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Analysis of Blockchain's Impacts on and Applicability to the Maritime Industry
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CHAPTER 1: INTRODUCTION AND APPROACH TO WORK

Blockchain is, in simple terms, a growing list of records, called blocks, that are linked using cryptography. It is a distributed ledger system that can record transactions between two parties efficiently and in a verifiable and permanent way. Over the last few years, blockchain has been touted as a technology that will totally revolutionize the way many businesses function. This report will test that assumption for the maritime industry. Chapter 2 will explain blockchain in a more detailed manner.

According to one author (Labazova 2019), "ninety percent of current blockchain projects either do not need blockchains to meet their requirements or result in blockchain solutions not suitable for implementation in their current IT infrastructure." At the same time, individuals who are very excited by the possibilities blockchain offers, like Rahul Kapoor from Bloomberg Intelligence Singapore (Park 2018), say that blockchain will revolutionize the sector as much as containerization has because it will bring transparency and efficiency to an industry that is still behind other industries in technology use.

Some skeptical voices argue that there is an "artificial consensus" that blockchain will actually benefit the industry players as much as its proponents claim. Some researchers challenge the benefits and point out that more research is necessary to bring evidence of effective operational applications (Rodrigue 2018). However, other experts compare the potential benefits of blockchain to the application of radio frequency identification (RFID), very enthusiastically introduced in the mid-2000s. It too, was promoted as a technology that would totally disrupt traditional business practices. While it offered benefits, many analysts believe that it has not reached the level of an industry game changer (Johnson 2018). This is a manifestation of the uncertainty of the value added by blockchain.

This raises several questions this report attempts to address:

- Does blockchain meet the needs and requirements of logistics operations?
- Is the information technology (IT) infrastructure in the logistics environment ready for this new technology?
- What lessons have been learned from prior implementations that might make blockchain more effective for the marine shipping environment?

In this report:

- Chapter 2 provides a summary of an extensive literature review that offers an understanding of what blockchain is, what its limitations and advantages are, and how it is being used.

- Chapter 3 provides the findings from a survey of the Port of Houston user community. The survey probed their understanding of blockchain technology and their level of implementation of the technology.
- Chapter 4 provides a case study of the implementation of blockchain in the maritime/port environment. The case study focuses on the project undertaken by the Port of Veracruz, Mexico, to move its export functions to blockchain.
- Chapter 5 summarizes interviews and investigation into TradeLens, a blockchain system developed by Maersk and IBM to facilitate container logistics across all the various users involved in the supply chain.
- Chapter 6 summarizes key findings and recommendations for further research.

CHAPTER 2: LITERATURE REVIEW AND INTRODUCTION TO BLOCKCHAIN

Introduction

In 2015, the World Economic Forum published a report that included blockchain technology as one of six computing mega-trends that are likely to shape the world in the next decade (Kshetri 2018). This chapter documents the information collected from the literature review of the development of blockchain technology and its application to the international freight shipping environment. The objective of this chapter is to set the background and context for understanding industry's views on the subject and for determining the business case for blockchain in international shipping. There needs to be a basic understanding of what blockchain can and cannot do and how it works with the economy in trade. Making the most of this new technology requires solid policy (Norberg 2019). This chapter explores the following topics:

- What blockchain is.
- The pros and cons of blockchain technology.
- The applicability and usefulness of blockchain technology to international freight shipments.
- The status of investment in blockchain.
- The legal framework for blockchain.
- Considerations for developing blockchain applications.

What Is Blockchain?

Underlying Principles

There is no single definition of *blockchain*, just as there is no single definition of *computer operating system.*

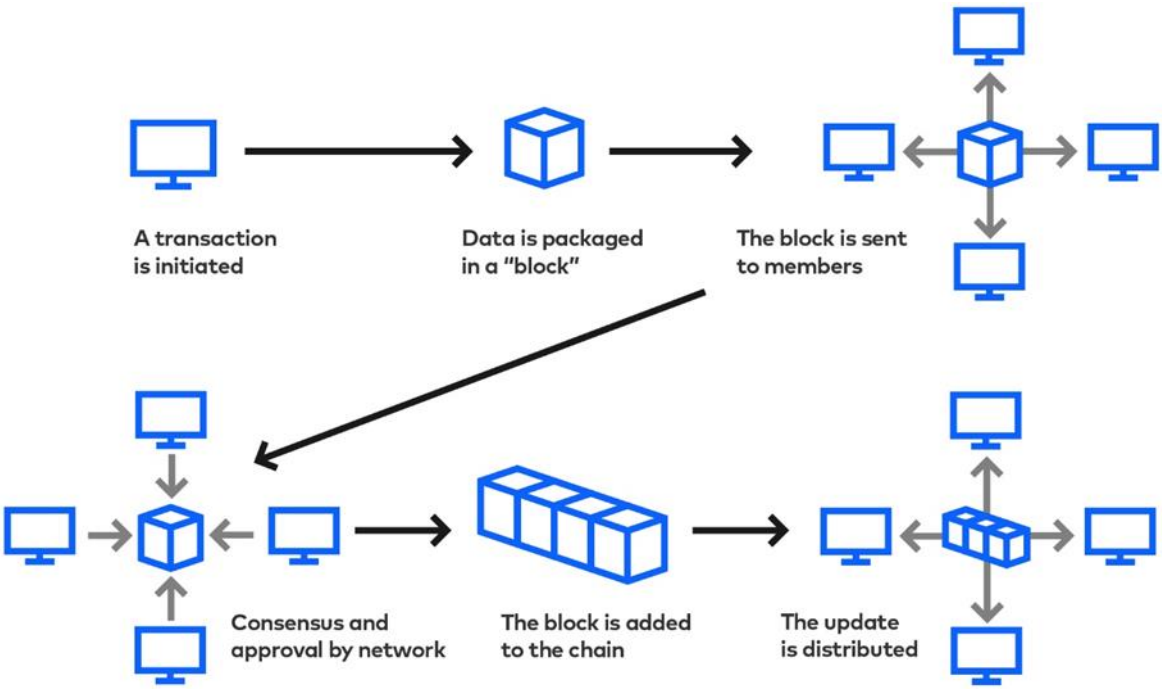
The first blockchain was conceptualized by a person (or group of people) known as Satoshi Nakamoto in 2008 and was used for creating and trading cryptocurrencies. Although blockchain is often linked to cryptocurrency, it is actually a group of technologies. Blockchain can be used to represent any transaction or information in any kind of organization in industry or society. Blockchain is often touted as a nascent technology with a lot of hype that promises to disrupt status quo operations in many industries and supply chains. Blockchain is not, however, an automatic solution although it does create trust in a complex, dynamic, and interdependent system.

Blockchain is a type of distributed ledger—a peer-to-peer system with no central authority. Other distributed ledgers have been developed, but blockchain is the most popular. This is a data structure that identifies and tracks transactions digitally and shares this information across a distributed network of computers. Blockchain is only one of many types of data structures that provide secure and valid achievement of distributed consensus (Suominen et al. 2018).

Blockchain is inherently decentralized. Blockchain users can see interactions made by any given node; however, identities are protected by using cryptographic user keys, and transactions are secure and carried out among anonymous private parties.

IBM states that blockchain is a shared, immutable ledger for recording the history of transactions. Blockchain has tremendous potential for creating cost-effective and efficient business networks for trading anything of value between and among interested traders without requiring an intermediary party or central authority (Shirani 2018).

Figure 1 illustrates the basic framework of a blockchain system.



Source: Slalom 2020

Figure 1. Blockchain System Framework.

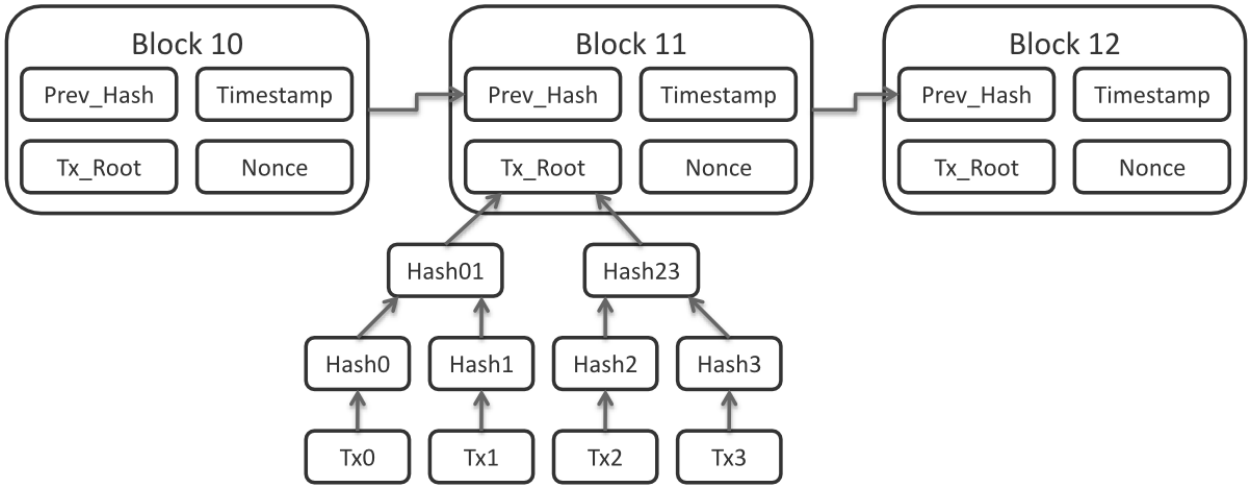
Because no central authority manages a blockchain, there is no single point of failure. And because the distributed ledger is spread across the whole network, tampering is difficult. All updates to a single ledger are automatically shared with other ledgers. To change the data, all the nodes need to make the change at the same time. A hacker would have to hack a large number of nodes (possibly thousands) at the same time and alter the history leading up to a transaction to gain complete control. This ensures the integrity and resilience of the entire data network. Updates are subject to voting by nodes and need to be agreed upon by the majority (called consensus).

Blockchain technology has a lot of variation in its security properties, functional requirements, costs, and transaction times as well as the consensus algorithms that validate, verify, and sign data to a block (Mylrea and Gourisetti 2018). There are many blockchain platforms such as

Bitcoin, Ethereum, Sidechain, Hyperledger Fabric, IOTA, Nebulas, Skuchain, Sheetbridge, and Microsoft Azure (Chang et al. 2019). The underlying technology is the same for all of them. In simplest terms, it is a chain of chronological blocks. A node starts a transaction by creating and digitally signing it using cryptography. The structure of a transaction is grouped into blocks that are encrypted using a hash function as a 256-bit number. A block can be thought of as a container for data. Data are added to a block by connecting it with other blocks in chronological order. Each block is cryptographically hashed and time stamped (Stein 2017). Each block calculates its hash using the previous block's hash. The authenticity of a new block must be verified by a computational process (validation or consensus) before it can be linked to the existing chain (Chang et al. 2019).

The hash function transforms an input of letters and numbers of any length into an encrypted output of fixed length through a mathematical algorithm. A secure hash function makes it mathematically and computationally infeasible to determine the input that was provided to the hash function. At this point, the majority of nodes must agree that the hash of the new block has been determined correctly (Chang et al. 2019).

Each block has a block header, block identifier, and Merkle trees. Figure 2 illustrates this arrangement. (Appendix B provides a brief introduction to Merkle trees.) Block headers contain the cryptographic hash and data structure to summarize the transactions. Each block header contains a field to identify the previous block in the chain and chronologically ties them together (Siddiqui 2018). The order in which a transaction took place is determined jointly by block number, the previous hash, and the current hash.



Source: Wander 2013

Figure 2. Simplified Block Chain Diagram.

Data can be exchanged directly without third-party involvement. The blockchain ensures that all nodes eventually achieve consensus about the integrity and shared contents of the ledger. No participant can modify a transaction after it has been recorded. To correct an error, a new transaction must be generated, which references the erroneous record. (This can cause a

problem if it contains illegal content or if a court orders content to be removed [Chichoni and Webb 2018].)

Public and Private, Permissioned and Nonpermissioned Blockchains

Blockchains can be public or private, and permissioned or nonpermissioned:

- Public blockchains allow anyone to participate in the network, with all participants possessing an identical copy of the ledger.
- Private blockchains only allow invited participants to join the network (Dave 2019).
- Permissioned blockchains establish rules for who can contribute data and how they will do so.
- Nonpermissioned blockchains essentially allow free access.

A consortium or federated blockchain is a quasi-private blockchain that is permissioned (the ability to enter or modify transactions must be granted) so that a number of companies might each operate a node on the network and share in its administration and governance. The administrators of a consortium blockchain may restrict users' participation rights (Cook 2018).

Public blockchains are designed to be decentralized and secure, which compromises their scalability. They can only achieve 7 to 15 transactions per second (Perboli et al. 2018). This can be due to the larger number of nodes that need to achieve consensus and, in some cases, outright limits on transactions or block sizes. If users need to store a large amount of data on the blockchain, a public chain can become unwieldly. Further, public blockchains are severely constrained in terms of size, processing speed, and cost of processing (Warren et al. 2019b).

Private or enterprise blockchain systems are governed by a restricted group of users and claim a higher number of transactions per second. Quorum has demonstrated dozens to hundreds of transactions per second, while Hyperledger Fabric claims 3500 per second (Perboli et al. 2018).

Private blockchains are regarded as more suitable for business-to-business applications when privacy concerns are considered. Private blockchains are also suitable for cases where public readability or audits are not necessary. Private blockchains have faster transaction speeds and lower transaction fees. Permissioned (consortium) blockchains are partially decentralized. Only a few participants have the right to access and validate the transactions. Permissioned blockchains usually require smart contract functionality (discussed in a subsequent section of this chapter) to perform business logic and validate identity before executing transactions (Chen 2016).

Vitalik Buterin, cofounder of Ethereum, states that private blockchains can prove beneficial for many industries such as banks and supply-chain-intensive organizations. He notes that permissioned blockchains reduce transaction times significantly and provide privacy (Jain 2018).

Private blockchains appear to require higher upfront investments than public blockchains. In private blockchains, participants should be focused on similar goals and objectives from the outset, so governance of the system should be less of a concern than with public blockchains.

Smart Contracts

While not unique to blockchains, one of the most interesting features of blockchain technology, in particular in the context of international trade, is smart contracts. Smart contracts are not a type of blockchain *per se* but rather a functionality of the blockchain technology (Ganne 2018). Blockchain allows computer programs to execute and be stored on the ledger. These programs are called *smart contracts*. Essentially, smart contracts are the digitized business logic used to help exchange any asset of value (e.g., money, real estate, or retail products) without the need for third-party services. In practice, smart contracts are coded onto the blockchain as "if-then" statements that automatically execute transactions and record information onto the ledger (IBM 2018).

Smart contracts began in 1994 (Jain 2018). The term *smart contract* is, in fact, a misnomer: smart contracts are neither smart (there is no cognitive or artificial intelligence component to them, only the automatic execution of a predefined task when certain conditions are met) nor contracts in a legal sense (Deloitte 2018). Smart contracts can 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. Smart contracts work without the involvement of third parties and can be generated automatically from the process model. Supply chain participants interact with each other by sending messages through the blockchain. A trigger can translate conventional service calls to blockchain transactions. Conditions can be specified directly so that a process is automatically activated when certain conditions are met or events observed (Staples et al. 2017).

Smart contracts provide time and cost savings and more secure documents. Automated contracts are faster and cheaper in terms of performance and ensure accuracy of information. They not only authenticate themselves, but can also execute all transactions that are programmed. They provide protection against duplicate invoice financing because the contract will not allow for an invoice that has already been financed to receive additional financing (Civelek and Özalp 2018). By including banks and distributors, sellers are able to show that all parties have agreed upon the receipt of goods, giving buyers assurance a shipment will arrive in due course. Manufacturers get paid faster, and banks are repaid without delay. Smart contracts increase financial liquidity and reduce transaction costs on all parts (Okazaki 2018). One shortcoming is that the code may have loopholes that make smart contracts susceptible to hackers (Jain 2018).

Smart contracts are truly the driving force behind blockchain for supply chains because the business rules they contain are what assures that actual transactions are carried out pursuant to the original agreement (Boschia et al. 2018). However, for smart contracts to be effective and produce value, participants in the blockchain system must address some basic questions:

How can participants verify that the code accurately represents agreed-upon conditions? What is the approval process for implementing changes and new smart contracts? Additionally, there are legal concerns, which will be discussed later.

Pros and Cons of Blockchain Technology

The literature provides a fairly extensive list of the pros and cons of blockchain technology. Several of the pros have already been mentioned in the overview material:

1. The system can be relied upon to produce accurate information that has not been tampered with. It is immutable.
2. One strong feature of this technology is that people and businesses can trust each other without the need for banks, credit card companies, governments, associations, and notaries. Each activity is tracked, recorded, and fully traceable.
3. There is no central hub, authority, or clearinghouse. This removes the issue of a single point of failure (where a problem with one node affects the integrity of the entire system).
4. The system has the potential for creating cost-effective and efficient business networks for trading anything of value.

Two more pros are mentioned in the literature that discusses the implementation of blockchain:

1. Blockchains enable individuals to secure personal data and identities; help overcome lack of trust between two parties who do not know each other but wish to engage in transactions; save intermediation costs between two parties by automating verification and compliance with contractual obligations; and reduce coordination costs among players needing access to the same information at the same time (Suominen et al. 2018).
2. Benefits to blockchain include time savings, security improvements, auditability, enhanced levels of trust and transparency, enhanced operational efficiency, potential for cost savings, and traceability (Chichoni and Webb 2018).

More cons than pros are discussed in the literature although the degree of severity of each of these items varies significantly:

1. To correct an error, a new transaction must be generated that references the erroneous record. (This can cause a problem if it contains illegal content or if a court orders content to be removed [Dave 2019].)
2. Transactions should not contain a high volume of data or plain text data that must be kept confidential. Blockchains are not suitable for storing big data because of the massive redundancy from the large number of processing nodes holding a full copy of the distributed ledger (Staples et al. 2017).

3. Public blockchains may be limited in their scalability. Blockchains are currently not highly scalable (Staples et al. 2017).[1]
4. Compared with conventional databases, public blockchain costs more to add records. However, the data become globally replicated, and the blockchain ecosystems retain these data indefinitely at no additional cost (Staples et al. 2017).
5. One of the drawbacks to blockchain can be the time it takes to validate and add a transaction, often several minutes. Because of the delay that computationally heavy consensus protocols have, the theoretical throughput of transactions is limited (Staples et al. 2017). Hertz-Shargel and Livingston (2019) state, "The duplication of data hosting and processing across every node in the blockchain network dramatically limits both capital efficiency and scalability to real-world data and transaction volumes." The delay in validating and achieving consensus could create a substantial security issue because data could be altered before being chained to the last block (Roeck 2020).
6. The worldwide pool of computers performing this cryptographic puzzle creates significant electricity usage, much of which is wasted. Massive redundancy of blockchains will always mean that more electricity is used than in a centralized non-replicated database (Staples et al. 2017).
7. Blockchain technology is subject to several technical limitations that are especially relevant for supply chain use. These relate to the governance model of data ownership and typically low data quality in supply chain settings (Gregor et al. 2019).
8. The IT tools for handling large data sets may not be sufficiently developed for a broad spectrum of users to be able to manage a blockchain node (Saberi et al. 2019). Due to the requirement of a high degree of computerization, not all countries are ready to participate in blockchain-based solutions (Kshetri 2018).
9. Smart contracts may move *too* quickly. Sometimes delays can be useful to prevent a bad decision or outcome (Suominen et al. 2018).
10. Blockchain has three types of vulnerabilities:
    - Access to blockchain systems. Who should be able to access the data on the blockchain?
    - The possibility that a blockchain could be hijacked and hacked if 51 percent of the chain is controlled by a bad actor that wants to tamper with the results.
    - The centuries-old garbage-in-garbage-out problem (Suominen et al. 2018).
11. Blockchain can assure its users that data have not been modified or deleted over time. However, the authenticity of the data that are uploaded on the ledger in the first place still depends on the users (Caneve 2018).

[1] Scalability must take into account throughput, bandwidth, block size, and latency (the time it takes for a transaction to be submitted and integrated into a blockchain).

One author summed up the cons by saying that problems with blockchain could be throughput rate, latency, centralization risk, transaction costs, inaccessibility for average users, and lack of standards, industry adoption, public opinion, and regulation (Caneve 2018).

Applicability and Usefulness of Blockchain Technology to International Freight Shipments

Overview

Blockchain is best applied where there is friction across multiple parties and those parties can each benefit from addressing it (IBM 2018). Banks were the first industry group to take note of the possibilities offered by blockchain. Banks were followed closely by the insurance and trade finance sectors. Blockchain was first deployed commercially in the financial services industry to make trade/claim settlements and international payments more secure and efficient. The potential of blockchain is that it could be used in any industrial sector including agriculture, utilities, mining, manufacturing, retail, transport, tourism, education, media, health care, and the sharing/peer-to-peer economy. Some examples are as follows (Staples et al. 2017):

- Blockchain can be used in supply chains to track physical assets and provide a chain of custody. Automatic payments can be linked with smart contracts. For example, receipts of inventory entries are automatically created by blockchain accounting systems when inventory is scanned upon receipt at a facility (Swan 2018).
- The Internet of Things (IoT) can use blockchain as a storage solution, use smart contracts to provide a global distributed computing capability, and rely on the blockchain as a secure channel for receiving information about software and configuration updates and dynamically delegated access control.
- A blockchain can provide a trusted registry of media assets or other intellectual property. (Media are not necessarily stored on the blockchain itself. Instead, cryptographic hashes, metadata, and other identifiers stored on the blockchain might be integrated with bulk off-chain storage.)
- A blockchain can create a metadata layer for decentralized data sharing and analytics.
- A blockchain can record evidence of the existence of data or documents.
- Regulators can gather more reliable, authentic, and sufficient information about traders. The credit of traders is a key factor affecting food safety (Mao et al. 2018).

Supply chains appear to be a promising domain for blockchain, especially those supply chain problems requiring fairly narrow and well-understood functionality that is not likely to change much over time (Stinnes 2019). Table 1 provides some of the more common use cases for blockchain.

Table 1. Common Use Cases for Blockchain.

Use Case	Description	Supply Chain Objective	Examples
Product provenance and traceability	Blockchain-based systems support safeguarding the accuracy of product certificates and reduce risks of fraud and adulteration.	Improved product safety, authenticity, provenance, and pedigree, resulting in a reduction of fraud. The provenance link also helps producers and channel partners to create more intimate ties to consumers. Equally important, tracking goods throughout the production process improves the accuracy of forecasting and collaborative planning within the supply chain.	**OriginTrail's** solution delivers verifiable supply-chain traceability and product authenticity, with existing applications including traceability for genetically-modified-organism-free dairy products, free-range poultry, and fresh vegetables; prevention of counterfeiting in wine exported to China; and integration with the IoT smart products platform. **Skuchain's** solution enables tracking of goods on the stock-keeping unit level. Its transformations in production are particularly useful for tracking critical components such as sub-assemblies, parts, and raw materials used to make finished products.

Use Case	Description	Supply Chain Objective	Examples
Streamlining (global) supply-chain operations	Blockchain enables efficiencies for information transfers and data sharing as well as for transaction execution among multiple entities in a supply-chain environment.	Digitalized global trade (paperless trade), end-to-end visibility, and secure information sharing between organizations. This allows parties to take full advantage of essential blockchain features (information cannot be altered, is more secure, and is jointly agreed upon) when sharing or transferring electronic documents or other information.	A few solutions exist today where blockchain is used to automate and digitize the bill of lading (BOL) or other trade documents. Examples include Wave4 and CargoX. Ocean carrier **Zim** (using Wave's solution) offers customers the opportunity to switch to blockchain-based electronic BOLs on select trades. Separately, some port community systems (members of the International Port Community System Association [IPCSA]), carriers, shippers, and banks participate in the development of a BOL proof of concept based on blockchain and smart contracts. **Truckl**, a start-up focused on over-the-road transportation, writes every supply-chain event that occurs to the public blockchain, enabling higher trust between supply-chain partners while ensuring that parties act responsibly.
Automation and smart contracts	Blockchain systems can automatically enforce rules and process steps. Once launched, smart contracts are fully autonomous: when contract conditions are met, prespecified and agreed-to actions occur automatically.	Increased transaction efficiency through faster and more automated supply-chain processes, which takes cost out of the supply chain and also enhances the trust multiple parties place in each other.	**IPCSA** exploits smart contracts for BOLs. The smart contract controls the endorsement process of the BOL, while the application synchronizes the logistic process for entities holding the BOL. In addition, delivery orders are released automatically upon the presentation of the BOL from the importer back to the import shipping agent.

Use Case	Description	Supply Chain Objective	Examples
Trade finance	Bringing trade finance products and processes (e.g., a letter of credit) onto the blockchain enables more secure commercial transactions as well as the sharing of information between exporters, importers, and their respective banks on a secure blockchain-based platform.	Secure financial transactions in global trade along with increased efficiencies for transactional processes and reductions in operating costs.	Project **Voltron** (Documentary Credits) and Project **Marco Polo** (Open Account) each provide solutions that expand finance to a greater number of subject matter experts and introduce new opportunities to finance trade. The **Bank of America Merrill Lynch**, **HSBC,** and the **Infocomm Development Authority of Singapore** have developed a prototype to bring the paper-intensive letter of credit process onto a blockchain.
Anti-corruption and humanitarian operations	Blockchain can deter supply-chain actors from behaving unethically or opportunistically while providing a full audit trail of the spending of financial aids.	A fairer, more transparent, efficient, and reliable humanitarian supply chain.	The **World Food Programme's** Building Blocks pilot project uses blockchain technology to help refugees of the Syrian Civil War. In the Azraq refugee camp in Jordan, 10,000 people receive food from entitlements recorded on a blockchain-based computing platform. Refugees purchase food from local supermarkets in the camp by using a retina scan instead of cash, vouchers, or e-cards.

Source: Warren et al. 2019a

A number of industries are now working to employ blockchain in supply chain logistics. Blockchain presents a number of potential opportunities to increase the cybersecurity of a supply chain that is increasingly distributed, data driven, global, and vulnerable. Blockchain has been touted as the best available technology to securely manage and trace all the variables in a complex supply chain (e.g., textiles) (Rusinek et al. 2018). Supply chains on blockchain have the benefits of visibility and data integrity for logistics and commercial documentation. Blockchains provide evidence to manage risk, enabling trade finance and insurance applications (Staples et al. 2017).

Blockchain benefits as applied to global supply chains include time savings, security improvements, reliability, enhanced levels of trust and transparency, potential for cost savings, and traceability (Chichoni and Webb 2018). Blockchains reduce the cost of documentation of every step related to logistics and financing while providing visibility in terms of delivery and

transfer of funds. With blockchain, it is possible to track an asset from production to delivery (Okazaki 2018). Blockchain technology can highlight and detail at least five key product dimensions: what it is, how it is, how much of it there is, where it is, and who owns it (Saberi 2019). This new technology provides a level of supply-chain transparency that allows supply-chain managers to obtain the information consumers are demanding and thus contribute to their companies' competitive advantages (Francisco and Swanson 2018). (Other technologies can do this but not as securely.)

The need for a better transaction management system for supply chains is well documented. A pilot recently completed with avocados shipped from Mombasa to Rotterdam showed that replacing paperwork and administrative procedures with blockchain technology could reduce the cost of international shipping between 15 and 20 percent (Allison 2017). Biggs et al. (2017) estimate a 30 percent savings in transaction costs. Maersk calculated that an exporter of cut flowers from Kenya needs 200 separate communications involving 30 players to move a shipment to the Netherlands (Suominen 2018). Maersk estimates that costs associated with trade documentation and administration are one-fifth of the actual physical transportation costs (Chichoni and Webb 2018). Estimates prepared by the United Nations suggest that moving Asia Pacific's trade-related paperwork online would save as much as 44 percent in time by putting trade-related paperwork in a blockchain system (Shirani 2018).

Unfortunately, assessing the success (or lack thereof) of individual initiatives is difficult because of the novelty and confidentiality of many projects. Initiatives are dominated by large supply-chain actors and only a limited number of small and medium-sized enterprises (Roeck 2020).

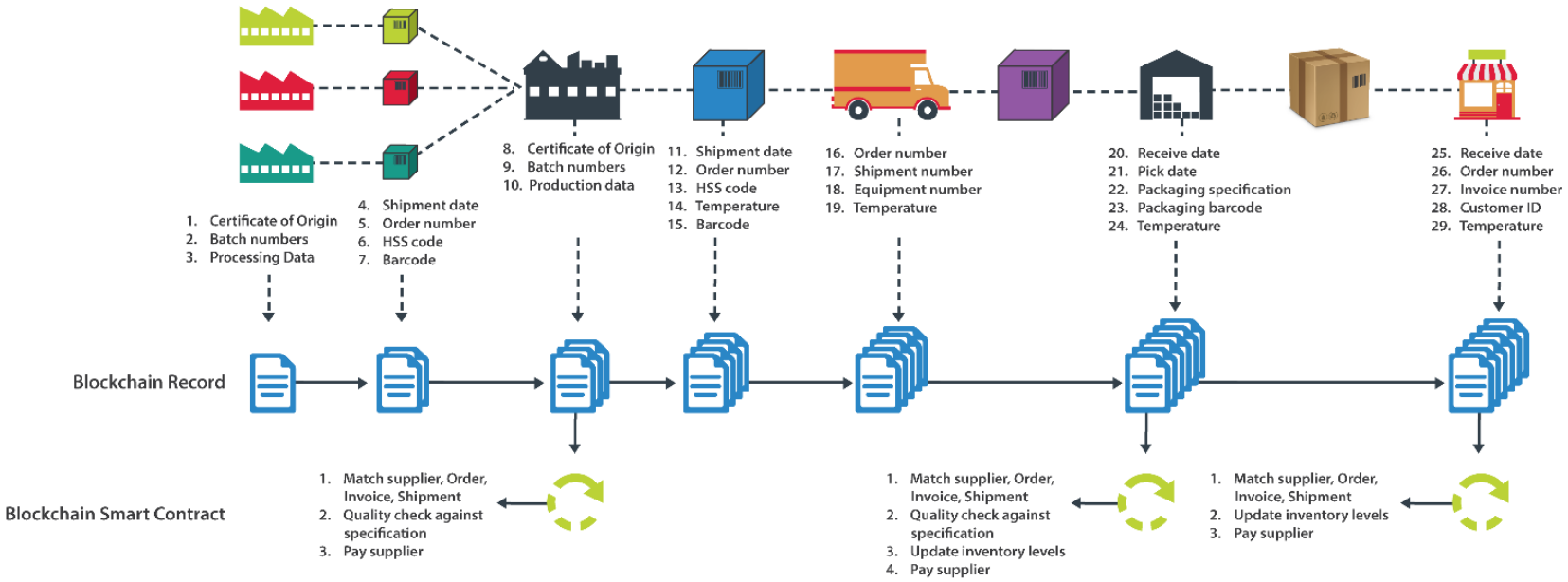
The literature does provide several examples of benefits in actual implementation:

- Walmart conducted an experiment on its mango supply chain and learned that while in the old system it took seven days to find out the origin of a mango, with blockchain it was done in a few seconds (Caneve 2018).
- Walmart established a blockchain platform to manage its supplier relationships that tracks and traces the quality of food products along the supply chain. Walmart and IBM expanded their partnership to include other food giants. The participants widened the scope using blockchain to integrate their online and offline traceability for food safety and quality management channels. The results of Walmart's partnership and blockchain implementation are greater traceability, transparency, time savings in discovering origins of products and potential hazards, greater satisfaction for end consumers, and safer food (Chichoni and Webb 2018).
- Accenture, a leading global management consulting firm, is leveraging blockchain technology for supply chain networks. Accenture proposed eliminating the dependence on printed shipping documents and streamlining the entire flow of documents. Trials showed that blockchain can cut down on inefficient data entry by as much as 80 percent (Chang et al. 2019).

- According to estimates from IBM, blockchain could raise the gross domestic product by almost 5 percent and total trade volume by 15 percent (Chen 2016).

In published statements and press releases, port and terminal operators have indicated that the most important benefits of blockchain are enhanced levels of trust, improvements in security, enhanced operationally efficiency, and cost savings. The transportation industry indicates that the most important benefits are enhanced operational efficiency, cost savings, traceability, improvements in security, time savings, and enhanced levels of trust (Chichoni and Webb 2018).

Figure 3 illustrates how the blockchain system and the document flow would interact for international shipments.



Source: Van Rooyen 2017

Figure 3. Interaction of Document Flow and Blockchain System for International Shipments.

Blockchain is developing rapidly in Southeast Asia. Businesses are using blockchain to facilitate trade logistics, trade finance, customs clearance, and supply chain traceability. Blockchain has tremendous potential to facilitate and secure trade, close trade finance gaps, and help small and medium-sized enterprises engage in trade. Blockchain is accelerating development solutions in the region's poorer economies: enhancing access to electricity in the Philippines, professionalizing microcredit in Myanmar, and helping people vote in elections in Indonesia. The greatest challenge encountered thus far is that blockchain needs workers with the skills to use it and apply it in various areas. In half of the countries, less than half of the young people have completed upper secondary education (Suominen 2018).

Sensitive Data and Security

Two basic categories of confidentiality must be dealt with in the blockchain environment: commercially sensitive data and legally protected data. Complete transparency is not possible or desirable in many instances. For instance, some points in supply chains actually depend on a lack of transparency (e.g., the identity of suppliers or compliance status).

Security issues for blockchain technology are for the most part traditional. Blockchain does not guarantee security. While blockchain provides security advantages, it is not a panacea. Key security considerations include (Ogee and Hewett 2019):

- **Confidentiality.** Only those authorized to access a piece of information can access it.
- **Integrity.** Data inputs are valid and accurate (no garbage-in-garbage-out practices).
- **Availability.** Data can be accessed when needed.
- **Balance.** The proceeding three issues must be balanced—changes in one area can affect the others.
- **Layered approach.** Controls are layered and can detect unauthorized access before the system's core is compromised.
- **Holistic approach.** Security governance is established to decide what tradeoffs, if any, are acceptable.
- **Security process.** Constant attention is given to new methods and skills employed by attackers.
- **Simple security.** Systems are avoided that are so complex that securing them is excessively complex.

While decentralization is touted as a virtue of blockchain systems, this makes it more difficult to ensure physical security and shut down a system if necessary. Further, when the system interacts with sensors as part of the IoT, whose responsibility is it to secure devices and ensure they are functioning properly?

Consensus mechanisms are used to ensure that only valid transactions are added to the system. There are a number of consensus mechanisms, and they all come with their own requirements and levels of security.

Cryptographic keys are an asset that must be secured. Tampering with a cryptographic key can wreak havoc on a system.

Trade Finance

Blockchains are especially relevant for trade finance. In fact, much of the initial private blockchain-based development is taking place in the financial services sector, often within small networks of firms, so the coordination requirements are relatively modest (Iansiti and Lakhani 2017). According to Roeck (2020), applications for trade and inventory financing and the exchange of trade documents are the second and third most frequent applications, respectively, after proof of origin.

Blockchains with smart contracts could eliminate inefficiencies that limit the value of the letter of credit. Some 56 percent of banks' costs for a letter of credit arise from manual document handling and checking (Suominen 2018). Smart contracts can codify the terms and conditions of a contract by abstracting and expressing conditional clauses as separate independent or interdependent functions that provide pass/fail outputs based on the exporters'/sellers' input information (Okazaki 2018).

Bank-to-bank payments can be facilitated by blockchain technology. Distributed ledgers enable real-time and cross-currency payments while minimizing the costs associated with these transactions. Distributed ledgers enable the transfer of value without requiring the capital to be placed into a corresponding bank. The banks face no cost for transaction fees, and funds are transferred in seconds instead of days (Okazaki 2018). Because of this, blockchain can speed up clearance of payments in trade and reduce time to clear cross-border payments from 48 hours to less than two seconds (Suominen 2018).

Blockchain is expected to improve cash flow in supply chains. Blockchain creates a common platform to facilitate improved exchange of trade information and end-to-end transparency of the entire supply chain. The fast exchange of data can increase speed efficiency and security in financing. The real-time visibility implies that invoices can automatically trigger transfer of ownership or execution of payment. This can help improve credit ratings and risk assessment procedures, leading to improved financing terms for both buyers and sellers (Chang et al. 2019).

Specific financial services applications using blockchain technology may include (Staples et al. 2017):

- **Digital currency:** transferred between parties, often without those transfers being processed or recorded by banks or payment services. With smart contracts, blockchains may be able to support new kinds of programmable money, where automatically enforced policies are attached to specific parcels of currency. Blockchain digital currency can have much lower fees than conventional money transfers. A lot of companies now accept payment in virtual currencies (de Caria 2017).

- **International payments:** often via digital currency on a blockchain, with local exchanges between the digital currency and fiat currencies.
- **Reconciliation for correspondent banking:** A single shared ledger replaces reciprocal nostro/vostro accounts held between two banks.
- **Securities registration, clearing, and settlement:** The joint exchange of payment and security holdings is enacted as a transaction on a blockchain.
- **Markets:** Smart contracts on blockchains provide a platform for making and accepting offers to trade assets or services. Individual smart contracts could themselves carry the digital currency required to be paid on fulfilment of these offers. This functions as a kind of escrow, without the need for a trusted third-party organization. However, blockchains are not suitable for high-frequency (low-latency) market trading.
- **Trade finance:** The blockchain is used to evidence trade-related documents in order to reduce lending risk and improve access to finance for industry, and smart contracts could control interorganizational process execution and transparently automate delayed or installment payments.

Insurance

Trade-related insurance also stands to gain from the implementation of blockchain. Blockchain technology would enable better communication between different insurers. With the immutability of a distributed ledger and proper access controls to protect data security, insurers could record every transaction in a secure and permanent manner, collaborating with each other to identify suspicious behavior or clues leading to the detection of fraud within and across the ecosystem of the industry (Okazaki 2018).

Product Provenance

Product provenance tracking also appears to be in a position to benefit from blockchain. In fact, according to Roeck (2020), the most frequently used application of distributed ledger technology in supply-chain management is to provide proof of origin in order to display the chain of custody.

Blockchain creates an immutable chain of custody for food goods from origin to destination (Chichoni and Webb 2018), but blockchain does not guarantee the data recorded are accurate. Checks and balances must be applied outside blockchain. Blockchains enable holistic product life-cycle data management by providing a common platform where the producers, laboratories, logistics operations, regulators, and consumers can have full access to and share all related information such as provenance, testing, certification, and licensing. Blockchain could also ensure that an e-certificate is appropriately issued and signed, protecting it from any risks of alteration or manipulation (Okazaki 2018).

Food supply chains are becoming blockchained. With blockchain, it is possible to quickly determine the origin, processing, and shipping information for a given product (Chichoni and Webb 2018). Walmart, for one, is confident that its use of blockchain will lead to better control

in food sourcing, ultimately diminishing risk of contamination. Even in the event of contamination, the greater controls and visibility offered by blockchain enable tracing for proper corrective actions or even preventive actions for future disaster scenarios (Biggs et al. 2017).

In addition to the supply chain for a given product, blockchain could be used to trace the origin of raw materials, changes in condition, transfers of ownership, environmental conditions, working conditions, and compensation for factory employees (Tribis et al. 2018). Blockchain can help companies avert consumer lawsuits and reputational harm, saving on consumer litigation and public relations. Companies can potentially improve their environmental, social, and governance ratings and their overall corporate social responsibility ratings (Bhandari 2018).

Blockchain-based solutions may give consumers more confidence that products are genuine and of high quality and make them significantly more willing to purchase the brand. Besides traceability, huge benefits can be reaped in terms of reduced labor, costs, and food waste (Kshetri 2018).

A side benefit to being able to track an asset's history is that it helps the different parties enhance their reverse logistics plans as well (Eljazzar et al. 2019).

Efforts are under way to leverage other closed-based open-source technology including artificial intelligence, IoT, and data analytics to allow for tracing of traded goods across borders. Participants will know where an in-transit container is and be able to check the status of customs while reviewing BOLs and other shipping documents.

Status of Investment in Blockchain

Blockchain companies saw over 650 equity investments totaling $2.1 billion between 2012 and 2017. Fortune 500 companies such as Walmart and General Electric (GE) participated in over 140 deals totaling $1.2 billion (Suominen et al. 2018). Corporate spending on blockchain technology is estimated to exceed $2 billion in 2018 (Shirani 2018).

In a recent survey of 152 European participants, about 43 percent declared they were not actively looking into blockchain or were observing from a distance. Only two were experimenting with blockchain technology. Three-quarters of the 152 participants expected logistics service providers, senders, receivers, and technology providers to benefit from blockchain technology. The most cited barrier to blockchain adoption (cited by 56 percent of those surveyed) was regulatory uncertainty (Hackius and Petersen 2017).

In a 2019 survey of more than 1000 corporate executives, the consulting firm Deloitte found that more than half of respondents (53 percent) said that blockchain technology has become a critical priority for their organization. Eighty-three percent see a compelling case for using blockchain. That said, only 23 percent had actually initiated a blockchain deployment, and 43 percent still see blockchain as overhyped (Deloitte 2019).

A recent Eyefortransport report indicated that nearly 62 percent of supply chain executives surveyed claimed to have engaged with blockchain technology. Overall, the business value added of a blockchain is expected to grow to more than $176 billion by 2025 and exceed $3.1 trillion by 2030 (Min 2019).

IBM claims to have conducted engagements with over 400 clients around the world and over 40 networks that have graduated to active states (IBM 2018). According to Biggs et al. (2017), IBM has launched services including providing an environment for companies to test and improve their own blockchain networks and infrastructure. IBM sees the potential for improvement in the exchange of information, interaction of systems, and innovation of processes.

Blockchain is a work in progress that needs time to mature and become perfected. When it comes to new technology, few businesses want to go first, but even fewer want to be last. It can be challenging to create a value proposition that is equally compelling for all parties and induce everyone to share data. There can also be political economy challenges given that blockchain can disintermediate intermediaries that benefit from informational asymmetries in trade and generate revenue from preparing trade documents and managing trade transactions. Several of the largest banks have concluded they can leverage their large networks of users to profit from blockchain, but smaller banks, law firms, customs brokers, and freight forwarders may feel threatened by the technology. Also, there is a question internationally of who is liable for blockchain interactions and transactions (Suominen 2018).

Jain and Mishra (2018) believe that blockchain as a disruptive technology will develop its impact predominantly in the long term. Most experts expect the market breakthrough in about five years. Most experts consider the technical challenges solvable in the future—even the limited scalability. The main problem is the lack of general openness toward this innovative technology. People associate it with the dark net and have a negative association with it—others have never heard of it. IDC forecasts that by 2021 manufacturers will depend on a secure backbone of embedded intelligence to automate large-scale processes and speed execution times by up to 25 percent. This will use IoT and blockchain (Knickle 2017).

PricewaterhouseCoopers states that it is possible to imagine that 10 to 20 percent of global economic infrastructure will be running on blockchain-based systems by 2030. PricewaterhouseCoopers cites a study that forecasts that blockchain will generate an annual business value of more than $3 trillion by 2030. In response to the question, “How far along are companies with blockchain?” they present the graphic shown in Figure 4 (PricewaterhouseCoopers 2019).

Source: PricewaterhouseCoopers (2019)

Figure 4. How Far Along Companies Are with Blockchain.

In the Deloitte 2019 survey, respondents were asked what the most important organizational barriers to greater investment in blockchain technology are. They responded with the following (Deloitte 2019):

- Implementation (replacing or adapting existing legacy systems) (30 percent).
- Regulatory issues (30 percent).
- Potential security threats (29 percent).
- Lack of in-house capabilities (skills and understanding) (28 percent).
- Uncertain return on investment (28 percent).
- Concerns over sensitivity of competitive information (25 percent).
- Lack of a compelling application of the technology (23 percent).
- Technology is unproven (20 percent).
- Not currently identified as a business priority (17 percent).

Legal Framework

Local and international law, industry-specific regulations, data-sharing regulations, intellectual property, liability, and general commercial agreements—such as service level and performance assurances—are just a few areas that can create complexity and require a careful approach. Additionally, a blockchain network may span numerous jurisdictional boundaries, making determining legal jurisdiction tricky.

A comprehensive legal framework for blockchains does not exist (de Caria 2017). Do blockchain technologies, virtual currencies, and smart contracts require new legal avenues to be developed? It is not clear how domestic laws in areas such as data privacy and transfer and identity protection apply to blockchain.

Legal and regulatory challenges exist for wide adoption of blockchain. They include distributed jurisdiction and laws, the legal framework to ensure legal validity, responsibility and accountability, and data privacy. Government agencies have made few efforts to invest in blockchain (Chang et al. 2019). Additionally, the concept of antitrust violations has to be considered. Anytime two or more entities in the same industry begin sharing information, a

variety of competition laws can be triggered (IBM 2018). There is lack of guidance on how blockchain technology can be used to support the exchange of trade documents (Segers 2019).

The node locations and the type of data stored on the blockchain must be considered because they can trigger additional laws and regulations that must be followed, including the Health Insurance Portability and Accountability Act of 1996, the Family Educational Rights and Privacy Act, and the European Union's General Data Protection Regulation (IBM 2018). In Deloitte's 2019 Global Blockchain Survey, half of respondents cited privacy-related regulations as a matter of concern—more than any other blockchain regulatory issue (Deloitte 2019). Blockchains appear to be subject to the same privacy laws that govern the internet. Blockchain needs to be able to remove sensitive data (Suominen et al. 2018).

The legal enforceability of smart contracts depends entirely upon a jurisdiction's recognition and acceptance of electronic and digital signatures. The legal status of smart contracts as legal contracts is currently debated. A legal contract is an agreement between parties, and a computer program is either the text of source code or an executing physical machine. Blockchain problems may arise such as disputed transactions, incorrect addresses, exposure or loss of private keys, data-entry errors, or unexpected changes to assets (Staples et al. 2017).

Michigan has recently introduced a bill that imposes criminal penalties for manipulating data on blockchains in order to commit fraud (Suominen et al. 2018).

PricewaterhouseCoopers (PwC)recently unveiled a "blockchain validation solution" that combines a patent-pending risk framework with proprietary continuous auditing software. It provides real-time testing for anomalies covering a full population of transactions. It is meant to be an integrated component of the client's data processing system. The firm says it will find longer-term patterns of indicators that are not evident to humans, is immediate and predictive, and provides objective results. PwC claims "It is currently the only standard that exists for risks and controls in the blockchain space for private business blockchain processes (Whitehouse 2018)."

Finally, one aspect of the legal framework that is often overlooked is that law firms will also have to innovate and adapt. They will have to change to make smart contracts viable and will need to develop new expertise in software and blockchain programming.

Considerations for Developing Blockchain Applications

Appendix A provides a partial listing of examples of blockchain implementation identified in the literature.

A blockchain is almost never a whole system in itself. Blockchains are usually combined with other components in a broader system. For example, some data may be stored on blockchain while other data are stored and communicated using conventional computer systems.

A common theme in the literature is that "because blockchain's benefits come from decentralisation, there is little point replacing one technology with another without changing the business model" (Martin 2018). Many IT solutions have made the following mistakes (De Rossi et al. 2019):

- Misunderstanding or ignoring the purpose of blockchain technology.
- Assuming that current technology is ready for production use.
- Viewing blockchain technology purely as a database or storage mechanism.
- Ignoring funding and governance issues for a peer-to-peer distributed network.

A blockchain solution could actually represent a negative value if the governance and business models are not clearly understood. There is also a concern that there are not adequate standards for governance models; enterprise-grade security; legal, tax, and accounting frameworks' native interoperability; and scalability. Narrow-scoped blockchain prototypes have experienced issues with scalability, waste of computational resources used for consensus mechanisms, traceability of users, and lack of network protection fraud. Many proofs of concept and system designs appear to be based on trial and error rather than a well-thought-out design (Labazova et al. 2019).

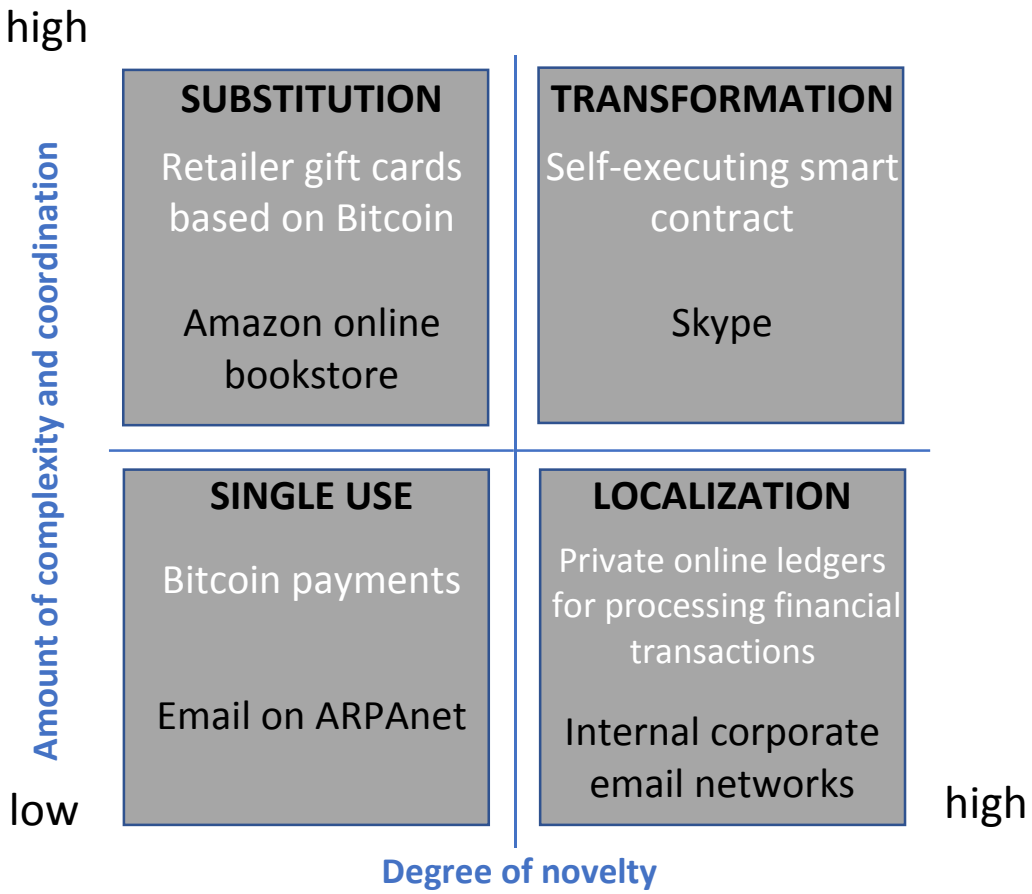
The true value of IT projects is manifested in process improvement, productivity gains, increased consumer surplus, profitability enhancement, or improvements in supply chains as well as innovation at the interorganizational level (Hassna 2020). To create value, an information system must be technically, economically, and operationally feasible (French 2020). Although different sources rank items differently, almost all applications embody the four main characteristics of transparency, availability, authenticity, and trust.

Blockchain is particularly useful where there are large networks of players, high intermediation costs, significant informational asymmetries among the players, and concerns about the veracity of data and fraud (Suominen et al. 2018). Successful operation of a blockchain relies on several key elements (Staples et al. 2017):

- Appropriate integrity criteria to be checked for each transaction and block.
- Correctness of the system's software and technical protocols.
- Strong cryptographic mechanisms to identify parties and check their authority to add new transactions.
- A suite of incentive mechanisms to motivate processing nodes to participate in the community and behave honestly.

Blockchain is actually a foundational technology in similar terms that transmission control protocol/internet protocol (TCP/IP) was when the internet was founded. Blockchain, however, will require broader coordination due to its unique characteristics: distributed database, peer-to-peer transmission, transparency with anonymity, irreversibility of records, and

computational logic. Figure 5 illustrates the typical four phases of adoption that foundational technologies go through.



Note: Blockchain applications are in white.
Source: adapted from Iansiti and Lakhani 2017

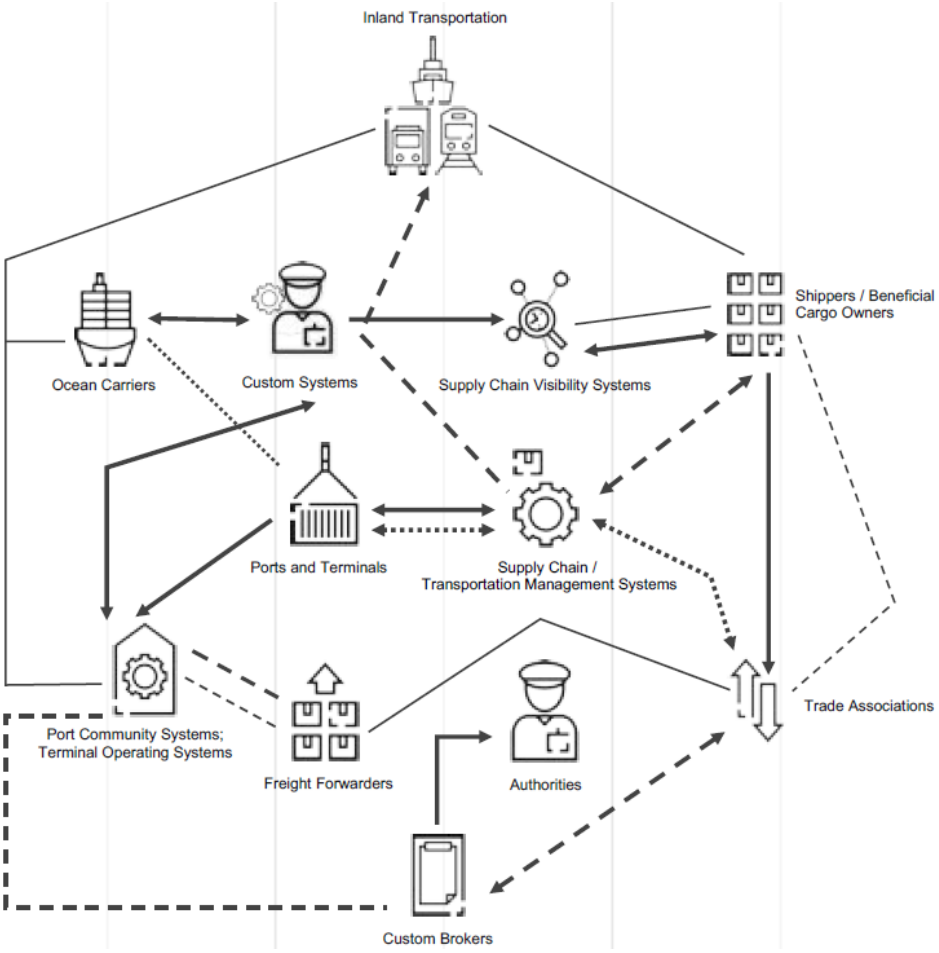
Figure 5. The Four Phases of Foundational Technology Adoption.

The matrix in Figure 5 combines the "degree of novelty" (x-axis) with the "amount of complexity and coordination" (y-axis) needed so that a technology can go from single use (phase 1) to local network (localization) (phase 2). Once the novelty effect is exhausted, the technology goes to a broader application, which requires a higher degree of coordination and represents a substitution effect (phase 3). Finally, when the new technology gains a successful status on a large scale including major economic, social, legal, and political changes, it reaches the transformation stage (phase 4). Phase 4 has been attained by some applications of smart contracts and more widely in the financial sector led by the case of Bitcoin.

Despite blockchain being used by financial organizations for a little more than 10 years, the academic literature on blockchain is relatively new in transport and logistics, as presented in very recent studies by Saberi et al. (2019) and Kamble et al. (2018). The literature on blockchain in the maritime sector is almost nonexistent, with the exception of Weernink et al. (2017), who

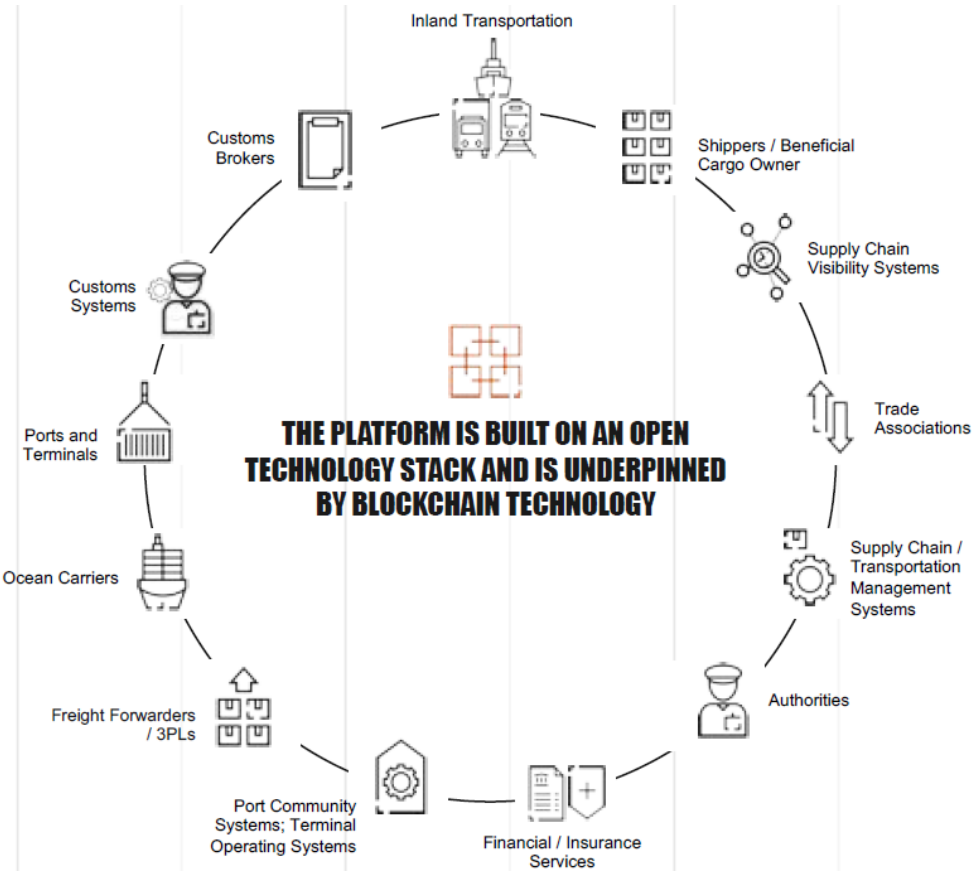
studied the potential applications to port logistics, and Gausdal et al. (2018), who investigated the experience of Norwegian offshore companies. The IBM partnership with Maersk forming the TradeLens project is probably most the robust project of blockchain application and integration to the maritime shipping industry (discussed further in Chapter 5).

Figure 6 and Figure 7 illustrate what blockchain could do for the maritime shipping sector. That is, by applying blockchain technology, processes could be performed in a more time-efficient manner and, consequently, reduce costs.



Source: Schapell 2018

Figure 6. Global Trade Is Highly Inefficient and Burdened by Paper-Based Processes.



Source: Schapell 2018

Figure 7. The TradeLens Platform: Digitizing the Global Supply Chain.

Technology

The choice and combination of technical characteristics of a particular system are key to the success or failure of the system.

Blockchain IT architecture consists of three layers (De Rossi et al. 2019):

- **Top layer:** blockchain application. The final service developed by the company using the blockchain.
- **Middle layer:** blockchain ledger. The distributed ledger on which the blockchain application is built.
- **Bottom layer:** blockchain hardware/network.

Each layer has different considerations and design issues.

De Rossi et al. (2019) define a continuum of architectural solutions for blockchain ranging from a type of IT architecture close to the ones currently deployed by enterprises to one completely decentralized and distributed within the members of a public ecosystem:

- **Proprietary ecosystem.** The entire ecosystem is internalized within a company or a group of companies (e.g., a consortium) through the development of a completely new

blockchain environment, over which the founding member(s) has full and direct control. The company or consortium will need to develop a dedicated hardware infrastructure, a new blockchain ledger, and a dedicated application equipped with user interface software. This model would typically be a private and permissioned blockchain.

- **Semi-proprietary ecosystem.** The company provides part of the ecosystem—that is, the ledger and the IT infrastructure—and allows authorized third parties to use its blockchain solution in exchange for a fee. This would require a public and permissioned blockchain. The entire ecosystem is maintained by one (or more) central user or user group who verifies each transaction. The main source of income of the blockchain provider is the fees charged for each transaction occurring in the network (ecosystem fees). The software provider can either charge some fee to the customers who are using the service or just integrate the software within its legacy systems. In this case, the blockchain is used to solve a specific problem related to transparency, immutability, and/or security.
- **Proprietary software solution.** In this case, the company develops a specific software solution in an open blockchain environment. The company does not need to create its own blockchain ledger, nor dedicate a proprietary hardware infrastructure to create a blockchain-based service. The company simply exploits a totally transparent blockchain ledger and leverages a decentralized hardware infrastructure to build any type of software on top. This scenario typically relies on a public and permissionless blockchain. The blockchain ledger and the infrastructure are totally outsourced.
- **Fully decentralized ecosystem.** In this model, a company exploits a freely available software solution based on an open blockchain environment. No real IT developments are required, and the entire blockchain architecture is actually outsourced. The difference between this model and the others is at a software level. In fact, in this case, the company will create or exploit a:
  - Publicly available software.
  - Public and permissionless blockchain ledger.
  - Decentralized hardware infrastructure.

Table 2 summarizes the characteristics for these four models.

Table 2. Blockchain Architecture Continuum.

		1	2	3	4
Technical	Application layer	Proprietary	Third party	Proprietary	Third party
	Ledger layer	Proprietary	Proprietary	Third party	Third party
	Hardware layer	Proprietary	Proprietary	Third party	Third party
Governance	Type of ownership and governance	Private and permissioned	Public and permissioned	Private and permissionless	Public and permissionless
Business	Revenue models	No new revenue stream	Ecosystem fees	Application fees	Raised funds; application fees

Source: De Rossi et al. 2019

The governance issues for a blockchain system are typically defined along two dimensions: permissioned/permissionless and public/private. These dimensions are discussed in the section "Public and Private, Permissioned and Nonpermissioned Blockchains." The distinction between permissioned and permissionless is important when evaluating desired operating performance. In a permissionless blockchain, anyone, including malicious actors, can participate in the consensus process. Anyone is free to be an active part of the network. This requires a more elaborate consensus protocol, which results in costs being higher and speed being slower than on a permissioned chain.

Roeck (2020) states that permissioned blockchains are often used in supply chain management. Labazova et al. (2019) determined that smart contracts work on public unpermissioned blockchains with a proof-of-work consensus mechanism.

According to Labazova et al. (2019), eight dimensions of technical design must be addressed:

1. **Reading access.** Private reading allows only authorized members to access the blockchain. Public reading allows everyone to read data from the blockchain.
2. **Writing access.** Permissioned writing requires users to be authorized to add transactions.
3. **Main consensus mechanism.** This deals with the means for updating blockchains. Proof of work is common for cryptocurrencies; the requester must perform some work, usually solving a computationally difficult puzzle. A proof-of-stake paradigm asks users to prove the ownership of a certain amount of digital data to establish their stake.
4. **Anonymity level.** This dimension assesses whether users can be matched to identities.
5. **Event handling.** This dimension discerns whether blockchains can handle application logic or events.
6. **Data exchange type.** This focuses on the type of information sharing between users and includes the characteristics of the transaction and content.

7. **Encryption.** This dimension specifies whether data on the blockchain are encrypted.
8. **History retention.** This ascertains whether the whole blockchain or only a certain number of recent updates are kept and distributed between the nodes.

Rossi et al. (2019) detail several more considerations related to blockchain protocol. The protocol must define the technical rules under which the blockchain is produced. These rules primarily deal with rights to validate transactions (per the consensus protocol) and to read and submit transactions. The protocol can also incorporate additional rules such as the existence and extent of transaction fees and the maximum number of transactions the blockchain can handle within a given time. The protocol must deal with information privacy, scalability, security, and environmental sustainability.

New IT tools are needed. Increasing the size and number of blocks is a storage dilemma for handing big data in real-time usage. Improvement in storage management and advanced cloud computing infrastructure will be required (Saberi et al. 2019).

The implementation of blockchain use in the United States is still in the very early stages. Technological, governance, organizational, and even societal barriers need to be addressed. Because of this, blockchain needs time to mature. The development of blockchain applications can be fueled by industry standards. Blockchain standards can provide for the interoperability of blockchain ledgers, help clarify how smart contracts work, create common terminology, further common understanding of how the origin of products is tracked and determined, and clarify how data flows are secured between on- and off-chain databases (Suominen et al. 2018). Unfortunately, there is no evidence in the literature of a data standard for blockchains that would enable integration among systems.

IBM strongly recommends focusing on a use case with the greatest amount of friction—that is, where there are more points at which a transaction can be delayed or incorrectly recorded. Doing so can ensure a reasonably scoped initial solution and increase the likelihood of solving real pain points. This then allows the definition of areas of interest and focus moving forward. IBM poses three questions that indicate whether a blockchain applications is appropriate (IBM 2018):

1. Does the solution require trusted data to be shared across multiple parties without a central authority?
2. Are assets being transferred between parties?
3. Is there the need for greater trust inside the current business network?

An affirmative response to any of these questions indicates that blockchain might be an appropriate solution.

Stinnes (2019) adds a couple of conditions that may indicate that blockchain is an appropriate solution:

- Are the business problems that the solution addresses centered on intercompany processes?
- Does the solution involve simple, well-defined, highly transactional processes with few or no variations?

Again, an affirmative response may indicate that blockchain is an appropriate tool (Stinnes 2019).

Iansiti and Lakhani (2017) suggest that testing out single-use applications will help organizations develop the skills they need for more advanced applications. A low-risk approach is to use blockchain internally as a database for applications like managing physical and digital assets, recording internal transactions, and verifying identities (Iansiti and Lakhani 2017).

The World Economic Forum has developed a list of seven questions that should guide how a specific blockchain is configured (Warren et al. 2019b):

- Is there a blockchain consortium or trade partnership that is already active in our industry or specific to the use case?
- Are shared data proprietary and confidential?
- Do the data contain personal information?
- Is proof of existence enough for your case?
- Does your solution require smart contracts?
- Does your solution require near real-time processing, or does it need to handle large data sets?
- Do you require a high degree of control over blockchain performance?

Organizational/Societal Concerns

There is more to IT system development and implementation than just the technology. In today's environment, organizational and societal issues must be addressed. The broader societal, political, and legal questions must be understood.

Unlike centralized databases, blockchains have no single administrator who can change the roles of participants. Distributed ledgers (i.e., blockchain) require a joint agreement to adjust roles; the system has a democratic component to govern the distribution of data and transparency of the data (Roeck 2020).

Human agents govern the blockchain protocol, and the blockchain governs their interactions. There is governance *of* IT and governance *through* IT.

The three major applications for supply-chain management (proof of origin, trade financing, and trade documentation) do not call for drastic changes to the current supply chains (Roeck 2020). This may explain why these applications have been the starting point. Research has

highlighted the fact that many IT investments do not lead to productivity gains because they require organizations to change their business processes. This is why emerging technologies often have low acceptance rates (Mendling et al. 2018).

There are no guidelines for development of blockchain-based systems, which hinders the development of successful blockchain projects (Labazova et al. 2019). Entrepreneurs need regulatory clarity because it gives them a level of certainty regarding the legality and taxation of their ventures (Mendling et al. 2018).

Aside from technical considerations, users and society must determine the relative importance of different features (e.g., privacy, security, usability, and latency) that determine end-user adoption. Even though blockchains are supposed to be trust free, users may not consider blockchain transactions to be trust free since they still require a certain amount of trust in the blockchain providers and smart contract developers. A lack of understanding of the technology may imply legislative risks. Specifically, in an attempt to prevent money laundering, fiscal fraud, and illegal activities, societies and legislative bodies may try to apply their established system of legal rules unchanged to blockchain systems that are largely based on pseudonymity of users and transactions that are not tied to a physical location (Risius and Spohrer 2017).

Research is still needed to examine concepts that are independent of applications. For example, market regulations in different countries will have an influence on how systems can be designed. The question remains whether more or less anonymity is feasible and desirable from an individual or societal perspective. Scholars anticipate strong changes to the current state of intermediaries in transactions and to the need for legal boundaries. Currently, it is unclear for which intermediaries public or private blockchains will be a threat or opportunity (Risius and Spohrer 2017).

CHAPTER 3: SURVEY OF THE HOUSTON PORT COMMUNITY

Blockchain and the Maritime Industry

This research provides a review of the state of the art of blockchain implementation in the maritime sector using the Houston maritime cluster as the case study. First, the research identified the main characteristics of blockchain and examined the state of the art of blockchain applications and implementations aiming to map the benefits applicable to the maritime sector as well as the business drivers for the adoption of blockchain. Second, the researchers identified implications for training and education considering the disruptive and transformative potential of blockchain. The research employed a survey method, asking both multiple-choice and open-ended questions of key stakeholders operating in the greater Port of Houston area. Survey responses were analyzed using descriptive statistics.

A recent survey by Deloitte (300cubits.tech 2017) interviewed U.S.-based executives in the shipping sector and found that 39 percent have little or no knowledge about blockchain. Still, 55 percent believed that failure to implement blockchain would put their company at a disadvantage; 25 percent said that their companies viewed blockchain as a critical top-five priority. These responses showed that the maritime sector, in comparison with other sectors, might possibly be fearful of its reputation of being behind on technology implementation.

Maersk, a major player in the maritime sector, and IBM, the implementer of blockchain across all business sectors, announced their joint venture TradeLens. They planned the venture to develop blockchain applications to simplify visibility for customers and other stakeholders in the maritime sector. Other logistics giants, such as Kuhne+Nagel, continued testing application with the European Customs in a consortium with AB Inbev, Accenture, and APL (Tirschwell 2018). It is clear to maritime shipping industry members that cargo tracking is an important function for customer satisfaction because it ties the physical movement of goods with payments and inventory management. In this sense, blockchain might be of higher relevance than initially thought.

The researchers investigated several research questions arising from the application of blockchain to maritime supply chains and logistics. In an era of fierce competition where information represents a competitive advantage, it becomes critical to examine how much or to what level of detail companies are expected to share information. Several questions arise from blockchain adoption and application, as noted in Chapter 2. When information represents a competitive advantage, how much information and how detailed should the information be that is shared in this ledger system? What is the value added for all participants in blockchain applications? Is the system really as safe against cyberattacks as proponents claim?

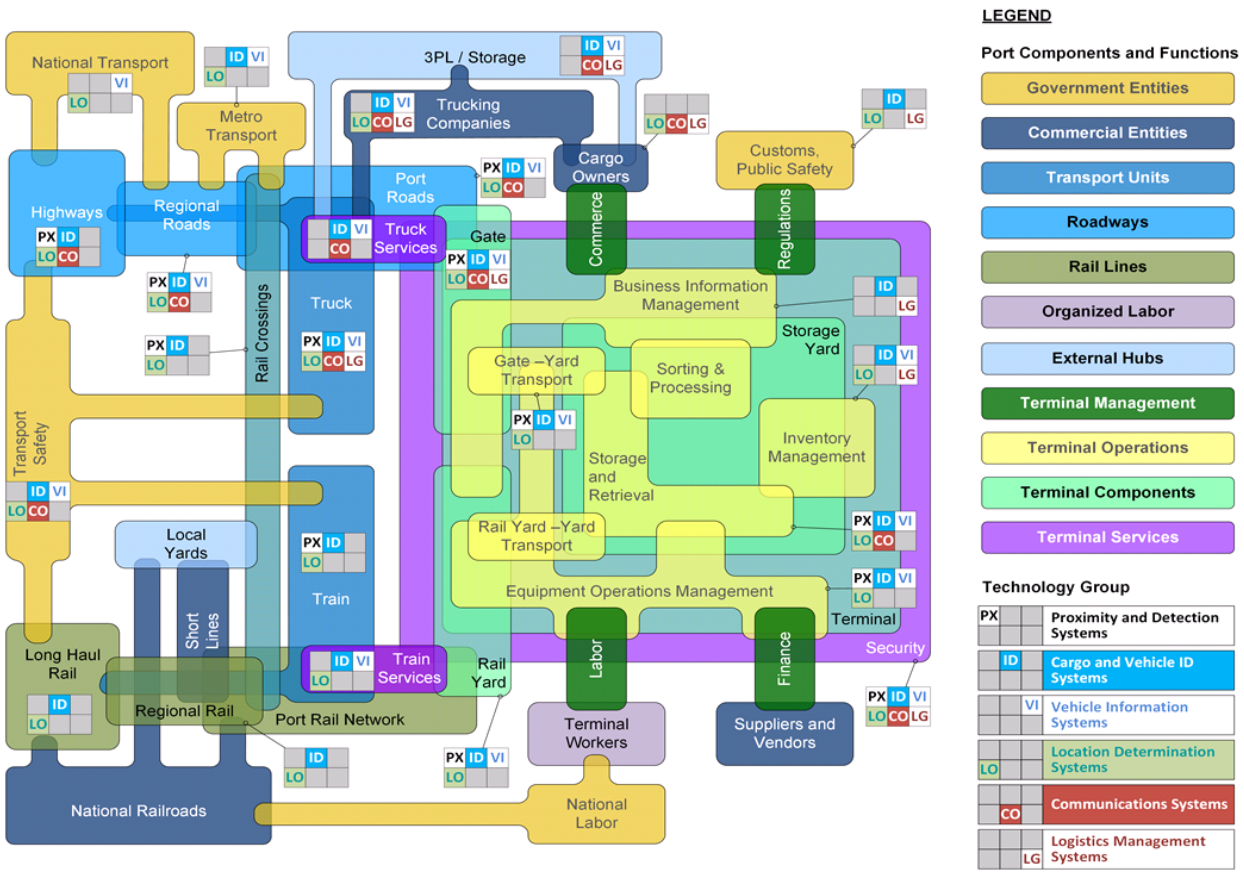
In addition to these issues, there are other concerns in the specific case of the maritime industry, such as the level of digitization, need for standardization, and network and market structures (containers are very different from break-bulk cargo, for example). These issues are

mainly associated with the implementation of blockchain. However, whether blockchain is actually relevant or critical for maritime business has yet to be proven. In a network structure, sharing of information might add value to the process and make the whole network more efficient and effective. However, in an era of fierce competition where information represents a competitive advantage, concerns are associated with the level of information to make the network more efficient while ensuring at the same time that individual members will not be less competitive.

Given that blockchain applications are a relatively new topic in the maritime sector, the main contribution of this research is insight into the value added by a system that requires a high level of information sharing. The goal of the research was to investigate the foundations and the main applications of blockchain to the maritime business sector. In view of its relevance to local, regional, and national maritime logistics, the Houston maritime cluster provided a good case study. The research approach employed application of network theory (Ibarra and Andrews 1993) to examine the relationship of blockchain members as nodes of the network and used case study methodology (Yin 1989) to investigate the case of the Port of Houston.

First, the research identified the main characteristics and state of the art of blockchain applications and implementation in the greater Port of Houston maritime complex, aiming to map the benefits applicable to the maritime sector as well as the business drivers for the adoption of blockchain. Second, the research studied the implications for training and education, as identified by Gromovs and Lammi (2017), because the implementation of blockchain requires an innovative approach to maritime business and logistics education.

Research by Carlan et al. (2019) provides a strong indicator that the success of any blockchain application in the maritime sector has to be a significant standardization of data that might require not just changes on the shipping or trade side, but major changes in the way information is collected and reported to/from ports and other local authorities. In other words, for blockchain to succeed in the maritime sector, it has to go beyond the coordination and transparency of information and financial transactions. Blockchain must address the particularities of the actual transfer of cargo custody and all official inspections and paperwork requirements. The complexity is unprecedented, and as the researchers understand it, ports and port terminals will have a major role to play, as shown in Figure 8, which illustrates the main dimensions of typical maritime cargo flow with information technologies.



Source: Adapted from WSP USA (n.d.)

Figure 8. Port Interactions and ITS Technologies.

Data Gathering and Methodology

The literature review and preliminary interviews with industry members shed light on how the survey should be designed. The survey focus was to determine how blockchain application is relevant for the maritime sector, considering this sector is an international multi-stakeholder business and has ports as the central piece of any implementation process. These characteristics of the maritime shipping industry led to the decision to survey multiple stakeholders present and operating at the greater Port of Houston area.

The greater Port of Houston region is one of the largest maritime clusters in the United States, consisting of a 25-mile-long complex with 200 private and public industrial terminals. The area also encompasses a 52-mile-long Ship Channel and eight public terminals that are owned, operated, managed, or leased by the Port of Houston Authority (POHA) (2018a). The port has been instrumental for the city's and region's urban and industrial development, in particular for the petroleum sector. Per 2018 data (POHA 2018b), the Port of Houston is ranked first in the nation in foreign tonnage; first in petroleum, steel, and project products; and sixth in container volume throughput. POHA is also the first U.S. port authority to receive International Organization for Standardization (ISO) certification for its environmental management system

and the first in the world to receive ISO certification for its security management system. POHA is the local sponsor of the Houston Ship Channel and is a part of the Greater Port of Houston. The Houston Ship Channel economic impact in Texas corresponds to 1.35 million jobs (direct and indirect), $339 billion in statewide economic value (20 percent of the Texas gross domestic product), and $5.6 billion in state and local tax revenue (POHA 2018b).

The research team worked with the Greater Houston Port Bureau (GHPB) to execute the survey. GHPB is a non-profit trade organization founded in 1929 (the Port of Houston Authority was founded in 1914) and represents a combination of private, public, and semi-public agencies involved in the development and activities of the port area. GHPB is a member-driven association that currently has 220 members led by a board of directors from the leading companies in and affiliated with the Houston maritime industry (GHPB 2020).

GHPB offers various services and benefits to its members, mainly associated with four core areas of interest: vessel information, port information, networking, and advocacy. GHPB works in collaboration with POHA but is a totally separate organization. Since 2016, GHPB has allowed academic institutions to join as associate members. The Department of Maritime Business Administration (MARA) of Texas A&M University at Galveston (TAMUG) is an associate member.

Given the scarcity of publicly available data about new technologies and business models in the maritime business sector, the research team determined that a survey was the most adequate tool to meet the research goals. The selection of the population to be interviewed was based on the availability and easy access of maritime professionals operating in and around the Port of Houston. The MARA TAMUG membership with GHPB gave the researchers access to the GHPB directory of members containing the company and contact information of the executives to be surveyed.

The data collection process can be summarized in the following four steps:

1. **Create a questionnaire that addresses the research main goals and that the respondents can easily understand.** The questions were discussed in three rounds of internal discussions and then submitted to a few industry members as a pilot. This was done to ensure reliability of the instrument. A freight forwarder, a marine terminal, and a barge operator responded to the questions and made some minor suggestions for amendments. The questionnaire consisted of seven questions—three multiple choice and four open ended (Appendix C provides the questionnaire and the contact email).
2. **Classify the GHPB membership directory information by sector as reported by GHPB.** The directory provided 370 email addresses from 220 companies in 54 different sectors Table 3 shows the number of potential respondents by sector.

Table 3. Number of Email Recipients per Sector.

Sector	Number of Email Recipients	Share
Banking	25	6.8%
Steamship agents	24	6.5%
Steamship lines	19	5.1%
Terminals liquid bulk	19	5.1%
Towing, tug, and barge	19	5.1%
Legal services	15	4.1%
Logistics services	15	4.1%
Engineering	14	3.8%
Stevedore companies	13	3.5%
Port: public	11	3.0%
Trucking	11	3.0%
Equipment supply	10	2.7%
Oil/chemical manufacturers	10	2.7%
Terminal operators	10	2.7%
Accounting	8	2.2%
Dredging and marine construction	8	2.2%
Insurance	8	2.2%
Surveyors: cargo	8	2.2%
Vessel construction and repair	8	2.2%
Industry associations	7	1.9%
Chandlers	6	1.6%
Fuel/lubricant distributor	6	1.6%
Line handlers	6	1.6%
Medical services	6	1.6%
Ship management	6	1.6%
Waste management	6	1.6%
Bunkering	4	1.1%
Consultants: marine	4	1.1%
Emergency response	4	1.1%
Finance	4	1.1%
Industrial construction	4	1.1%
Pilots	4	1.1%
Rail transportation	4	1.1%
Real estate services	4	1.1%
Security	4	1.1%
Consultants: business	3	0.8%
Government agencies	3	0.8%
Seafarers services	3	0.8%
Consulates	2	0.5%
Consultants: software	2	0.5%
Crew transportation	2	0.5%
Education training	2	0.5%
Hotel	2	0.5%
Industrial park	2	0.5%
Printing	2	0.5%
Ship owner	2	0.5%
Terminals: break bulk and roros	2	0.5%

Sector	Number of Email Recipients	Share
Trade publications	2	0.5%
Warehousing: general	2	0.5%
Marine repair	1	0.3%
Port: private	1	0.3%
Surveyors: hydrographic	1	0.3%
Third-party logistics	1	0.3%
Transportation	1	0.3%
Total	**370**	**100.0%**

3. **Send questionnaire requests to all email addresses.** To facilitate response collection, the actual questionnaire was sent using a web-based platform software application (Qualtrics) with a Qualtrics link inserted in the email request. This email included a voluntary consent form (Appendix C provides the consent form). The data collection took place from October 22, 2019, to February 5, 2020, in four separate requests—one original request and three reminders—to secure a higher participation rate. Emails considered not valid were discounted from the total 370; as a result, emails were sent to 349 contacts. Table 4 summarizes the number of contacts that were determined to be valid or invalid in each request cycle.

Table 4. Summary of Validity of Contact Email Addresses.

	Date	Number of Email Recipients	Invalid Emails	Valid Emails	Remarks
First request	Oct. 22, 2019	370	1	369	Removed TAMUG from the list
Second request	Nov. 8, 2019	370	4	366	Four recipients asked to be removed or not contacted because they were not relevant to the survey
Third request	Dec. 7, 2019	366	17	349	17 emails bounced back as “not delivered”; an additional attempt was unsuccessful
Fourth request	Feb. 5, 2020	349	0	349	Final number of email recipients

4. **Generate Qualtrics final report.** The analysis was completed in a Microsoft® Excel® spreadsheet using descriptive statistics as detailed in the next section.

Data Findings, Analysis, and Validation

The responses were analyzed in four steps:

1. **Examine the total number of entries for validation (completeness).** The final Qualtrics report had 68 entries. From those, 28 were discarded because they represented invalid entries due to incomplete information, tests, or duplicated responses, as summarized in Table 5. Table 6 provides the number of valid responses per request. The total number of valid entries was 40, which corresponds to 11.5 percent of the 349 emails recipients,

which is considered to be slightly above average (a 10 percent response rate) for online surveys.

Table 5. Summary of Response Entries.

	Number of Entries	Remarks
Test	4	Entries made by the survey administrator
Invalid	20	Completely blank responses
Duplicate	4	Only one entry was accepted
Valid	**40**	Final number of entries for analysis
Total responses	**68**	

Table 6. Summary of Responses per Request.

	Date	Valid Emails	Number of Valid Responses
First request	Oct. 22, 2019	369	30
Second request	Nov. 8, 2019	366	22
Third request	Dec. 7, 2019	349	12
Fourth request	Feb. 5, 2020	349	4
Total			**68**

2. **Analyze the profile of respondents considering job title and sector.** Researchers ensured that the respondents were properly qualified (in managerial positions) to respond and that a significant number of sectors were represented. Table 7 and Table 8 detail the results. There were 26 sectors represented (out of the original 54) with no specific domination by any one sector; 72.5 percent of the respondents were in an upper-level managerial position (e.g., owner, partner, director, president, chief executive officer, or chief financial officer).

Table 7. Summary of Responses per Job Title.

Job Title	Number of Entries	Share
President, chief executive officer, owner, or superintendent	8	20.0%
Vice president	8	20.0%
Senior manager	7	17.5%
Director	5	12.5%
Chief financial officer	1	2.5%
Operations manager	6	15.0%
Sales	1	2.5%
Others	4	10.0%
Total	**40**	**100.0%**

Table 8. Summary of Responses per Sector.

Sector	Number of Entries	Share	Remarks
Banking	1	2.5%	
Consultants: marine	1	2.5%	
Engineering	2	5.0%	
Finance	1	2.5%	
Fuel/lubricant distributor	1	2.5%	
Industrial park	1	2.5%	
Industry associations	3	7.5%	
Insurance	1	2.5%	
Line handlers	2	5.0%	2 entries from the same company
Logistics services	2	5.0%	
Medical services	1	2.5%	
Oil/chemical manufacturers	3	7.5%	
Pilots	1	2.5%	
Port: private	1	2.5%	
Port: public	3	7.5%	2 entries from the same company
Ship management	2	5.0%	
Ship owner	1	2.5%	
Steamship agents	2	5.0%	2 entries from the same company
Steamship lines	3	7.5%	
Surveyors: cargo	2	5.0%	
Terminal operators	1	2.5%	
Terminals liquid bulk	1	2.5%	
Towing, tug, and barge	1	2.5%	
Transportation	1	2.5%	
Trucking	1	2.5%	
Vessel construction and repair	1	2.5%	
Total	**40**	**100.0%**	

3. **Analyze questionnaires using descriptive statistics and content analysis of the open-end answers.** Table 9 details the results, summarized as follows:
   - **Question 1:** 87.5 percent of the respondents said that their firms were not in the process of implementing a blockchain-related initiative. The others who responded affirmatively were still in the pilot stage of the study. There was no report of a fully implemented blockchain initiative.
   - **Question 2:** 70 percent of respondents said that they had not been approached (by shipping companies or terminal companies) to participate in a blockchain-related project or initiative. As a consequence, 60 percent of the respondents had not discussed how a blockchain project/initiative idea would fit into their organization's business model and strategy or potential shortcomings.
   - **Question 3:** 32.5 percent of the respondents said there was no adaptation or there were unknown adaptations of their business processes into blockchain.
     Thirty percent of respondents said there will be adaptations needed in one or more aspects of their business (electronic data interchange [EDI], logistics, title or bill of

lading, payment process, and investment needed are the most common key words found in their open-end answers); 37.5 percent of the responses to this question were blank.

- **Question 4:** As for the value of blockchain to their organization, 15 percent of the respondents said "no or not applicable." Another 25 percent said they were not sure or the value was unknown, and another 25 percent pointed to a goal such as reducing paperwork and improving communication, improving the level of security and transparency in each transaction, optimizing asset utilization, and improving the decision-making process; 35 percent of the responses to this question were blank.
- **Question 5:** With regard to fitting of blockchain into the current business strategy or model, 17.5 percent said "no or not applicable." Another 15 percent said they were not sure or it was unknown. Another 22.5 percent said there was some type of fitting, and the most common terms used were "streamlining documentation" and "improving asset utilization with potential cost reduction effect"; 42.5 percent of the responses to this question were blank.
- **Question 6:** With regard to adoption plans for blockchain in the next two to five years, 43 percent of the respondents replied it was very improbable or improbable; 35 percent replied it was probable or very probable; 20 percent of the responses to this question were blank.
- **Question 7:** When asked how valuable blockchain features would be to their organization, responses were very divided: 13 percent of the respondents said it is a must-have or has a high value, 27.5 percent said it has medium value, 20 percent said it has low value, 10 percent said it has no value, and 7.5 percent were not sure; 22.5 percent of the responses to this question were blank.

Table 9. Summary of Survey Responses.

Question and Responses	Number of Entries	Share
1. Is your firm in the process of implementing a blockchain-related initiative? If so, please describe the main challenges and proceed to question 3.		
Yes	4	10.0%
No	35	87.5%
No answer (blanks)	1	2.5%
Total	**40**	**100.0%**
If so, please describe the main challenges and proceed to question 3.		
Software that can capture everything and all of the detail in a meaningful way	1	2.5%
Study implications	1	2.5%
We have been involved with some pilots related to marine packed cargo moves	1	2.5%
No answer (blanks)	37	92.5%
Total	**40**	**100.0%**

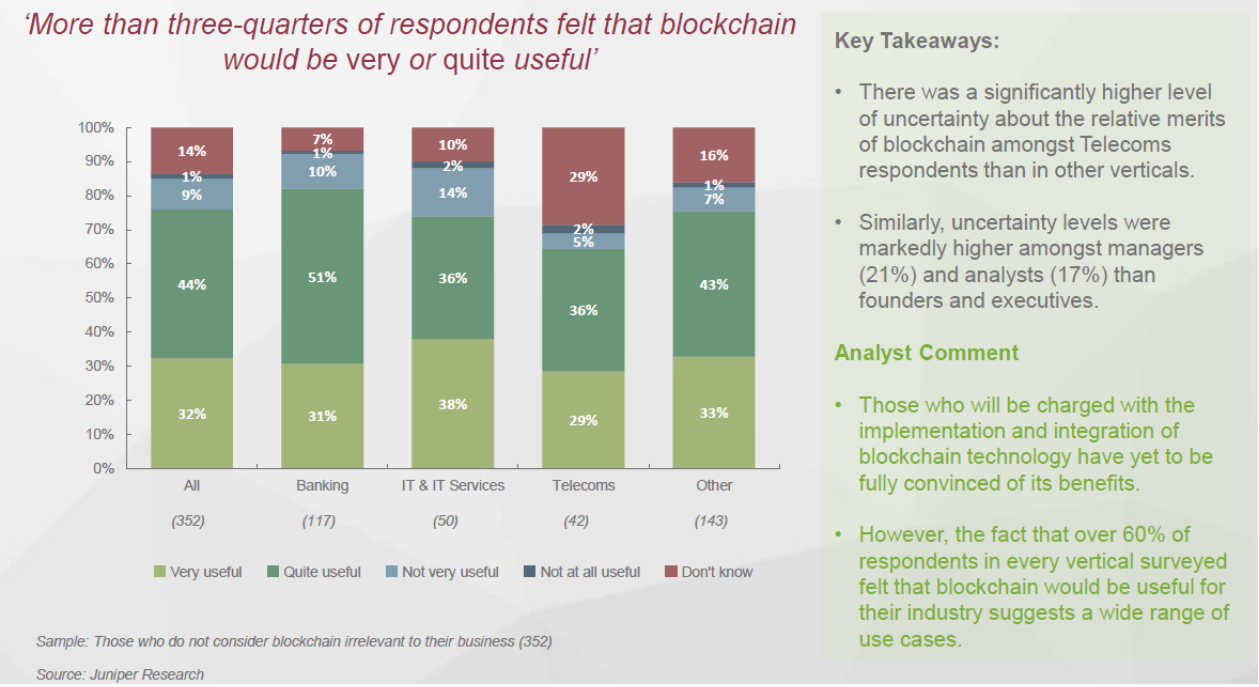
Question and Responses	Number of Entries	Share
2. Has anyone (shipping companies or terminal companies) approached you to participate in a blockchain-related project or initiative? If so, please describe the potential blockchain project or initiative.		
N/A	1	2.5%
No	27	67.5%
No answer (blanks)	12	30.0%
Total	**40**	**100.0%**
2a. Have they discussed how this project/initiative idea would fit into your organization's business model and strategy? If so, please describe how.		
N/A	5	13%
No	19	48%
I have mentioned it to colleagues but only as I have seen it mentioned in the news	1	3%
No answer (blanks)	15	38%
Total	**40**	**100%**
2b. Did they discuss any shortcomings? If so, please describe the identified shortcomings.		
N/A	6	15.0%
No	17	42.5%
Not sure	1	2.5%
No answer (blanks)	16	40.0%
Total	**40**	**100.0%**
3. How might blockchain require adaptations to your business processes?		
N/A	2	5.0%
No or no idea	3	7.5%
Not sure	3	7.5%
Too soon to say	2	5.0%
Unknown	3	7.5%
Yes	1	2.5%
Logistics management	1	2.5%
Enhancements of EDI or other methods of communication	1	2.5%
It seems it could eliminate many current positions in the maritime industry	1	2.5%
Well suited for ship management	1	2.5%
Significant financial investment in accounting software	1	2.5%
The first applications would involve transfer of title or the bill of lading. We would need to change much of that process.	1	2.5%
Minimal change in operations	1	2.5%
Somehow in the data or payment transfer	4	10.0%
No answer (blanks)	15	37.5%
Total	**40**	**100.0%**

Question and Responses	Number of Entries	Share
4. How would blockchain add value to your business processes?		
N/A	3	7.5%
No or no Idea	3	7.5%
Not sure	9	22.5%
Unknown	1	2.5%
Not currently being considered. If implemented, it would reduce paperwork and speed communication. With the new fuel blends, it might provide documentation of the blend and analysis at the different stages.	1	2.5%
Add levels of security and transparency to each transaction	1	2.5%
I believe it will streamline the documentation process, in turn helping to automate the industry	1	2.5%
Known returns well in advance of providing a service. Affords almost contractual protection with all the advantages of spot trading.	1	2.5%
The time stamp on the electronic ledger and the trail on all transactions for any process are a game changer in transparency. Transparency is a key in "purpose of a corporation"—the new mantra in the business world.	1	2.5%
Ease of access and use, confidence in security	1	2.5%
Potentially optimizing asset utilization when scheduling fuel/lube deliveries in different ports	1	2.5%
We are not totally sure that it will at this point. Theoretically, it could significantly alter the way we currently do export documentation, significantly reduce email, and speed decision making.	1	2.5%
Our FX Rate Integrity service might be an element of the blockchain process someday	1	2.5%
More data	1	2.5%
No answer (blanks)	14	35.0%
Total	**40**	**100.0%**
5. How does or would blockchain fit into your organization's business model and strategy?		
N/A	2	5.0%
No or no idea	5	12.5%
Not sure	4	10.0%
Unknown	2	5.0%
Yes	1	2.5%
Streamlining documentation, such as bills of lading, customs paperwork, etc.	1	2.5%
Forward assignment of transport tonnage at a known and non-negotiable rate.	1	2.5%
Easier and more rapid transactions	1	2.5%
We are a trucker employed by others, would just need to adapt communications as required by customers	1	2.5%
Blockchain could potentially make asset utilization more efficient, which would help us operate in the most cost-efficient manner	1	2.5%

Question and Responses	Number of Entries	Share
It currently does not and would most likely be focused around logistics efficiencies surrounding ship traffic. Looking forward, it would also potentially improve efficiency of truck transportation scheduling and gate traffic.	1	2.5%
Something to consider	2	5.0%
As a service company, we do not own the cargo. As a non-asset-based service provider, we do not own ships, planes, trucks, or warehouses. Our strategy is to have the technical knowledge to be able to support blockchain structures of our clients and carriers.	1	2.5%
No answer (blanks)	17	42.5%
Total	**40**	**100.0%**
6. Do you see your company adopting or implementing any type of blockchain systems in the next 2 to 5 years? (Please tick the box that corresponds to your current situation.)		
Very improbable	5	12.5%
Improbable	12	30.0%
Probable	13	32.5%
Very probable	1	2.5%
We are already using it	1	2.5%
No answer (blanks)	8	20.0%
Total	**40**	**100.0%**
7. In your role in your organization, how valuable do you think blockchain features would be to your organization? (Please tick the box that corresponds to your current situation.)		
Must-have	2	5.0%
High value	3	7.5%
Medium value	11	27.5%
Low value	7	17.5%
Low value, unsure/not applicable	1	2.5%
No value	4	10.0%
Unsure/not applicable	3	7.5%
No answer (blanks)	9	22.5%
Total	**40**	**100%**

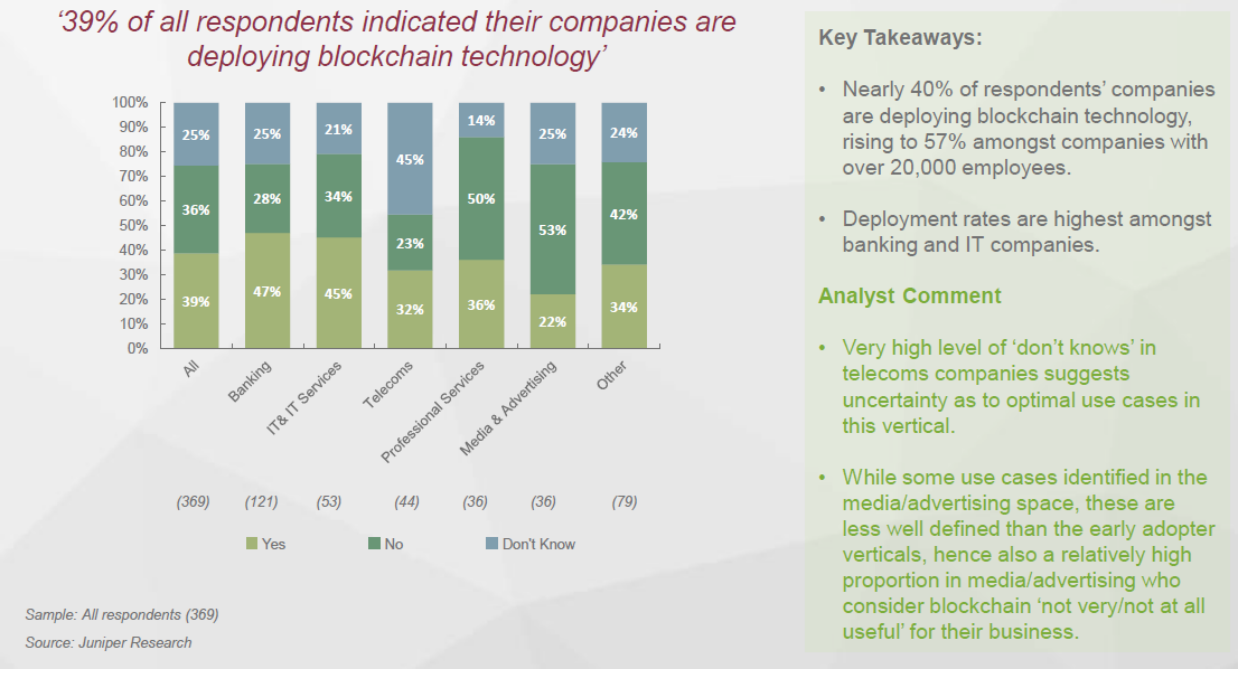
4. **Confirm the validity of the instrument and the results.** This was done through the pilot survey but also by comparing the results of this survey in the Port of Houston with a general survey taken in the general business sector by Juniper Research using similar survey methods and questions. Source: Holden and Moar (2017)
5. Figure 9 through Source: Holden and Moar (2017)
6. Figure 15 present the detailed results of the Juniper research conducted in 2017 entitled Blockchain Enterprise Survey: Deployment, Benefits and Attitudes. Juniper's research targeted general business and was non-maritime specific. However, the research results are comparable because Juniper used a similar methodology of surveying senior

managers and their respective organizations. The comparison of Juniper research results with the Port of Houston survey was based on the main takeaway messages they had for questions similar to the Houston survey, as shown in Table 10.



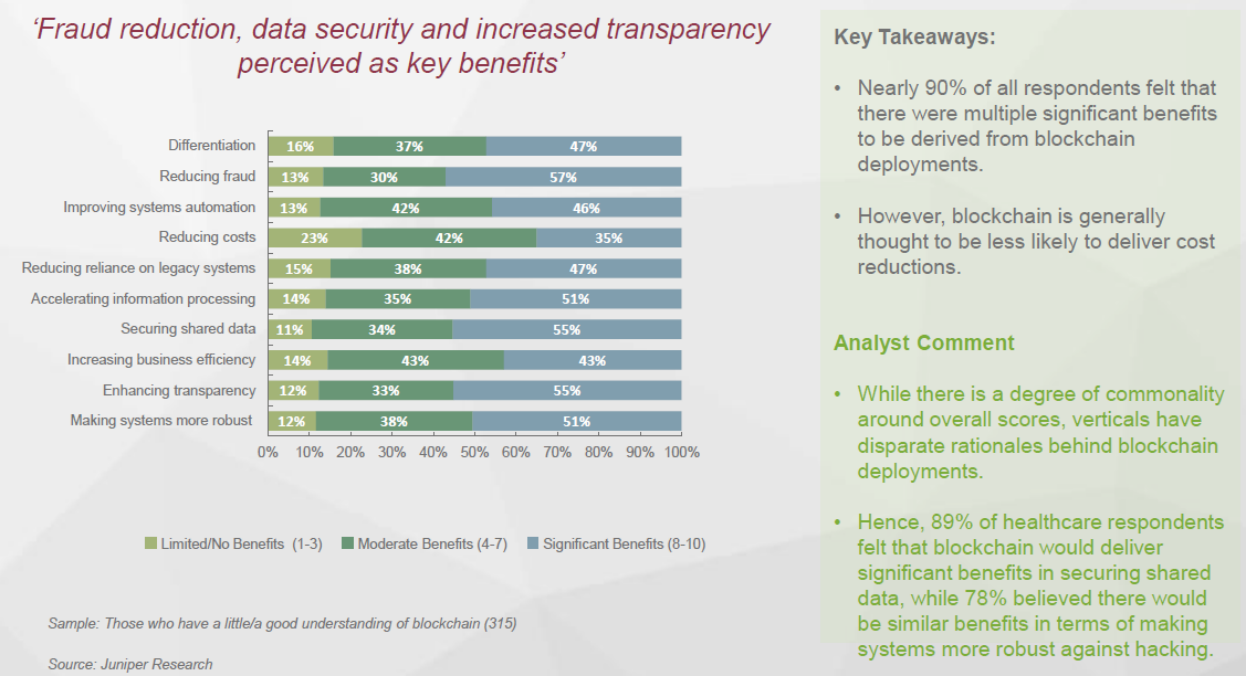
Source: Holden and Moar (2017)

Figure 9. Juniper: How Useful Will Blockchain Be for Me?



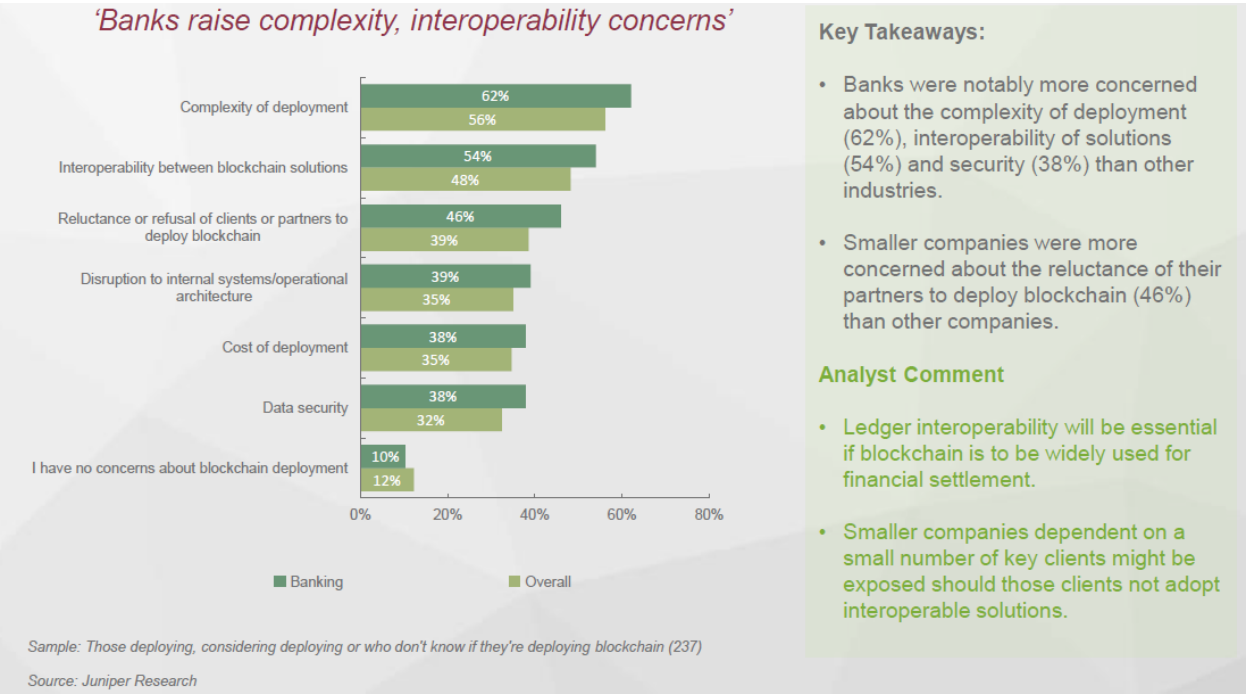
Source: Holden and Moar (2017)

Figure 10. Juniper: Who Is Deploying Blockchain Technology?



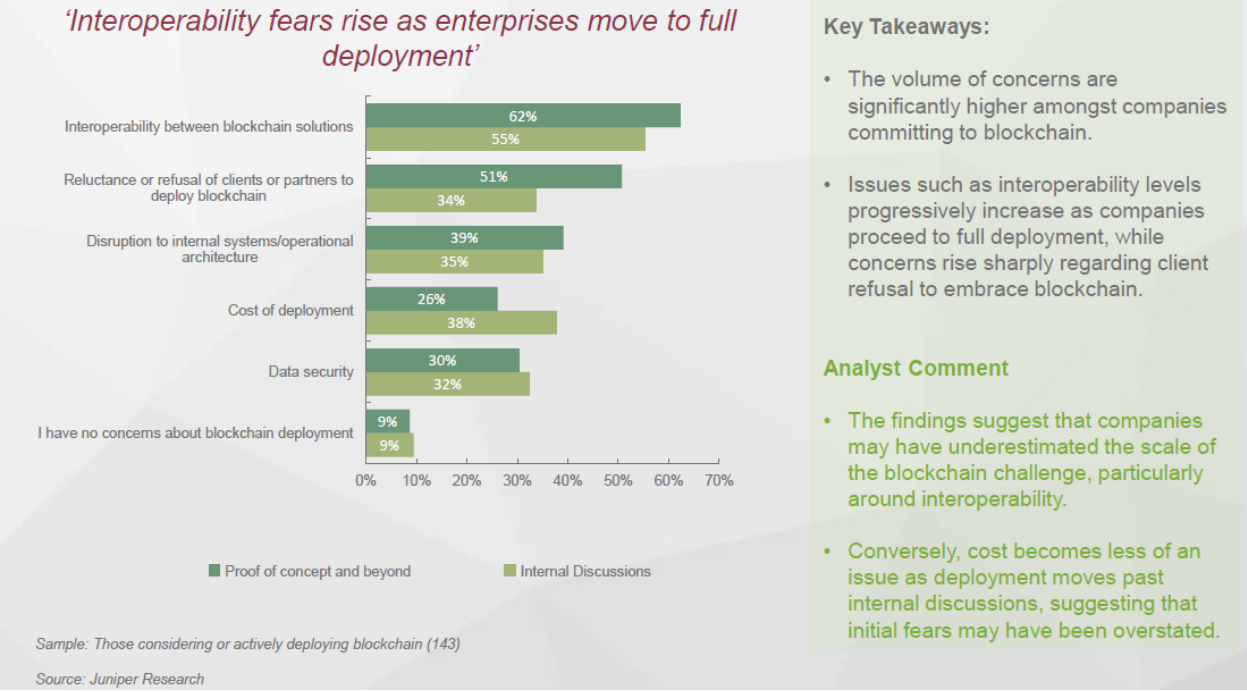
Source: Holden and Moar (2017)

Figure 11. Juniper: What Benefits Will Blockchain Bring?



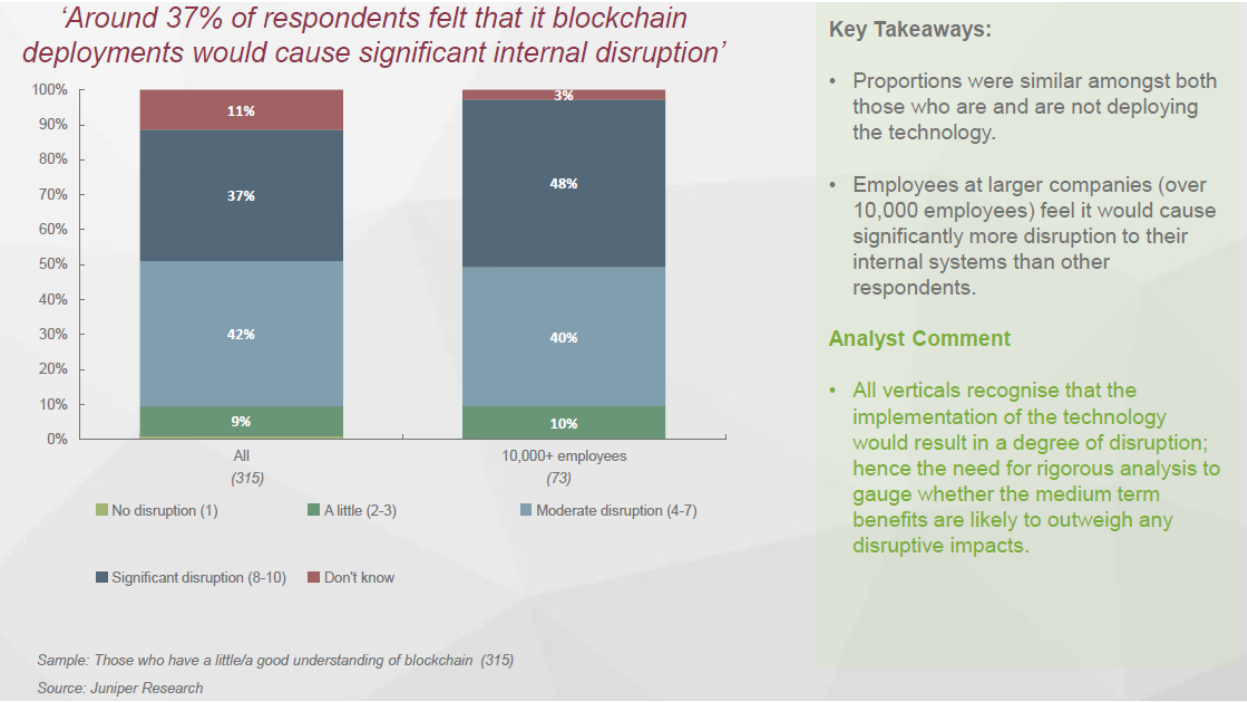
Source: Holden and Moar (2017)

Figure 12. What Are Your Concerns about Blockchain Deployment? (Part 1).



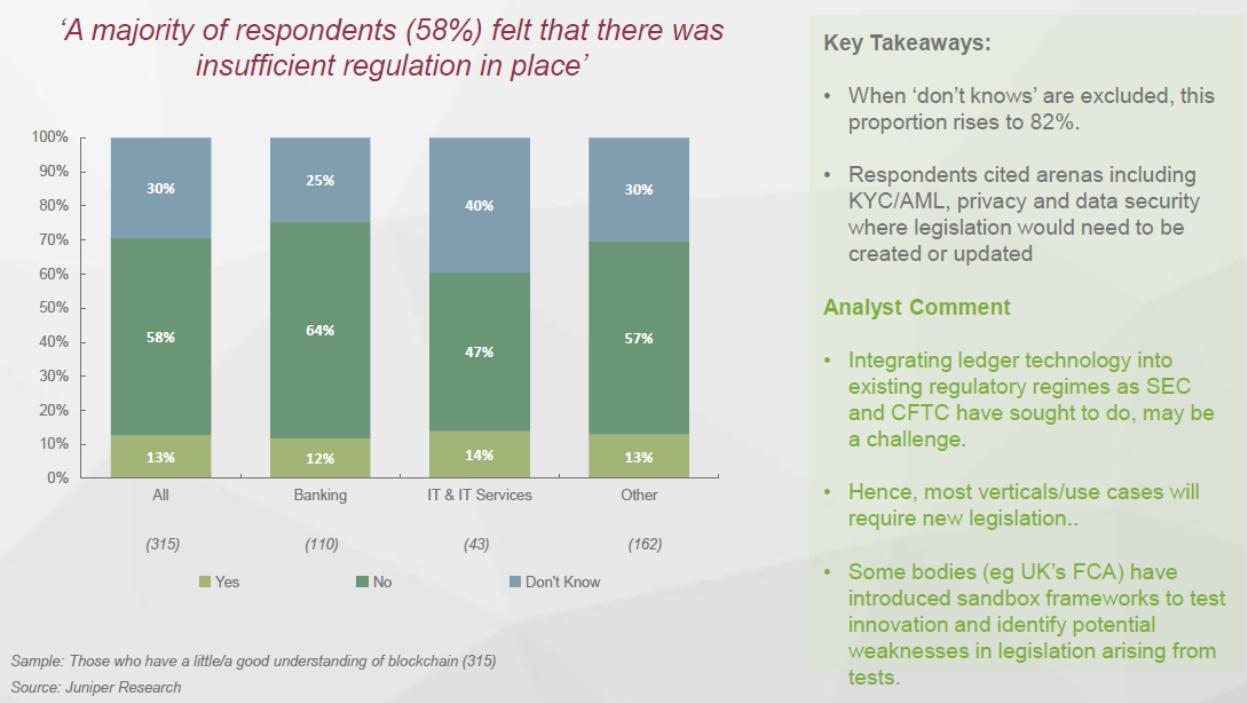
Source: Holden and Moar (2017)

Figure 13. What Are Your Concerns about Blockchain Deployment? (Part 2).



Source: Holden and Moar (2017)

Figure 14. How Much Internal Disruption Will Blockchain Cause?



Source: Holden and Moar (2017)

Figure 15. Does Blockchain Require Additional Regulation?

Table 10. Comparison of Juniper versus Houston Survey Main Takeaway Messages.

Juniper Question/Main Takeaway Message	Houston Question/Takeaway Message
How useful will blockchain be for me? "There was a significantly higher level of uncertainty about the relative merits of blockchain amongst Telecoms respondents than in other verticals. Those who will be charged with the implementation and integration of blockchain technology have yet to be fully convinced of its benefits." (p. 10)	**How would blockchain add value to your business processes? (Question 4) In your role in your organization, how valuable do you think blockchain features would be to your organization? (Question 7)** There was no dominant percentage of respondents pointing to clear benefits; 40 percent of the respondents said that they saw no value, not applicable value, or were not sure of the value of blockchain.
Who is deploying blockchain technology? "Nearly 40% of respondents' companies are deploying blockchain technology, rising to 57% amongst companies with over 20,000 employees. Very high level of 'don't knows' in telecoms companies suggests uncertainty as to optimal use cases in this vertical." (p. 11)	**Is your firm in the process of implementing a blockchain-related initiative? (Question 1)** In this case, there was a clear trend—87.5 percent of the respondents said "no," which is an indicator of uncertainty.
What benefits will blockchain bring? "Nearly 90% of all respondents felt that there were multiple significant benefits to be derived from blockchain deployments. However, blockchain is generally thought to be less likely to deliver cost reductions." (p. 14)	**How does or would blockchain fit into your organization's business model and strategy? (Question 5)** Again, there is no clear dominant trend here—22.5 percent said there was some type of fitting, and the most common terms used were *streamlining documentation* and *improving asset utilization with potential cost reduction effect*. But there was a high level of blank responses (42.5 percent).

Juniper Question/Main Takeaway Message	Houston Question/Takeaway Message
What are your concerns about blockchain deployment? "Banks were notably more concerned about the complexity of deployment (62%), interoperability of solutions (54%) and security (38%) than other industries. Smaller companies were more concerned about the reluctance of their partners to deploy blockchain (46%) than other companies. Issues such as interoperability levels progressively increase as companies proceed to full deployment, while concerns rise sharply regarding client refusal to embrace blockchain." (p. 16–17)	**Did they discuss any shortcomings? If so, please describe the identified shortcomings. (Question 2b)** There is a clear trend of lack of discussion about concerns because 60 percent of the respondents had not discussed how a blockchain project/initiative idea would fit into their organization's business model and strategy or potential shortcomings.
How much internal disruption will blockchain cause? "All verticals recognise that the implementation of the technology would result in a degree of disruption; hence the need for rigorous analysis to gauge whether the medium term benefits are likely to outweigh any disruptive impacts." (p. 18)	**How might blockchain require adaptations to your business processes? (Question 3)** There are very divided responses—about one-third of the respondents said no adaptations at all, one-third said some adaptation (EDI, logistics, title or the bill of lading, payment process, and investment needed), and another one-third had blank responses. This is another indicator of uncertainty.

Final Remarks and Implications for Managers and Educators

The research results point to four key takeaway messages:

- From the survey data, none of the respondents expressed the idea that blockchain was a driving force in the maritime industry. Also, their responses did not mention any sense of who is in the leadership of this process. On the contrary, some did mention that they will go with the market or follow the trend when required to.
- From the TradeLens case, it is evident that a more comprehensive approach was needed in the platform capabilities, beyond the original "shipment-tracking function" as it was created.
- Based on the literature review case analysis, the port or the marine terminals have a pivotal function, which also explains the changes that TradeLens has made from a predominantly shipping-centric to a maritime supply-chain-centric ecosystem.
- The full cost/benefits are yet to be found compared to the risks and disruptions presented.

There is still a need to advance the implementation stage across the maritime sector. That is not a surprise because the maritime sector is known for being reluctant in adapting or even creating new technologies that enhance its business model. However, when comparing that result in the maritime sector with the general business survey (by Juniper), researchers found similar results, expressed in terms of concerns related to the uncertainties of benefits and issues with systems' full interoperability.

In summary and to answer the original research question, blockchain application and implementation are in their infancy for the maritime industry. Furthermore, the research revealed three types of customers for blockchain:

- **Shipping companies** can use blockchain to inform their customers about the status of the shipment and provide governmental (e.g., customs) paperwork.
- The different **intermediators** in the supply chain can have more information about when their services are required.
- Other **software groups** can develop further competencies using blockchain for the future needs of the maritime industry

Considering the structure and design of blockchain projects, virtually any stakeholder in the maritime business could be impacted.

The finding from this research will contribute on three fronts:

- For **academia**, this research creates expertise for research on a trendy topic for both ports and shipping companies. This expertise can also be used for educational purposes on the emerging topic in maritime business.
- For **industry stakeholders**, the research provides information about best practices that can be considered for operations.
- For **policy makers**, the research provides analysis that helps them face the challenges of policy recommendations and regulatory framework in the ports and shipping sectors.

CHAPTER 4: CASE STUDY—PORT OF VERACRUZ, MEXICO

Background

This case study provides an understanding of the level of complexity and detail that is required to develop blockchain applications for marine shipping interests. In this case study, the application was narrowly focused on containerized export shipments. Even with this narrow focus, the complexity of such a system is readily apparent.

Veracruz is the third busiest port in Mexico. In 2019, the Port of Veracruz continued a growing trend, handling more than 28 million tons of cargo, including 1.14 million twenty-foot equivalent units (TEUs) (Administración Portuaria de Veracruz 2020).[2] In 2019, Veracruz began operations in its new port facilities, which tripled the port capacity by volume. That volume is expected to reach 5 million TEUs by 2030.

Expected growth at the Port of Veracruz requires modern technology to make it more efficient and competitive. As is the case with many ports around the world, information systems were developed to serve specific stakeholders with no system-oriented approach. Some of these outdated legacy systems and processes are still in use, making the port operation inefficient and uncompetitive.

In order to improve overall port efficiency, the Port of Veracruz recently created a port community system (PCS), which encourages all stakeholders to take a systematic approach and participate in joint efforts to plan and apply changes in the way the port is operated, implementing innovative technologies that will increase the port's competitiveness. The Veracruz port community decided to develop an open and neutral electronic platform that provides an effective and efficient form of communication between users. This will have the following benefits:

- Reduce trade barriers in the Port of Veracruz by reducing IT development and maintenance costs and by improving cargo flow coordination.
- Provide best-in-class service to shippers and consignees with total transparency and accountability.
- Develop knowledge and skills to position Veracruz as a leader in innovation and establish a sustainable ecosystem that develops and disseminates technology.

New digital technologies, specifically blockchain, would help the Veracruz PCS meet its needs by providing security and transparency that enable collaboration and reduce the cost of maintaining trust between its users.

[2] TEU is the standard unit of measure for container activity. A 20-foot container is 1 TEU; a 40-foot container is 2 TEUs.

Veracruz Port Community System

A PCS is an electronic platform of business-to-business information exchange (Long 2009). The common goal of all PCSs is to provide an effective and efficient form of communication to improve port operations. Features of PCS include logistics, navigation, hazardous cargo declaration, and customs that enhance the cooperation between players that take part in the same maritime supply chains within a certain area (Carlan et al. 2016).

Information exchanged among PCS members includes port procedures, shipping, customs, and specific vessel information, which is valuable to connect transport and logistics chains (Le et al. 2016). These electronic platforms provide real-time information through the technical adaptation and modification of existing hardware, telecommunications, software, and data models, as well as organizational change (Rodon and Ramis-Pujol 2006).

The Veracruz PCS is the first of its kind in Mexico and the first to leverage blockchain and cloud technologies to provide an effective and efficient form of communication to improve port operations. This system, under development, will exchange information among members including port procedures, shipping, and customs information as well as specific vessel information used to connect maritime transport and land logistics supply chains.

Through the development of new systems and modifying existing hardware, telecommunications, software, and data models, as well as organizational changes, the Veracruz PCS will provide the port stakeholders with modules tailored to their needs that include:

- Digitizing trade transactions on a single platform, reducing transaction cost and time and standardizing information exchange processes.
- Designing a flexible and scalable platform that enables intelligent and secure information exchange between the Veracruz PCS's public and private stakeholders and that meets current and future requirements of confidentiality, integrity, and transaction security.
- Developing smart services for stakeholders, increasing efficiency and transparency in logistics and supply chains.

The platform will also allow third-party service providers to build applications to aid particular sets of stakeholders with services such as payments, machine learning, appointments, and insurance.

The Veracruz PCS is envisioned as a single-window platform that is available to public and private stakeholders that operate at the Port of Veracruz. The neutrality of the platform is maintained by using blockchain technology, which provides an immutable ledger of port operation transactions. The underlying ledger is neutral and equally accessible to all stakeholders that operate on it.

Similar to many platforms, the Veracruz PCS is a three-layer platform. The approach is important in order to provide maximum flexibility and accessibility for third-party services to build applications on top of the platform. Figure 16 illustrates the three-layer platform. The layers are as follows:

- The **foundation layer** includes back-end components such as blockchain technology and smart contracts, cloud database and storage, and identity and access management. These components store transactions, have a ledger, and perform identity verification so that stakeholders can perform core interactions.
- The **core interaction layer** is where entities that operate in the port use web applications and mobile apps for daily operations. Core interactions mean they are critical activities that happen inside the port, and include:
  - Customs broker staff.
  - Cargo declarations with Mexican Customs (Servicio de Administración Tributaria Aduanas) and other agencies.
  - Tariff payment.
  - Customs gate staff and inspectors.
  - Integration with customs broker systems.
  - Port of Veracruz Authority (Administración Portuaria Integral de Veracruz [APIVER]) system.
  - Terminal operator systems.
  - Tugboat operations.
  - Servicio de Administración Tributaria (SAT) (Tax Administration Service) systems.
  - Banking and payment systems.
  - Inspection notifications.
  - Docking information.
- The **services layer** will be an open application programming interface (API) for third parties to connect and build services on top of the PCS platform to build customer-facing applications that enhance the core interactions. These services are external to the port operation.

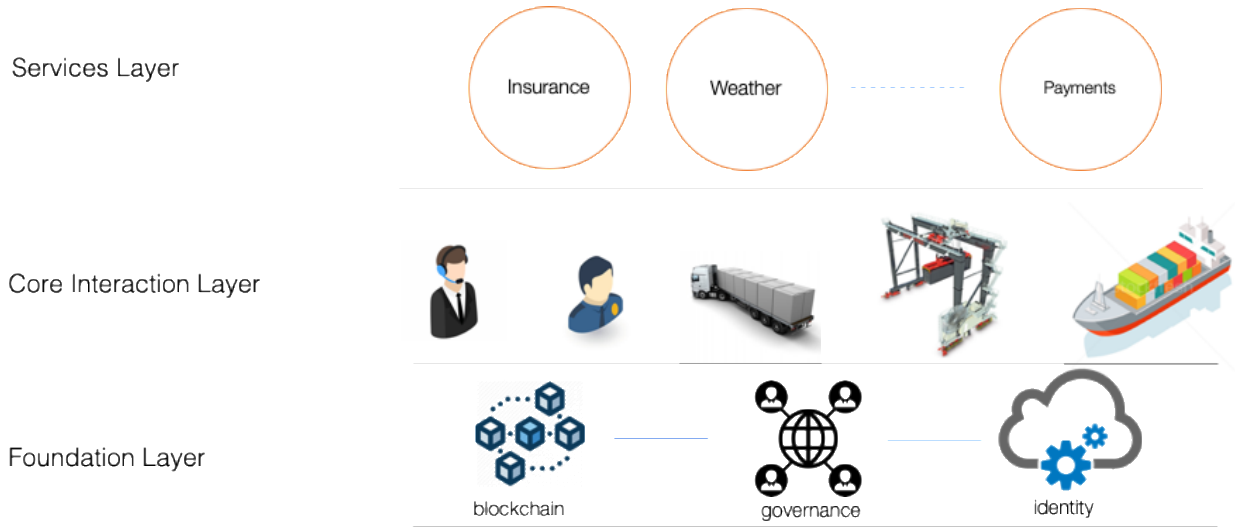


Figure 16. Veracruz PCS Three-Layered Platform.

Figure 17 presents the actual applications that could be developed in each of the three system layers. For example, in the foundation layer, blockchain smart contracts will include specific applications that are required by the Veracruz PCS. The governance of the system will be defined, identifying stakeholders' interaction. Not all stakeholders will have access to all information. In the core interaction layer, various mobile apps will be developed to communicate and exchange information, and the services layer will provide alternatives for third-party applications to be connected with the platform through the APIVER. Components can be added and upgraded or replaced as necessary.

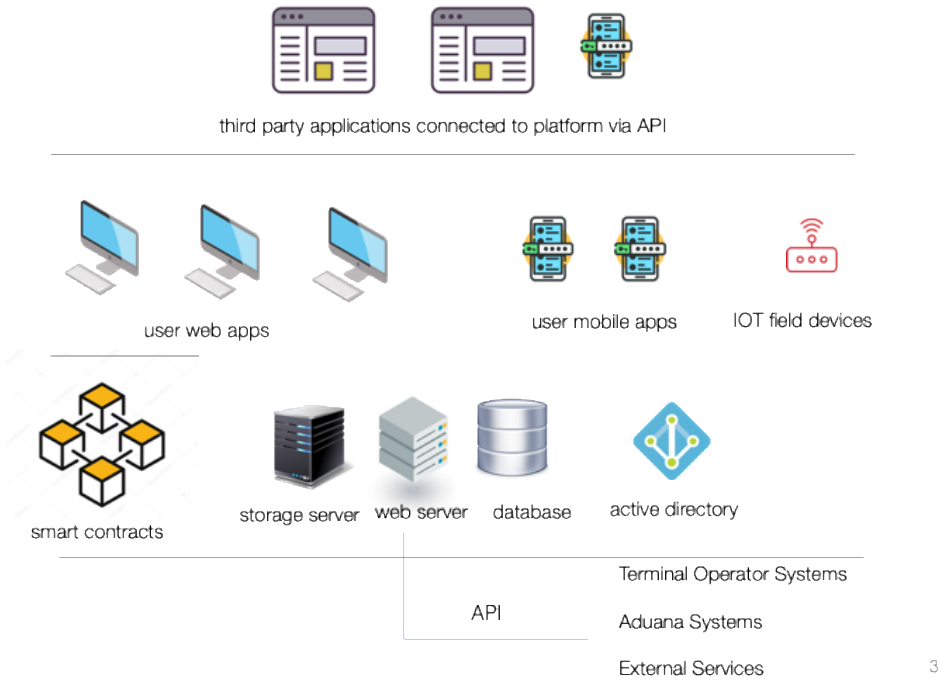


Figure 17. Core Components in the Veracruz PCS Platform.

Blockchain Proof of Concept

In order to develop the system architecture, an analysis of current container import and export procedures at the APIVER was conducted. The analysis led to defining the initial application that will serve as a proof of concept for the blockchain-based application. A specific workflow in the container export process was defined as the proof of concept. The container export process was selected because the number of stakeholders that participate in the process is less than in the container import process; however, it is complex enough that it is deemed an issue to stakeholders and requires streamlining.

Proof-of-Concept Development

The initial step to develop the system was to map the physical and information flows and subflows between systems of individual stakeholders. This helped identify blind spots and facilitate the integration between stakeholder systems and decision points. Blockchain and other technologies would reduce the identified blind spots. The following steps in the container export process were documented.

Step 1: Create Anexo 29

The customs broker receives an email from a freight forwarder and/or exporter with cargo information for export. The customs broker, in order to reserve a space in the shipping vessel, enters cargo information to a third party or shipping line's application (e.g., INTTRA). Using its own system, a customs broker prepares Anexo 29[3] based on the cargo information provided by the exporter.

Step 2: Generate an Appointment with the Terminal Operator

The customs broker sends Anexo 29 to the terminal operator to obtain an appointment using the terminal operator's system. Anexo 29 can be generated by the customs broker simultaneously with the appointment process. Alternatively, the customs broker can simply enter the information about the cargo in the terminal operator's system to request an appointment. The terminal operator sends the Transportation Access Number (Folio de Ingreso al Transporte [Folio FIT]), which includes the vessel information, container ID, and entry schedule when the container has to be dropped at the terminal.

Customs brokers typically access the terminal operator's web-based system to send Anexo 29 information and receive the Folio FIT document. For example, Hutchison's container terminal, known by its Spanish acronym ICAVE, has a system called CR-WEB. The customs broker selects the appropriate time slot from a list of appointment times in the CR-WEB system.

[3] **Anexo 29** is a document (electronic or paper form) that allows shipments to enter the port facility and is based on Article 23 of the Mexican Maritime Law. Anexo 29 includes information such as the name of the exporter and importer, cargo description, cargo value, vessel name, container ID, customs broker's information, and date of departure.

Step 3: Send Maneuvers to the Trucking Company

The customs broker then sends via email (or printed) the Folio FIT and Anexo 29 to a trucking company, which is responsible for picking up and dropping off cargo or containers to and from the terminal. Most of the time, exporters and shipping lines already have a trucking company available to transport containers to the port.

Step 4: Enter through the APIVER Facility

The trucking company's truck driver seeks approval from the APIVER to enter the port. The APIVER has to verify that the trucking company, truck, and driver have been properly registered in the Transportation Logistics Support Center (Centro de Apoyo Logístico al Transporte [CALT]) system prior to allowing entry to the port. The CALT system is operated and maintained by the APIVER. The system manages the flow of trucks in and out of the port and ensures only trucks and drivers with proper authority, permit, and insurance are granted entry into the port facilities.

Step 5: Validate Anexo 29 at the Mexican Customs (Aduanas) Booth

The truck driver then arrives at the entrance to the port facility at the customs (Aduanas) booth. Empties and car carriers form a separate line from other trucks, which go through gamma ray screening. In both cases, a truck driver presents a printed Anexo 29 (provided by the customs broker) to Aduanas staff, who visually validate it against the terminal operator's system by entering the license plate of the truck in Anexo 29. Aduanas staff also verify the container ID information and contents using gamma rays. Anexo 29 is verified by comparing the printed copy with ICAVE's CR-WEB system.

Aduanas staff enter the license plate and validate it against the CALT system to ensure the truck and driver are registered with the APIVER. Aduanas staff bring up the terminal operator system to validate Anexo 29 and the trucking company's authority to enter the facility using the CALT system. If the printed Anexo 29 does not match the one in the terminal operator's system, the truck is sent to a separate area for correction.

Step 6: Validate and Verify Documents at the Terminal Operator's Gate

The truck then arrives at the terminal operator's gate. Terminal operators verify and validate whether the container seal ID is the same as in Anexo 29, whether the license plate of the truck has been registered in CALT, and whether an electronic tag is on the vehicle. Terminal operator staff at the terminal gate use their respective systems to verify information and provide a location to store the containers.

Step 7: Generate, Validate, and Pay Duties through the Customs Manifest (Pedimento)

The customs broker prepares a customs declaration (*pedimento*) using cargo information received from the exporter. He/she can generate the *pedimento* before the trucking company enters the port facility or after it has entered. The *pedimento* is a standardized legal document sanctioned by SAT and is used at other ports in Mexico. The *pedimento* is primarily used to pay duties to SAT.

The customs broker then sends the draft *pedimento* to a pre-validator, who checks it against SAT's standard definitions. This process takes a few seconds. If there is an error, the pre-validator notifies the customs broker. If there are no errors, then SAT is notified along with a digital stamp. SAT approves the *pedimento* for the pre-validator, which forwards it to the customs broker.

The customs broker uses a bank's web service to pay SAT for the particular *pedimento* ID. The bank uses the SAT system to check if the ***pedimento*** is valid. The *pedimento* is then stamped as paid.

Step 8: Process the Pedimento

Aduanas staff may receive a request from one of several federal agencies requesting inspection of a container or may choose to send a container to inspection due to an error in documents or suspicious items detected during gamma ray screening. The Aduanas Operations Deputy Administration may notify the terminal operator that a container needs to be detained for inspection. All containers that arrive at the container terminal have a physical seal.

Step 9: Clear Customs

Mexican Customs has a green light/red light system to identify which containers require a physical inspection and which containers can continue through the process. If a container receives a green light from Aduanas, then the container is ready for loading on a vessel and the terminal operator is notified.

If red, it is necessary to program a customs inspection with the following three steps.

Step 10: Detain the Container

Depending on the nature of the inspection (who requested the detention of the container and why), the container can be detained directly from a dedicated system between Aduanas and the terminal, or requested via email from the Customs Operations Deputy Administration Office.

Detention from the dedicated system is a semi-automated process that enables Aduanas to detain the container in the terminal's operating system (TOS). The container will be added to a special list within the TOS and will effectively be blocked from programming any further handling by the customs broker, especially the loading of the container onto the vessel.

When a container is detained using the dedicated system, an email is automatically sent to a predefined distribution list that includes all the terminal's operations personnel involved in the inspection of the container. Alternatively, Aduanas manually generates an email with little standardization in the format. All coordination to move the container to the inspection area is performed by radio between the control tower and the yard personnel.

Step 11: Inspect the Container

Depending on the nature of the inspection, a container can be programmed to be inspected at a specific time and date, or requested to be inspected immediately. In the case of a red light at

customs clearance, the inspection is requested to be performed immediately. The terminal is given 45 minutes after the red light to place a container to be inspected in the inspection area. While the terminal is informed which containers are detained by Aduanas immediately, the terminal may want to wait until this status is confirmed by the customs broker to start the process.

The customs broker personnel are required to make the programming of the maneuver on site, confirming the customs result and accepting the charge for this operation. After the maneuver is programmed and confirmed, the process to place the container in the inspection area begins with an extremely uncoordinated process among stakeholders. The terminal operator has the commitment to place the container within 45 minutes, which causes stress on yard operations because the inspection cannot occur until the Aduanas inspector and the customs broker are physically present in the inspection area. Once the container is placed in the inspection area, no further notice is given to the customs inspector or customs broker. Customs broker personnel time is typically wasted as they wait for the arrival of both the container and the Aduanas inspector to the inspection area.

Step 12: Clear the Terminal Operator

The inspection is performed by the Aduanas inspector in the presence of customs broker personnel. If cleared, the container will be closed, a new seal will be provided, and the inspector will need to update in the system that a container has been cleared.

Due to distrust in network communications, Aduanas has refused to record the red inspection process from a mobile application and requires the transaction to be performed from its offices. The clearance of the container consequently is not performed until the Aduanas inspector gives that instruction to office personnel or he or she physically arrives at the office to clear it. After the clearance, the container is cleared for making payments to the terminal and loading onto a vessel.

Touch points indicate instances when a document is either physically touched, viewed, or transmitted by stakeholders. For example, Aduanas staff at a port gate receiving a printed Anexo 29 from a truck driver is a touch point. The goal of a PCS is to reduce the number of physical touch points of the same document by multiple stakeholders in a single container flow process.

One of the objectives of process mapping is to understand the touch points of both the *pedimento* and Anexo 29. Figure 18 illustrates the touch points of both documents for export containers until the green/red checkpoint and after the red handling.

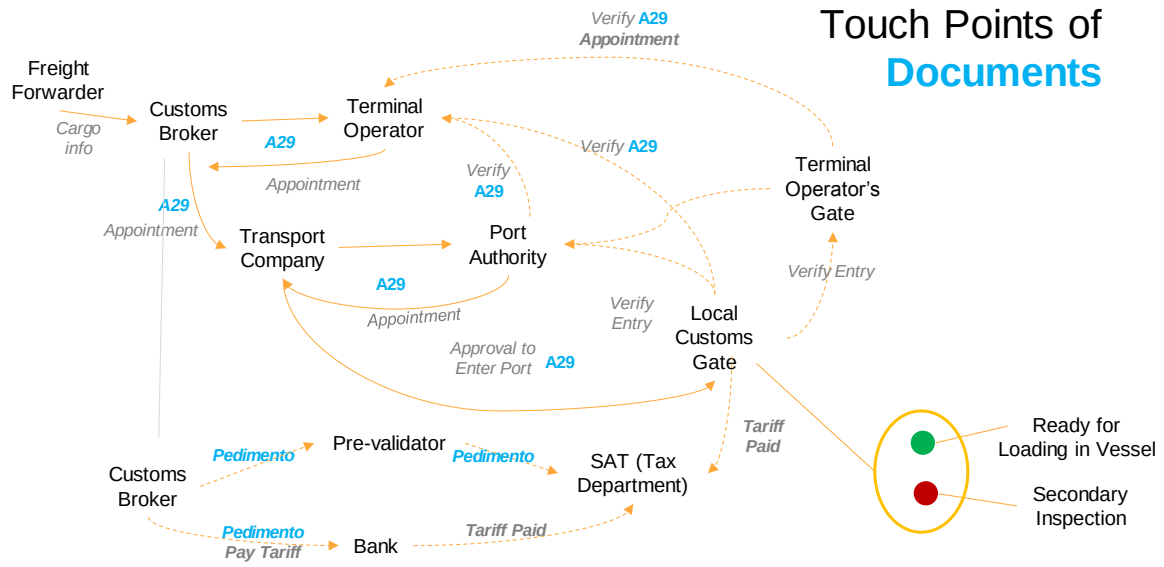


Figure 18. Container Export Process Touch Points.

Figure 19 shows the red inspection process touch points.

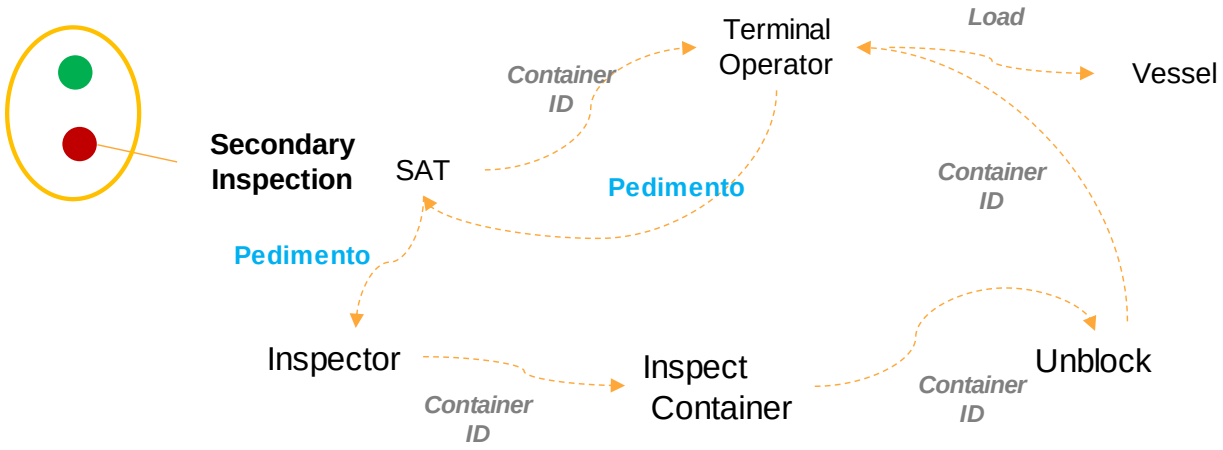


Figure 19. Container Export Process Secondary Inspection Touch Points.

Export Red Inspection Blockchain Application

A blockchain application was developed to streamline the red inspection process. This is the most relevant pain point in the container export process. The stakeholders that participate in the process include the customs broker, the terminal operator, and the local Aduanas inspectors.

The application was developed as a consortium or federated blockchain, which is a private, permissioned blockchain. The system uses Pantheon, which includes a suite of Ethereum-based services in a Google Cloud platform, and has three nodes managed by the developer.

The objective of the application is to facilitate a secure and efficient transfer of data so that all parties involved in the container secondary inspection have access to the right information in a timely and secure manner. Figure 20 depicts the application architecture.

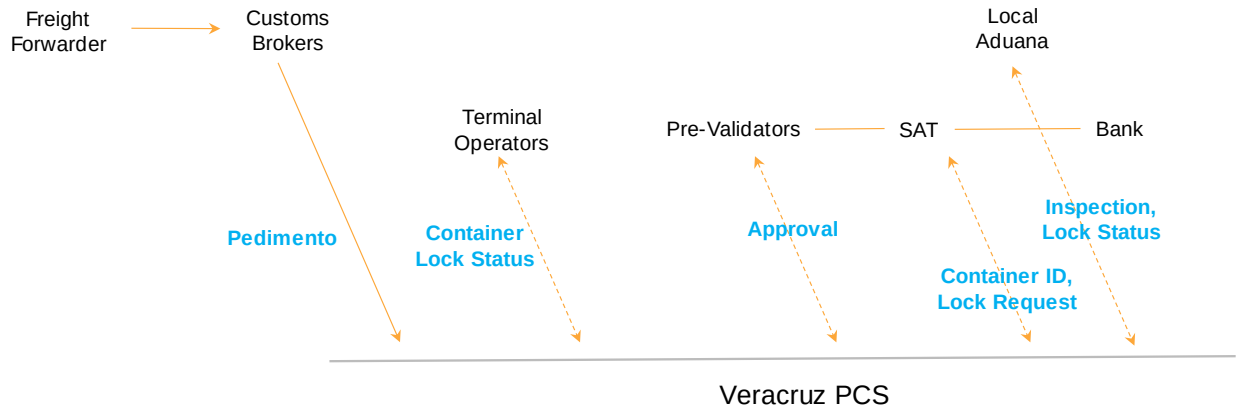


Figure 20. Container Export Process Blockchain-Based Application.

The application has been tested and includes the following main sections:

- The **dashboard** provides a general view of all the shipments in the system. The dashboard has two sections:
  - The Estado de Contenedores (Container Status) shows the status of the containers in the system with a chart.
  - The Estado de Envíos (Shipment Status) provides general information on the shipments in the system and their status in the queue, and a listing of the latest shipments that have been entered into the system (Figure 21).

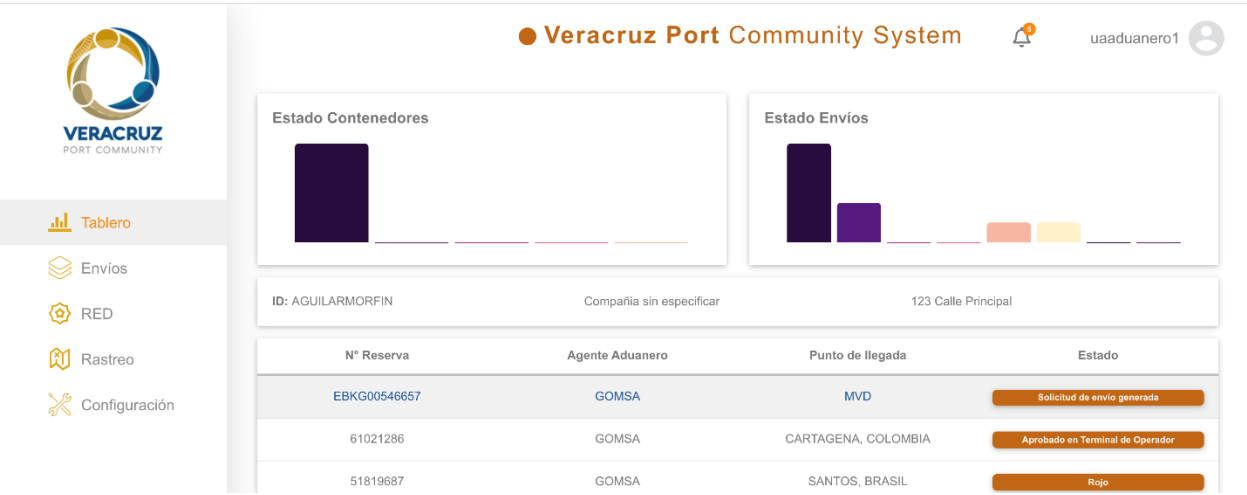


Figure 21. Veracruz PCS Dashboard Screen.

- The **shipment** screen provides a list of all shipments in the system. The list could be sorted by different keywords such as reservation number, Anexo 29, pedimento ID, and

stakeholder (Figure 22). The shipment page can also provide this information in a chart (Figure 23).

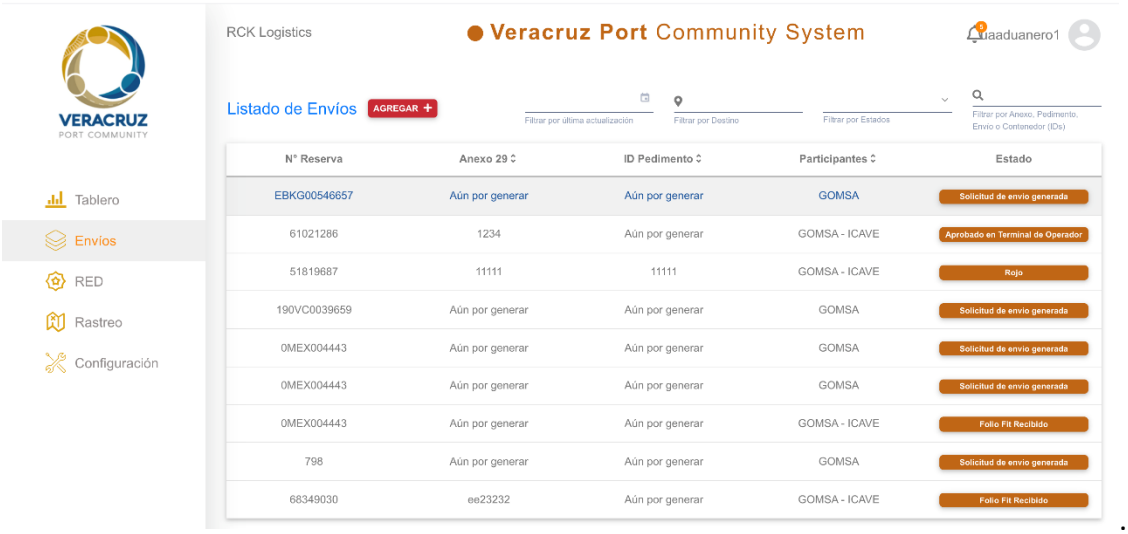


Figure 22. Veracruz PCS Shipment Screen List.

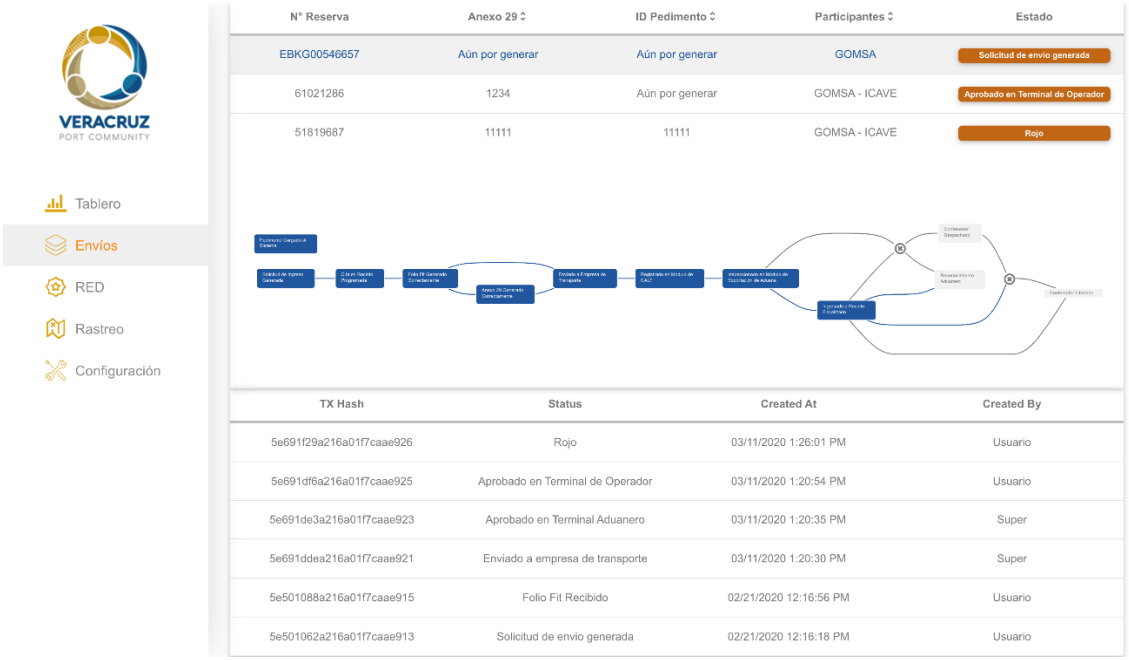


Figure 23. Veracruz PCS Shipment Screen Flow and Status.

- The **shipment details** screen provides historical information and can be accessed by any stakeholder involved in that particular shipment (Figure 24).

Figure 24. Shipment Historical Data.

- The **red** screen has the list of all containers and shipments selected for a secondary or red inspection. The user can access the detail of each movement, as shown in Figure 25.

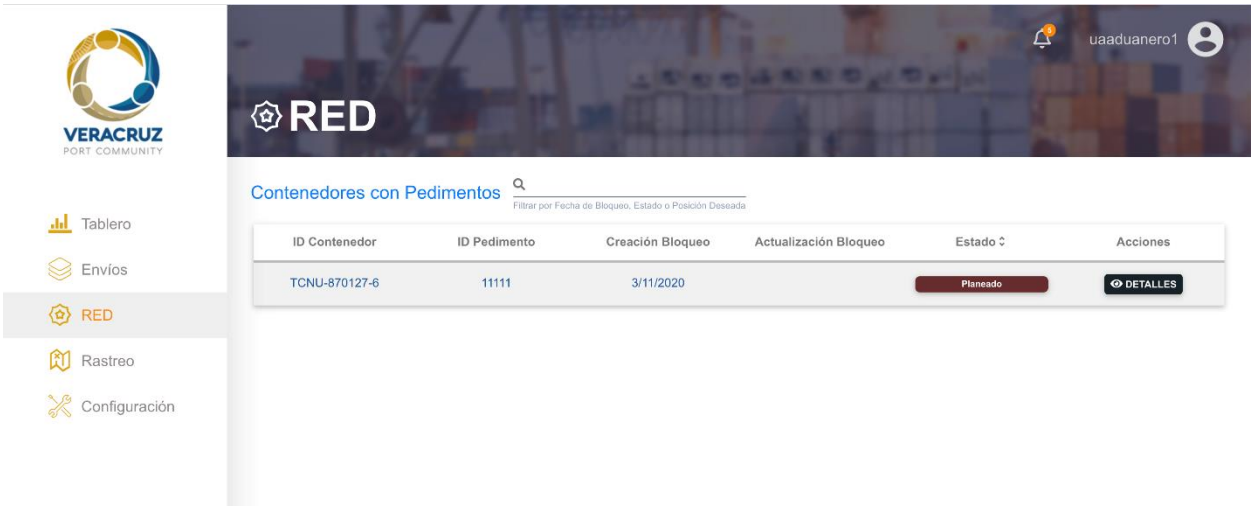


Figure 25. Veracruz PCS Red Inspection Container List Screen.

CHAPTER 5: INSIGHT INTO TRADELENS

One particular attempt to make blockchain a major part of international trade processes is being developed by Maersk and IBM: TradeLens. This software-as-a service offering has been covered extensively by the press and trade journals and appears to be the leader in this arena at this time. Several container terminals have joined the system, including Global Container Terminals, PSA International, APM Terminals, and Modem Terminals. Participating shipping lines include Maersk, CMA CGM, Mediterranean Shipping Company, Ocean Express Network, and Hapag-Lloyd—five of the six largest container lines (the sixth being COSCO). According to the *Journal of Commerce*, the system has more than 100 participants, including several beneficial cargo owners (Johnson 2019b).

In August 2018, Maersk jointly with IBM developed the TradeLens platform that applies blockchain to the global supply chain. It evolved from pilot projects that implemented the data pipeline concept (Segers 2019). The basic starting point was cargo-tracking information that is needed for multiple purposes in the operations, financial, and logistics steps of any movement of goods by sea. The partnership soon recognized the need of integration of organizations of different sizes (e.g., the various carriers) and nature (e.g., ports and official authorities involved in the cargo inspection and clearance) located in different jurisdictions. TradeLens empowers multiple trading participants and partners to securely share information and collaborate by establishing a single shared view of a transaction without compromising details, privacy, and confidentiality. Multiple parties can interact by accessing real-time shipping data and documents. These parties include liners services, warehouses, freight forwarders, ports, customs, exporters, importers, and trade finance banks (Suominen et al. 2018).

As of mid-2019, TradeLens had more than 100 organizations under its umbrella (Smith 2019). According to IBM (2020), “TradeLens is already handling more than 700 million events and 6 million documents a year, expediting decision-making and lowering the administrative frictions in trade.” The number of events captured on the platform is increasing by 1 million per day (Chang et al. 2019).

Figure 26 displays the TradeLens port and terminal network per world region.

Note: The number of partners is indicated
Source: adapted from IBM (2020)

Figure 26. Map of the TradeLens Port and Terminal Network per Region.

TradeLens is a simple but secure system that uses mathematical algorithms and high authentication. The Tradelens ecosystem goes beyond simple cargo tracking functionalities, offering some sophisticated capabilities that cover shipping instructions, the BOL, and automated notifications and alert systems that can be set up by the customer to follow up on key events and data transmission.

Some pilot trials are also under way for the electronic title-based BOL, which would result in digital BOL issuance, transfer, and surrender.

ClearWay, the trade document module of TradeLens, uses smart contracts to enable collaboration in cross-organizational business processes and information exchanges in a secure, non-disputable manner. TradeLens prevents delays caused by document errors, information delays, and other impediments. Its implementation can reduce the transit time of a shipment of packaging materials to a production line in the United States by 40 percent (Chang et al. 2019).

Because multiple container lines are involved in the system, there is concern that a violation of the U.S. Shipping Act of 1984 could occur or be perceived to occur, but dominance of any one party does not appear to be an issue (Civelek and Özalp 2018)—the lines are not allowed to engage in any form of price fixing or setting capacity among the participants. Because of these

concerns, the five container lines participating in TradeLens have filed an agreement with the Federal Maritime Commission that would allow them to exchange data related to U.S. trades within TradeLens. The agreement specifically states that members will not be allowed to discuss rates or capacity issues. The agreement went into effect on February 6, 2020 (Neuberger 2020).

Researchers interviewed top developers at Maersk and IBM for this research project. Despite Maersk and IBM being two major players in the information service industry and container shipping, researchers found the companies faced some severe challenges in the process of developing a blockchain application for the maritime shipping segment. These challenges related to data standardization and inefficiencies within the maritime supply chain, which resulted in the expansion of TradeLens from a primary shipping platform to a maritime supply chain ecosystem, as its current development shows. This finding was not a complete surprise, considering the results from a study by Carlan et al. (2019) that looked at 33 maritime cases and how blockchain could help overcome these inefficiencies. Figure 27 highlights the cases and the respective scope examined, and Figure 28 summarizes the data-related inefficiencies.

Asset management/ traceability	Documents ownership/ information transfer	Order management/ traceability	Autonomous Logistics Operations	Others
Riddle&Code	Terminals' gate pin codes	NextPakk	Swarm Logistics	Dinalog blockchain
Blockfreight	Digital B/L	Dafza	AIDA service	Kouvola / Smartlog / IBM blockchain
Slync	Phytosanitary certificate	Anonybox		Marine Transport International (MTI)
NetObjex	Global shared container platform	Ubims		Alfaliner -300cubits
TychoSolutions	Cargocoin			EY Marine Insurance
Shipchain	GateChain			Un-bloc (solas-vgm)
Skyfchain	Open trade docs			ShipNext
VeChain	WaveBL			TradeIX

Legend:

Production environment tested

Early technical solution

No technical solution

Figure 27. Blockchain Initiatives Studied by Carlan et al. (2019).

		Port and hinterland stakeholders									Authorities					Other third parties		
Data-related inefficiencies	Shipper	Freight forwarder	Customs declarant	Shipping line	Terminal operator	Hinterland transport			Goods receiver	Port Authority	Customs	Harbor master	Others (e.g. Police, Sanitary and vet.	Agent	Financial institutes	ICT providers
						Road	Rail	Inland nav.								
Information/document flow																
Information/ownership tracking (CMR, B/L, phytosanitary…)	X	X			X	X	X	X	X				X	X		X
Operation planning				X	X	X	X	X	X				X			X
Customs declaration	X	X	X	X		X	X			X	X		X	X		
ETA/ATA estimation				X	X	X		X	X		X	X				X
Financial flow																
Late shipment payment	X	X	X	X					X						X	
Late service (non-transport related) payment		X		X		X	X	X								
Cargo flow																
Cargo movement		X		X	X	X	X	X	X		X					
Shipment fragmentation (under-capacity utilization)	X	X				X	X	X	X				X			
Loading units management				X	X	X	X	X								

Figure 28. Maritime Supply Chain Inefficiencies by Carlan et al. (2019).

Barriers TradeLens has had to deal with include delays in standardization because of the rapid pace of evolution; latency due to the sheer size and volume of transactions, which could impede widespread adoption of blockchain technology; collaboration challenges because firms may not be accustomed to sharing data across their supply chain; and data interoperability—having to decide what data belong on the network and the structure, format, and meaning of the data. Participants will have to decide what data they are willing to share with others (Chichoni and Webb 2018).

The TradeLens project is now—and probably will be in the future—the main ecosystem in the maritime sector as it develops capabilities to address the complexity of multiple stakeholders of this segment. Due to the absence of other available alternatives to solve the communication problem in shipping, blockchain is likely to become an attractive and cost-effective option (Kshetri 2018). TradeLens might also represent a problem or challenge because it could turn into a monopoly of information.

CHAPTER 6: CONCLUSIONS AND KEY TAKEAWAYS

A number of conclusions and takeaways can be derived from this research. This list is not exhaustive; depending on the focus of investigation, different readers will draw different conclusions.

1. The blockchain technology is complex, and very few corporate executives understand it. As the technology is further enhanced and applications are built on it, the need for IT professionals who are knowledgeable and engender trust will grow.
2. There is more to a blockchain system than just the technology. Governance, legal issues, acceptance by users, frameworks for handling confidential information, and other such issues must be addressed. Society must determine the relative importance and appropriate tradeoffs for many system features. The lack of the necessary legal and regulatory systems is a particular concern.
3. Blockchain holds promise for the shipping industry although most inroads have taken place in the finance and trade/documentation arenas. It appears to do a good job of dealing with sensitive data and security, trade finance, insurance, and product provenance.
4. A number of proof-of-concept trials and project implementations are taking place that can provide a wealth of lessons learned if one can penetrate the secrecy and confidentiality of many of these systems.
5. As a technology, blockchain is still in the infancy stage. It will be years before it is well enough tested and tried for it be accepted on a broad scale.
6. The Port of Houston survey revealed several key takeaways:
   - Blockchain is not a driving force in the maritime industry at this time.
   - A very comprehensive and complex approach is required to be successful.
   - Many different stakeholders have pivotal roles in the system.
   - There is little understanding of potential costs and risks versus benefits.
7. The Veracruz case study illustrated how even one small piece of the international logistics chain is complex and requires a detailed understanding of the processes involved.
8. The TradeLens platform appears to be taking hold and merits attention and tracking by anyone wishing to see if blockchain will work for shipments involving ocean transport.
9. Currently, the most prominent blockchain projects in the maritime sector are initiatives by the shipping segment. However, the results presented in this research point toward the fact that ports and marine terminals have a pivotal role in the blockchain functionalities. Future research should examine the possibilities of a port-centric blockchain adaptation.

As this research project was reaching its conclusion, it was announced that six major players are working towards application programming interface specifications to facilitate data exchange for port and maritime services transactions, which indicates that data standardization is still a major challenge to be overcome in the maritime logistics sector (Chambers 2020).This initiative could have a direct influence on the development of blockchain applications for the maritime services industry.

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APPENDIX A: EXAMPLES OF BLOCKCHAIN IMPLEMENTATION

Sector	Company/ Organization	Blockchain Application	Source(s)
Supply chain management	Walmart	Walmart has incorporated blockchain technology in its live food business. The world's largest retailer uses blockchain to track, identify, and, if need be, remove food from its shelves. Walmart has pitched the project as a method to cut down removal times during food recall from weeks to a matter of seconds. One example is the project with Tsinghua University to follow the movement of pork in China.	Suominen et al. 2018 Jain 2018
Additive manufacturing	U.S. Department of the Navy and GE	The U.S. Navy and GE are on their respective fronts using blockchain to enhance the authentication and tracing of three-dimensional printed parts in supply chains.	Suominen et al. 2018
Logistics management	IBM and Maersk	Maersk and IBM's joint venture blockchain started in June 2016. Since then, the network has connected shippers, ports, customs offices, banks, and others in Maersk's global supply chains to track freight and replace redundant and time-consuming paperwork. As the program has scaled, it has earned converts including DuPont and Dow Chemical.	Suominen et al. 2018
Cross-border e-commerce	Alibaba	Alibaba's T-Mail uses blockchain-based technology for its cross-border supply chain with logistics company Cainiao. The technology allows parties to record information on exports and imports onto a blockchain that keeps track of the products' country of origin, shipping and arrival ports, shipment method, and customs information. The technology has reduced shipping costs by a fifth and has lowered time of shipping, allowing better competition with rivals.	Suominen 2018 Suominen et al. 2018
Trade finance	HSBC	In May 2018, HSBC announced it had completed "the world's first commercially viable trade-finance transaction using blockchain, opening the door to mass adoption of the technology in the $9 trillion market for trade finance." HSBC's proof of concept was a blockchain-based letter of credit for a transaction with Cargill.	Suominen et al. 2018
Customs administration	U.S. Customs and Border Protection (CBP) Korean Customs Service (KCS)	CBP formed a group that will research the agency's potential use of blockchain. Already, the group has identified 14 specific use cases, ranging from tracking licenses and permits to certificates of origin. In Korea, Malltail and KCS have signed a memorandum of understanding to launch a blockchain-based customs platform. The goal is to use blockchain to speed customs clearance times in seven Malltail distribution centers across the United States, Japan, and Germany.	Suominen et al. 2018

Sector	Company/ Organization	Blockchain Application	Source(s)
Health care data	MedRec SimplyVital Health	Conceived by the Massachusetts Institute of Technology, MedRec provides medical data management using blockchain and smart contracts. Medical researchers provide the computer power blockchain requires using a permissioned Ethereum network. Researchers are enticed to participate through access to medical data they can use in their research. SimplyVital Health uses blockchain to help health care providers streamline data and save money, as well as share customer data more securely.	Suominen et al. 2018
Insurance	Etherisic	Etherisic is building a platform for decentralized insurance application. The platform aims to allow corporations, not-for-profit groups, and insurtech startups to provide better products and service through blockchain technology.	Suominen et al. 2018
Farming	AgriLedger	AgriLedger uses an app to connect various small farmers with one another. It helps them join together in co-ops with increased transparency that no longer rely on paper-based records or verbal promises.	Suominen et al. 2018
Mobile voting and vote integrity	West Virginia	West Virginia became the first U.S. state to allow internet voting using blockchain. The project applied to a small group of voters in the state's most recent primary election.	Suominen et al. 2018
Energy management and trading	LO3 Energy	Brooklyn startup LO3 Energy champions Exergy, a permissioned blockchain platform that enables localized peer-to-peer marketplaces for trading energy across existing grid infrastructure among users.	Suominen et al. 2018
City administration	City of Dubai	Dubai wants to use blockchain by 2020 in over 100 million annual government documents, including all visa applications, bill payments, and license renewals. According to estimates, Dubai could save 25.1 million hours of work, or $1.5 billion each year, by using blockchain. Dubai created a Global Blockchain Council with the goal to implement every facet of blockchain into the city. The system will be used in trade finance to effectively exchange goods and streamline the financing for those goods. The system will be able to automate the completion and submission of the required documentation in real time through smart contracts and a permissioned version of blockchain. Required documentation such as visa applications, bill payments, and license renewals account for over 100 million documents each year. The system will save up to 114 metric tons of carbon dioxide output emissions from trip reductions and up to 25.1 million hours of economic productivity in saving document processing time. Dubai stands to unlock 5.5 billion dirham (1.5 billion USD) in savings annually in document processing alone.	Suominen et al. 2018 Chichoni and Webb 2018

Sector	Company/ Organization	Blockchain Application	Source(s)
Logistics management	DP World Australia	DP World Australia, a container port and supply chain operator, and DB Schenker (both logistic and supply chain giants) have created a consortium to use blockchain architecture developed by the Australian-based company TBSx3, a blockchain startup, to address the issue of counterfeits on a global scale while protecting global supply chains. The ultimate aim of this initiative is to help companies to restore consumer trust in supply chains.	Okazaki 2018
Trade finance	Monetary Authority of Singapore (MAS) and Hong Kong Monetary Authority	MAS and Hong Kong Monetary Authority are working to develop the Global Trade Connectivity Network (GTCN) to enable cross-border flows of digital trade data using the distributed ledger technology. It will connect the GTCN with the National Trade Platform in Singapore and the Hong Kong Trade Finance Platform, with the aim of developing an information highway between the two platforms	Okazaki 2018
Trade documentation	Bank of Tokyo-Mitsubishi and NTT Data Corporation	The Bank of Tokyo-Mitsubishi and NTT Data Corporation have initiated a proof of concept pilot to connect the National Trade Platform in Singapore with a prototype blockchain trade platform. The pilot will endeavor to provide digital solutions to technical challenges prevalent in international trade including regulatory disparities and differing documentation standards. The companies expect this to be a paperless system aiming to make cross-border flow more secure, efficient, and transparent, fostering greater trade and supply chain integration across the region. The digital ledger technology would reduce the volume of paperwork and bureaucratic interventions.	Okazaki 2018
Trade finance	We.Trade	We.Trade is a joint venture company that develops and licenses the first blockchain trade platform for commercial clients and their banks. Through distributed ledger and smart contracts, the system provides a secure innovative environment for banks' commercial clients engaged in import/export transactions to trade in a user-friendly, efficient way.	Civelek and Özalp 2018
Logistics management	PSA International, Pacific International Lines, and IBM Singapore	PSA International, Pacific International Lines, and IBM Singapore use blockchain to execute bookings of multimodal logistics and check regulatory compliance to track cargo movement.	Suominen 2018
Delivery service	Thailand Post	Thailand Post used blockchain to track high-value parcel deliveries.	Suominen 2018
Trading	Stock Exchange of Thailand	The Stock Exchange of Thailand launched a startup trading marketplace based on blockchain and already has over 600 companies registered.	Suominen 2018

Sector	Company/ Organization	Blockchain Application	Source(s)
Product provenance	BHP Billiton	BHP Billiton is tracking mineral analysis done by outside vendors, and Everledger uploaded identifying data on a million individual diamonds to build quality assurances and help jewelers comply with regulations.	Jain 2018
Logistics management/ product provenance	Merck	Merck in a partnership with SAP, AmerisourceBergen, and Cryptowerk created an advanced track and trace blockchain network that can run on a mobile app that uses barcode scanning. Through blockchain's immutability features (e.g., permission and cryptography) and consensus features (e.g., smart contracts and PBFT), Merck is able to maximize the security of all participants in the supply chain. Blockchain's smart contract functionality, along with the use of IoT devices, enables continuous drug-tracking capability for participation in the pharmaceutical supply chain.	Chichoni and Webb 2018
Airline management	British Airways	British Airways tested a blockchain flight information system to ensure data consistency to prevent displaying inconsistent information at different locations such as airline gates, monitors, and websites.	Shirani 2018
Port community system	Port of Antwerp	Antwerp, the largest seaport in Europe, is taking steps in using blockchain to create a Smart Port incorporating IoT. The port is considering mapping the full physical flow of a container, automating the document flow, connecting data silos, and automating joint business processes across the enterprise-to-enterprise (E2E) chain. The port is trying to create a blockchain platform for secure and efficient container release. T-Mining, a startup in Antwerp, has developed a blockchain solution to the port's container release operations. All necessary data for releasing a container are in a database and restricted to the involved parties. Digital rights are created, and blockchain ensures that these rights can be transferred between parties and the sender no longer owns the right once a recipient receives it. Therefore, no unauthorized entities can show up at the terminal to claim containers except the true owner, and all transactions are securely and permanently stored on the blockchain. The port and T-Mining also developed a project to automate and secure the flow of documents by means of smart contracts. The project used blockchain to transfer phytosanitary certificates to the competent authorities without duplicating documents, guaranteeing the authenticity of the document. The smart contracts automate and secure the document flow with predefined rules in real time without delay.	Chang et al. 2019
Delivery service	United Parcel Service (UPS)	UPS uses blockchain and distributed ledger technology to route packages throughout an international supply chain.	Chang et al. 2019

Sector	Company/ Organization	Blockchain Application	Source(s)
Delivery service	DHL	DHL uses blockchain to address invoice inaccuracies for one-off shipments that lie outside its typical contractual relationship—shipments that can be supported by DHL but are not part of the standard contract.	Johnson 2019a
Music distribution	IBM, American Society of Composers, Authors and Publishers (ASCAP), and PRS for Music	In 2017, IBM partnered with ASCAP and PRS for Music to adopt a blockchain-based alternative for music distribution.	Music Business Worldwide 2017
Food supply chain	Nestle SA	Nestle SA is testing blockchain to track the fruits and vegetables that go into its Gerber baby products. Nestle and nine other large food companies are on a blockchain system called Food Trust to trace ingredients worldwide.	American Association of Port Authorities 2018
Freight and payment network	Walmart and DLT Labs	Walmart claims this will be the world's largest full-production blockchain for any industrial application. The system tracks deliveries, verifies transactions, and automates payments and reconciliation among Walmart Canada and its carriers. All Walmart's third-party carriers are scheduled to be live by February 1, 2020.	Walmart 2019

APPENDIX B: INTRODUCTION TO MERKLE TREES

This introductory material comes from the website Hackernoon.com. It provides an introduction for the reader who is not conversant in cryptography. The complete explanation is available at https://hackernoon.com/merkle-trees-181cb4bc30b4.

> Merkle trees are a fundamental part of blockchain technology [see Figure B-1]. A Merkle tree is a structure that allows for efficient and secure verification of content in a large body of data. This structure helps verify the consistency and content of the data. Merkle trees are used by both Bitcoin and Ethereum.
>
> How do Merkle trees work?
>
> A Merkle tree summarizes all the transactions in a block by producing a digital fingerprint of the entire set of transactions, thereby enabling a user to verify whether or not a transaction is included in a block.
>
> Merkle trees are created by repeatedly hashing pairs of nodes until there is only one hash left (this hash is called the Root Hash, or the Merkle Root). They are constructed from the bottom up, from hashes of individual transactions (known as Transaction IDs).
>
> Each leaf node is a hash of transactional data, and each non-leaf node is a hash of its previous hashes. Merkle trees are binary and therefore require an even number of leaf nodes. If the number of transactions is odd, the last hash will be duplicated once to create an even number of leaf nodes.

Figure B-1 illustrates how the tree is structured.

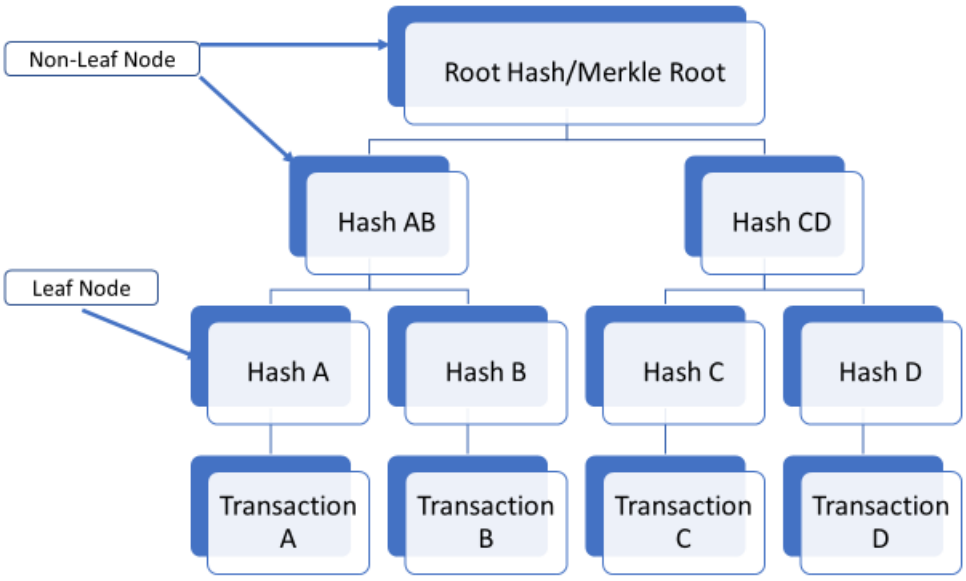

Figure B-1. Merkle Tree of Transactions A, B, C, and D.

The website continues:

> The Merkle Root summarizes all of the data in the related transactions and is stored in the block header. It maintains the integrity of the data. If a single detail in any of the transactions or the order of the transactions changes, so does the Merkle Root. Using a Merkle tree allows for a quick and simple test of whether a specific transaction is included in the set or not.

APPENDIX C: EMAIL AND QUESTIONNAIRE SENT TO INDUSTRY MEMBERS

Dear Sir/Madam,

We are researchers from Texas A&M University at Galveston (TAMUG) and Texas A&M Transportation Institute (TTI) who were recently awarded a research grant to investigate the impact and application of blockchain to the maritime industry. Our research will focus on companies in and around the Port of Houston.

This survey is ***voluntary, and all responses are confidential*** and will serve solely to inform the academic research. We will provide a report summarizing the results at your request.

Benefits to you: This research should provide companies with information on the management practices that could improve your company's decision-making and competitiveness. The knowledge gained will be freely shared with you in final tabulated form and a project report. We will not reveal the source of any individual response to any outside party.

Why you? You are a manager in a company operating in the greater Port of Houston area.

The survey will take approximately 15 minutes to complete, and we ask you to read the consent form below. We know you are busy, and we appreciate your help with this voluntary survey. If you would like to participate, please read the detailed consent form below and click the arrow below to complete the survey: **(link was included here)**

Please do not hesitate to contact us with any questions. We highly appreciate your participation and request your feedback by **(deadline was included here).**

Sincerely,
Joan Mileski, Principal Investigator at TAMUG (mileskij@tamug.edu)
Jim Kruse, Principal Investigator at TTI (j-kruse@tti.tamu.edu)

CONSENT FORM TO RESPONDENTS

Analysis of Blockchain's Impacts on and Applicability to Maritime Industry

Introduction

The purpose of this form is to provide you information that may affect your decision as to whether or not to participate in this research study. If you decide to participate in this study, this form will also be used to record your consent.

You have been asked to participate in a research project studying the application of blockchain to maritime supply chains and logistics, in particular the possible integration with existing technologies, such as automatic identification systems (AISs).
The purpose of this study is to identify the main characteristics of blockchain applications in general, the benefits applicable to the maritime sector, and the main business drivers for the adoption of blockchain, including a critical analysis of challenges faced by the maritime sector that is different from other service industries fully considering existing technologies, such as AIS.

You were selected to be a possible participant because your company does business in the Port of Houston. This study is being sponsored/funded by the Maritime Transportation Research and Education Center.

What will I be asked to do?

If you agree to participate in this study, you will be asked to answer the question posed above. This study will take you about 15 minutes to answer.

What are the risks involved in this study?

The risks associated with this study are minimal and are not greater than risks ordinarily encountered in daily life.

What are the possible benefits of this study?

You will receive no direct benefit from participating in this study; however, you may receive the aggregate results of the study.

Do I have to participate?

No. Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University at Galveston or the Texas A&M Transportation Institute being affected.

Who will know about my participation in this research study?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely, and only the principal investigators will have access to the records.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact Dr. Joan P Mileski, 409-740-4978, mileskij@tamu.edu.

Whom do I contact about my rights as a research participant?

This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at 979-458-4067 or irb@tamu.edu.

Please be sure you have read the above information, asked questions, and received answers to your satisfaction. You will be given a copy of the consent form for your records. By signing this document, you consent to participate in this study.

===Questions to be shown on the electronic form (one on each page)===

Questions for ports/shipping companies on blockchain (items marked with a star and in red are required).

*Your name:

*Your email address:

*Your organization

*Your job title:

Please consider the following definition to answer the questions: Blockchain is defined as a *"shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network."*

*1. Is your firm in the process of implementing a blockchain-related initiative? If so, please describe the main challenges and proceed to question 3.

2. Has anyone (shipping companies or terminal companies) approached you to participate in a blockchain-related project or initiative? If so, please describe the potential blockchain project or initiative.

2a. Have they discussed how this project/initiative idea would fit into your organization's business model and strategy? If so, please describe how.

2b. Did they discuss any shortcomings? If so, please describe the identified shortcomings.

3. How might blockchain require adaptations to your business processes?

4. How would blockchain add value to your business processes?

5. How does or would blockchain fit into your organization's business model and strategy?

6. Do you see your company adopting or implementing any type of blockchain systems in the next 2 to 5 years? (Please tick the box that corresponds to your current situation.)

- Very improbable
- Improbable
- Probable
- Very probable
- We are already using it

*7. In your role in your organization, how valuable do you think blockchain features would be to your organization? (Please tick the box that corresponds to your current situation.)

- Must-have
- High value
- Medium value
- Low value
- No value
- Unsure/not applicable