Improving the process of container shipping using blockchain

by

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ABSTRACT

Container shipping is one of the most important aspects of the global supply chain. Currently, approximately 60% of all seaborne trade is moved through containers. However, despite the growth in trade, there has been little investment in process improvements which has led to the growth of supply chain issues in the containership industry. Three critical issues were identified that have marred the overall efficiency of the supply chain. The first is customs clearance that creates barriers to trade and inefficiencies. Second is aging technology in the container shipping industry which is creating a lot of wastage in the system. Third is inefficient contracting practices. We create a value stream map as well as a re-engineered process using blockchain. With the use of blockchain, we see that despite certain limitations, the process can be made more efficient as blockchain has the potential to build trust amongst various participants in the supply chain.

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1 INTRODUCTION

Container shipping is one of the most important aspects of the global supply chain. According to statista.com, the global container shipping industry amounted to approximately 60% of all world seaborne trade which was valued at 12 trillion US Dollars in 2017.

It was not until 1956 that containers were used in shipping. Before that goods were transported mostly in sacks and barrels which was highly inefficient and time consuming. In 1956, an American trucking entrepreneur, Malcom P. McLean bought a steamship company with the idea of transporting entire truck trailers with their cargo still inside. He realized it would be much simpler and quicker to have one container that could be lifted from a vehicle directly on to a ship without first having to unload its contents.

Slowly and steadily, container shipping became one of the most efficient ways to transport goods from one place to another. According to freightos.com, by the 1980's, 90% countries had container ports, an increase of 89% from 1966. By 1983, container ships were carrying 12 million TEUs, with trade routes extending to the Middle East, South Asia and Africa. In the 90's the internet started to gained popularity and connected organizations with consumers globally. This led to the growth of e-commerce led by companies such as Amazon and Alibaba. However, with this growth in cross border trade, supply chains became increasingly complex and regulated (as the volume of high value goods started to increase).

Despite the growth in trade, there has been minimum investment in process improvements which has led to the growth in supply chain issues in the containership industry. In the following

pages, we discuss some of the critical issues in the containership industry and how technology can help address them.

1.1.1 Barriers to trade

According to a 2013 report by the World Economic Forum, reducing supply chain barriers to trade could increase the world GDP by nearly 5% and trade by 15% annually. The report identifies border administration as a key supply chain barrier. Further, the report discusses three main aspects of border administration that cause supply chain disruptions. These aspects are:

1. Efficiency of customs administration: Efficiency of customs administration refers to the speed and ease with which imports and exports can clear customs and the quality and range of services national customs authorities provide. Inefficiency usually reflects an insufficient allocation of resources to customs agencies or a failure to adopt best practices in customs procedures. These barriers can include frequent inspections and long wait times.

2. Efficiency of Import-Export Procedures: Border delays and burdensome requirements can extend beyond a customs administration to include a lack of coordination between border agencies and compliance with import-export standards. These barriers weigh especially heavily on industries like chemicals that are regulated by multiple agencies. For example, when a chemical company exports into the US, its products can fall under the jurisdiction of up to 12 regulators, including the FDA, the Drug Enforcement Agency (DEA), the Department of Commerce Bureau of Industry and Security (BIS) and the Department

of Homeland Security. These agencies operate independently and often lack effective coordination of communications, which results in the imposition of additional rules and regulations and increased delays.

3. Transparency of border administration: Transparency of border administration reflects barriers associated with corruption, which could include the direct costs of making "facilitation payments" (bribes) or the added delays that result if a bribe is refused or not forthcoming.

1.1.2 Technology adoption in the maritime industry

The shipping industry, recently has been going through a period of unprofitability and excess capacity. However, according to a 2017 report by Business Performance Innovation (BPI) network, overcapacity is not solely responsible for the woes of shipping industry. The industry also faces significant problems from inefficiency and waste due to aging technology infrastructure and business processes that lack real-time information sharing and effective collaboration.

According to McKinsey and Co. there is some $17 Bn of waste in port and carrier business. As per the report by BPI, Carrier-to-terminal collaboration is beset with significant inefficiencies due to the decades-old information systems that are too inflexible to enable real improvements in stowage planning, port arrival coordination and other processes. But other challenges, such as coordination with inland transport carriers, cargo flow transparency for importers and exporters, and overall planning and decision-making, are also plagued by the lack of visibility and data integration in today's ocean supply chain.

BPI surveyed more than 200 executives in the Ocean shipping industry and found that around 60% believed that potential improvements could be achieved across a wide range of ocean supply chain processes. Some 57% of executives indicated that poor coordination between partners and others in the supply chain is one of the biggest challenges they face. Another 50% point to a lack of transparency and visibility across the supply chain as a top challenge. Around 90% of the respondents said that real time access and information sharing between shipping partners is one of the key to improve efficiency and performance of the global shipping industry. Table 1 illustrates the areas that require the most improvement

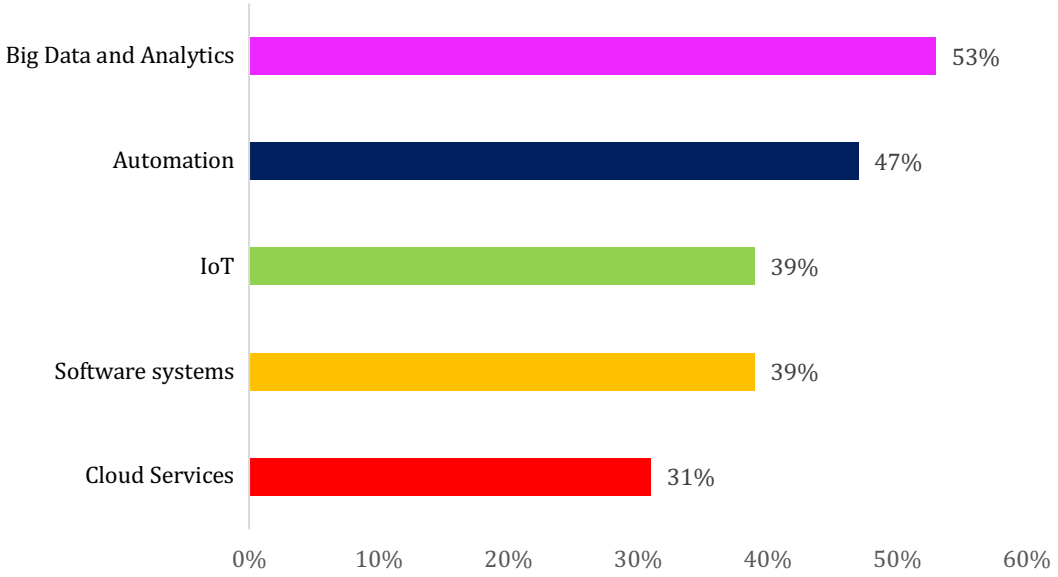
Table 1: Areas that require the most improvement according to executives

Area of Improvement	% of executives who responded positively (n~200)
Carrier to terminal coordination and planning	35
Supply chain visibility and information sharing	35
Coordination across shipper and shipper alliance	24
Terminal operations	24
Cargo flow and visibility	24

Source: Competitive gain in the ocean supply chain, BPI network, 2017 (Note that $\Sigma > 100$)

Further, the executives showed confidence in technologies such as Big Data and Analytics, Automation, IoT and believed that these technologies can help improve the existing inefficiencies in the shipping industry. Figure one gives the details of responses.

Figure 1: Technologies that can improve efficiency in shipping industry



Source: Competitive gain in the ocean supply chain, BPI network, 2017(Note that $\Sigma > 100$)

1.1.3 Inefficient contracting practices

Slow, inefficient contracting practices and a high degree of unreliability are some other concerns that are plaguing the containership industry. These result in poor contract compliance, booking downfalls, blanked sailings (where to adjust capacity or freight rates, either a particular port is missed or the sailing is altogether cancelled), excessive inventory costs to shippers, and other supply chain disruptions.

The fundamental problem lies in the contracts (Tirschwell, 2015). In the shipping industry, the parties involved treat the signed annual agreements or individual cargo bookings more as a formal procedure than as a performance guarantee. By non-performance we mean that, when the market is slow, the shipper chooses to go to the spot market to book its capacity simply to save money. This results in loss of business and unutilized capacity for the carrier. On the other hand, the shipper has his own fears. The shippers generally fear that their cargo may not be loaded on to a vessel it was scheduled to sail because the vessel ran out of capacity (known as

rolled cargo). This may happen if there is no minimum quantity set in the agreements between the shipper and the carrier or the shipper booked the capacity through spot market.

To avoid such situations and build trust with the carriers, most shippers agree to a minimum quantity commitment (or MQC) in their contract and stick to it. They minimize the risk for the carrier where no cargo shows up. This brings some amount of certainty for the carriers who can then plan the capacity better. However, when spot rates are low, some shippers do not honor the MQC and ship under the lower spot rates.

A top executive of one of the largest carriers serving the U.S. market remarked that 20% of import shippers do not meet their MQC (Tirschwell, 2015). In either case, if the shipper fails to deliver its MQC or the carrier gives its space away to higher-paying freight, the result is the same. One party is negatively impacted and frustrated but does not seek legal recourse; there is too much long-term mutual dependence on both sides.

With the above issues plaguing the containership industry, we try to evaluate if the current and upcoming technologies such as blockchain, can help in reducing such inefficiencies. In the next section (Section 2), we deep dive into the current literature available on blockchain. Then in Section 3, we do a value stream mapping of the existing process and then re-engineer it using blockchain. Section 4 covers the conclusion and future recommendations.

The methodology for this study is mostly based on secondary research. In terms of primary research, interviews were conducted with some industry experts.

2 LITERATURE REVIEW

In this section we review the current literature available on blockchain. We first evaluate what a blockchain is and how it works. We then focus on discussing the different types of blockchains. After this, we narrow down and understand the specific use of blockchain in supply chain and smart contracts.

2.1 What is a Blockchain?

The first work on a cryptographically secured chain of blocks was described in 1991 by Stuart Haber and W. Scott Stornetta. In 1992, Bayer, Haber and Stornetta incorporated Merkle trees to the design, which improved its efficiency by allowing several documents to be collected into one block.

However, it was not until 2008 that blockchain came into existence. The first blockchain was conceptualized by a person (or group of people) known as Satoshi Nakamoto in 2008. It was implemented the following year by Nakamoto as a core component of the cryptocurrency Bitcoin, where it serves as the public ledger for all transactions on the network. It is an algorithm and distributed data structure for managing electronic cash without a central administrator among people who are not familiar to each other. Through the use of a blockchain, Bitcoin became the first digital currency to solve the double spending problem[1] without requiring a trusted authority [2]and has been the inspiration for many additional applications.

[1] Double spending problem is unique to digital currency. Digital currencies can be replicated and thus there is a risk that the holder could make a copy of the digital token and send it to a merchant or another party while retaining the original. (Investopedia.com)

[2] In cryptography, a trusted authority is one that issues the digital certificates. A digital certificate certifies the ownership of a public key by the named subject of the certificate. This allows others (relying parties) to rely upon signatures or on assertions made about the private key that corresponds to the certified public key. (Wikipedia.com)

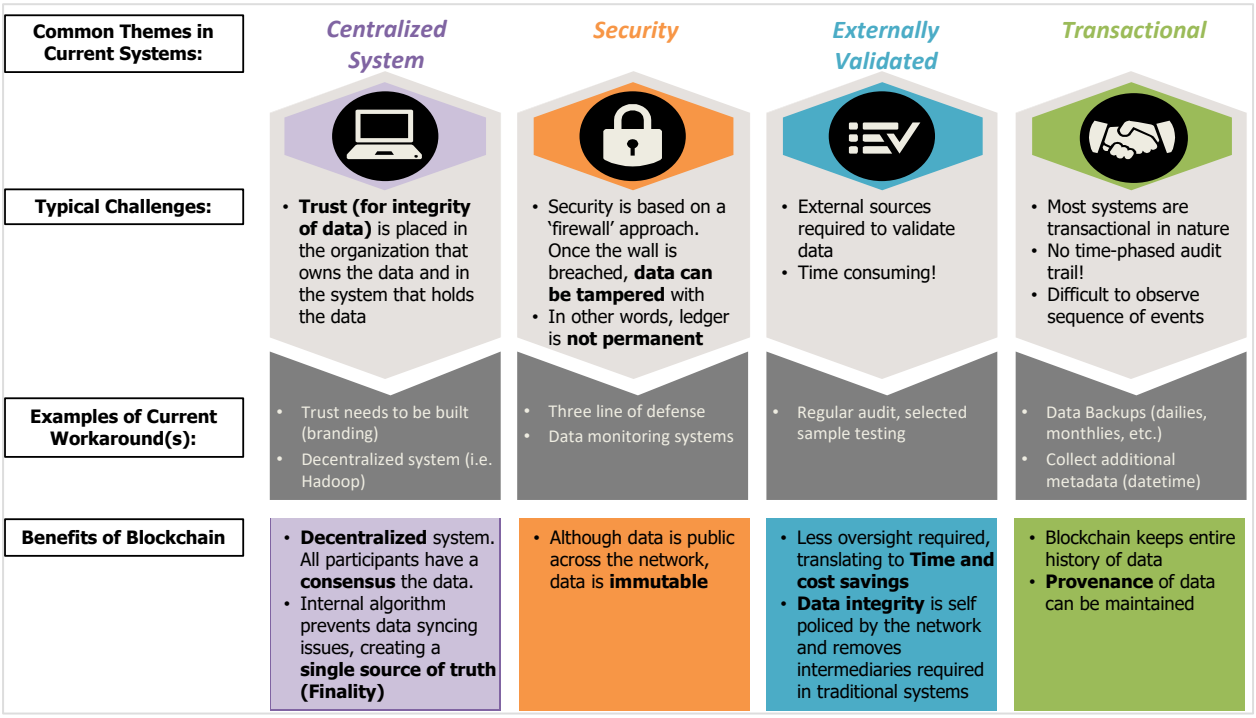
Blockchain is a special instance of Distributed Ledger Technologies (DLTs), almost all of which have emerged in Bitcoin's wake. A blockchain is the structure of data that represents a financial ledger entry, or a record of a transaction. Each transaction is digitally signed to ensure its authenticity. This provides integrity to the ledger and existing transactions.

These digital ledger entries are then distributed among several computers/servers each of which act as a node. These additional nodes and layers in the infrastructure serve the purpose of providing a consensus about the state of a transaction at any given second; they all have copies of the entire existing authenticated ledger distributed amongst them.

In short, blockchain can be thought of as a ledger that keeps track of all accounting records. As a book has numbers for each page, in blockchain, these pages are denoted by blocks. Although the blocks do not have a number, each block has a timestamp which fulfils the exact same function. A new block is always added after the block with the most recent timestamp. This creates a chain of blocks.

Blockchains use cryptography to make sure that if any changes are made to the block, the users are able to notice these changes instantly. This property makes it a good data structure to keep track of records of anything of value. Figure 2 shows the potential of blockchain.

Figure 2: Potential of blockchain



Source: blockchainhub.net

The benefits of blockchain over current systems are evident in the figure above. A single source of truth in generated in blockchain due to decentralization compared to current systems which are mostly centralized. Further there is an enhanced level of security with blockchain as the data is immutable. In current systems, the data is mostly externally validated (for example through audits) while in blockchain external validation is not required. The data on blockchain has a date and time stamp which serves as the proof of validation. All these transactions are stored online in blocks. In Satoshi's bitcoin blockchain, the blocks contain information about transactions in Bitcoin. The block states who sends which Bitcoins to whom.

As the blockchain keeps a track of the movement of all Bitcoins since their inception, the ledger can be checked to know exactly who owns which Bitcoin at any point in time. This ownership mechanism that helps track the bitcoins is called the current 'state' of the blockchain. A

transaction occurs only when it is added to a block. As new blocks are then added, the state of blockchain gets updated. As all the transactions are updated on the blockchain, the user is able to access the blockchain at any point and see what transactions were made. This is known as the peer to peer network which we discuss in the next section.

2.1.1 The role of peer-to-peer networks

To use the blockchain as a ledger for transactional data, the user should be able to check in the blockchain if there was a transaction actually made to his/her address or wallet (a digital space where cryptocurrencies are held). If there was only one computer/server storing this information then the accessibility of data would have been dependent on that computer/server. If that computer was not functional or out of order, then no one could access the data. This is where blockchain is useful. The current state of the blockchain is downloaded, synchronized and made available to a large number of computers worldwide. These computers are called 'nodes', and they work together in a peer-to-peer network to ensure that the blockchain is secure and up-to-date. Each one of these nodes stores the complete, updated version of the blockchain. Every time a new block is added, all the nodes update their blockchain. Using a peer-to-peer network has the following advantages:

- It is not reliant on one node. As there are multiple nodes, the information is accessible to anyone at any point in time.
- It makes the blockchain secure as the data is not stored on just one computer. It is stored on multiple computers and to change the data, all the nodes need to make the change at the same time. This is virtually impossible thus making the data immutable.

- A hacker will have to hack thousands of nodes at the same time to gain complete control of the blockchain. This will never be easy considering the computing power that will be required to make this operation possible will be humongous.
- As the data is immutable, it cannot be edited or deleted.

The peer-to-peer network validates the transactions and the blocks through a consensus mechanism. When a block is created in a blockchain, it has to be accepted by everyone in the chain and only then deemed valid. We discuss this mechanism in the next section.

2.1.2 The consensus mechanism

In centralized systems, an administrator manages the database and decides what files to store and how to update them. For example, consider an organization where a database administrator is responsible for managing the data on servers and deciding which documents to keep or to delete. If we assume each document to be a transaction then we can say that the administrator is a single person or computer (known as node) that approves, edits or deletes any transaction. No one else in the system can see on a real time basis what changes are being made to the database. This makes this system vulnerable to fraud, misuse, or error.

With decentralized public ledgers, such as blockchains, no administrators exist. A single node does not have the authority to approve, edit, or delete any transaction. Each node on a blockchain must come to a consensus in order to decide which transaction is valid. So, this brings to mind certain questions such as how each node comes to a consensus and how is the status of the public ledger updated in real time. The answer lies in Mining which is a mechanism that validates and updates transactions in real time.

Mining is when the nodes in the network participate in a form of lottery where they compete to solve a cryptographic puzzle. The owners of these nodes are known as Miners. Miners validate new transactions and record them on the blockchain. On an average, it takes a miner 10 minutes to mine a new block. This is done when the miners compete to solve a difficult mathematical problem based on a cryptographic hash algorithm. In bitcoin, the solution found is known as the Proof-Of-Work. Proof-of-work validates that a miner spent time and resources to solve the problem. When a block is 'solved', the transactions contained are considered confirmed, and the bitcoin concerned in the transactions can be spent (Damien Cosset, 2018).

In public blockchains, apart from proof-of-work (which is bitcoin specific), there are many other consensus mechanisms. We discuss the three most common ones below:

2.1.2.1 Proof-of-Work (PoW)

The consensus mechanism used by bitcoin is known as proof-of-work. Under this, the nodes need to prove that they have done work to be eligible to add new transactions to the blockchain. The work is energy intensive, as it involves the nodes hashing data. This needs a lot of computing power.

The nodes need to solve complex cryptographic puzzles in order to prove their work. This requires a high amount of computational power. Thus, the high cost of electricity and the initial capital needed to acquire the appropriate mining hardware makes blockchain networks that use PoW, such as Bitcoin, difficult to mine. One of the major drawbacks of proof-of-work is that it uses a lot of energy in form of computational power. Thus, a miner who has invested a lot in

computational power always has a higher probability of creating a block making the whole process expensive. The miner earns cryptocurrencies each time he validates a transaction or creates a new block.

Aside from Bitcoin, other blockchain networks that use PoW include Ethereum, Ethereum Classic and Litecoin. (Bitcoin.com.au, 2018)

2.1.2.2 Proof of Stake

Proof of stake is another consensus mechanism that is gaining popularity. The idea was first suggested on the bitcointalk forum back in 2011, but the first digital currency to use this method was Peercoin in 2012, together with ShadowCash, Nxt, BlackCoin, NuShares/NuBits, Qora and Nav Coin.

Unlike proof of work, where a user validates transactions and creates new blocks based on the computational work done, proof of stake system requires the user to show ownership of certain cryptocurrency units. Depending on the user's wealth also known as stake, the creator of a new block is chosen. (Shaan Ray, 2017).

Although proof of stake does not require a lot of computational power as it doesn't solve a puzzle in real time, it does require investments in terms of cryptocurrency. If a miner has to increase his probability of creating a block, he needs to increase his wealth. This means that huge amount of investment is required in cryptocurrencies.

2.1.2.3 Proof of Capacity

The proof of capacity protocol is similar to proof of work in the sense that a puzzle is solved in both mechanisms. However, in proof of capacity, the solution is not created in real time. The idea is that, instead of constantly changing numbers in the block header and hashing for the solution, proof of capacity involves plotting of the computer's hard disk. By plotting it means that the user stores multiple solutions on his computer's hard disk before the mining even begins. If one user's hard drive happens to have the fastest solution to the most recent block's puzzle, that user wins the block. This means that more is the capacity of a user's hard drive, more is the probability of that user solving the puzzle. The benefit of proof of capacity is that it uses much less power compared with proof-of-work. (Paul Andrew, 2018).

In addition to the above mechanisms, there are several other consensus mechanisms such as Proof of Reserve, Proof of Elapsed Time, Proof of Importance, etc. which have not been discussed in this paper.

2.2 Types of blockchains

There are three popular types of blockchains – Public, Federated and Fully Private. These different types of blockchain have been discussed below ("types of blockchain", blockchainhub.net):

- **Public blockchain:** A public blockchain is the most common form of blockchain. It is where anyone and everyone has the view to validate or view any transaction that happens on the network. Anyone can download the code and start running a public node on their local device, validating transactions in the network and participating in the consensus process. This gives anyone the right to participate in the process that determines which blocks get added to the chain and what the current shape and size of the Blockchain is.

  Several state-of-the-art public Blockchain protocols based on Proof of Work consensus algorithms are open source and not permissioned. It simply implies that anyone can participate, without permission. Examples include Bitcoin, Ethereum, Monero, Dash, Litecoin, etc.

- **Fully private blockchain**: The consensus mechanism is centralized in the hands of a single entity which mission is to verify and add all transactions to the blockchain. A network based on a private blockchain, therefore does not need to use a mechanism such as "Proof of Work" or "Proof of Stake" which are complicated to implement and expensive.

- **Federated or consortium blockchains**: Federated blockchains are mostly used in the banking sector. They are a type of private blockchain which is not controlled by a single

node but multiple pre-identified nodes. The consensus process in federated blockchains is different from that in public blockchains. Here, the consensus is controlled by a pre-selected set of nodes; for example, one might imagine a consortium of 15 financial institutions, each of which operates a node and of which 10 must sign every block in order for the block to be valid. The right to read the blockchain may be public or restricted to the participants. They are also known as private permissioned blockchains.

Table 2 shows the difference between public and private, federated blockchain

Table 2: Difference between Public, Private and Federated blockchain

Attribute	Public	Private	Federated
Participants	Permissionless, anyone can participate	Permissioned with pre-approved participants	Permissioned with pre-approved participants
Consensus Mechanism	Proof of Work, Proof of Stake, etc. Requires high amounts of energy.	Voting or multi party consensus algorithm which is faster and requires low levels of energy.	Voting or multi party consensus algorithm which is faster and requires low levels of energy.
Transaction approval Frequency	Long, for example in bitcoin it is 10 minutes or more.	Short, typically 100x ms	Short, typically 100x ms
Differentiating factor	Decentralized, needs no middle men	Low or inexpensive transaction costs. Faster transaction times and more transparency	Known identities
Asset (such as cryptocurrency)	Native assets (for example Bitcoin for bitcoin blockchain)	Any asset	Any asset
Privacy	Data publicly available	Defined by the company.	Privacy policy for data same as in traditional database
Transaction fee	Transaction fee required	Completely free/inexpensive transactions	Completely free/inexpensive transactions
Immutability	Secured by Hashing power	Mutable	Secured by distributed consensus
Examples	Bitcoin, Ethereum		Ripple, Blockstream, Multichain, Hyperledger Fabric

Source: blockchainhub.net

There are many differing opinions on the validity of private permissioned blockchains and whether they are as good as public blockchains. Buterin (2015), co-founder of Ethereum, notes that private blockchains can actually prove beneficial for many industries such as banks, supply chain intensive etc. If the industry doesn't really need a decentralized model and just needs the data to be hosted on a real time basis and a centralized database, it makes more sense to implement a permissioned blockchain. He further notes that permissioned blockchains reduce the transaction times significantly. For example, currently bitcoin blockchain can handle around 7 transactions per second (Brandon, 2017) which may not be a feasible option for a banking or a supply chain related company. Also, the transaction fee is a big obstacle in implementation of a public blockchain. On the other hand, in a permissioned blockchain up to 1000 transactions can be processed per second and they are generally either free or inexpensive.

Another very important feature that makes private blockchains more suitable for supply chains is that it provides privacy. For example, consider an example where say a company X located in the US buys the same component from three different suppliers based out of China. Now, if company X implements a public blockchain, then its data is on an open source and any supplier or individual can see the price at which company X purchases from other suppliers. This will lead to a problem for company X as depending on multiple factors, it may be buying the same component from different suppliers at a different rate. Thus, in such a scenario, the most logical solution is to implement a permissioned blockchain.

One interesting platform that is gaining popularity in the supply chain industry is Hyperledger. Hyperledger (or the Hyperledger project) is an umbrella project of open source blockchains and related tools, started in December 2015 by the Linux Foundation, to support the collaborative

development of blockchain-based distributed ledgers. Hyperledger has many frameworks but the most notable one is Hyperledger Fabric which was introduced in July 2017. It has been developed by IBM as a permissioned blockchain and as per IBM, it is a framework for building enterprise grade blockchain networks that can quickly scale as new network members join with transaction rates as high as 1000 transactions per second. IBM is already exploring this with companies such as Walmart and Maersk to improve the supply chain processes through implementation of Hyperledger fabric. In the next section, we specifically talk about use cases of blockchain in supply chain.

2.3 Blockchain in supply chain

Blockchain was first deployed commercially a few years ago in the financial-services industry to make trade/claims settlements and international payments more secure and efficient. Once the industry recognized the benefits of blockchain, other industries such as retail and consumer goods, have started to pilot blockchain applications.

Kristoffer and David (2018) note that in a supply chain context, transparency refers to information available to companies involved in a supply network. For the supply chain to be transparent, it is important that there is end to end traceability of the origins of a product or service. Thus, transparency and traceability are correlated.

Blockchain technologies indeed provide increased supply chain transparency, but more importantly they create an immutable and distributed aspect of the custody record by nature of the protocol which lends itself well to traceability applications.

Consider the use case of dry aged beef as an example to understand the use of blockchain for traceability. Consumers are increasingly demanding local and organic products with clear origin. In response to this, for example, retailers could provide selected product-related data through an app. With a simple QR-code scan on their smartphone, customers could validate every step the beef has taken through the supply chain and match that journey against their expectations. Consumers will be able to access data such as the provenance (such as feed or breeding), timing (such as aging duration, time in transport, best before date), location (of the farm and of the beef throughout the supply chain) or additional information (such as recipes and wine suggestions). The value of blockchain lies in the fact that there is a single source of truth that is consistent and cannot be tampered with. This brings an end to end transparency (Oliver Wyman, 2016)

In today's data many major companies are leveraging blockchains to improve their supply chains. Provenance, a UK-based startup, is giving its clients access to its blockchain so that they can share their product details, journey and other facets with their consumers. Walmart is working with IBM and Tsinghua University, in Beijing, to follow the movement of pork in China with a blockchain. Mining giant BHP Billiton is using the technology to track mineral analysis done by outside vendors. The startup Everledger has uploaded unique identifying data on a million individual diamonds to a blockchain ledger system to build quality assurances and help jewelers comply with regulations barring "blood diamond" products (Casey and Wong, 2017).

However, there are challenges that need to be overcome. One challenge is how the development and governance of technology will be done. Both public and permissioned blockchains have their limitations and benefits. There needs to be interoperability across permissioned and public blockchains, which will require standards and agreements. Closed ledgers led by consortium of companies will also rise as their members seek to protect market share and profits.

Another big challenge is that of regulations and law. A complex array of regulations, maritime law, and commercial codes governs rights of ownership and possession along the world's shipping routes and their multiple jurisdictions.

2.4 Smart Contracts

Of the various proposed benefits of blockchain that we discussed earlier, one important benefit is in the form of smart contracts. A smart contract may be understood as a set of algorithms and programs in a digital environment that can be partially or fully executed or enforced when certain conditions occur.

The main principles of work around a smart contract were originally described by computer scientist and cryptographer Nick Szabo in 1994. However, at that time there were no appropriate technologies to realize them. With the advent of bitcoin and blockchain, things started to change and smart contracts started to become a reality. While Bitcoin was the first cryptocurrency; however, it could not meet all the needs of a smart contract. The appearance of Ethereum put smart contracts into operation. (Andrew Tar, 2017).

So, in the context of blockchains, smart contracts may be defined as below:

- They have a pre-written logic (a computer code)
- They are stored and replicated on a distributed storage platform (e.g. a blockchain),
- They are executed/run by a network of computers (usually the same ones running the blockchain),
- and they can result in ledger updates (cryptocurrency payments, etc.).

Broadly, they work on “if then” clauses that are run and verified by many computers to ensure trustworthiness. The core functionality of a blockchain is to provide the users with a distributed trustworthy storage. Similarly, the core function of a smart contract is to provide the users with distributed trustworthy calculations.

A smart contract is made up of a computer code which is used to automate the "if then" parts of a traditional contract. The benefit of a computer code on a blockchain is that it has a very low probability of manipulation as there are less potential points of contention. The code is replicated on many computers and run by those computers, that come to an agreement on the results of the code execution.

Imagine a contract between a buyer in United States and a seller in China. Both of them define certain terms and conditions for payment to be made once the goods reach their destination. For example, the buyer may define a condition that if the goods are received broken or are received after the due date then the seller will be penalized. Similarly, the seller may define a condition that if the buyer doesn't order a minimum quantity of goods or cancels the order in a particular time frame then the seller gets paid a compensation. Now, both the parties get these conditions built into a smart contract with the required if-then clauses and use cryptocurrencies such as Ethereum as the escrow. Now consider that the goods reach the destination at the specified time and date and are accepted by the buyer. The buyer then makes an entry into say the ERP system about the receipt of goods. The ERP system will in turn send this data to a blockchain and that will be recorded on the smart contract. Once this happens, the payment gets released as all the conditions have been met. One may argue that ERP systems are susceptible to tampering. Thus, alternatives such as Internet of Things (IoT) are now being connected to blockchain to make such flow of information free of human contact. This area is currently out of the scope of this paper.

Thus, smart contracts provide the following benefits:

- Self-executing conditions: The if-then clauses build a self-executing contract. It reduces the need for human interaction. If a certain set of conditions are met, the seller gets paid. If the conditions are not met then one of the parties gets penalized automatically.
- Security: The smart contract is encrypted and distributed among nodes. This guarantees that it will not be lost or changed.
- Speed and Cost: Due to automation, the process is really quick. For example, the seller doesn't have to wait for payment if everything is in order. Once the conditions are met in the smart contract, the payment is triggered automatically. It also helps eliminate intermediaries which saves cost.

Despite great benefits, there are many shortcomings with smart contract. These have been discussed below:

- Human Factor: Coding and programming are done by people which means that there can be possible loopholes in the codes. This leaves the smart contract susceptible to attacks from hackers. One such example of this is the Decentralized Autonomous Organization Case (DAO). DAO was a decentralized autonomous organization for venture capital funding. It was launched in May 2016 with $150 Mn raised through crowdfunding. The organization had no employees and existed entirely as computer code on the Ethereum blockchain. Three weeks later, it was hacked and approximately $ 50 Mn in cryptocurrency were stolen. The hacker, who was one of the investors, had discovered an unintended loophole in the code of the contract and was able to take the money out. He didn't hack the system as such, rather just took advantage of the flawed code.

- Legal Complexity: Currently smart contracts are not under the ambit of government. However, in the recent past, the soaring price of cryptocurrencies has brought many countries to regulate the cryptocurrency industry. Smart contracts are legal documents that will be executed on a digital platform. Currently they do not require any government approvals and the parties can execute them based on their own understanding. If smart contracts get regulated and need government approvals, then the efficacy of smart contracts will be lost.
- Contractual terms: Smart contracts are mostly useful for “if then” sort of executions. In real world, people like optionality. In many contracts, clauses are written into things on purpose to create a channel for arbitration. For example, the force majeure clause which is present in most sea freight contracts. The question remains that how can a smart contract address such clauses through coding? Such clauses will require human intervention and judgement.

3 RESULTS AND ANALYSIS

In the section 1, we discussed the various supply chain issues in the containership industry. The three main issues that were highlighted were barriers to trade, technology adoption in maritime industry and Inefficient contracting practices. We discussed how these issues are plaguing the industry and currently there is no concrete solution in place.

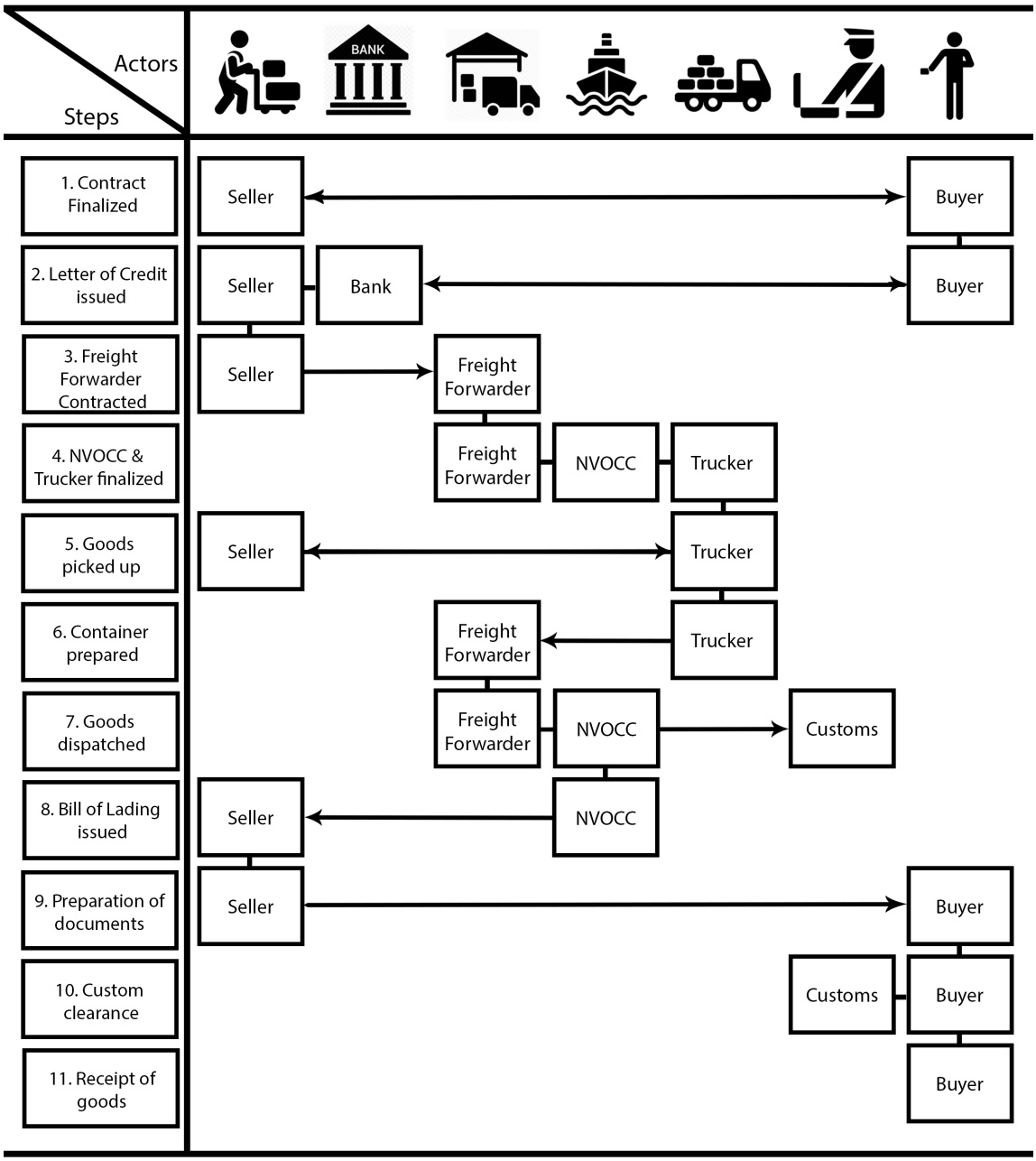
In section 2, we discussed about blockchain and its potential in the supply chain industry. We discussed how various applications of blockchain such as smart contract can be useful in bringing transparency and traceability in current supply chains.

In this section, we aim to tie both the things together and see how we can use blockchain to solve the issues in the maritime industry. We first talk about the current (As-is) process in containership industry and how the flow of information happens. We then re-engineer the existing process with the help of blockchain and see what improvements can be brought about. We also discuss the benefits and limitations of using blockchain.

3.1 As-Is Process of Shipping

As discussed in section 1, shippers face three critical supply chain issues. These lead shippers to face unnecessary delay and costs due to an overload of paperwork. The current process of shipment of goods and the importance of documentation is discussed below Figure 3

Figure 3: The current process of shipping containers



1. This is where the buyer and the seller interact for sale and purchase of goods and,
    - The seller and buyer enter into an agreement for sale of goods. This is done through traditional paper-based contracts. The contracts are physically signed thus they are exchanged over physical mail.
    - In most cases where there is a high value transaction and where the buyer and seller are not known to each other, the seller asks the buyer to provide a letter of credit (LOC) from the buyer's bank. A LOC is a document from the bank that guarantees payment.
2. The buyer and seller interact with their respective banks to issue and validate a LOC and,
    - The buyer requests a LOC with its bank (issuing bank). When the buyer requests for the LOC, he also specifies the terms according to which the payment shall be made. For example, on which date and time the seller should ship the product or from which port should the products be shipped. These guidelines are the ones according to which the bank shall issue the payment.
    - The issuing bank then sends a copy of the letter to the seller's bank (negotiating bank) along with the list of documents that shall be required from the seller for payment.
    - Once the negotiating bank confirms the status of the LOC, it then informs the seller. The seller needs to carefully go through the terms of the LOC as the payment shall be made based on the LOC.
3. Once the agreements are signed and the LOC is approved, the seller prepares to ship the goods

- The seller starts to prepare the goods according to the terms agreed. For example, the type of packaging, the physical appearance of the goods, brand labels etc. These things are generally agreed in the initial contract.
- Parallelly, the seller also looks for a freight forwarder who will assist the buyer in shipping the goods. The seller generally issues a freight quote request which could be via email, phone call, or on online form. The freight quote request will have all the information that is required to ship the goods, for example it will have the data the goods have to picked, the quantity/weight of the goods, type of goods (HAZMAT or not), the port of dispatch etc.
- Based on information provided, the freight forwarder prepares a freight quote breaking down the individual legs of a shipment including surcharges:
    i. Routing information - where the cargo is the being shipped to and from.
    ii. The transport mode and equipment (e.g. by ocean on pallets).
    iii. The shipment details, including the dimensions, weight and a description of the goods, such as whether they are hazardous.
- Once the seller accepts the quote from a certain freight forwarder, he provides him the following documents:
    i. Commercial Invoice: Suppliers selling to importers issue a Commercial Invoice. Like other invoices, it is a proof of sale, and it includes the same information included on a standard invoice. What makes it different is that it also includes freight-related information required by Customs for Customs Clearance.

ii. Certificate of Origin: Most countries need this document for customs clearance, to determine what duties may be relevant, and for advance cargo reporting (e.g. for government import statistics)

iii. Material Data Safety sheet (only for HAZMAT): This is a declaration for Hazardous goods.

iv. Shipper's Letter of Instruction: This contains information such as Consignor/consignee details, Routing Information, Incoterms,

4. After the freight forwarder (FF) receives the contract and relevant documents from the seller, he sets out to book the capacity with a trucking company and a non-vessel operating common carrier (NVOCC). An NVOCC is an aggregator who aggregates the containers from multiple FF's or shippers and then book capacity with a liner. This optimizes the cost and capacity for both the shipper and liner:

- The FF releases a quote request to multiple trucking companies and NVOCC's. The FF may contract the trucking company/NVOCC based on a long-term contract or spot market. The trucking companies and NVOCC's then go through the terms and conditions and accordingly accept or decline the request. This is generally done over emails.
- The NVOCC provides the FF with a booking confirmation which includes Booking number, Equipment size and quantity, Transport plan, Load itinerary with the cut off time for goods to reach the port etc. This is sent via an email.
- The FF, then communicates the information to the seller through an email.

5. Once the seller has the information from the FF, the shipper then prepares the goods for pickup by the trucker.
    - The trucker arrives at the seller's facility to pick up the goods. It also collects the following documents:
        i. Container weight declaration: The document will include shipper details, consignee details, type of container, commodity, total weight of products and type of cargo.
        ii. The booking confirmation that the FF would have provided to the seller.
6. Once the good have been picked up from the seller's warehouse, the trucker then
    - Takes the goods to the FF's warehouse. The Freight forwarder then starts to prepare the containers that will go to the port for loading. The freight forwarder will consolidate the volume from different customers and prepare full load containers. This maximizes capacity and minimizes costs.
    - The FF also ensures that the packing list which contains information such as Shipper/Consignee, Equipment/Skid/Crate, Packing Details, Goods description and HAZMAT is ready.
    - The trucker then takes the containers to be delivered at the port along with the packing list. The packing list, booking confirmation etc. are required by the trucker to gain entry at the port.
7. The trucker then arrives at the port and gains entry by showing the relevant documents. However, the FF has more work at this stage.

- The FF liaisons with the custom to get the goods cleared. This is a daunting task as the customs verify all the documents and ensure that the declarations are fine. If there is any discrepancy, the goods are not loaded on the vessel and will incur demurrage cost if they stay on the port.
- The FF also liaisons with the NVOCC for the bill of lading. Bill of lading (BOL) is an important document that states the complete details of the goods, their dispatch, condition etc. This document serves as a proof that the goods were cleared by the customs and were dispatched on a said date and time. Any discrepancy in the bill of lading would mean that the buyer will not be able to take the possession of the goods.
- The NVOCC will generate a draft BOL and send it to the FF who will verify all the details and rectify any mistakes.

8. Once all the formalities are over and the FF approves the draft BOL, the containers are loaded on the vessel and shipped and
    - The NVOCC issues 3 original copies of the BOL to the FF.
    - These are paper based copies which are delivered to the seller through hand or through an express courier service by the FF. This process takes time depending on the location of the seller.
9. After receipt of the copies of BOL, the seller does the following:
    - The seller then keeps one copy of BOL with himself a
    - He sends one copy to the bank to get the payment released. The BOL would state all the important information that is required for the payment to be released such as the time of departure of goods, the quantity, the port of departure etc.

- The 3rd copy is dispatched to the buyer who would need it to get the cargo released at the destination port. This copy is generally sent through a courier or express post.

10. Once the buyer receives the BOL, he prepares all the necessary documents that he will require to get the possession of the goods. Once the cargo arrives at the destination port, the importer needs to present the following documents to get the cargo released:
    - Bill of Entry: Bill of entry is one of the major import documents for import customs clearance. Bill of Entry is one of the indicators of 'total outward remittance of country' regulated by Reserve Bank and Customs department. Bill of entry must be filed within thirty days of arrival of goods at a customs location. After completion of import customs formalities, a 'pass out order' is issued under such bill of entry. Once an importer or his authorized customs house agent obtains 'pass out order' from concerned customs official, the imported goods can be moved out of customs.
    - Commercial Invoice
    - Bill of Lading
    - Import License
    - Insurance Certificate
    - Purchase Order
    - Letter of Credit
    - Any other tax documents.
11. If all the documents are in order, the goods are released from the port and the buyer gets the possession of the goods. However, if there is any discrepancy in the documents, the goods are not released and the buyer incurs additional cost in form of demurrage.

3.2 Limitations of the As-Is process

The As-Is process of shipping has multiple limitations that make it cumbersome and expensive. First is the extensive documentation that is required at every step. Generally, high value and high-risk contracts are executed on paper to maintain legal status. Further, all the documents that are presented for customs clearance are generally printed on paper. This leads to a lot of wastage in terms of time and resources and mars the efficiency of supply chain. According to the World bank, it takes around 7.5 days globally to clear exports through customs (The World Bank, 2016).

As discussed in section 1.1.3, payment of performance penalties is a major issue. Most of the times the shipper or the carrier does not pay for service deficiencies. The contracts are generally loose verbal agreements put on paper.

Another aspect that creates inefficiency is the need for a Bank Guarantee. Generally, the buyer is expected to provide a letter of credit (LOC) to the seller as an assurance that the seller will be paid once certain conditions are met. Banks from both the parties are involved in this process and the seller doesn't ship the goods until he is satisfied. This is especially true in case of small buyers. The real problem here is that the LOC only describes certain overall conditions such as port of dispatch, time of dispatch, the quantity of dispatch etc.; however, it generally has no condition that speaks about the quality of the goods received. Thus, even if the supplier ships defective goods, he is liable to get the payment from the bank if the LOC conditions are met.

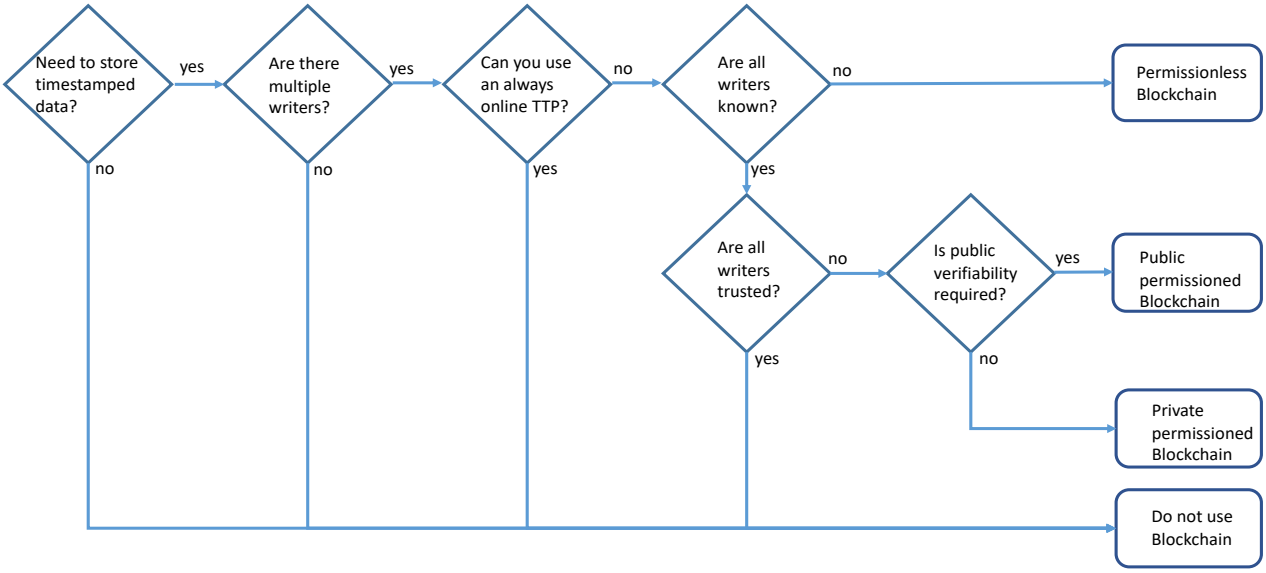
These are some of the major issues that we face in the current containership supply chain. In the next section, we try to re-engineer the existing process using blockchain and evaluate if the process can become more efficient.

3.3 To-Be state

The As-Is state of container shipping is both inefficient and expensive. In the last section, the challenges with the as-is process were discussed. Blockchain as an enabler may help solve many problems for this process and make the process lean and efficient.

The framework shown in Figure 4 explains why a blockchain may be a good fit to re-engineer the existing process.

Figure 4: Framework to decide if a blockchain is needed



Source: Do you need a blockchain: Karl Wust, Arthur Geravis

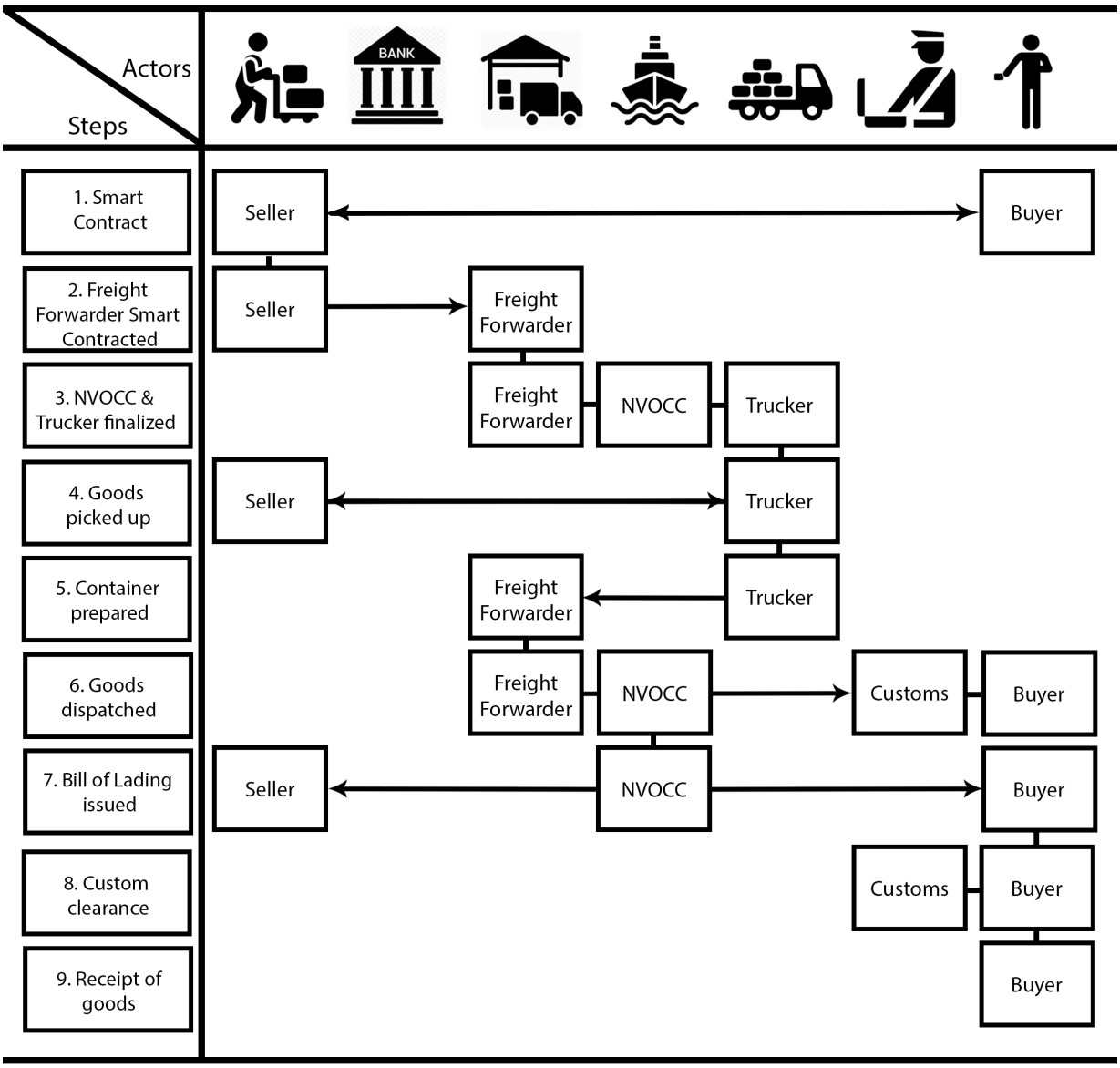
Based on the above framework, we determine that for our existing model we need to have a private permissioned blockchain. Below are the facts to decide on the type of blockchain we need:

- We would need timestamped data and there will be multiple writers such as seller, buyer, freight forwarder and customs
- We do not have a single trusted third party (TTP)
- All the writers are known but are not trusted

- We do not need public verifiability (which means that we do not need miners to validate transactions).

The first step towards the implementation of blockchain is that the buyer, seller, Freight forwarder, NVOCC/Shipping line and customs, all join the blockchain. This will be a private permissioned blockchain in which different parties have different view rights. For example, customs can't view any sale, purchase information i.e. information on cost price of goods.

Figure 5: To-Be process of shipping containers



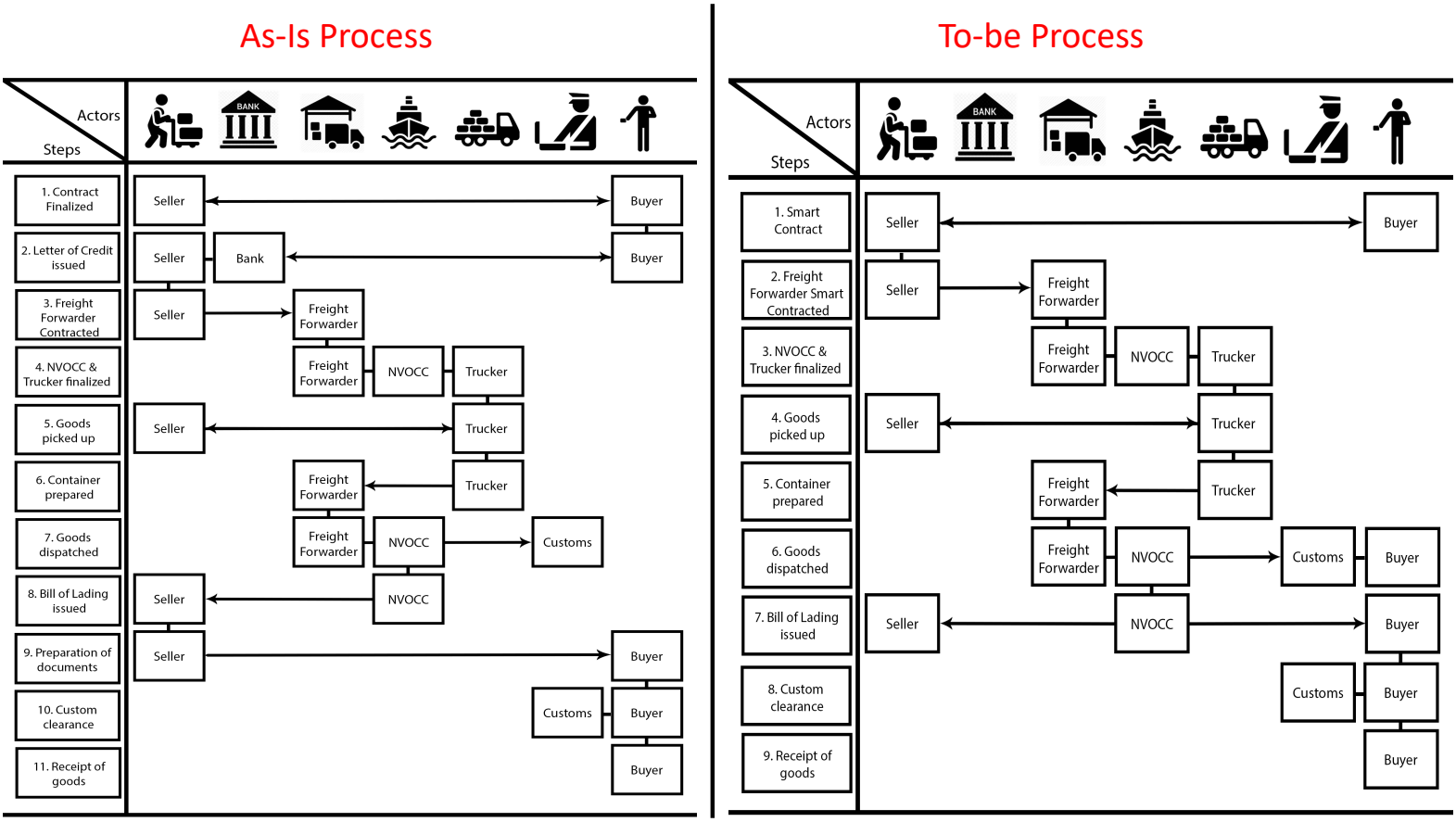
1. The buyer and the seller enter into an agreement as below:
    - The contract is executed as a smart contract over the blockchain. We discussed what a smart contract is and how it is executed in section 2.4.
    - The bank may not be required as a party in the blockchain enabled platform. The smart contract is a self-executing contract based on certain “if-then” clauses. The money may be held in cryptocurrency. If all the conditions in the contract are met, the seller gets paid else, the money is withheld under a dispute.
2. The seller then contracts a freight forwarder (FF).
3. Once the FF is finalized, he further contracts a NVOCC and a trucking company. All the information is transmitted through blockchain.
4. The trucker gets all the information required from the seller. Details such as pick up time, details etc. are sent to the trucker. A trucker may or may not join the blockchain. A trucker is generally a sub-contractor and will not have to load any special documents, so it will not hurt the process if the trucker is not on blockchain.
5. The trucker then takes the goods to the FF’s warehouse where the container is prepared for shipping.
6. The information is then transmitted to the NVOCC/shipping partner over blockchain. This information is necessary for the NVOCC to prepare the bill of lading. The FF no longer needs to have a physical copy of documents to produce at the port. All the required information such as commercial invoice, packing, material data sheet etc. are transmitted to the customs department electronically through the blockchain by the freight forwarder or the seller.

- The need for producing physical documents is not required under the blockchain process. This will save time for the FF as he can verify the documents with customs electronically.
- Once the trucker picks up the shipment from the supplier, it goes directly to the port. Customs has all the required information over blockchain. The only document that the trucker may require is the entry pass.
- Once the shipment is inside the port, the customs official may do a physical inspection of goods based on the information provided by the shipper over blockchain.

7. Once cleared by customs, the NVOCC prepares for dispatch. The bill of lading is generated electronically and transmitted to the seller and buyer customs on the blockchain. There is no need of a physical copy anymore.
8. Once, the shipment arrives at the destination port, the buyer doesn't need to gather all the documents. All the documents are transmitted over blockchain to the port authorities and customs on the blockchain. The customs officials verify the goods against the documents uploaded over blockchain.
9. Once verified, the buyer takes the possession of the goods.

3.4 Comparing the As-Is and To-be process

Figure 6: As-Is vs To-be process



When we compare and contrast both the processes, we can see the possible improvements. First, the number of steps in the process drop from 11 to 9 which indicates enhanced efficiency. Another significant thing to note is that the Bank is no longer a participant in the process. Thus, reducing the number of intermediaries.

In steps 1 and 2 of the To-Be process, we use smart contracts between buyer, seller and freight forwarder instead of traditional paper-based contracts. This makes the process more efficient and dynamic. This will help minimize inefficient contracting practices that we discussed in section 1.1.3.

In step 7 of the to-be process, we note that the Bill of Lading (BOL) is now transmitted through the blockchain to the seller as well as the buyer. This is a key improvement. A BOL is generally sent through physical email to the buyer or seller. Thus, there is a risk that the BOL might get lost or damaged. If the buyer is not able to produce the BOL to customs, then he risks demurrage charges at the port. In this process, such risks will be minimized or completely eliminated.

Overall, with the use of blockchain, we see that the data moves faster across the chain, limits use of paper documentation, and brings efficiency to contracting practices. Also, as there is a mutual trust amongst various participants, there is no external validation of data required. Currently as per the World Bank, it takes on an average around 7.5 days for an export shipment to clear customs. With the re-engineered process, this time will reduce significantly.

According to McKinsey and Co. there is some $17 Bn of waste in port and carrier business. A portion of this waste is in terms of poor communication, excessive documentation and aging technology. With the new process, this waste will be reduced. We will have better communication between the parties as the whole process is digitized thus making communication faster and easier. Also, the need for physical documentation will reduce. Customs will have the ability to receive and validate all the required documents electronically thus reducing the manual effort.

3.5 Benefits from Blockchain implementation

Implementation of blockchain in the shipping process can have multiple benefits. The need for physical documentation reduces significantly. The seller and buyer can save a lot of time in terms of documentation. All the documentation is relayed electronically to the partners such as freight forwarder, NVOCC and most importantly customs. The custom officials will receive the documents electronically for each shipment. Following are some major benefits for customs (Canham, 2017):

i. With Blockchain, the seller can submit the customs declaration electronically and it's visible in non-reputable form to all the associated parties on the import side. The importer can trust the information about what's in the consignment, while also being able to check whether the related finance is legitimate.

ii. One of the major challenges for customs is the trade finance fraud. The fraudsters generally portray that they are shipping the same consignment to three or four places at once and get finance from different parties by showing the same documents. With blockchain, when the customs access the consignment details, they can see the link to finance thus eliminating fraud.

The significant benefit of blockchain here is that customs can trust the data transmitted. The data that shall be uploaded onto the blockchain will have a date and time stamp. Also, if the customs or any of the parties want to edit the documents or change the time stamp, they will have to gain approval of most people in the system. So, neither the customs official, nor other parties can

make the changes easily. There will be a trail of records of the changes made. In current systems, we may achieve the level of permissions; however, the system remains centralized. The difference that blockchain brings to the system is in terms of decentralization and that all the parties need to agree before any changes can be made.

As per a report by Commercial Customs Operations Advisory Committee (2017), the US Customs and Border protections (CBP) is evaluating the applicability of blockchain to trade processing. The group came up with 14 proposed use cases. They included ideas such as capturing and keeping track of partnering government agencies licenses, permits, certificate of origin reporting and free trade agreement product qualifications, carnets and bonded movement tracking.

Further, we can also initiate performance-based payments. As discussed in section 1.1.3, shippers and carriers generally do not get paid for deficient services from either side. This issue may be taken care of by the smart contracts. As the smart contracts use the "if-then" clause to make payments, either party may penalize the other party on the basis of deficiency of service. For example, if the carrier didn't deliver the cargo on time as per the contract, the carrier will automatically be penalized. Similarly, if the shipper doesn't ship the agreed quantity, then the shipper is penalized automatically through the smart contract. This will benefit all the parties equally. We understand that many shippers or carriers forego the penalties based on mutual understanding. However, a lot of times, they do it to maintain the relationship and not get into an awkward situation. With smart contract, there will be an option where no human judgment is involved. Based on the performance, either party is paid or penalized.

Another key benefit of the blockchain implementation is that the intermediaries or brokers will be reduced or be totally eliminated. For example, the seller and buyer may not go to a bank for a letter of credit or the freight forwarder may not require a customs broker. Further, either party on the blockchain can be assured of transparency which will lead to greater trust in the supply chain. As the data on blockchain is immutable, thus the parties involved can be assured that the documents or data uploaded on blockchain can never be tampered or manipulated. This limits the need for documentation for authenticity.

Further, as discussed in section 1.1.2, overcapacity is not solely responsible for the woes of shipping industry. The industry also faces significant problems from inefficiency and waste due to aging technology infrastructure and business processes that lack real-time information sharing and effective collaboration. The implementation of blockchain would bring the required technological advancement in the industry.

3.6 Limitations of blockchain implementation

The first limitation of a private permissioned blockchain is that each time a new participant joins the chain, he needs to go through a process of approvals. In a permissionless public blockchain, any new user just needs to get on the blockchain and he becomes a part of the blockchain. There are no strings of approvals required. Therefore, in a permissioned blockchain, it may take time for a new participant to join the blockchain depending on the approval process.

Another important fact is that the permissioned blockchain is open and vulnerable to attacks. The nodes are limited and known to each other. A hacker who is aware of these nodes can hack into the system and steal the data. However, in a public blockchain, there are multiple nodes that are not known to each other and spread across the world. This makes the public blockchain less susceptible to attacks. In a

Acceptability of the new system also poses a major challenge. Our model above requires all the parties involved to adopt blockchain. This may prove to be a cumbersome task especially with the customs involved. First, each country's customs department needs to execute blockchain and accept documents through it. This may be subject to many approvals and will take time. Next, the destination countries customs should also be linked to the origin countries customs to let the information flow seamlessly. This brings up the issue of interoperability (connecting different blockchains together). Currently, blockchains are not interoperable which means that a bitcoin blockchain that uses bitcoins can't trade with an Ethereum blockchain in ethers. It will have to convert bitcoin to a fiat currency (fiat currencies are referred to a currency that has been declared

as a legal tender by the government but is not backed by a commodity) and then from that fiat currency will have to buy ethers.

Another important point to note is that each country may not be willing to invest in this technology right away. As government backed agencies need to be involved, it will involve a lot of bureaucracy and red tapism (especially in developing countries) to be addressed.

4 CONCLUSION

This research focused on exploring the role of blockchain in resolving the supply chain issues in the containership industry. Specifically, it sought to answer how the existing process of shipping containers can be made more efficient. In summary, the research effort found that blockchain can act as an enabler and improve the current process in the containership industry. With the immutable nature of blockchain, it has the potential to build trust amongst various parties such as customs, shippers, freight forwarders etc. It can also help reduce waste in terms of paper documentation due to digitization.

Also, blockchain can help resolve the issue of inefficient contracting practice in the industry with the use of smart contracts. The algorithm of a smart contract is self-executing based on a certain set of conditions. Once, the conditions are met, the payment is made else the payment is withheld in form of cryptocurrencies. This builds trust in both the buyer and seller that only when both the parties are satisfied, the payment is released.

We propose a private permissioned blockchain that will have many of the critical features that a Supply Chain will require. It will be scalable, low cost (transaction) and will provide privacy to the implemented supply chain. These are some challenges that relate to a public blockchain.

Having said that, there are some limitations of a permissioned blockchain. For example, it is susceptible to attack by hackers as the number of nodes are limited to the participants, interoperability and acceptability of the technology is an issue, it is susceptible to human error

and 100% adoption by the consortium will always be an issue. Such issues raise many questions that remain to be answered.

Despite these limitations, we feel that the implementation of blockchain in the containership industry does hold value. The US Customs and Border protections (CBP) is already evaluating the benefits of blockchain through a pilot. If successful, it may be replicated in other countries and may re-engineer the way border administration is done. Also, one of the major benefits of blockchain is that reduces the need for paper documentation thus reducing carbon footprints.

In future research, the role of insurance companies in containership industry may also be evaluated. Insurance companies may stand to benefit a lot from the implementation of blockchain as they can have real time data of shipments and this will help them minimize fraud. Also, it will be interesting to see how Internet of things (IoT) can process real time data for containerships and send it directly to blockchain thus eliminating any human interface which will build greater confidence in this technology.

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