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# Application of Blockchain in Supply Chain

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***Abstract*— The supply chain system consists of four subsystems; mainly, planning, sourcing, operation and logistics. Supply chain is transforming raw material to products that customers use by executing many coordinated processes, utilizing many valuable resources and performing numerous interrelated and integrated activities. The supply chain profitability is measured as an overall value of the chain, not only by a single subsystem in the chain. The supply chain industry is suffering from several problems such as trust, traceability and sustainability. Although the existing technology already contributed to solve some of the problems, the solutions provided are not sufficient yet. The blockchain is the horizon for future supply chain. Blockchain is a set of linearly connected information containing blocks secured with cryptography. Each block contains records and transactions. A block contains: *The block number or the block height, Time stamp, The hash of the block and its previous block, Transactions and Nonce which* is the number that miners can manipulate in order to find a new block. There are three types of blockchains; Public, shared permission and Private or permission blockchain with different degrees of trust and decentralization. Blockchain can improve trust and traceability of the supply chain. The aim of this paper is to provide a framework for the application of blockchain technology in the field of supply chain. Also, this paper provides fundamental knowledge about supply chain system, blockchain technology and literature review of the current implementations as well as some recommendations on future potentials of blockchain applications in supply chain systems.**

***Keywords—Blockchain, Supply Chain, Logistics, Applications, Technology***

## I. INTRODUCTION

Supply chain is the corner stone of global trading and have direct impact on economy. The subject started as simple as farming and utilizing natural resources around us, moving materials to nearby villages, going all the way to international trading and shipping processes. Supply chain is getting more complex and hard to manage every day. This complexity comes from products customization, very fast national and international delivery requirement and the demand for lower products costs by customers. Also, with the increase of products consumptions globally, a certain problem of sustainable and reversible supply chain has appeared to manage wastes effectively.

Early in the 20th century, Ford car manufacturer developed their supply chain system by integrating all manufacturing processes in-house including the parts and the car body. The supply chain was very efficient that time. Producing one car including all manufacturing processes with specific model and black color only takes no longer than 81 hours. The system efficiency came at the cost of the flexibility of the product, which is only one model and one color. Later in 1960s, Toyota car manufacturer took different approach in supply chain. Toyota decided to develop bowl of vendors to provide the car parts for manufacturing, and some of the parts are manufactured out of Toyota. As a result, Toyota had the advantage of flexibility to provide wider range of cars. Later, a company called Dell in 1995 developed a website that allows customer to directly order online by utilizing the IT revolution that time. There was no retailer to provide Dell products, instead there is only the website. This allowed the customer to select and modify the product as he likes. Later in 2006, Dell products became available through retailers for those who want to buy directly without much customization.

The supply chain is developed over the last decades very fast. The technology advancement contributed to improve efficiency of the supply chain. However, the complexity of the supply chain has increased even faster with global trading. There are too many variables in supply chain system that requires special handling and deep understanding of how to effectively achieve the best overall value stream of the final product. The concern of supply chain is not only to produce products, but also to make the product affordable, safely produced, transferred and accurately delivered on time.

There are many trials and contributions to achieve efficient supply chain. The development and improvement of industrial sector directly affect supply chain positively. Also, when computerized system started to get involved in supply chain process, too many problems were also solved. Now and in the era of technology adoption and advancement, companies are trying to use internet of things, deep learning, big data analysis, blockchain and artificial intelligence. These new technologies can absolutely solve many problems in supply chain but not all the problems.

Before the beginning of blockchain, there were two research scientists, Stuart Haber and W. Sscott Stornetta who asked an interesting question on how to keep digital information safe and resist tampering? In 1991, these two scientists published a paper that uses blocks of chains that are secured using cryptography to protect the data from tampering. Their aim was to protect data and they didn't have any idea that this approach can be used as cryptocurrencies nowadays. In 1993, there was too much spam on the internet that led to establish the concept of proof-of-work to act as countermeasure to spam. In 2008, blockchain first application was prepared by Satoshi Nakamoto. The application was a cryptocurrency that is famously know today as Bitcoin. Therefore, *Bitcoin* is an application of blockchain, and it is not the blockchain itself as the terms cannot be used interchangeably. In 2014, Ethereum was created, and its application has exceeded what Bitcoin is capable of. Bitcoin is simply a record of transaction while the Ethereum is more than a currency. The Ethereum is not only cryptocurrency, but also it can run computation by using Ethereum Virtual Machine (EVM) which allows the creation of smart contracts. These smart contracts and other programs can be used on the

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blockchain. EVM is considered as distributed computer that runs on a blockchain. In 2016, blockchain is embraced by the financial industry. Today, the world is heading towards decentralized future.

This paper is going to present some valuable literature on supply chain system concepts, principles of blockchain technology and present how blockchain technology can be used in supply chain systems.

## II. LITERATURE REVIEW

In this section, the interest of researchers to use blockchain in supply chain will be revealed. Also, an example of real application of blockchain in supply chain will be shown.

In a paper entitled, *"When blockchain meets supply chain: a systematic literature review on current development and potential application,"*[1] a complete literature review from 2016 to early 2020 was sited about the applications of blockchain in the field of supply chain. The journal authors started the literature review by 433 articles. By following systematic approach and eliminating non directly related topics, authors focused on only 106 papers. The purpose of the paper was to summarize the current development and potential application of blockchain based supply chain.

The authors in this papers concluded that the following topics are the most discussed and researched as application of blockchain in the field of supply chain:

- Traceability and transparency: the traceability and transparency are considered the most painful issues related to supply chain. The intermediaries and over centralized are the main players to make traceability hard for supply chain. The blockchain can help to give a decentralized platform that combines all members with high security and trust through consensus mechanisms. The transparency is improved by blockchain because every node in the network have a copy of the database and validation is shared among network members[2]. As a result, the transactions are immutable and secure. The integration of blockchain with internet of things IoT technology can improve actual time of activities in transportation and logistics[3]. Process automation can be achieved by using smart contract by blockchain[4]. The digital signature and encryptions used in blockchain can increase the security and confirm correct validation to avoid counterfeit products[5,6].
- Stakeholders Involvement and Collaboration: when the supply chain nodes work together in harmony, the potential of improving blockchain ecosystem is higher [7,8]. The design of blockchain must be suitable for the stakeholder's criteria of management. The selection of blockchain type is an important concern that must satisfy information sharing and system interoperability [9,10].
- Supply Chain Integration and Digitalization: digitalization by blockchain can provide great information sharing[11,12] and trusted value transfer[13]. Blockchain offers great financial solution in terms of transaction fees and synchronized ledger that make supply chain more efficient[14]. Digitalization using blockchain is offering value transfer within distributed ledger that is cyber-attack proof[15] and data integrity featured[16].
- Common Frameworks and Blockchain-Based Platforms: smart contracts are the corner stone of event based mechanism application used in supply chain[17,18]. The smart contract are programmable that can trigger a specific function once an action is occurred like receiving an item. The interaction between stakeholders are selected in the design phase of blockchain and that is achieved by selecting type of blockchain. The future of blockchain frameworks must consider a wise selection of blockchain type to be sustainable[19].

In another paper entitled, "Enhancing Vendor Managed Inventory Supply Chain Operations Using Blockchain Smart Contracts,"[20], the authors discussed the importance of the vendor role to manage the buyer inventory. The vendor managed inventory (VMI) concept is to allow the vendor to manage the inventory of the buyer by taking decisions of replenishments automatically to achieve win-win situation. The inventory cost plays a vital role in overall supply chain profitability. Using VMI can solve several problems as follows:

- Cost of inventory: the effective replenishment can ensure reduced cost of inventory. The VMI can allow better management of stocks and clear vision to supplier when to replenish.
- Safety stock elimination: since the supplier knows and manage the inventory of the buyer, the buyer will not keep safety stock.
- Collaborative and effective communication between buyer and supplier: when the suppliers have full details of production rates and materials needed, the management of restocking is easier for supplier and efficient for buyer. The buyer will only provide the needed data to supplier, and the supplier will be fully responsible of inventory management including delivery.

The blockchain technology is a best fit solution for the above problems. The trust, traceability and data security are the main improving areas when adopting blockchain technology. The blockchain can automatically generates alarms when replenishment is needed using smart contracts. The blockchain offers permissioned platform to control data integrity.

*The proposed* model is to use on chain and off chain transactions as shown in figure (1). The on chain processes are performed in Ethereum platform while off chain processes are performed outside blockchain network. For example, the decentralized storage system is on chain process while negotiations for the replenishment point is off chain process. The followings are the main nodes in the proposed model:

- Vendor**:** to register trusted distributors and retailers. Also, vendor should upload agreed prices from off chain processes.
- Distributor: to update the vendor about delivery status and accept prices of delivery.
- Retailer: to upload sales report and accepts new prices from vendor.
- Ethereum Smart Contract: it is coded using Solidity. The essential variables are Ethereum address (EA), delivery cost, and reorder quantity.
- Decentralized storage system: it is used to ensure integrity and tamper proof of the data.

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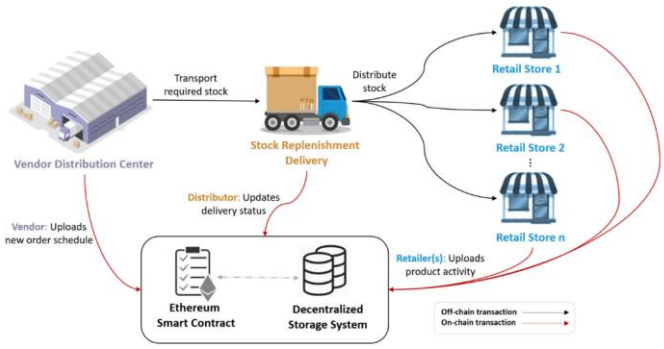


Fig. 1. Proposed On-Chain and Off-Chain Model by Authors[20]

*The result* that authors figured out by developing several algorithms to test the model. These algorithms are for the vendors, retailers and distributers. Also, the authors utilized GitHub repository functions, then the smart contract is created to follow the algorithm requirements. Each function and algorithms consumes specific amount of gas. The average cost incurred by vendor is 4.821 USD. The average cost incurred by retailer is 0.388 USD. The average cost by distributor is 0.27 USD.

In a third paper entitled, "A Trusted Blockchain-Based Traceability System for Fruit and Vegetable Agricultural Products,"[21], the traceability of production by blockchain was presented. The traceability is very important to track production of agricultural food in order to avoid any disease. The agriculture food industry consists of two entities as internal and external to the supply chain. The internal supply chain entity is concerned about production, processing, logistics and sales. On the other hand, the external supply chain entity is concerned about regulatory agencies and consumers. The agriculture food industry is facing several challenges. For example, tampering with the data is applicable with current systems. Also, the information transparency is not applicable safely and securely. The blockchain offers a great choice to improve traceability of agricultural food industry.

*The proposed* model utilizes blockchain technology to improve traceability and transparency of information. The authors used on-chain and off chain data storage to maximize the speed of transaction. Also, the authors used cryptography to keep data secured. The blockchain is built using Hyperledger Fabric and by using C# programming language. The traceability is performed by tracking the following processes:

- Production: the activities of watering, planting, picking operations, and record of key information like seedling.
- Processing: the activities of packaging, weighing, giving barcodes, and record of product information.
- Transportation: the activities of transporting in production, processing, transportation and sales.
- Sales: the retailer storage and selling points in the market.

*The result* of the proposed model revealed low latency and high throughput. The average latency is between 0.12 seconds to 0.2 seconds. An actual application is used in apple supply chain in China. The actual application revealed how blockchain can provide authentic and reliable data.

In a fourth paper entitled, "A Secure and Efficient Supply Chain Framework via Blockchain-Based Smart Contracts,"[22], the concept of smart contract in supply chain was discussed. The supply chain complexity comes from information flow, transportation by logistics, and capital flow. These three functions must work together in order to have an efficient and secure supply chain. Also, achieving these three functions will ensure traceable and transparent supply chain. Using blockchain along with other technologies like radio frequency identification (RFID) can solve smoothen flow of information, logistics and capital.

*The proposed* model is a secure and efficient blockchain-based supply chain framework (SESCF). This model uses blockchain, smart contract, RFID, and payment channel. There are three layers in proposed model as briefly illustrated bellow:

1- User layer: this layer is responsible to handle transportation between entities using RFID to record goods information. The processes are mostly offline.
2- Transaction layer: this layer is online layer that facilitates trading event, payment event and delivery event.
3- Blockchain layer: this is recording layer that store all data and allows for tracking. Also, blockchain layer is responsible to give strict access to avoid fraud activities in the network.

The authors focus on solving three flows in the supply chain. Each flow has its smart contract developed by authors and a detailed algorithm to achieve secure and efficient supply chain. These three flows are:

- Information flow: the main information to be solved here is the demand and supply.
- Logistics: tracing the transportation and storage of goods are improved by blockchain.
- Capital flow: off-chain payments channel is used to improve operation quality.

*The result* of using blockchain with smart contracts are feasible. The authors developed efficient blockchain-based supply chain system called SescfDapp. The consensus mechanism used is consortium with Certification Authority (CA) for specific nodes in the system to validate a transaction. After conducting several tests, the highest latency is 4.78 seconds (for compute function) while the lowest latency is 3.45 seconds (for trace function).

## III. PRINCIPLES OF SUPPLY CHAIN

Considering the supply chain is a broad area, the definition is changing over time, but the main idea and practice is the same. The council of supply chain management professionals defines the supply chain management as "Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies". In simple words, supply chain is transforming raw material to a product that a customer uses including all processes like planning, sourcing, manufacturing, operation and logistics.

Supply chain management is concerned with finding the best integration between four activities as shown in figure (2).

International Journal of Engineering Research & Technology (IJERT)
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Vol. 12 Issue 01, January-2023

These activities are planning, sourcing, operation and logistics. Supply chain profitability is measured as an overall value of the chain, not only a single stage in the chain (supplier or manufacturer … etc.).

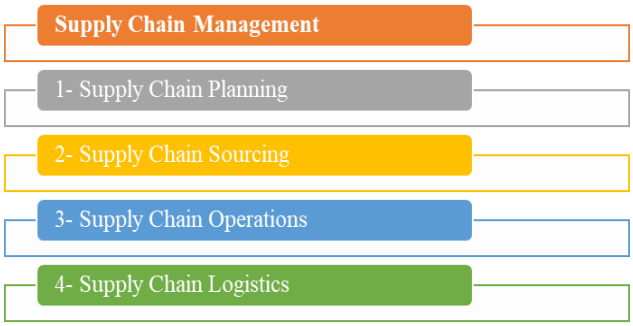


Fig. 2. Supply Chain Management

### A. *Supply chain planning*

The first step in planning of supply chain is forecasting. Forecasting is the prediction of the demand behavior in the future. Forecasting is the core for every business. It represents continuous action that should always be monitored and repeated based on the variables around. Figure (3) shows the different forecasting methods.

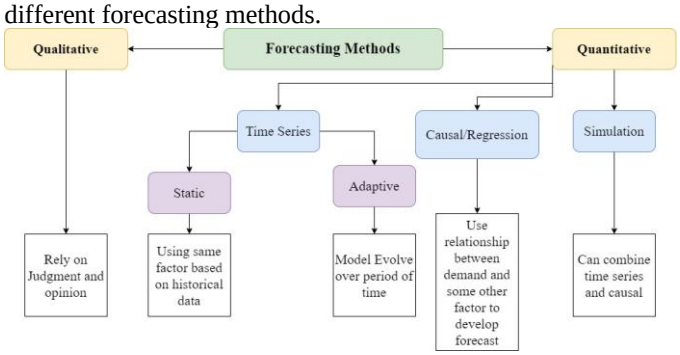


Fig. 3. Forecasting methods

### B. *Supply Chain Sourcing:*

The purchasing and procurement serves different roles in supply chain. The difference between purchasing and procurement will be clarified.

Purchasing: The purchase for businesses is quite complicated. This starts from buying the raw material up to buying the land and building the factory. For manufactures, purchases cost is around 70% while it represents 40% for service companies. Purchasing is the activity of the buying goods or services. The purchaser must make sure of the right material, right quantity, right quality, right source, right price, right delivery time, right location, right transportation mode, right level of service, right contract and right payment terms.

Procurement: Procurement is a broader area than purchasing. Procurement should care not only about the suppliers, but also for all internal processes, plans, logistics and manufacturing. Procurement purpose is to centralize all activities related to suppliers and manage the relationship with suppliers proactively. Procurement doesn't care only about the price, but also the sustainability of the firm, service level and quality as well.

### C. *Supply Chain Operations*

The operation is the transformation process of inputs into outputs. There are four primary goals of operation; these are cost, quality, speed and flexibility. There can be tradeoffs for some of these goals in the advantage of the other. For example, Toyota considered seven types of wastes in its excellent operation and productions system. These seven types of wastes are transportation, inventory, motion, waiting, overproduction, over processing and defects. Toyota is the first who started lean operation, waste minimizing and continuous improvement philosophy. The six sigma and ISO are quality control tools that are widely used in the supply chain industry to improve performance, enhance quality and reduce waste.

### D. *Supply Chain Network and Logistics*

The supply chain network is the key for successful logistics in supply chain system. The network includes suppliers, manufacturers, warehouses and retailers or customer's locations. The network design in supply chain is either to be responsive or cost effective. The right balance is determined based on the business strategy and by applying operation research techniques. Figure (4) represents the relation between number of facilities and total cost. The right balance between facilities, inventory and transportation can provide the best cost possible.


Fig. 4. Number of facilities and total costs[23]

## IV. PRINCIPLES OF BLOCKCHAIN

Blockchain is a set of linearly connected information containing blocks secured with cryptography. In other words, blockchain is a set of protocols and cryptographic methods that enable a network of computers to work together to securely record data within a shared open database. Each block contains records and transactions. Figure (5) shows an example of what the block contains:

Firstly, let's look at the block from inside as an example of what the block contains:

1- The block number or the block height: every block has an incremental number which is unique for each block.
2- Time stamp: represents a unique time and date of the block in which the network is already validated the block.
3- The hash of the block and its previous block: each block relates to its previous block by a specific hash number. Therefore, each block has two hashes; the hash of the previous and the hash of the block itself.
4- Transactions: each block contains set of critical information like transactions. Figure (5) shows only 2 transactions while in Bitcoin for instance, there can be more than 2000 transactions.
5- Nonce: is the number in which miners can manipulate in order to find a new block.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 01, January-2023

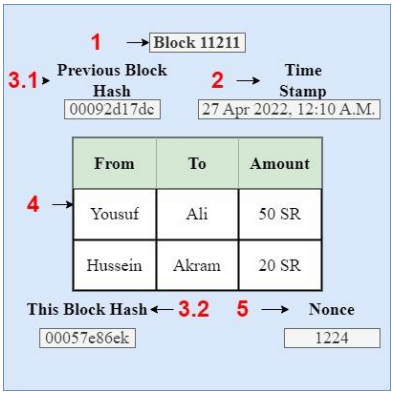


Fig. 5. Basic important contents of a blockchain

Blockchains are several types and not all are the same. Based on applications, the blockchain type should be selected. Figure (6) shows three kinds of blockchains.

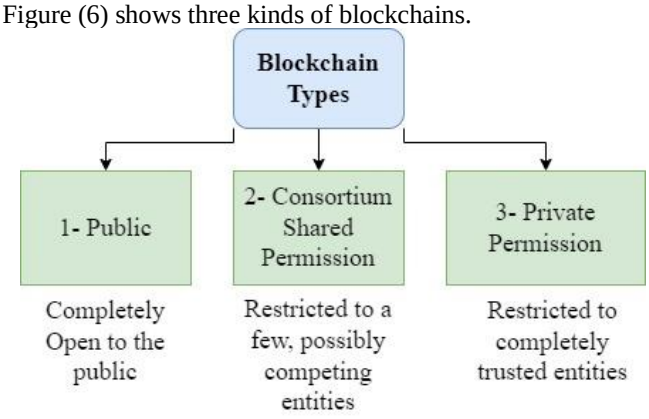


Fig. 6. Blockchain types

1- Public blockchain: it is considered as open and public network that anyone can join. In the public blockchain, anyone can download the software and create a node. *The main challenge* here is the trust is not shared between the members, and because of that there is crucial *need to use computing powers to reach consensus by proof-of-work.* As a result, the algorithm and the mechanism of proof-of-work is implemented to build the trust instead of giving trust to members.

2- Consortium or shared permission blockchain: there is only certain member of nodes in this type of blockchains. The trust level here is low and public cannot see the transactions. The performance of consortium blockchain is better than public blockchain because there is no need for proof-of-work to reach consensus.

3- Private or permission blockchain: in this type of blockchain there is high degree of trust and is considered as a centralized system. The difference here is getting the advantage of traceability over time. Developers can utilize the private blockchain to test their prototypes. Another benefit of the private blockchain is that it doesn't require proof-of-work to reach consensus because the nodes are controlled via centralized members.

Considering the blockchain technology is quite new, there are many terminologies that needs to be explained before we understand the technology. These terminologies will provide a reference to check every time a new work shows up. The following are the most common terminologies related to blockchain technology:

- Blockchain: Blockchain is a set of linearly connected information containing blocks secured with cryptography. In other words, blockchain is a set of protocols and cryptographic methods that enable a network of computers to work together to securely record data within a shared open database. Each block contains records and transactions; these blocks are shared across multiple computers and should not be altered without an agreement (consensus) of the entire network. Figure (7) is a simple representation of a blockchain.

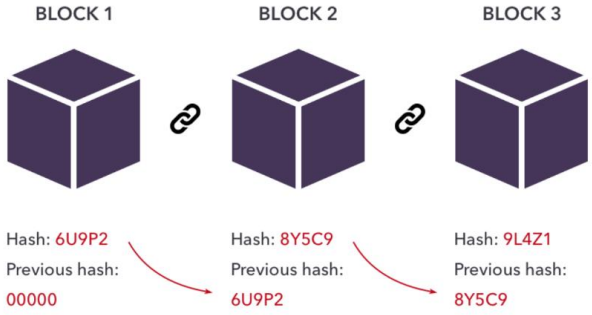


Fig. 7. Blockchain representation[24]

- Decentralization: Decentralization is shifting of power and authority in a community away from one central entity and making that power available to the members themselves. For example, instead of having a bank responsible to handle money transfer between two individuals, a protocol with high security can handle the transfer without intermediaries, only the network and specific processes involved to ensure the *execution of the transaction safely.*
- Ledgers and Distributed Ledgers: The ledger is a book that records the debits and credits of accounting transactions in a company. Ledger accounting system is responsible for the financial transactions of a business. The ledger is no longer registered as books, instead it is registered in *digital form*. If the digital ledger is on the network, it would be very easy to tamper with or copy. Here it comes the new concept of distributed ledgers. The distributed ledger is the same digital ledger but distributed to all individuals in the network. To make all data on the distributed ledgers consistent and aligned, protocols and consensus formation are used. Therefore, blockchain is not distributed ledgers and distributed ledgers are not blockchain. In fact, the power of blockchain comes when combined with distributed ledgers.
- Consensus: Since there are no centralized components to verify the alteration of database, the blockchain depends on distributed consensus algorithm. To make entry to the blockchain database, all the computers must agree about its state so that no one computer can make an alteration without consensus of the others. When someone join the blockchain, a user can get the full blockchain of all the other nodes and must verify that it is not tampered with (consensus). The concept of *consensus is used to provide the security for the distributed ledgers*, which makes tampering with blocks almost impossible. The *consensus is achieved* by applying proof of work, peer-to-peer protocols, and cryptography.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 01, January-2023

- Cryptography and Public/Private Key: There are two important concepts needed to be explained first; these are *encryption* and *decryption*. *Encryption* is a process of converting a message into code so that only authorized parties can access it. *Decryption* is reversion of the encryption process so that the message can be converted to the original message. *Cryptography* is using the techniques of encryption and decryption to send and receive messages. Cryptography is being used since war times when the messages to be sent must be private, and only the one who knows the algorithm can read the message. For example, Julius Caesar has used cryptography to send messages in war by shifting each letter to the left by 3 in the alphabet. Figure (8) shows a representation of shifting letters.

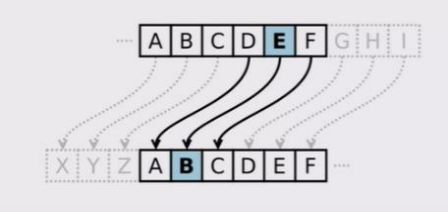


Fig. 8. Cryptography by Shifting 3 Letters to Lift[25]

- Cryptographic Hash Functions: The cryptographic hash function can transfer any input (letters, numbers, documents, images, and videos) into an output of fixed hexadecimal number. There are many specific characteristics of this function such as fast working, irreversible, deterministic and the output is fixed in length. There is a possibility that two different inputs can give the same output from a hash function only if the output is small. Therefore, there are several cryptographic hashing functions that starts from 128 bits and 256 bits of output length. For example, secure hashing algorithm 128 (SHA 128) and its output is 128 bits in length. Also, another example is SHA 256 which has an output of length of 256 bits. The higher the length of the output is, the more secure is the function and that can help to avoid collision for having 2 inputs with the same output.
- Mining, Validity, and Proof of Work: *The purpose of having mining computers* is to validate transaction, add them to the block they are building, then broadcast the completed blocks to the network. There is a mechanism called proof of work. *The proof of work* slows down the creation of new block to secure the blockchain and stops tampering with blocks easily. In conclusion, mining is the process done to validate a new block in the blockchain. *The proof of work* is when the miners are able to add a new block. Validation is making sure that a block is added under certain complexity or difficulty level. For example, the first 19 digits of the hash from the left are zeros.

## V. APPLICATION OF BLOCKCHAIN IN SUPPLY CHAIN

Blockchain is not only a financial cryptocurrency tool. In fact, the application of blockchain is extended to contribute in supply chain. There are too many participants in the success of the supply chain. In this section, the focus is concerned on supply chain planning, supply chain sourcing and supply chain operations. This section will discuss the existing problems in each area and the solution that blockchain can provide.

### *A. Blockchain Application in Supply Chain Planning*

Supply chain planning is a crucial part in the supply chain network. The planning must decide the market need of the product based on a forecast. Once the forecast is ready, all the parts in the *supply chain start to work*. The accuracy of the forecast depends on the quality of the data. The current data collection methods are absolutely not saving the privacy of the consumers. If the methods used are not accurate can result in un-accurate forecast. There are many applications used to collect data from customers without their knowledge. These data are being sold and used without their knowledge and payment to the data owners.

Blockchain can provide an identity to all customers. These identities do not necessarily expose their personal data when they purchase through blockchain technology. Instead, customer can have the right to select what data to be shared and have full control over their data. Also, customer can allow to share data that are not private. For example, the age and gender of the customer is shared without sharing the name and identity number or house location of the customer. Also, the customer can be rewarded each time his data is used. The security provided to customer through blockchain is very high, and that requires the use of public blockchain.

### *B. Blockchain Application in Supply Chain Sourcing*

Supply chain sourcing is concerned with the procurement of material in the supply chain network. There are several items from the viewpoint of procurement. These items are strategic items, bottleneck items, leverage items and non-critical items. The current supply chain system involves *a lot of processes to make a single procurement securely*. These processes are related to comparison between suppliers, selecting the best quality versus price, submittal of the purchase order, collection of the invoice, processing the invoice and payment. These processes are sometimes get missed and requires a lot of efforts to keep the relation with the supplier in healthy condition. Furthermore, delayed payments can cause direct effect on the relationship as well. The procurement responsibility is not to get involved in every single process. Instead, the procurement should always look for new technologies and best product worldwide to improve the overall supply chain profit as well as to provide lower costs to end customers. The followings are bullet points showing the *challenges and issues related to the current supply chain sourcing:*

- Too many processes related to procurement, and possibility of human error.
- Troubles between procurement (buyer) and supplier related to quantity, quality, delivery and delayed payments.
- Very low trust to automate payment.

Blockchain technology contributes to application of the smart contracts with suppliers. The smart contract can ensure and automate the processes of procurement, especially for the repeated items. Also, the smart contract can save the rights of

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delivering the goods and payment release on time. Blockchain contributes the most in procurement by processing the payments automatically, even if there are special terms and conditions related to divide payments into several payments. These improvements can effectively keep the relation between supplier and buyers in great condition. Figure (9) shows the current supply chain sourcing issues and the proposed solution by blockchain. Considering that invoice processing is very sensitive and trust level is very low, there are many processes to confirm the delivery and the payment from both buyers and suppliers. The smart contract application can provide a secure transaction system that ensure the rights of both parts with a very high security. The trust is provided by the system and the smart contract. Most of the processes in the current system are only to achieve one thing, that's trust. Therefore, the blockchain type to be selected here is the public blockchain with excellent security features.

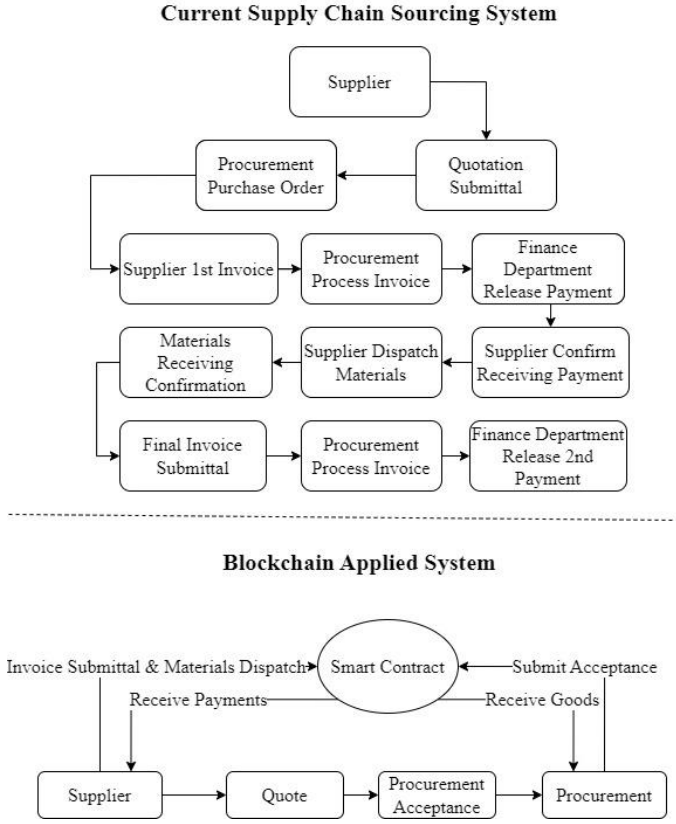


Fig. 9. Current Supply Chain Sourcing and Proposed solution by Blockchain

### C. *Blockchain Application in Supply Chain Operations*

Supply chain systems have two problems related to operations that causes delays and uncertainties. These problems are mainly related to quality and insufficient control over the inventory. There are too many processes in order to control the quality of the final product. For example, there are external quality processes related to ordering and receiving the material as per factory specs, then releasing the final product as of factory acceptance test. This involves several steps to ensure the right quality of the received goods, the right handling and storage of the products, and the right authentic assurance of the tests done on the product. On the other hand, there are internal quality processes concerned about processing the row materials in each step in the factory. These include checkup and tests before and after each phase of manufacturing as well as storage control. Some of the challenges and issues that may rise in a supply chain system are:

- The received goods are having fake certificate that is provided by a supplier.
- Only central authorities concerned to do specific test.
- The origin of the material is not time stamped and not traceable.

The blockchain technology provides great value to the supply chain operations in several aspects. First of all, the immutability of the blockchain can prevent any tampering with the quality tests provided in the phases of supply chain. If the certificate data is stored in the block, then it is impossible to change the data in that block. On the other hand, the origin of the goods can be traced all the way back not only to manufacturers, but also to the suppliers as well as to consumers to check the quality of the materials used for that particular product. Figure (10) shows how the factory and customer can refer to blockchain to check the originality of the data recorded. The tracing function of blockchain contributes very well in the field of supply chain operation. The type of the blockchain is public here because of the trust level is low.

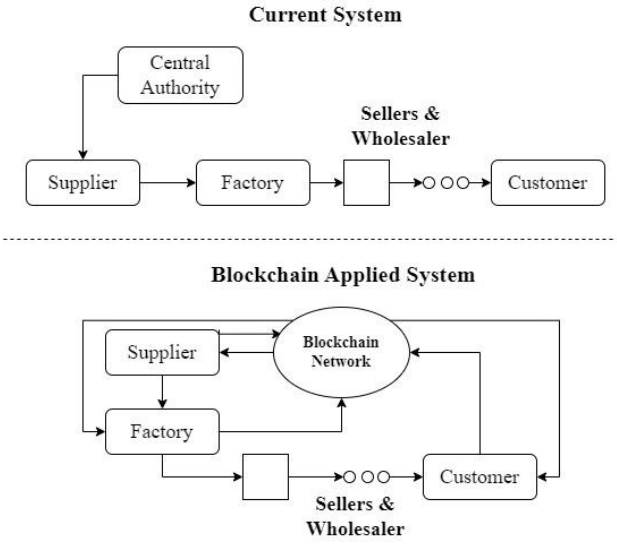


Fig. 10. Current Supply Chain Operations and Proposed operation by Blockchain

### D. *Blockchain Application in Supply Chain Network and Logistics*

Transportation success in logistics depends on proper documentation and coordination. Without the documentation, delays and storing cost at ports increase. The certificate of origin and certificate of conformity are critical documents in logistics systems. The documentations are generated without ability to trace. Also, there is no digital signature ensuring that no one can manipulate the document. Some of the challenges and current issues related to transportation documentation in logistic systems are:

- Lack of digital traceability for sensitive documents.
- Digital signing on the documents.

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Vol. 12 Issue 01, January-2023

Blockchain technology can add the traceability function easily over the network. The traceability is reliable because once document is created, there is no way back to modify the data recorded. Document signing using blockchain is a secure process using hashing functions, public and private key cryptography.

*E. Proposed Integrated Framework*

Blockchain contributions in supply chain is mostly concerned with immutability and security, identity and authenticity of record, decentralization of authorities, as well as the value transfer management. All these features can be achieved to improve the current supply chain and logistic systems. The type of blockchain to be selected is mostly public blockchain, considering low trust between the parties and the requirement to have a very solid consensus algorithm that build the trust of individuals on the system. However, consortium or even private blockchain can still be used with some specific application within supply chain industry. Figure (11) shows the general blockchain framework application for supply chain and logistic systems.

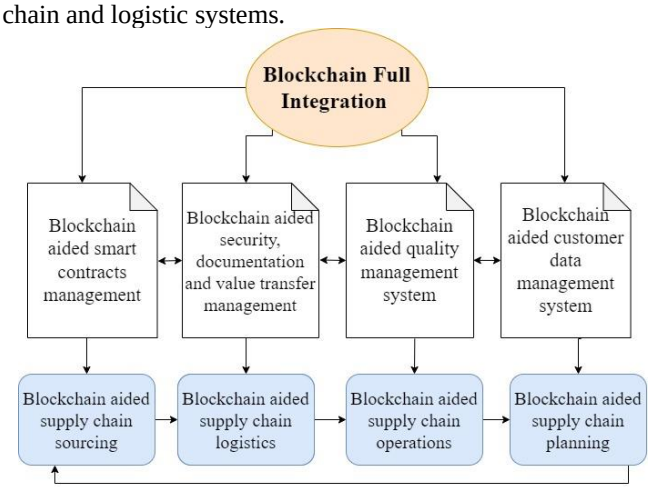


Fig. 11. Blockchain Application Framework for Supply Chain and Logistic systems

By looking at figure (11), there are several applications could be proposed and built. These applications are:

- Smart contract management system: this system is responsible to manage relations between suppliers and factories in need of materials. The system must provide a simple interface for users to create agreements and contracts that are automatically executable.
- Documentation and value transfer management system: this system allows to generate authentic traceable documents and value transfer within the logistics network and entities. The system provides a user interface to communicate easily with authorities in need of critical documents to process shipments. Also, the system provides digital traceable signature.
- Operation and quality management system: the system should provide immutable records of tests on internal and external quality measures to manufacture a product. Also, the system should provide a timestamp traceable document on product origin and productions data.
- Customer data management system: this system should provide a secure data sharing process for customers by providing identities. Also, the system should allow customers to select either to share data or not as well as a rewarding system for customers willing to share their data.

The proposed system integration adds a great value to the overall supply chain systems. Cost of delays can be reduced and human error can be avoided by integrating all these applications together.

## VI. CONCLUSION AND RECOMMENDATION

Blockchain technology provides decentralized solution. The building blocks of blockchain is based on shared database across networks of nodes. This shared database consists of blocks that contain information that is impossible to modify once created. With these features, the blockchain can do the followings when implemented in supply chain systems: *Information sharing, Immutable records, Integration with other technologies and Traceability.*

Blockchain is still facing issues related to scalability. The core reason behind scalability is the consensus mechanisms used. The information integrity is important for the entire processes of supply chain, logistics, and that includes reverse supply chain as well.

A framework is proposed in this paper, to show the potentials of blockchain technology application in the supply chain systems. The blockchain contributions in supply chain is mostly concerned with *immutability* and *security, identity and authenticity of record, decentralization of authorities*, as well as the *value transfer management*. All these features can be achieved to improve the current supply chain and logistic systems. Some of the proposed applications to be developed that would greatly improve the efficiency, effectiveness, performance and the overall profitability of the supply chain system are: *Smart contract management system*, *Documentation* and *value transfer management system, Operation and quality management system* and *Customer data management system*. The integration of these applications adds a great value to the overall supply chain systems. Cost of delays can be reduced human error can be avoided faster flow of material and traceability can be accomplished and higher profitability could be achieved by integrating all these applications together.

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