPs connected to the centralized blockchain network will deliver the speed and flexibility necessary to support omnichannel distribution.

Here, a private or permissioned blockchain is optimal since the network only contains distributors and its suppliers and customers. Permissioned networks do not require miners. The blockchain network will contain the complete ledger information of inventory, orders, in-process inventory, open orders, backlogs, and forecasts. Further, each customer order can leverage smart contracts to understand customer preferences such as branch, area, location, or supplier preference based on type of order. Smart contracts will also help identify the right discounts for the customer. Finally, integrating customers, suppliers, and distributors will provide real-time visibility of price and availability.

The challenges are different for specialty distributors such as those who handle electrical equipment, commodity products like metals, wired products, autocomponents, and home essential products. These distributors face challenges of identifying the correct part (item), the right product manufacturer/supplier, the right price (pricing agreements) of an item, product origin, and calculating the right claim (ship and debit claim). Here, the root cause is asynchronous data between the distributor, manufacturer, and customer and the lack of a central governing system.

While electrical distributors use independent third parties like Trade Service (a Trimble Company) or Industry Data Warehouse (IDW) to gain data for item (and its related information ranging from physical characteristics to

technical information), cost, and price details in electronic formats, such agencies do not offer information on product origin. In cases where data is available, the challenge lies in regularly updating these data feeds into the transactional system of distributors (or any consumer of the data). This underscores the need for a centralized system for real-time data.

Blockchain can address these challenges by synchronizing data among the manufacturers, distributors, and suppliers. This will accelerate order processing, enable accurate pricing and discounts, identify product provenance, and, most importantly, identify the right item through technical attributes. Blockchain is particularly useful for warranties as there is no need to store the installed base data in individual ERP systems. Instead, the immutable transactions in the blockchain network will provide details of the purchase and available warranty for the product, and this information will be accessible to manufacturers, distributors, and customers.

Microsoft has partnered with Mojix to leverage Azure and provide blockchain-as-a-service solutions for retailers and distributors [34]. Mojix is a leading provider of RFID and IoT solutions. Through this partnership, suppliers/distributors get access to location-based and real-time data of the status of inventory even when it is in transit. Materials are scanned when they pass certain check points and these insights are captured using Mojix technologies and pushed to the Azure blockchain, thereby providing immutable and real-time data. Such visibility helps distributors track orders and get real-time updates.

10. CHALLENGES AND FUTURE OUTLOOK OF SUPPLY CHAIN WITH BLOCKCHAIN AND ERP

ERP has successfully integrated departments and operating entities within an enterprises. The adoption of blockchain will, over time, provide the opportunity to connect individual ERP systems to the blockchain. The future of the supply chain is one where blockchain will be able to track activity beyond an enterprise's boundaries. While such capabilities will transform supply chain functioning, it comes with its own share of challenges. It is important to remember that the present challenges in adopting a technology may evolve into a different set of challenges as the technology itself evolves. Currently, the key challenges in adopting blockchain for supply chains are:

1. Infrastructure and network: Blockchain needs online transactions, communication, and data storage. All of this consumes significant internet

bandwidth and CPU power, which can be challenging in developing and underdeveloped economies.

2. Interoperability: As highlighted by Banerjee [12–14], blockchains should seamlessly work across ERP and other blockchain systems. Only when blockchains are allowed to communicate with each other and transfer data/information to other ERP/transactional systems can companies or supply chain realize the tangible benefits and full potential of the technology.
3. Costs of on-boarding and maintenance: In a blockchain-enabled supply chain, the nodes are supply chain partners, i.e., suppliers, customers, distributors, and manufacturers. On-boarding and maintaining these nodes, particularly for high volume transactions, are a significant cost and must be laid out clearly in smart contracts.
4. Data storage cost on blockchain (data per transaction): Blockchain data is stored on the cloud. A blockchain database must store data indefinitely and such indefinite storage of data involves high cost. This will require a different type of storage model as recurring payment models will not work. The indefinite retention of data is costly and data models has to evolve for these. These are going to cost and impact every node members.
5. Data validation latency: In an open network blockchain, the blocks of data are queued and validated by miners for every transaction. There is a latency before the block is verified and becomes available as a valid block in every node. In a Bitcoin network, the average latency ranges from 8 to 19 min, but this can even increase to hours. From a transaction perspective, considering these are real life transactions with business decisions based on it these values are quite high. Ideally, the latency must be in seconds if blockchain is to be a viable solution for supply chain transactions with corresponding business decisions and actions based on it.
6. Payload size restriction: There is a payload size restriction for any blockchain network whether open or private. As the payload is not infinite, there will be transactions that become invalid due to size. While the limit for Bitcoin is roughly 1 MB, there is no standard for payload size as it depends on the network's capability of nodes. This raises concerns about network and infrastructure challenges when it comes to payload restrictions. While this challenge may change over time, currently it is a key concern.

7. Regulatory and legal acceptance: Blockchain has no legal framework. Countries vary on their view of Blockchain and cryptocurrencies; while some are excited, others are suspicious. In the United States, cryptocurrency is regulated by state jurisdiction. The EU is open to blockchain and cryptocurrency. However, the lack of a global regulatory framework poses challenges for global acceptance and adoption.
8. Trust: This is the last and the biggest concern from a supply chain perspective. Blockchain can improve visibility, real-time tracking, and seamless transfer of data. However, the central design element for blockchain is implicit trust between partners. For blockchain to be a part of supply chain transactions, every node (suppliers, customers, distributors, and manufacturers) should be open to sharing their data.

Most of these challenges revolve around cost, network infrastructure and legal aspects. These may change over time as technology makes progress and laws change and adopt blockchain technology. But those will bring forward a new set of challenges. Similarly, the challenges in supply chains themselves may transform in future. For instance, data security in blockchain-enabled supply chains is a concern as data is shared outside the enterprise. While blockchain is designed to be robust, secure, and anonymous, there have been incidents where it is misused by hackers who seek ransom payments in bitcoins. There have also been reports of hacking in cryptocurrency exchanges. Even though these incidents do not directly impact supply chain operations, we can expect that innovation in blockchain networks will address these loopholes and improve security.

11. CONCLUSION

Blockchain networks can be connected to ERP systems within and outside an organization to facilitate information and transaction sharing across enterprises. As a transparent and decentralized platform, blockchain can complement and simplify supply chain operations by enabling connected supply chains that share information across all transactions. Blockchain is set to revolutionize various aspects of daily life as it provides consumers with more information on the products they buy through product provenance. It will encourage the formation of consortiums where companies can improve their supply chain operations. Some of the benefits of blockchain-based supply chains include improved supply chain decision-making, sourcing, inventory tracking, transparency, and visibility. These benefits not only improve supply chain operations but reduce cost and time.

When coupled with the Internet of Things, blockchain can drive instant sharing of real-time data and accurate updates. In future, we can expect blockchain to bring people and countries closer, making this world a better place to live in.

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