ΠΑΝΕΠΙΣΤΗΜΙΟ ΔΥΤΙΚΗΣ ΑΤΤΙΚΗΣ
Τμήμα Μηχανικών Βιομηχανικής Σχεδίασης και Παραγωγής

&

ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΙΓΑΙΟΥ
Τμήμα Ναυτιλίας και Επιχειρηματικών Υπηρεσιών

ΔΙΙΔΡΥΜΑΤΙΚΟ
ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ
«ΝΕΕΣ ΤΕΧΝΟΛΟΓΙΕΣ ΣΤΗ ΝΑΥΤΙΛΙΑ ΚΑΙ ΤΙΣ ΜΕΤΑΦΟΡΕΣ»

ΤΙΤΛΟΣ

Προκλήσεις της τεχνολογίας Blockchain στη ναυτιλιακή βιομηχανία: Διερεύνηση των κύριων παραγόντων και της πρόθεσης για την υιοθέτησή της από την Ελληνική ναυτιλιακή βιομηχανία.

ΤΙΤΛΟΣ ΑΓΓΛΙΚΑ

Blockchain challenges in Maritime Industry:

An empirical investigation of the willingness and the main drivers of adoption from the Hellenic Shipping industry.

Ονοματεπώνυμο Σπουδαστή:

Γεώργιος Π. Καπνίσης

Ονοματεπώνυμο Υπεύθυνων Καθηγητών:

Ελένη - Αικατερίνη Λελίγκου

Γεώργιος Βαγγέλας

ΔΙΑΤΡΙΒΗ

ΜΑΙΟΣ 2020

ΤΙΤΛΟΣ

Προκλήσεις της τεχνολογίας Blockchain στη ναυτιλιακή βιομηχανία:

Διερεύνηση των κύριων παραγόντων και της πρόθεσης για

την υιοθέτησή της από την Ελληνική ναυτιλιακή βιομηχανία.

ΟΝΟΜΑ ΦΟΙΤΗΤΗ

Γεώργιος Π. Καπνίσης

Μεταπτυχιακή Διατριβή που υποβάλλεται στο καθηγητικό σώμα για την μερική εκπλήρωση των υποχρεώσεων απόκτησης του μεταπτυχιακού τίτλου του Διϊδρυματικού Προγράμματος Μεταπτυχιακών Σπουδών «Νέες Τεχνολογίες στη Ναυτιλία και τις Μεταφορές» του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών του Πανεπιστημίου Αιγαίου και του Τμήματος Μηχανικών Βιομηχανικής Σχεδίασης και Παραγωγής του Πανεπιστημίου Δυτικής Αττικής.

Δήλωση συγγραφέα διπλωματικής διατριβής

Ο κάτωθι υπογεγραμμένος Γεώργιος Καπνίσης, του Παναγιώτη, με αριθμό μητρώου 8056107 φοιτητής του Διιδρυματικού Προγράμματος Μεταπτυχιακών Σπουδών «Νέες Τεχνολογίες στη Ναυτιλία και τις Μεταφορές» του Τμήματος Ναυτιλίας και Επιχειρηματικών Υπηρεσιών του Πανεπιστημίου Αιγαίου και του Τμήματος Μηχανικών Βιομηχανικής Σχεδίασης και Παραγωγής του Πανεπιστημίου Δυτικής Αττικής, δηλώνω ότι: *«Είμαι συγγραφέας αυτής της μεταπτυχιακής διπλωματικής διατριβής και ότι κάθε βοήθεια την οποία είχα για την προετοιμασία της είναι πλήρως αναγνωρισμένη και αναφέρεται στην διατριβή. Επίσης έχω αναφέρει τις όποιες πηγές από τις οποίες έκανα χρήση δεδομένων, ιδεών ή λέξεων, είτε αυτές αναφέρονται ακριβώς είτε παραφρασμένες. Επίσης βεβαιώνω ότι αυτή η διατριβή προετοιμάστηκε από εμένα προσωπικά ειδικά για τη συγκεκριμένη μεταπτυχιακή διπλωματική διατριβή».*

Ο δηλών	Ημερομηνία
Γεώργιος Π. Καπνίσης	24-05-2020

Στην οικογένειά μου, για το χρόνο που τους στέρησα και που τους στερήθηκα.

Ευχαριστίες

«.....Η Ιθάκη σ' έδωσε τ' ωραίο ταξίδι. Χωρίς αυτήν δεν θα 'βγαινες στον δρόμο. Άλλα δεν έχει να σε δώσει πια.

Κι αν πτωχική την βρεις, η Ιθάκη δεν σε γέλασε. Έτσι σοφός που έγινες, με τόση πείρα, ήδη θα το κατάλαβες οι Ιθάκες τι σημαίνουν.»

Κωνσταντίνος Π. Καβάφης (1863 – 1933)

Με την ολοκλήρωση της μεταπτυχιακής μου εργασίας, θα ήθελα να εκφράσω τις θερμές μου ευχαριστίες για τη στήριξη, την άψογη συνεργασία, την επιστημονική καθοδήγηση και τη πολύτιμη συνεισφορά, στους Επιβλέποντες καθηγητές μου κ. Ελένη Αικατερίνη Λελίγκου και κ. Γεώργιο Βαγγέλα.

Ιδιαίτερες ευχαριστίες οφείλω στην κ. Μαρία Ντουμή, για την υποστήριξή της, καθότι η συμβολή της ήταν καθοριστικής σημασίας για την ολοκλήρωση του έργου μου.

Επίσης, ευχαριστίες οφείλω σε όλους φίλους και συναδέλφους που πολλές φορές κάλυψαν δικές μου υποχρεώσεις και έτσι συνέβαλαν με τον τρόπο τους στην ολοκλήρωση των σπουδών μου.

Τέλος, ένα μεγάλο ευχαριστώ οφείλω στην οικογένειά μου για τις θυσίες που έκαναν, τη συμπαράσταση, την υπομονή, την ανοχή και την κατανόηση που υπέδειξαν και το χρόνο που τους στέρησα και στους οποίους αφιερώνω αυτή τη μεταπτυχιακή εργασία.

Γεώργιος Π. Καπνίσης

Αθήνα, 2020

Sub Igne Immotus

Περίληψη

Στη ναυτιλιακή βιομηχανία, παρά τις διάφορες προσπάθειες εκσυγχρονισμού που έχουν γίνει τα τελευταία χρόνια, ένα σημαντικό μέρος των εγγράφων εξακολουθεί να διακινείται με την παραδοσιακή έντυπη μορφή, κυρίως λόγω ανησυχιών που υπάρχουν στο θέμα της ασφάλειας. Η τεχνολογία Blockchain έρχεται να αποτελέσει τον συνδετικό ιστό μεταξύ της υπάρχουσας και της μελλοντικής κατάστασης, προσθέτοντας βασικά χαρακτηριστικά, όπως η εμπιστοσύνη, η διαφάνεια, η ασφάλεια και η μείωση του κόστους. Ωστόσο, ενώ έχουν πραγματοποιηθεί πολλές μελέτες σχετικά με τη νέα αυτή τεχνολογία τα τελευταία χρόνια, στη βιβλιογραφία δεν υπάρχει μια ολοκληρωμένη έρευνα σχετικά με τη σχέση της ναυτιλιακής βιομηχανίας και του blockchain. Αυτή η διατριβή, στοχεύει να γεφυρώσει αυτό το κενό, εστιάζοντας σε τρείς κυρίως βασικούς άξονες. Πρώτον, θα παρουσιάσει την τεχνολογία με απλό και κατανοητό τρόπο και θα προσδιορίσει τις διαδικασίες της ναυτιλιακής βιομηχανίας που μπορούν να επωφεληθούν από το blockchain. Στη συνέχεια, θα παρουσιάσει τις πιο σημαντικές περιπτώσεις χρήσης blockchain που χρησιμοποιούνται σήμερα και θα αναλύσει τα χαρακτηριστικά τους. Τέλος, θα μετρηθεί την πιθανότητα υιοθέτησης του blockchain από την Ελληνική ναυτιλιακή βιομηχανία.

Για τους σκοπούς της έρευνας, κατασκευάστηκε ένα ελαφρώς τροποποιημένο μοντέλο της κλασικής ενοποιημένης θεωρίας αποδοχής και χρήσης της τεχνολογίας (UTAUT). Το μοντέλο, εκτιμήθηκε χρησιμοποιώντας τη μέθοδο της γραμμικής παλινδρόμησης και τα αποτελέσματα που προέκυψαν μας δείχνουν την πρόθεση υιοθέτησης της τεχνολογίας blockchain από την Ελληνική ναυτιλιακή βιομηχανία, καθώς και το επίπεδο εξοικείωσης των φορέων της Ελληνικής ναυτιλιακής βιομηχανίας με το blockchain. Τα παραπάνω ερευνητικά αποτελέσματα και πληροφορίες μπορούν να γίνουν ένα σημαντικά ισχυρό εργαλείο που μπορεί να χρησιμοποιηθεί για τον στρατηγικό σχεδιασμό και τη χάραξη του μελλοντικό οράματος της ελληνικής ναυτιλιακής βιομηχανίας.

Λέξεις κλειδιά: Blockchain, DLT, ναυτιλιακή βιομηχανία, UTAUT.

Abstract

Shipping is one of the most traditional industries in the world and despite the various efforts that have been made to modernized it in the recent years, significant part of the documents exchanged still have the traditional paper form, mainly due to security concerns. Blockchain technology will act as the connective tissue between the existing and the future status, by adding to this transition essential features such as trust, transparency, security and cost reduction. However, while many studies on this new technology have been conducted in recent years, the literature on the relationship between maritime industry and blockchain does not report an integrated research case. This thesis, therefore, aims to bridge this gap, mainly focusing on three main axes. Firstly, the technology will be presented in a simple and understandable way and the processes of the maritime industry that can benefit from the blockchain will be identified. Subsequently, the most important use cases of blockchain platforms that are used today we will be illustrated and their characteristics will be analyzed. Finally, the likelihood of adoption of the blockchain from the Hellenic shipping industry will be measured.

For the purpose of the thesis, a slightly modified model of the classic Unified Theory of Acceptance and Use of Technology (UTAUT) was constructed. The model, which was developed was then estimated using the Linear Regression Analysis method, and the results that emerged show us the intention of the blockchain technology adoption by the Hellenic shipping industry, as well as the familiarization level of the Hellenic shipping stakeholders with the blockchain.

The above research results and information can become a significantly powerful tool to be used for the strategic planning and future vision of the Hellenic shipping industry.

Key-words: Blockchain, DLT, Maritime industry, UTAUT.

Table of contents

Table List

Figure List

1.0 Introduction

At the time of interconnection, the need to adapt to changes, created in the external environment by new technologies, is becoming increasingly important for the survival of business sector. It needs to be transformed from the traditional form into automated businesses absorbing new data. Human resources play a key role in this new digital business form and employees can have a huge impact on the ecosystem of business so as to have a competitive advantage in the market. The way in which employees and the industry are adapted, lies in the concept of dynamic capabilities, which was first mentioned by David J. Teece (1997) and applied by Eisenhardt on technological changes in 2000. The concept of absorbing capacity is important for the full adaptation of the industry to new technologies. Technologies such as Blockchain with a variety of applications (Cryptocurrencies, Stable coins, IoT applications, Decentralized Autonomous Organizations) came into our society in order to change the daily routine and the traditional form of business processes.

All of the above technologies will have a use in an industry that will change dramatically in the following 10 years and this is the Maritime Industry. The Maritime Industry is the most traditional form of business industry, governed by rules of trust, procedures, and communication that follows a traditional operational way (e.g. email has become the main communication tool over the last 5 years). Something similar to maritime tradition form applies to the public sector and organizations that retain a traditional form of procedures. The difference between these sectors is that the Maritime Industry wants to make a fully autonomous operation system (i.e. vessels that will be unmanned with tons of freight sailing on the oceans).

The shipping industry is the most important transport industry by transferring more than 90% of goods in global transport and the Hellenic seagoing maritime industry carries almost the 20% of the worldwide cargo transported, while it owns 8,7% of the world fleet and 17,8% of the Dead-weight tonnage (UNCTAD, 2019), being a lead country based industry on the global maritime map. Therefore, the adaptation of the

Greeks to new technologies is what is needed in order for their application to be enforced within the business activities of the companies.

Already corporate giants such as IBM and MAERSK, apply Blockchain Technology with the introduction of TRADELENS but corresponds to a broader supply chain process and not purely shipping activity (Charter parties, Bill of lading).

When implementing technology, it is important not to forget the need for governmental participation with the IMO to be an important organization overseeing the processes and could exist in any internal channel transaction or the wider network that giving a valid legal form of transactions.

1.1 Problem Formulation and Research Questions

In the maritime shipping industry, inter-enterprise information sharing systems are outdated and manual processes are still used in many cases. This results in a lack of coordination among industry actors, poses security risks, low speed of transactions, high cost and an increased workload for authorities, reduces trust between parties doing business in the industry, and ultimately reduces the overall efficiency of the business processes (Jensen, 2014).

The invention of blockchain in 2008 and the understanding of the characteristics of this new technology has motivated IT enterprises to create Blockchain-based applications that promise to address these issues in various ways. The existing literature on blockchain has reported various benefits of this technology that can directly have an impact on the Maritime Industry. By enabling real-time updates and faster processing time of documents, using a fast, secure, and low-cost way, they allow to automate tasks that are currently performed manually. Consequently, they improve documents' accuracy, reduce mistakes and ultimately improve the overall business process efficiency (World Bank, 2002; Opensea, 2017).

The information stored on a blockchain-based application would be visible to all interested parties and allowed market participants, hence enabling trust among them. Furthermore, its inherent immutability and use of powerful encryption technology offers high security from fraudulent activities, such as document manipulations.

Finally, it reduces the presence of intermediaries allowing market participants to develop direct channels of communication, lowering costs and barriers to global trade (Opensea, 2017).

While it is obvious that the majority of maritime industry actors will agree on the aforementioned benefits provided by future blockchain applications, not many are able to envision a future of the industry with blockchain and provide an assessment of how likely its adoption may be (Rodriguez, 2015). Hence, once the benefits related to the introduction of an innovation such as blockchain have been understood by the future users, two needs arise for the shipping industry actors in order to welcome the new blockchain solutions and applications within their business.

First of all, to identify the possible key shipping areas and sectors (such as Chartering, Brokering, Port Clearance, Bill of Lading, training and Class certificates and so on) in which blockchain and DLTs (Distributed Ledger Technology) in general, can transform and remodel them dramatically.

Secondly, to understand and measure how likely it will be for the blockchain technology to be adopted by the shipping industry.

In order for this thesis to address these concerns, the following research questions have been developed:

RQ1: What key shipping processes can benefit by blockchain-based platforms, and which applications are more suitable?

RQ2: How likely is for the blockchain technology to be adopted by the Hellenic shipping industry actors, and what are the main drivers of adoption?

In order to provide an answer for these questions an academic and a practical approach is applied. To answer the RQ1, this study draws on the recent literature on DLTs and maritime procedures, whereas for the RQ2 a theoretical framework (UTAUT) is adopted, as the primary objective of this thesis is related to the blockchain adoption, which presents the determinants affecting the likelihood of technology adoption models (Yi, Jackson, Park, & Probst, 2006).

1.2 Research Purpose and Objectives

The purpose of this thesis is to investigate how and if Blockchain applications are able to replace existing shipping industry processes (for instance, Bill Of Lading, maritime insurance, distribution and document flow), to identify them, to illustrate the advantages and disadvantages of the new technology and mainly to investigate whether the Hellenic shipping industry intends to adopt them and accept their use, in replacement of the current procedures.

In addition, it aims to introduce blockchain technology to the shipping industry in an easy, simple and clear way, as well as, to some extent, to the existing platforms that offer solutions to replace the shipping processes of present days.

Finally, the results of the measurement of the willingness to adopt and use the blockchain will aid shipping and IT companies to use these data for their future strategic planning.

1.3 Research Scope

The maritime industry is very broad, containing a wide set of sub-industries and activities. Therefore, the investigation will focus on specific sectors. These are the merchant shipping companies, port segments and shipping agents. There are two main reasons for this choice. First of all, these segments are the most influential in maritime industry. The merchant shipping segment provides the highest share of total turnover, shipping agents are the common link between the ocean carriers and the freight forwarders, while ports are fundamental hubs for commercial operations (Stopford, 2009). Secondly, as presented in Chapter 4, most of the blockchain and DLT applications and solutions are currently being developed and designed for use within these three segments. Ultimately, from now on, whenever the common term “shipping industry” is referred in this thesis, it will refer to these specific sub-industries.

1.4 Research Design

The research design is divided into three Stages. The first stage of this thesis (Stage One) is a detailed literature review so as to gauge the properties and the characteristics of the Blockchain technology, and analyze the maritime sectors and processes in where this technology can be used.

The next stage (Stage Two), is going to present use cases and solutions that are already applied in the maritime industry.

On Stage Three, the willingness of the Hellenic shipping industry to adopt blockchain will be measured using an online questionnaire sent out to Hellenic shipping companies, selected major Hellenic ports and ship agency companies located in Hellas. This design was chosen because an online survey allows data to be collected easily and at once. The survey ran from March to May 2020.

For the online questionnaire, a model has been developed based on a slightly-altered version of the classic unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003). This model was chosen because it is widely recognized as an established tool for determining the acceptance and use of innovative technologies. Consequently, the model was estimated using the Linear Regression Analysis method.

1.5 Structure of the Thesis

This thesis is organized in Six Chapters. Chapters Two and Three correspond to Stage One. Specifically, these Chapters present the blockchain and the processes/sectors of the maritime industry which can benefit from this technology, respectively. Afterwards, Stage Two, which includes Chapter Four, presents the use cases and solutions that are already applied in the maritime industry. In the sequel, the Fifth Chapter corresponds to the Third Stage of this thesis. This chapter describes the survey conducted in order to identify the willingness of the Hellenic shipping industry to adopt blockchain and presents its results. Finally, the Sixth Chapter summarizes the conclusions which emerged from the entire thesis.

STAGE ONE

2.0 Study Context and Technology

This chapter provides the reader with background knowledge regarding the activities of the shipping industry in which the Blockchain can be used and the Blockchain technology, as well as the DLTs in general, whose adoption will be investigated. More specifically, the following sections will allow the reader to familiarize themselves with the recurring concepts and terminology throughout the thesis.

2.1 The Role of Ledgers

Ledgers are used to record economic activities and prove the ownership and the transfer of the value of assets among various stakeholders such as consumers, suppliers, producers and market makers. The assets recorded in a ledger can be:

Tangible i.e. motor vehicles, houses or, intangible i.e. money, stock certificates, digital rights.

2.1.1 Centralized Ledgers

We are surrounded by centralized ledgers. Some of them can be found in our bank account transactions, our credit card transactions, the list of title deed holders at the land registry office, the records relating to your citizenship, such as your national ID number. These centralized ledgers (with trusted third-parties) are taken for granted, because, never before have we had a practical alternative.

Trusted third parties are in charge of all ledgers of importance in modern society, whether it is a bank which "stores" your accounts, or the land registry office. However, they are not perfect, because trusted third parties are not always trustworthy, act as gatekeepers and represent a Single Point of Failure. Also, they might exclude parties that they disapprove, or might lose important transaction records, even if they are well-intentioned, due to carelessness, natural disasters and so on.

2.1.2 Decentralized Ledgers

A decentralized ledger, is a ledger that offers a way for parties who do not know or trust each other to have peer to peer payments without a trusted intermediary and it is

- Invulnerable to censorship and exclusion
- Invulnerable to malfeasance by record-keepers
- Immune to loss of records

2.2 The Blockchain Technology

Blockchain became one of the most revolutionary technology of the 21st century. It is followed by titles such as 'THE NEW INTERNET', 'INDURSTRIAL REVOLUTION 4.0', 'BLOCKCHAIN TRANFORMING BUSINESS' and major papers illustrate the value of blockchain in our modern interconnection times.

As soon as Digital Cash came in existence around 1983 by Chaum, to handle double sending problems and based on cryptography which was used at the time, failed to deliver an established centralized transaction currency system. After, some decades a person or a group of persons by the name Shatoshi Nakamoto (2008) published through email sending a revolutionary Decentralized Currency system, which was a peer-to-peer electronic cash system that allowed two parties to perform payments directly, excluding the need for a trusted third party or intermediary, in financial transactions (K. Czachorowski et al. 2019). He created 'Bitcoin' which is essentially a chain connecting several digital signatures and verified by a timestamp server. "Nakamoto developed a cryptocurrency to enhance trust among peers and to allow direct transactions, overcoming the need for intermediaries in financial transactions, thus reducing costs. He created a digital foundation, a technology to allow such transactions, which is now known as blockchain." (K. Czachorowski et al. 2019, p 563)

Although blockchain was firstly created together with Bitcoin, the technology evolved to apply to several uses and businesses and the concept should not be confused with the concept of Bitcoin

According to IBM, blockchain is:

> *…a shared, distributed ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible — a house, a car, cash, land — or intangible like intellectual property, such as patents, copyrights, or branding. It can also be used to help companies manage the flow of goods and related payments, or enable manufacturers to share production logs with original equipment manufacturers (OEMs) and regulators to reduce product recalls. Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved.*

Finally, Bitcoin and blockchain solved the issue of double sending that Chaum stated. We can read about Blockchain and the power of this technology changing the way used to transact or exchange anything and we can already see its impact on Fintech Industry.

The principles of Blockchain are:

- Decentralization: Blockchain is a Peer to Peer network where no one from the participants (users) controls the transactions. Power has been distributed among the network participants. No one holds the network, hacks or manipulates the chain of blocks. This distributed (decentralized) mechanism is free from any hacks or frauds.
- Integrity: The trust in the system is not forced but is totally guided by user intuition. According to Tapscott "For the first time, we have a platform that ensures trust in transactions and recorded information no matter how the other party acts"
- Cryptography: blockchain has been designed to provide high level of security and authenticity to the user. To ensure this principal, it uses the power of cryptography. The blockchain transaction mechanism is favorable and rewarding for an authentic user. At the same time, it is very harsh on the user that has a reckless attitude. So, this means that the blockchain system is fair to

all of those who behave well and harsh with the ones that want to use it in bad faith.

- Security: There is no central point of failure and also no single person can behave as the coordinator. PKI (Public Key Infrastructure) encryption mechanism makes your transaction over the network highly secured.
- Inclusive: Everybody can enroll to public network no matter which their status is, making the network fully acceptable to anyone. Also, it does not require a transaction fee to a third party.
- Privacy: With its core strong, Hash Key encryption is quite secure and helps keep your privacy to make transactions. Blockchain's Smart Contract is a perfect way to execute agreements between two parties securing your rights without revealing your identity.

2.2.1 Blockchain Types

Before we go through types of blockchain, it is important to understand how blockchain works. For instance: You are a "node" and you have a file with transactions on your computer "ledger". Two governance accounts "miners" have the same file "Distributed". As you make a transaction, your computer sends an email to each account and informs them. Each account tries to check whether you are trustworthy. The first to confirm, replies to all nodes and attaches a block with his logic of verification of the transaction, which is called "PROOF OF WORK". If the other accounts agree, then everyone updates their file. This example came from Richard Bradley.

There are three types of blockchains. The Public blockchain (like crypto coins Bitcoin, Ethereum, Litecoin, etc.), Federated or Consortium blockchain (like R3, B3I, EWF) and the Private Blockchain (Hyperledger Fabric of Linux Foundation is a perfect example). The first one is public and anonymous with open source computing code, it is permissionless, meaning that there is no requirement for software or permission, allowing anyone to participate by adding or verifying data, thus, it is completely decentralized. This public chain uses a Proof-of-Work or Proof-of-Stake consensus system to validate and maintain the nodes. The other two types are also decentralized within their users, or in other words, centralized to the permitted users. Their consensus system is similar to the one developed by Nakamoto (2008), but they differ in accessibility. Table 1 shows their differences and particularities. On the other hand, in a private blockchain, the validity of records cannot be independently verified as the integrity of a private network relies on the credibility of the authorized nodes.

Now that we understood the concept, we can see below the types of blockchain Technology.

Table 1 Types of Blockchain and their Characteristics

	Public Blockchain	**Private Blockchain**	**Federated/Consortium Blockchain**
Access	Anyone	Single Organization	Multiple Selected Organizations
Participants	• Permission less • Anonymous	• Permissioned • Known IDs	• Permissioned • Known IDs
Security	• Consensus mechanism • Proof of Work (PoW) • Proof of Stake	• Pre-approved Participants • Multi-party consensus	• Pre-approved Participants • Multi-party Consensus
Transaction Speed	• Slow	• Faster • Lighter	• Faster • Lighter

Known Networks for those types of blockchain are:

- Bitcoin (BTC) and Ethereum (ETH) (Public)
- Hyperledger Fabric (Private)
- LIBRA (Consortium Blockchain)

2.2.2 Distributed Ledger Technology Types

There is a misunderstanding about Blockchain and Distributed Ledger Technology (DLT). First of all, Blockchain is a subcategory of DLT. Their main difference lies in that the blockchain requires a sequence of blocks that DLT does not. Distributed ledger technology does not need PoW (proof of work) and has better scaling options. DLT, does not necessarily need to have a data structure in blocks. All blockchains are DLT's but not all DLT's are Blockchain's. To gain a better understanding of the concept of DLT's, let us examine the below DLT's types:

2.2.2.1 Hashgraph

The Hashgraph technology is the invention of Leemon Baird, the co-founder and the CTO of Swirlds, and has been available for public use since August 2018. Hashgraph and Blockchain serve a similar purpose which is a peer-to-peer transparent system that does not require a trusted third-party. Their major difference lies in how Hashgraph's consensus mechanism is accomplished. In Hashgraph the consensus is achieved "via Virtual Voting & Gossip techniques, which bring higher scalability & lower storage requirements. Unlike Blockchain, multiple transactions can be stored in a parallel stack in the Hashgraph ledger within a single timestamp called an 'Event'. " (Faisal Khan, n.d.).

While in Blockchain the "miners" have the authority to choose which transaction to verify and when to do it, in Hashgraph, verifications of the transactions are accomplished on a first can first served bases, and in this way, it reduces the transaction time significantly. Once a "transaction" is initiated, every node on the network chooses randomly a neighboring node with the aid of a gossip protocol, in order to transmit the information to other nodes. After a few minutes, the information is spread across the network, and everybody knows about the transaction. Finally, every node validates the transaction through virtual voting before adding it to the ledger. Since the transaction validation is achieved solely through consensus and there is no need for "Proof of work" for the validation process, Hashgraph becomes much less computation-intensive. Once all the nodes know about the transaction and can make the changes, then they can discard the transaction. This basically means that the nodes do not have to keep the transaction record indefinitely on the Hashgraph ledger lessening the storage requirements as well (Faisal Khan, n.d.).

2.2.2.2 Directed Acyclic Graph (DAG)

Directed Acyclic Graph or (DAG) is a highly scalable DLT, which uses a different data structure for the consensus mechanism. The greatest advantage of the DAG-DLT is the ability to offer free of charge Nano-transactions. Also, it claims that the more the transactions that take place on the network, the faster it becomes. The nodes on the DAG have a dual function. They validate a transaction and they represent a validated transaction as well. When a node initiates a transaction, it has to be verified by two previous transactions on the ledger. The selection is decided randomly by a strong algorithm. The sequence of transactions is called a branch. The longer a branch of a validated transaction by a person, the more trustworthy is considered, and in this way, it becomes more stable and difficult to alter or hacked. NXT is the first platform to use DAG since November 2015, and another two noticeable implementations are IOTA Tangle & ByteBall (Faisal Khan, n.d.).

Finally, DAG implementation has provided two more advantages in comparison with other DLTs. The first one is the Quantum-resistance Winternitz One-Time signature scheme, acting as a firewall against a break-in attempt by quantum computers, and the second is the Masked Authenticated Messaging (MAM) which allows secure and encrypted communication between two nodes (Faisal Khan, n.d.).

2.2.2.3 Distributed Hash Table (DHT), the Holochain Project

The Holochain Company presented a new DLT that claims to be the next generation of DLTs. The innovation that the platform has provided is that it has changed the data-centric approach to an agent-centric one. By avoiding the global consensus protocol gives to the Holochain-DLT virtually limitless scalability. Although Blockchain seeks to decentralize the transactions on the network, Holochain intends to decentralize the interactions between the individual nodes as well. Every individual node runs a chain of their own which has the independence to operate on its own network while being part of the bigger network consisting of thousands of other similar nodes. Users can store data in a distributed hash table (DHT) by using specific 'keys'. This data storage also remains distributed in different locations around the globe.

It is this decentralization of the network at every level which gives the Holochain-DLT the ability to achieve millions of transactions per second (TPS). The validation at a micro-level relieves the traffic congestion on the network. Since every node has their own ledger, they are identified by a specific value identifier called the "DNA." When the other nodes receive a message using the specific node DNA, they transmit it to the rest of the network. If there is a malicious attempt to add false information to the network or to alter it, the transaction would be rejected and the failed attempt would be reported to the rest of the network in order to avoid this action in the future. In this way, Holochain establishes a very strong security feature. Although in Blockchain the computational burden adds up with the addition of blocks, the addition of nodes on a Holochain means more room for computation. Also, transaction fees are not required since there is no need for "miners", making the platform energy-efficient. In addition to the above, no extra hardware equipment is needed, except an already owned PC. Finally, the individual nodes cannot only process transactions brought to them but also provide more space for the development of applications (Faisal Khan, n.d.).

Table 2: DLT Characteristics.

	HASHGRAPH	**DIRECTED ACYCLIC GRAPH**	**DISTRIBUTED HASH TABLE**
ADVANTAGES	• Doesn't need POW algorithm • High level of Scalability • High efficiency of gossip based consensus	• Very high number of transactions per second (TPS) • Quick Consensus • Focus on Scalability	• Large number of TPS with unlimited Scalability • Gossip Based Validation
DISADVANTAGES	• Focuses on permissioned systems	• Bit Centralized IOTA structure	• Security Issues

	• Lack of global testing and adoption • Unpowered decentralization	• Lack of used decentralized applications widely	• Doesn't suit for storing and exchanging private data
PROJECT	HEDERA HASHGRAPH	IOTA NANO	HOLOCHAIN

2.2.3 Useful Tools on Blockchain-based Applications

Among the various useful functionalities of the blockchain, there are two which are in particular interest to the shipping industry. These are the Smart Contracts and the Ricardian Contracts. Their function and characteristics are described below.

2.2.3.1 Smart Contracts

Nick Szabo introduced smart contracts in 1994 as "a computerized transaction protocol that executes the terms of a contract" (N. Szabo, 1994). Szabo suggested translating contractual clauses (collateral, bonding, etc.) into a code and embedding them into a property (hardware, or software) that can self-enforce them (N. Szabo, 1997), in order to minimize the need for trusted third-parties between transacting parties and the occurrence of faulty or improper executions.

So, "Smart Contracts" are self-enforceable contracts (working on an IFTTT logic (If-This-Then-That)) in the terms of the agreement between the counterparties being written directly in code lines. The code and the agreements contained in it, exist in a distributed, decentralized Blockchain network. The code checks the execution and transactions are detectable and irreversible. In this way, Smart Contracts promise to conduct confidential and secure transactions and agreements between unknown parties without the need for a central trusted authority, legal system or external enforcement mechanism.

Smart contracts exist today. When a purchase is made through an online store using a credit card, a smart contract that performs specific functions is activated. In this case, however, the existence of a trusted third-party (bank) is required, and it guarantees that the buyer has the funds to make the purchase and the seller will receive them.

Smart contracts on a blockchain platform do not need the presence of a trusted third-party, because in a decentralized system, the information of the existence of the buyer's funds are available in the blockchain and on the other hand, the smart contract ensures the seller's payment. After the activation of the smart contract, the execution of the transaction cannot be changed. This builds the required trust between the involved parties.

The smart contracts can replace the traditional contracts thanks to their assets. Some of the benefits of the smart contract are:

- **Total Transparency**

Smart contracts are transparent to all transacting members. All the relevant parties have access to the terms and conditions of the agreement and any changes must be decided before the execution of the contract. Once the contract is prepared, no one can change the agreement.

- **No Miscommunication**

The agreement will be executed as decided between the involved parties, in the same way, every time, with no changes.

- **Efficient Performance**
  A combination of speed, accuracy, and the automated feature ensure an efficient execution without any fault or any interruption of a trusted third-party. Also, they can efficiently process a significant number of transactions in a short time.
- **No Paperwork**
  It is self-evident that their use does not require the traditional printed form and the bureaucracy required to perform a contract, is not required any more.
- **Backup**

A Smart Contract on a blockchain-based application has the ability to permanently record all the transactions on the chain. This means that you can retrieve any of the information if there is any data loss.

2.2.3.2 Ricardian Contracts

Ricardian Contracts, invented by Ian Grigg in 1996, were described in an academic paper presented in 2004 (I. Grigg, 2004). Ricardian contracts, which were first displayed as contracts, were created in a human readable form that can adjust to machine language form. Therefore, this are contracts that can be dynamically change based on text editor approach and autonomously change to machine readable form. In other words, Ricardian contracts are double form contracts. They were first deployed as legally written documents to mirror the traditional signed contracts that are "written by lawyers for lawyers".

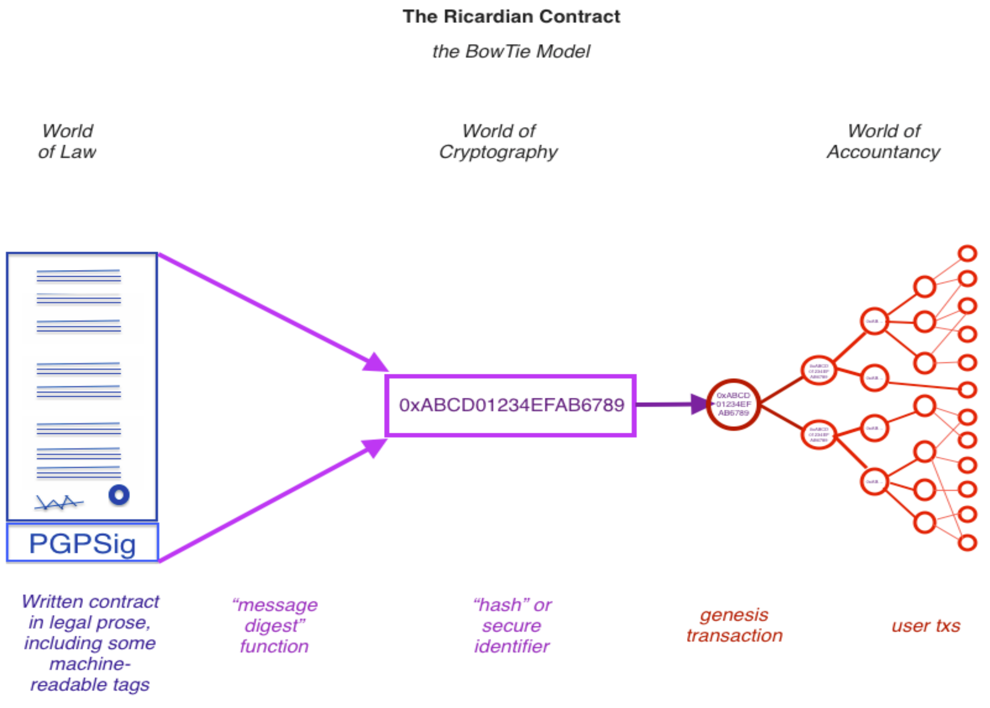

Figure 1 Diagram of Ricardian contract elements (Source: Wikipedia, Ricardian contracts)

We already have two cases that Ricardian contracts were enforced legally and those cases are: DigiGold.NET ltd v. Systemics, Inc that held in the Anguilla Supreme Court (2001) and the American Arbitration Association (2002). The use of Ricardian contracts could decrease transaction costs and promote machine automation of legal agreements. They are different from smart contracts because they serve a different purpose. Smart contracts are a digital agreement that can be executed automatically by a software or hardware whereas Ricardian contracts are a written agreement into the world of code through cryptography transforming a regular legal prose agreement into a machine readable contract.

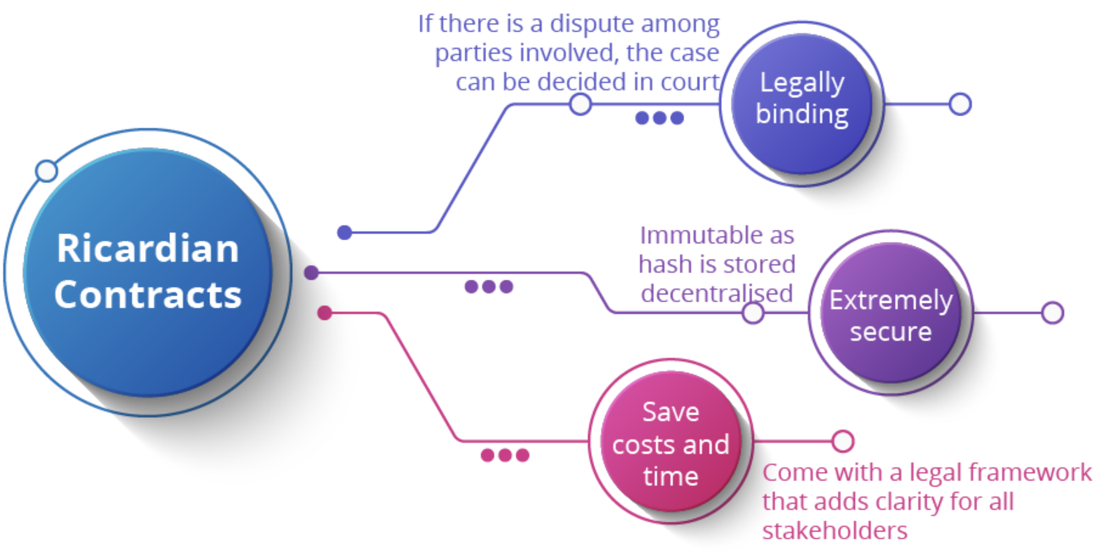

Figure 2 Benefits of Ricardian Contracts (Source: 101blockchains.com)

3.0 Processes of the Maritime Industry which can Benefit from Blockchain

The maritime industry, established as the main way of global freight transportation, is a billion-dollar industry that despite its traditional form, wishes to be benefited by adopting changes that new technologies have brought. In the future digitized shipping industry, with autonomous vessels, technologies like blockchain play a central role in creating bridges between tradition and autonomous industry form.

The first significant step in this research is to recognize "if" and "in which areas of shipping" the blockchain is really needed so as to continue to analyse the potential benefits gained from the transition of the current situation to the post-blockchain era.

However, the final decision to use a blockchain-based application, depends on us, but there are various models that can guide us and thus, give us a glimpse of the possibility or expediency of using this technology.

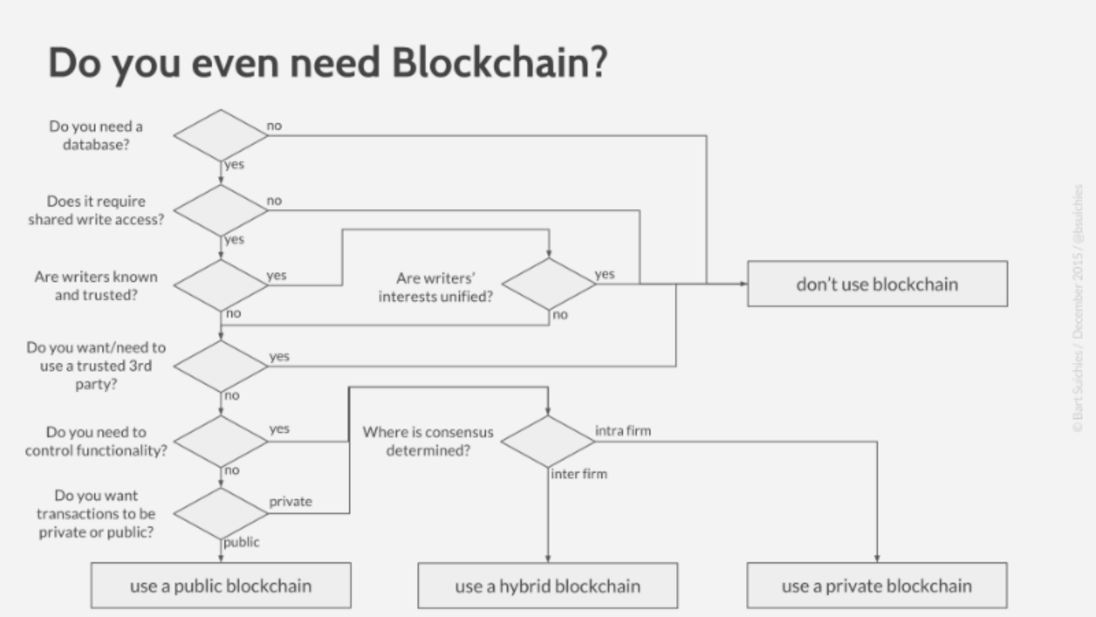

Figure 3: B. Suichies, Decision Model (Source: www.medioum.com)

The above decision model, was presented by Bart Suichies, Head of Digital & Software at SICPA. It is a great start to help us decide if a procedure in shipping industry requires the use of blockchain technology. After answering several questions, we will end up with four possible results: public blockchain, hybrid (Federated/Consortium) blockchain, private blockchain, or no blockchain at all.

By following the steps of the model and searching for use cases of blockchain-based applications and platforms for shipping industry, the writer concluded that the following sectors can be benefited from adopting and using blockchain:

- Chartering
- Bill of Lading
- Port Clearance
- Authenticity of records and certificates

3.1 Chartering

The Charter party is a written and therefore formal agreement between the charterer and the ship-owner, constituting the main contract on the merchant shipping. This document reflects the shipper's verbal promise to transfer legally the ship's full capacity to the charterer for one or more journeys. Thus, the Charter party is the basic contract of carriage. The terms of the Charter party are determined by the obligations and the rights of the Parties and the chartering agreement is considered valid and formulated as long as it is feasible to deal with all the issues that may arise. In order to minimize delays in closing an agreement, parties try the use of standardized and pre-designed Charter parties, according to English law or the national legislation of the country where the agreement was signed.

English law agreement has:

Expressed terms: They are explicitly described in the standard forms or in the additional appendix.

Implied terms: The terms are not in writing, but they are particularly strong, self-evident and are accepted implicitly by the parties (seaworthiness, due dispatch, proper route)

Representations: The terms concerning the presentations given during the negotiations. These are promises made by the parties. Such examples are the characteristics of the ship (name, mark, time of construction, etc.) and the cargo. If something is not as agreed, then the contract can be cancelled.

Conditions: Terms that, if violated by a Contracting Party, will provide to the other party the right to seek compensation and cancel the contract. Such are the nationality of ship, the geographical location at the time of signature and Class.

Warranties: conditions that if one party break them, the other party can claim refunds.

Innominate terms: The terms are sometimes treated as conditions and sometimes as warranties depending on the case. One example may be the ship's airworthiness.

Blockchain technology can ensure process automation, security and the shortest time possible to complete the contract. Many shipping companies do not trust the transmission of information to networks, but blockchain and more specifically the private network (Hyperledger Fabric) can become the appropriate platform for shipping companies to integrate their activities. The capability of creating internal channels in the wider network, where the information does not appear to those who are not in the inner channel, increase trust and security and augurs a fresh beginning for the chartering.

Charter-parties can be supported and formulated by Smart contracts and Ricardian Contracts. Thus, they will acquire characteristics like:

- Quick processing time and real-time updates
- Higher accuracy
- Transparency
- Increased security
- Cost Saving

The following is a simple example of comparing the old process to the new one so that the advantages of blockchain-based applications, can be understood:

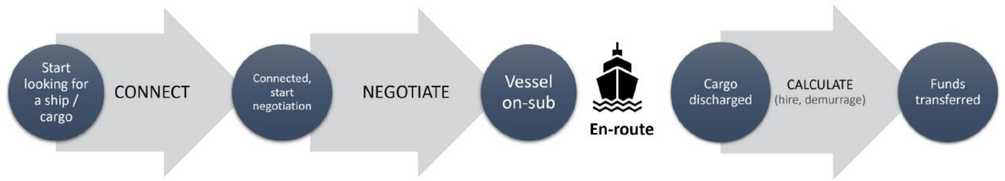

Figure 4: Chartering Flow-diagram (Source: Harshvardhan, MIT, p.2)

Firstly, a Charterer has to approach a pool of brokers in order to find a specific ship that covers their requirements. Mainly the challenge at this first stage is the availability of information. Brokers play this role and they get paid for this information matching, acting as a third-party, as there is no previous business dealings between the charterer and the ship-owner. This process is time-consuming and can take from a few hours to several days. This issue can be solved if the two parties interact directly on a Blockchain-based platform. The charterer and the ship-owner can upload all the relevant information to the blockchain platform, and a smart contract can query the database and display a list of matches. This can help them find each other instantly, as long as there is a suitable match.

The next step is to negotiate terms and conditions of the carriage. Lack of price transparency in a dynamic market lead to several rounds of communication between the relevant parties, through the brokers. Those terms and conditions can be added in a smart or Ricardian contract as algorithms, decreasing the negotiating time, and increasing the accuracy of the terms.

Once the agreement is signed, the ship transports the cargo. After discharging the cargo or at the end of the hire period, the calculation for hire and demurrage, in voyage charter, or the abstraction of the off-hire periods in time charter case, is done. Although this is a simple process, it is well known that it takes several days because of documentation and claims. Subsequently, international fund transfers are done through a network of banks, taking several days for funds to arrive. A Blockchain-based smart or Ricardian contract is a possible solution to these problems. It can take certain inputs from trusted third parties, like "time" of arrival and departure of the ship from a port control station, "speed" and "position" from a GPS or AIS equipment on board, in order to do calculations and fit these inputs into a pre-defined algorithm, so it will come up with a non-disputable figure and finally execute a fund transfer.

As smart contracts can be pre-loaded with funds like a credit card, it would guarantee the ship-owner that they will receive funds if they meet the obligations of the contract. Such a system will be trustworthy, and hence there will be no need for a broker for this purpose, reducing the time and the cost of the procedure (Harshvardhan, MIT).

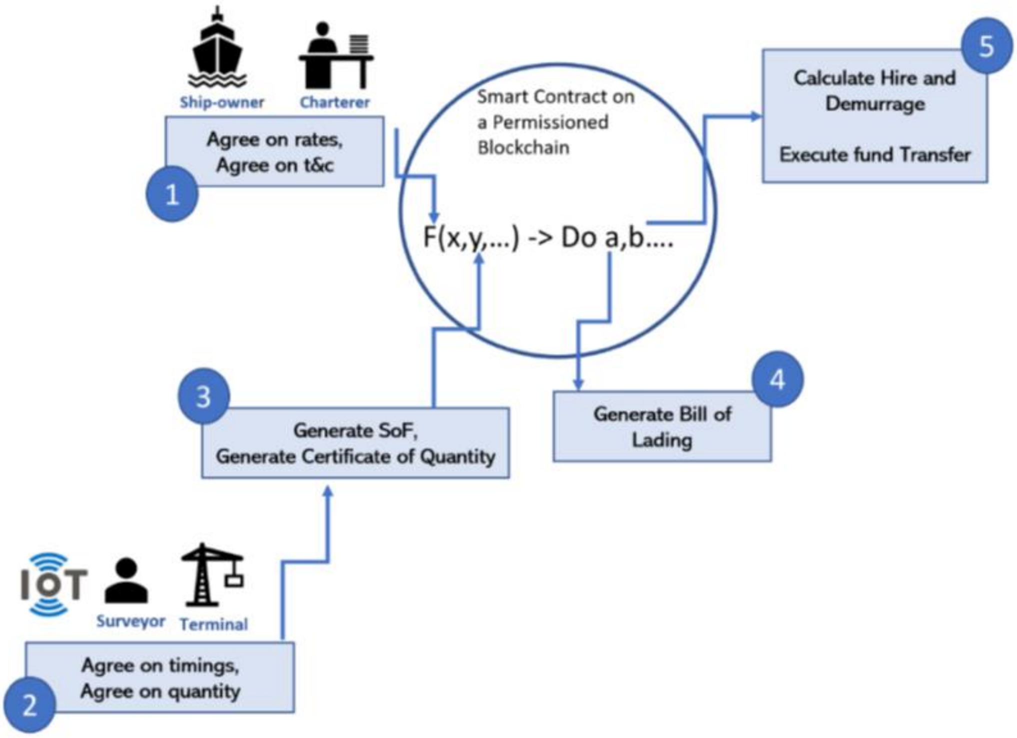

Figure 5: Chartering with Smart Contracts (Source: Harshvardhan, MIT, p.4)

3.2 Bill Of Lading (BOL)

One of the most significant documents in international commercial transactions, which have been an integral component in the maritime shipping industry, is the Bill of Lading. It was the result of the inability to ensure that goods were delivered by the carrier to the correct consignee and also arrived at the consignee in the same quantity and quality as when delivered by the producer, consignor or exporter, to carrier.

Thus, the consignees gave the carriers orders to deliver the cargo, with the details of the goods being transferred by them, as well as the details of the person to whom the cargo would be delivered at the port of destination (Murray, D., History, and Development of the Lading Bill, 1983). These orders are called Bills of Lading and have been the key documents for international and national trade, especially in the case of maritime transport.

At the same time, legislation began to emerge which soon made it possible for the bill of lading to confer rights on the person holding it (Kianadou-Pabouki, Maritime Law II, 2007).

Regardless of the types of BOL, as a document, in order to be considered valid, it must serve three basic functions, necessary for the separation of legal obligations and commitments between the parties:

1) It must be a conclusive receipt, i.e. an acknowledgement that the goods have been loaded

2) It must contain or evidence the terms of the contract of carriage

3) It must serve as a document of title to the goods, subject to the nemo dat quod non habet rule (literally meaning "no one gives what they do not have").

In addition to the above, various types of BOL have some additional features that allow them to be transferred as a transferable document of title, to another person while transferring the right to acquire and receive the goods they represent.

This thesis examines and analyses the Negotiable BOL in a Blockchain Solution Platform, as it is the most common BOL and the most complex subcategory as well.

3.2.1 Negotiable Bill of Lading (N/BOL)

A negotiable bill of lading is one kind of BOLs. The bill of lading is a legal document between the shipper and carrier, detailing the type, quantity, and destination of goods being carried. The negotiable bill of lading is distinguished by the fact that it is a document of title that can be transferred to a third party.

Under that definition, and in conjunction with its functions (BOL), a negotiable bill of lading (N/BOL):

1) Operates as a receipt providing evidence that goods conforming to the contract have been shipped as agreed and are in the physical possession of the carrier for delivery to the consignee at destination. This evidentiary aspect of the document is important, both for the seller and the buyer, in relation to obligations under the sale contract, and for a potential cargo-claimant and the carrier, if goods lost or damaged during transit.

2) Contains or evidences the relevant terms of contract with the carrier. Where goods are lost or damaged in transit or even delivered late or earlier than the agreed date, the cargo interests' party may be able to pursue a claim against the carrier.

3) Operates as a transferable document of title, and it is this feature, which sets the document apart from non-negotiable bill of ladings. A document of title in this context is a document, which provides its holder with the exclusive right to demand delivery from the carrier. The goods will only be released at the port of discharge against surrender of the bill of lading, possession of the document amounts to constructive possession of the goods. If the document is "negotiable", i.e. is made out "to order", or to the order of a named party, or to the bearer, the right embodied in the document can be transferred along a chain of sale contracts by delivery, with any necessary endorsement, of the document alone. Thus, while goods are in the physical possession of a carrier during transit, a seller is able to pass possession and property of the goods to a subsequent buyer simply by passing on the negotiable document of title. Also, the document can be pledged to a bank and thus may be used as a security to raise finance (UNCTAD, The Use of Transport Documents in International Trade, 2003).

Those N/BOL principles can be done by distributed Bill of Lading (DBOL) and mark the beginning of making Maritime Industry the truly autonomous industry in the next decade.

3.2.3 Issues and Obstacles with the Bill of Lading System

While necessary for ensuring trust in international transactions, BOL can be disadvantageous in many respects. Each BOL is often sent at least three times through a courier process, costing $100 on average. With more than 50 million B/Ls sent every year, the estimated total yearly cost of this process is approximately $5 billion. In maritime logistics, the shipper must mail the original and physical copies of the bill to the importer of the goods. If the goods reach the importer ahead of BOL, the importer will not have the requisite document of title to present to the carrier. Not only will the carrier not accrue liability — neither in trover nor under statute — for withholding the goods, but they may also have to place the goods in storage. This can result in demurrage costs as well as potential economic loss due to fluctuations in market value of the goods or an inability of the importer to meet obligations under other contracts (Jake Herd, ‘BLOCKS OF LADING’ Distributed Ledger Technology and the Disruption of Sea Carriage Regulation, QUT Law Review – Vol 18, No 2)

3.2.4 Electronic BOL: The Dematerialize of Paper Documents

The above reasons, along with the advent of the internet, the development and spreading of electronic information systems, have largely led to the development of electronic solutions for the processing and transaction of BOLs also known as EDI (Electronic Data Interchange). The most significant examples approved by P&I Clubs are Bolero, EssDocs, e-title, and edoxOnline.

A number of problems have arisen from this effort and as a result, there was a limited acceptance, adoption and an inability to replace the pre-existing situation with the new one. The most important of these are presented below and are based both on systems’ analysis and research among users (carriers, consignors and consignees) (Raphael Brunner, Electronic Transport Documents and Shipping Practice not yet a Married Couple, LL.M. Shipping Law, 2007):

1) Commodity traders did not like to have their transactions recorded in a central registry.

2) The ultimate buyers of commodities did not want to acquire bills of lading from a registry actually supporting and servicing intermediaries and speculators.

3) The liability of e-Bill of Lading platforms was not established. This resulted in relatively expensive insurance contracts for the registry operations.

4) If the goods are to be sold to a party not being a member of the specific e-Bill of Lading platform, the e-Bill of Lading may not be used anymore. In such a case, the parties may have to switch to a paper bill of lading to be issued on the spot by the carrier upon request of the actual consignee.

5) All Contracting Parties must be members of this e-Bill of Lading platform which have signed and accepted the terms and conditions of this platform.

6) The platforms depend on the liability of its users to assess if they comply with the laws of the country the user wishes to trade in or with. As the solutions are based on contractual relationships, legal uncertainty remains as to the acceptance and enforceability of the system in various jurisdictions.

7) In most cases, the platforms request, the trade transaction to be financed by a letter of credit.

8) Not all banks (which are a key factor in the equation of transactions) accept an e-BOL as a warrant to credit or withdraw money from an account.

9) Lack of international legal framework.

10) There must always be a trusted third party.

Beyond the literature review, which includes the above factors, the United Nations Conference on Trade and Development researched the involved parties, to identify from a practical point of view, the obstacles using electronic platforms, and arrived at the following results:

Table 3 Obstacles to the Use of Electronic Alternatives (Source: UNCTAD, The Use of Transport Documents in International Trade, 2003)

Obstacles to the use of electronic alternatives	**% of respondents**
Infrastructure/market/trading partners not yet ready	51
Legal framework is not clear enough or is not adequate	44
Electronic equivalents are not sufficiently secure	25
Technology and/or switch to electronic environment is too costly	12
Confidentiality concerns	10
Other reasons	2

Analysing the spotted factors, it is evident that we have two different types of obstacles. The first type includes legal issues and the second, technology issues which generate a chain of more obstacles.

Subsequently, it is vital to examine how DLT platforms solve and eliminate these problems while helping to solve the legal issues raised by the existing technology.

3.2.5 Legal and Technological Obstacles, and the UNCITRAL Model Law on Electronic Transferable Records

Due to legal issues, technological efforts to introduce electronic transferable records into the maritime industry, have yet to yield the expected results.

Considering that uncertainties as to the legal value of electronic transferable records constitute an obstacle to international trade, United Nations and in particular UNCITRAL (United Nations Commission on International Trade Law), adopted in 2017 the Model Law on Electronic Transferable Records which intends to generally plug the gap that was missing in e-commerce laws.

The UNCITRAL Model Law on Electronic Transferable Records, in addition to the aforementioned requirements for the bill of lading, has three key principles in mind:

1) Non-discrimination
2) Functional equivalence
3) Technological neutrality

Table 4 Comparison between Pre-DLT Efforts and DLT-based Solutions.

UNCITRAL Model Law on Electronic Transferable Records Requirement	Pre-DLT efforts	DLT-Based solutions
Electronic signature	☑	☑
Uniqueness	☒	☑
Singularity	☒	☑
Contains the information that would be required to be contained in a transferable document or instrument	☑	☑
Control A) Establish exclusive control of that electronic transferable record by a Person. B) Identify that person as the person in control	☒	☑
Retain the integrity of the electronic record	☒	☑
Ability to prevent unauthorized access	☑	☑

On the other hand, DLTs have by nature some unique characteristics which fit the Model Law requirements and can turn out to be the practical solution to the problem. Furthermore, they can eliminate the existing problems, created by pre-DLT efforts.

Additionally, the DLT-based solutions do not require to have the transactions recorded in a central registry, they need the parties to be members of a specific e-BOL platform, it is unnecessary no need to sign and accept the terms and conditions of a e-BOL platform, they eliminate the use of a letter of credit (and also the cost) and most importantly a trusted third party is of no use.

Under the pressure of technological innovation, the need to promote merchant trade, economic growth and the legal support that now exists, Bahrain has enacted the MLETR. (Takahashi, Koji. "Bahraini legislation based on the UNCITRAL MLETR". Blockchain, Cryptocurrency, Crypto-asset and the Law. Retrieved 12 February 2019.)

Czech and Singapore have also conducted public consultations on its adoption. Another public consultation has been conducted in Singapore in summer 2019, in the broader framework of the review of the Electronic Transactions Act ("Consultation Paper Issued by the Infocomm Media Development Authority on Review of the Electronic Transactions Act (ETA) (CAP. 88) 27 June 2019", IMDA.)

All of the above indicate that with the final embodiment of the legal requirements into the legal framework of the States across the world together with the configuration of DLTs to fully meet the requirements, a bright and wider path has opened for the paperless trading systems in the shipping industry.

3.3 Port Clearance

Ports play a significant role in Maritime Industry, as freight must be loaded and discharged on port stations. Additionally, automation is an important aspect to provide quick and efficient service. Ports like Antwerp and Rotterdam, developed automated systems and Blockchain could not be out of the picture. These ports, enabled blockchain on logistics process and found that blockchain has lots of opportunities such as:

- Real time insight and transparency in transactions are provided by the application of smart contracts in the fields of taxes, insurances, inspection and payments
- Digitalization of paper work results in fewer document flows
- Low-threshold access to large-scale transport systems
- More data becomes available, enabling individual parties and the chain as a whole to work more efficiently

In our era of interconnection, Stakeholders across the enormously complex logistics supply chain urgently demand faster, cheaper, more secure and sustainable flows of goods, services and energy, while global trade is becoming more complex and less predictable. Digitalisation has delivered some improvements, but a mountain of documentation, time delays and a lack of interconnectivity remain. Companies still operate with completely different administrative systems in their own little silo, which can be immensely time consuming and expensive. For example, it can take a week to trace a single product and all its components through the entire supply chain, and clarify its origin and ownership in every step in the timeline. A single PO number from beginning to end is typed over more than 100 times in emails, systems and documents. Current use of Blocklab at Rotterdam port, is a solution to make port supply chain an easier task to do.

3.4 The Authenticity of Records and Certificates

Another area of the shipping industry that can benefit from the blockchain is the paper or electronic document transactions.

The shipping industry and the supply chain, in general, require the handling of a plethora of records. Most of them need to be either prototypes or their authenticity be verified by many authorities. This validation often requires a lot of time, due to the many parties that get involved. These parties are often located in different time zones and thus, additional delays are added to the already slow process. In addition, document handling leaves a lot of space for fraud, as their counterfeiting (especially electronically transmitted documents) is easy.

Such documents that play an important role in the shipping industry, are the cargo documents, the ship's certificates from Classification Societies, and the training and education certificates of the crew members and so on.

And here comes the blockchain to provide a solution to this problem. The architecture of this technology is essentially based on this function, i.e. the validation of the origin of an electronic file as well as the validation that the holder of the file is unique and the rightful owner.

This certification is easy to be executed on all blockchain platforms and on all types of DLTs. A similar validation process for university diplomas is currently used by the University of Nicosia.

Subsequently, the cryptographic procedure and verification of the authenticity of an electronic file will be explained in some simple steps and this process can be used for any electronic file (like PDF files, a JPEG pictures, an Excel sheet, a Zip file, a video):

- **Step 1: Digital Fingerprint**
  Like human fingerprints which are unique, digital documents or files also have a unique "fingerprint". It can be created by using so-called cryptographic hash functions from publicly available algorithms, like “SHA-256” or "MD5". These functions can take a file of almost any size and type as input to create a string of letters, numbers and characters as an output. This process is a one-way process as it is impossible to reproduce the file from the digital fingerprint.

- **Step 2: Create A Signature**
  In the same way, we can sign a contract by using our hand-written signature, the digital fingerprint from above, gets signed. In order to achieve this, a Public and a Private Key (RSA Keys) are required for signing the digital fingerprint.

One common method to create digital signatures is JSON Web Tokens. JSON Web Tokens is an open tool for generating and verifying tokens.

- **Step 3: Commit Fingerprint and Signature to Blockchain**

  In the last step, the digital fingerprint and the signature (JSON Web Token) are 'uploaded' to the Blockchain. It is important to keep in mind that the digital file is not uploaded itself on the blockchain, but only the fingerprint and the signature get stored.

- **Step 4: Transmission of the Signed Digital Asset**

  The digital asset can now be distributed to any party since it is a file like any other, by using one of the existing ways of sharing information, such as email, etc.

  Any modification to the digital asset would also cause its digital fingerprint to change. As a result, the signature (JWT) stored on the Blockchain would no longer match the digital asset's new fingerprint. Hence the new digital asset can no longer be considered as 'valid' as no corresponding signature exists (Martin Stellnberger, 2020).

- **Step 5: Digital Asset Verification**

  For the recipient, the process to verify the authenticity of a digital asset is similar to the steps performed before. Firstly they have to start by re-creating the digital fingerprint from the file that has been received. After that, a request is launched to the Blockchain to retrieve the fingerprint's corresponding signature. Finally, they have to 'apply' the public key that corresponds to the private key that has been used in Step 2 to verify the signature and consequently the validity of the digital asset.

- **Step 6: Certificate Provider Identity Verification**

  The last step of the validation process is to verify if the institution which created the digital asset is a legitimate entity itself since anybody can create,

sign and commit information to the Blockchain (in case of a public blockchain) and pretend to be somebody else. In a private blockchain application, this step is not required.
The process is called Extended Validation SSL where the certificate authority is required to conduct a thorough vetting of the institution by:

- Verifying the legal, physical and operational existence of the entity and
- Verifying that the identity of the entity matches official records among further checks.

By using the URL that has been specified in the JWT we can now ascertain if and what SSL certificate (Secure Sockets Layer) has been provided by the institution behind this URL. This enables us to trust (or not) the legitimacy of the institution that created the signed digital asset in the first place (Martin Stellnberger, 2020).

In the same way, different shipping documents can be sent between authorities or collaborated parties, without the uncertainty of the authenticity of their origin. A single container has an end to end journey that involves almost 30 organizations such as the port of loading, the ocean carrier, the banks providing finance, government-provided certificates, and many more. Therefore, for these 30 organizations, we deal with at least 100 individuals, and multiple information are exchanged.

The usage of Blockchain-based applications and platforms will significantly reduce the cost and the time required for their exchange and many man-hours will be saved, which in turn will reduce the operating costs of the companies. Finally, cyber-attacks will be eliminated, as a blockchain-based application is impossible to be hacked.

An excellent example of blockchain-based platform for document exchange is TradeLens. IBM and global shipping leader, MAERSK have jointly-developed a “blockchain-based shipping platform”, named TradeLens, which promises to bring transparency, efficiency, real-time monitoring, and security to global supply chains. This is going to be presented in the next chapter.

STAGE TWO

4.0 Blockchain Use Cases

In this chapter, an extensive literature survey conducted, in order to find and locate blockchain-based applications already used by the shipping industry. Additionally**,** their capabilities and characteristics are to be analyzed**,** as well as their advantages and disadvantages.

4.1 Blockchain Solutions for BOL, Document Exchange and Port Clearance

One of the first and most known blockchain-based efforts to digitalize the BOL and other documents, is the CargoX dApp. It is a web-based decentralized application which allows customers to interact with Smart B/L and digital document. CargoX (the company) is an Independent Supplier of Blockchain-based Solutions for Logistics. The solution that it provides is based on the public blockchain Ethereum Network and it uses the CargoX B/L exchange Protocol with the ERC20 CXO token that serves as a protocol utility token, drives the core functionalities of CargoX's smart contracts and also serves as a payment method for logistics services (CargoX Business Overview and Technology Blue-paper).

At the moment, CargoX can only offer its customers a House Bill of Lading (HBL) which is a transportation contract between a NVOCC/Freight Forwarder and an end customer (shipper) and cannot be used as a Negotiable Bill Of Lading. Furthermore, the use of a public blockchain platform, although it significantly reduces the cost of transferring an e/BL, it does not eliminate it. This is due to the fact that transactions require payment of platform miners in order to execute and verify them.

Finally, CargoX does not seem to be a fully integrated solution, but unquestionable it plays the role of a remarkable ambassador between blockchain-world and maritime industry, which helps in the creation of critical mass for the massive adoption of blockchain and DLTs in international trade.

Additionally, two other companies have announced the use of blockchain technology in their electronic trading systems, in order to enable carriers, shippers, consignees, banks, freight forwarders and other parties to issue, exchange and sign a variety of supply chain encrypted documents and electronic BOLs, with no need for a central server or registry. These are Global Share S.A. edoxOnline platform (www.globalshare.com.ar) which have recently announced that it reaches 100,000 transactions, and WAVE network (www.wavebl.com). Both platforms have been approved by the International Group of P&I Clubs (International Group Circular – Bills of Lading and Blockchain Based System), a fact which is very important for the future of DLTs in maritime industry.

Especially, Wave Ltd. has collaborated with Israel-based Liner Company, ZIM Integrated Shipping Services and Sparx Logistics, and an Original Bill of Ladings was transferred to the receiver within less than two hours from Vessel's departure, a process that usually takes days or even weeks. All documentation processes, including endorsements, ownership transfers and so on were performed on the blockchain-based platform (ZIM news, 2019).

Also, Corda platform integrates Bolero's eBL (electronic Bill of Lading) solution for the issuance and management of eBLs. Ian Kerr, Bolero's CEO says "In its partnership with R3, Bolero is extending the reach of its eBL Title Registry based solution across the supply chain by developing an oracle on Corda, which enables carriers to connect with corporates and other supply chain participants. Relevant parties will be able to endorse and verify an eBL's title without needing to revert to paper".

On the other hand, EssDocs managed to collaborate with R3 and Corda and together created Voltron, a paperless electronic Bill of Lading with a view to providing a multibank channel for companies to digitally manage the issuance of LCs (Letters of Credit) and also the electronic presentation of trade documents, including documents such as Bill of Lading. It gives access to banks and corporates to all data (plus documents) within the Voltron Platform. The collaboration of EssDocs with Voltron wishes to create a community with access to all data and tradeable offers for everyone. It is more like a cross-platform solution.

TradeLens provides businesses and authorities involved in the supply chain with a single, secure source of shipping data. As of May 2019, participants on the ledger included more than 100 organizations and more than 40 worldwide ports and authorities (J. Gronholt-Pedersen, 2019).

TradeLens, is another very important “blockchain-based shipping platform”, jointly-developed by IBM and the global shipping leader, MAERSK. It is a platform based on Hyperledger Fabric, a permissioned ledger, which includes authorized users only. Verified stakeholders, such as exporters, freight forwarders, shipping companies, ports and terminals, customs authorities and importers, can participate on the platform. While participants are anonymous on a permissionless system, a permission-based DLT includes known entities who are authorized to join, view, and publish data. Permissionless ledgers rely on computationally intensive consensus algorithms to validate transactions, which presents a high risk of sabotaged blocks (Salimitari, Mehrdad & Mainak, 2019). In contrast, permission-based consensus allows transactions to be endorsed by relevant participants. Therefore, decision-making is authorized to specific members, providing controlled data consistency and preventing any illegitimate blocks or conflicts on the ledger (Biazetti, 2019). Another insight that TradeLens offers is that DLT can provide a high degree of cybersecurity assurances and mechanisms to accommodate multiple degrees of privacy.

4.1.1 Technical Aspects of Blockchain-based BOL and Document Exchange Solutions

A first assessment of the presented solutions is included in Table 5 where the type of each solution and its main advantages and disadvantages are listed. It is clear that any solution needs to deploy a private or permissioned platform so that access to the information is completely controlled. From the access control perspective, Hyperledger Fabric based solutions are advantageous because they are a private network constructed with inter-enterprise exchanges in mind. For this purpose, it supports the notion of "channels" where nodes communicate in the same "channel" forming a blockchain network. By deploying HLF based solutions, multiple blockchain networks can run in parallel. This capability gives a purely operational form to the network that makes it more appealing to shipping organizations. For example, the different channels could be exploited to segregate groups of shipping organisations. On the other hand, Corda is more tailored to financial processes which are indispensable of any shipping operation.

As the need to register and maintain continuously growing amounts of information is evident, scalability play a crucial role. Scalability refers to the capacity of the solution to register and manage larger amounts of information (at adequate speed to avoid the degradation of the user experience) and unfortunately scalability is an inherent drawback of blockchain approaches. Additionally, today the trend is to register continuously increasing amounts of information for all goods in an attempt to offer enhance security and added value services to the end users. Among the supply chains actors seek to provide evidence to end users that the goods are appropriately handled and safe to use. This is nowadays feasible through the integration of sensor systems which are capable of collecting information across the journey of the goods installed in all places where the goods are placed. The need for handling a continuously increasing amount of information due to a) the ordinary evolution and b) the integration of additional information sources render scalability of paramount importance. Considering the scalability features of the existing solutions, scalability is not among the advantages of Ethereum. Hyperledger Fabric exhibits better scalability than Ethereum as it can organise the blockchain network in channels which could be seen as independent networks. Currently, it is DLTs that exhibit better scalability features. For example, directed acyclic graph approaches come with higher scalability potential which of course depends on the way they are structured and operate.

Table 5: Advantages and Disadvantages of Blockchain-based BOL Platforms and Document Exchange Solutions

	Type	Advantages	Disadvantages
CARGOX	Public (restricted) Ethereum-based Blockchain	Well Known blockchain House of Landing Transactions are viewable to entire network Helped blockchain to be acceptable in Shipping Industry	Does not support negotiable BOL High Value of tokens make transaction unacceptable
EssDocs-Voltron	Permissioned Based on Corda	Cross-platform connectivity Use R3 Corda Ricardian Contract P&I Clubs accepted	Beta mode Finance based model Banks have access to all companies data Cannot use token
TradeLens	Private (based on Hyperledger Fabric)	Generic platform for supply chain solutions Promoted by IBM and Maersk	Doesn't provide maritime specific operations.
e-title	Peer 2 peer Hybrid platform	Accept any format of Document (PDF, IMAGE, XML, EDI) P&I Clubs accepted	Need of Paper Based bill of landing to convert it in electronic Bill of Landing
Edox Online	Web based blockchain	P&I Clubs accepted	Lack of privacy
Bolero	Cloud Based	P&I Clubs accepted Scan paper documents Manage Huge load of Documents	Contractual provisions binding only the contracting parties and cannot provide obligations to third parties Centralized

Let us now focus on the capacity of the solution to expand and interconnect with other enterprise systems like the RFID or sensor infrastructures installed in the vessels. This depends on the modularity or flexibility of the adopted platform/solutions to integrate. Hyperledger Fabric has been developed with modularity in mind. Corda (on which essDocs is built) is consciously designed as DLT for the Banking and Financial Industry, hence, the main focus is on financial services transactions. Its architectural design is simple when compared to Fabric. As the framework of Fabric is modular it is likely that it can be altered to resemble Corda. There are efforts made to integrate Corda into the Hyperledger project. In that sense, currently, Corda and Hyperledger Fabric cannot be seen as competitors but rather as a complementary platform. Additionally, CargoX and Bolero offer APIs (Application Programming Interfaces) facilitating integration with other platforms while e-title does not seem to offer such an option.

From a financial prospective, the use of these solutions costs significantly but solutions tailored to the needs of smaller businesses can be developed and offered. For example, a shipping company owning few ships finds it expensive to acquire a CargoX solutions for its needs. This may open a new niche where smaller IT companies come into the play and can use available platforms to offer solutions tailored to the needs of smaller businesses. With this in view, CargoX is more of a platform (which another company could use to develop a specific tailored solution) than a solution. It is important to understand that in this huge market, there cannot be a one-size-fits-all solution; it is more likely that many solutions embracing the same principles of operation can work together.

4.2 Blockchain Solutions for Chartering

In the chartering and brokering sectors, the landscape seems to be very poor, since only one platform has been spotted.

Singular Point, focused on logistics software market and dedicated to trading and shipping companies, is a young and innovative company based in Zug Switzerland. It has developed MARiS, a chartering solution for the shipping industry, which is a blockchain-based platform, launched in Geneva on September 20th, 2018. Using MARiS, ship owners and trading companies can be benefited from the advantages coming with blockchain technology such as high data quality and quantity, process integrity, configurable smart contracts, lower transaction costs, and many more.

It is the first in the market available chartering platform, where ship owners, brokers, and freight forwarders are able to execute their chartering process in full permission and distributed blockchain ledger. Beside MARiS' blockchain technology, the system has been awarded for its unique architecture and programmability covering all activities throughout the complete shipping and chartering lifecycle (Singular Point, press release, 2019).

MARiS is able to brake all the existing data boundaries and information silos that currently slow down the charter process so that the participants will face a new level of market efficiency, which will generate a better outcome for everyone.

STAGE

THREE

5.0 Research Methodology

The review of scientific papers and related articles that evaluate the adoption and the intention to use blockchain technology within several industries, such as supply chain, accounting, healthcare, and finance, shows that there is an optimistic perspective regarding the intention to use blockchain technology due to the expected improvement of the existing procedures. Also, concerns and potential limitations were identified, regarding the legal aspects, the shipping industry regulatory, and people's refusal to change the way they act. All these obstacles may result in a limited number of early adopters.

In order to measure the willingness of the Hellenic shipping industry to adopt and use blockchain applications in the near future, we conducted a quantitative survey.

The research model that has been used, was chosen among several theoretical technology acceptance models, and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) was identified as the most suitable because it is a synthesis of eight acceptance models. These include: TAM (Davis, 1989); theory of reasoned action (TRA) (Fishbein & Ajzen, 1975); motivational model (MM) (Davis, Bagozzi, & Warshaw, 1992); theory of planned behavior (TPB) (Ajzen, 1991); combined TAM and TPB (C-TAM-TPB) (Taylor & Todd, 1995), model of PC utilization (MPCU) (Thompson, Higgins, & Howell, 1991); innovation diffusion theory (IDT) (Moore & Benbasat, 1991); and social cognitive theory (SCT) (Compeau & Higgins, 1995).

An empirical testing by Venkatesh et al. (2003) determined that the UTAUT explained nearly 70 percent of the variance in usage intention, which was a significant improvement over any of the eight individual models evaluated.

5.1 Research Model

Drawing on the literature on UTAUT and its modifications, blockchain, maritime industry and the network theory, the model of Fig. 6 is presented to understand the willingness of blockchain adoption in the shipping industry field.

Upon review, the following constructs were identified as predictors of behavioral intention and behavioral expectation (derived and adopted from the literature on UTAUT and networks theory):

- Social influence
- Performance expectancy
- Facilitating conditions
- Effort expectancy

In the designed model, the constructs "Facilitating conditions" and "Effort expectancy" were excluded, as the technology is still new, has not yet used by the Hellenic shipping industry and the received answers would be unreliable.

Also, the Blockchains' transparency and trust among the Maritime's industry stakeholders, was chosen as an additional construct based on modifications of UTAUT model. Cullen et al. (2000) proposed that the relationship of mutual trust and commitment between organizations is essential for organizations to voluntarily share confidential information and knowledge and Nir et al. (2011) have proved that Inter-organizational trust has positive influence on inter-organizational knowledge sharing and collaboration. Blockchain, as described above, reinforces the trust between the related parties. Therefore, it has been decided to be measured as an additional construct in order to predict the behavioral intention and behavioral expectation.

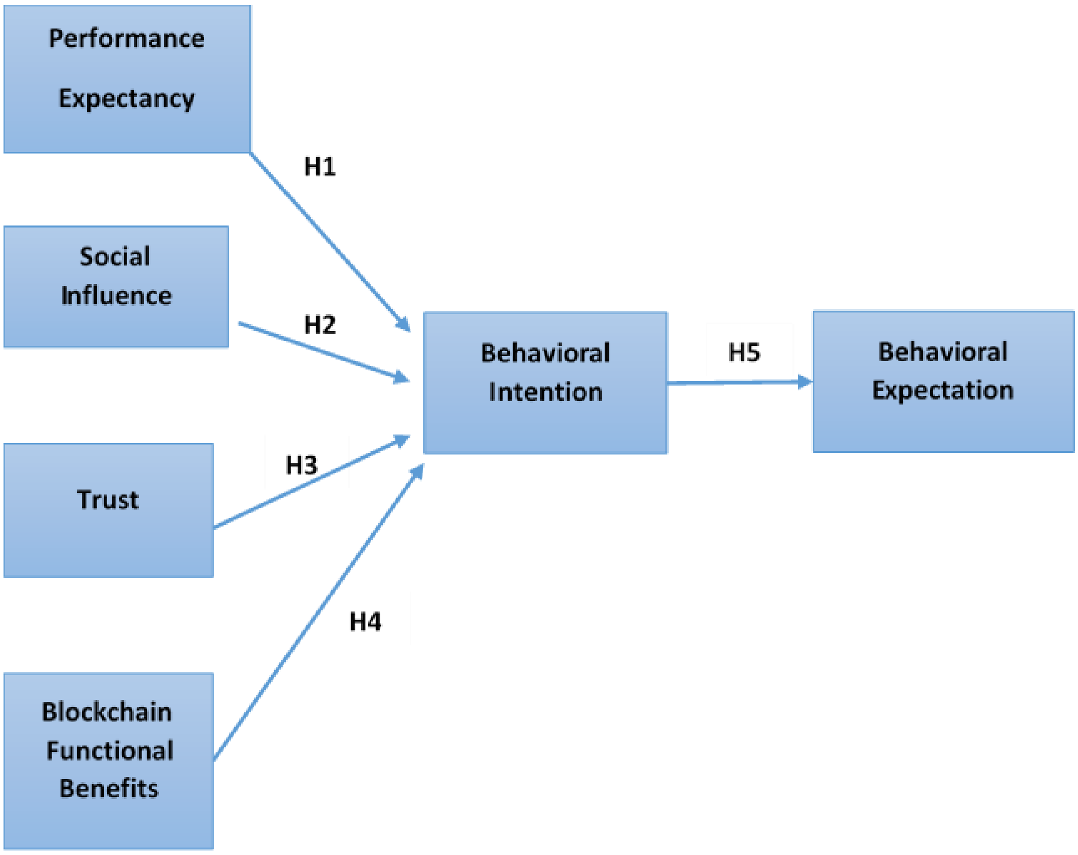

Figure 6 : Research Model

5.2 Development of Hypotheses

In this subsection, the selected constructs will be analyzed and the proposed hypotheses will be presented.

Performance expectancy (PEXP)

Performance expectancy (PEXP) is defined as “the degree to which an individual believes that using the system will help him or her to attain gains in job performance” (Venkatesh et al., 2003, p. 447). In this thesis, performance expectancy refers to the degree to which an employee in shipping industry perceives that using the blockchain applications will improve their productivity and performance (Queiroza & Wambab 2019). The blockchain applications can upgrade the efficiency and the quality of the provided services and they have raised expectations by improving the old fashioned processes of the shipping industry. Additionally, blockchain will minimize process complexity and uncertainty, especially with operations based on smart contracts (Kim & Laskowski, 2017). Alalwan, Dwivedi, & Rana (2017) have reported that the intention of employees to use and adopt a technology depends significantly on performance expectancy. Therefore, the following hypothesis is proposed:

H1. Performance expectancy positively affects the behavioral intention to adopt blockchain.

Social influence (SINF)

Social influence (SINF) is defined as “the degree to which an individual perceives that important others believe he or she should use the new system” (Venkatesh et al., 2003, p.451). For the purpose of this thesis, social influence will refer to the extent to which the employees are willing to adopt new technologies because other enterprises and organizations have already been using them. In the shipping industry, the interoperability of the IT systems, combined with the existing inter-firm relationships, has an important influence on whether to adopt the blockchain across the network. Hence, the following hypothesis is proposed:

H2. Social influence positively affects the behavioral intention to adopt blockchain.

Trust of shipping industry stakeholders (BTR)

Trust can be defined as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer, Davis, & Schoorman, 1995, p. 712). Trust is a fundamental aspect of all businesses. Its influence as a constructor on technology acceptance models is demonstrated in the literature (Liébana- Cabanillas et al., 2017; Lin, 2011; Riffai et al., 2012; Wu et al., 2011). On the other hand, the shipping industry is characterized by multiple and complex relationships, and as a result, cooperation needs trust in order to work effectively and smoothly. Unfortunately, the shipping industry network lacks transparency among the members, because most of the interested parties have never met or know each other. An efficient solution would be the use of Blockchain technologies, as they can minimize uncertainty and empower transparency throughout the entire industry. This is accomplished by the fact that Blockchain is a shared distributed ledger used in a network or ecosystem to record and verify transactions by a mechanism (consensus) that creates trust in the network. Therefore, the following hypothesis are proposed:

H3. Trust between Maritime's industry stakeholders positively affects behavioral intention to adopt blockchain.

Blockchain Functional Benefits (BFB)

The Blockchain Functional benefits or Net Benefits are defined as "the effect of an information system (IS) has on an individual which is often measured in terms of organizational performance, perceived usefulness, and effect on work practices" in accordance with Petter and McLean (2009, p.161), or "the extent to which IS are contributing to the success of individuals. For example, improved decision−making, improved productivity, increased sales, market efficiency, customer welfare, creations of jobs, and economic development" in accordance with Petter et al. (2008, p.239). These two empirical studies combined with the updated DeLone and McLean IS model (2003), define a relationship between net benefits and Intention to Use or Behavioral Intention. On the other hand, an Information System based on Blockchain technology has some benefits to add to the existing procedures in the maritime industry. Therefore, the following hypothesis is proposed:

H4. Blockchain Functional benefits positively affect behavioral intention for blockchain adoption.

Behavioral intention and expectation (BINT & BEXP)

Behavioral intention (BINT) is defined "as the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior (Warshaw & Davis, 1985, p. 214). On the other hand, behavioral expectation (BEXP), is defined "as the employee's evaluation of the probability to perform a particular behavior associated with the use of a technology in the future". Consistent with Venkatesh, "Behavioral expectation, reflects the strength of the focal behavioral intention over other (competing) behavioral intentions" (Venkatesh et al., 2008, p. 486). Consequently, the following hypothesis is proposed:

H5. Behavioral intention positively affects behavioral expectation for blockchain adoption.

5.3 Methodology

5.3.1 Questionnaire

An English questionnaire was created and reviewed for content validity by a group of university staff. The questionnaire was pilot tested by a group of 5 scholars and professionals involved in the shipping industry and IT, but they were not included in the main survey. After some corrections, the final questionnaire with a cover letter explaining the overall objectives of the survey was sent by email to the respondents. The Appendix A shows the constructs and their definitions as well as the literature on which the questions were based. The questionnaire contained a total of 30 questions (7 for constructing the demographic profile of the responders and 23 for measuring the selected constructs). All constructs were measured by a 7-point Likert scale (strongly disagree – strongly agree) (Akter, Fosso Wamba, & Dewan, 2017).

5.3.2 Sampling Design and Data Collection

The study's target sample was composed of maritime port corporations, shipping companies, shipping agencies, and shipping forwarders engaged in maritime shipping operations in Greece.

In accordance with www.greekshipping.gr, which is an unrivaled maritime database with detailed information and search capabilities, in March 2020, 772 shipping companies are registered in Greece. From these companies, we selected only those which have more than three ships and also we excluded the companies that possess passenger ships and tug boats. This exclusion was decided because shipping companies with less than three ships, are not probably stable and permanent in the shipping sector. In addition, the passenger and tug boat enterprises are not predicted to use blockchain in their operations and if they do so, they will use it when it becomes the only way to transact with their customers. On this bases, the number of the Hellenic shipping companies has been narrowed down to 368.

Additionally, the questionnaire was sent to officials from the port authorities of Piraeus, Thessaloniki, and Igoumenitsa as well as to five ship agents and two major freight forwarders. Finally, the questionnaire was distributed to a sample of 378 people. At the end of the survey, 63 answered questionnaires were collected, but only 57 were considered to have been appropriately filled out and therefore suitable for supplementary analysis (**response rate of 15.07%**).

5.4 Data Analysis

The data analysis has been conducted with the use of IBM SPSS Statistics v.21 software, in order to analyze the proposed model. The results are presented below, together with the measurement model.

5.4.1 Descriptive Analysis

Table 6 shows the respondents' demographic profile. The percentage of males and females respondents was 82.5 and 17.5 %, respectively. This was predictable as the maritime industry in Greece is a traditionally male-dominated sector. In terms of age, most respondents were between 42 and 49 years old (33.3 percent). Considering the education level, 59.6 percent of the respondents hold a postgraduate degree, whereas 26.3 percent hold a bachelor's degree. Descriptive statistics also indicate that 50.9 percent of the respondents have been working in an organization for at least 6 years, followed by those (38.6 percent) with 2–5 years' experience. The majority of the respondents belong to shipping companies' (82.5 percent), which have 21-50 ships (41.3 percent) and more than 50 ships 21.7 percent. Additionally, another very important fact which has been noticed is that **42.2 percent** of the respondents belong to C-Level or they are Directors/Managers/Supervisors. They belong to the decision-making group and they have the higher influence in the strategic decision process relating to blockchain technology adoption.

Table 6: Demographic profile (n=57)

	Frequency	%
Gender		
Male	47	82.5
Female	10	17.5
Age		
18-25	4	7
26-33	16	28.1
34-41	12	21.1
42-49	19	33.3
50+	6	10.5
Highest educational level		
No formal education	0	0
Primary	0	0
Secondary	2	3.5
Diploma/polytechnic	6	10.5
Bachelor’s degree	15	26.3
Postgraduate degree (Master/Ph.D.)	34	59.6
Number of years working in the organization		
Less than one year	6	10.5
2-5 years	22	38.6
6-10 years	11	19.3
11-15 years	7	12.3
16-20 years	7	12.3
Over 20 years	4	7
Industry / Field		
Shipping company	47	82.5
Port	3	5.3
Ship agent	5	8.8
Logistics/Freight Forwarder	2	3.6
Seniority		
C-Level	4	7.1
Manager/Supervisor/Director	20	35.1
Operator	33	57.8
No of ships (for the S.C.)		
3-5 ships	3	6.5
6-20 ships	19	41.3
21-50 ships	14	30.4
More than 50 ships	10	21.7

Willingness of the Hellenic shipping industry to adopt Blockchain

Introduction

By analyzing the Mean, Median and Skewness of BEXP, we will answer the first part of our RQ2, which is "**How likely is for the blockchain technology to be adopted by the Hellenic shipping industry actors**". The range of our constructs is from 1 to 7, so Means over 3.5 show a positive intention to adopt blockchain. Also a negative value of Skewness shows that more answers are distributed in the range of "Somewhat agree" to "Strongly agree".

Results

Table 7 shows the values of Mean, Median and Skewness of BEXP.

Table 7: BEXP Mean, Median and Skewness

			Statistic	Std. Error
BEHAVIORAL EXPECTATION	Mean		4.2807	.20281
	95% Confidence Interval for Mean	Lower Bound	3.8744	
		Upper Bound	4.6870	
	5% Trimmed Mean		4.3239	
	Median		4.3333	
	Variance		2.344	
	Std. Deviation		1.53114	
	Minimum		1.00	
	Maximum		7.00	
	Range		6.00	
	Skewness		-.500	.316

Behavioral Expectation (BEXP) has a Mean=4.2807 which is greater than 3.5 Median=4.3333 and Skewness=-0.500. These values are clearly verify that the Hellenic shipping industry has the intention to adopt blockchain technology.

5.4.2 Measurement Model

Our model was developed based on the prior literature and mainly on the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003). The constructs and its indicators were chosen from prior researches and they are suitable for explaining technology adoption. The three indicators related to BTR were chosen according to the literature on the supply chain, which includes the ocean transportation of goods. The indicators show the level of trust among shipping industry members when they make blockchain-enabled transactions. The four indicators related to PEXP contribute to measure the professional's expectancy in relation to their job improvement. The five BFB indicators are associated with the effect of an information system (IS) on an individual which is often measured in terms of organizational performance, perceived usefulness, and effect on work practices. The BINT has four indicators and reflects the intention to use blockchain in a short time. As for the BEXP, it also has three indicators and reflects both internal and external factors in predicting behavior.

Table 8 shows the outer loadings. It clearly appears that all have a value higher than the threshold value of 0.7 (Hair et al., 2017), except BFB 4, BFB 5, SINF 3 and BTR3.

Table 8: Outer Loadings

CONSTRUCT	ITEM	LOADINGS
BFB	BFB1	0.807
	BFB2	0.738
	BFB3	0.810
	BFB4	0.649
	BFB5	0.628
SINF	SINF1	0.788
	SINF2	0.750
	SINF3	0.687
	SINF4	0.750
BTR	BTR1	0.894
	BTR2	0.879
	BTR3	0.520
PEXP	PEXP1	0.810

	PEXP2	0.790
	PEXP3	0.840
	PEXP4	0.706
BINT	BINT1	0.959
	BINT2	0.937
	BINT3	0.913
	BINT4	0.712
BEXP	BEXP1	0.871
	BEXP2	0.899
	BEXP3	0.808

Shapiro-Wilk Test (Normality test)

Results

Shapiro-Wilk tests were conducted in order to determine whether the distributions of PEXP, BINT, SINF, BEXP, BFB, and TRUST were significantly different from a normal distribution. The following variables had distributions which significantly differed from normality based on an alpha of 0.05: PEXP (W = 0.88, p < .001), SINF (W = 0.90, p < .001), BEXP (W = 0.95, p = .017), and BFB (W = 0.84, p < .001). The following variables had distributions which did not significantly differ from normality based on an alpha of 0.05: BINT (W = 0.98, p = .435) and TRUST (W = 0.97, p = .149). Due to the non-normal distribution of the structures, nonparametric statistic tests are going to be used for the rest of the analysis.

Table 9: Shapiro-Wilk Test Results

Variable	W	p
PEXP	0.88	< .001
BINT	0.98	.435
SINF	0.90	< .001
BEXP	0.95	.017
BFB	0.84	< .001
TRUST	0.97	.149

Reliability

Introduction

A Cronbach alpha coefficient was calculated for:

- The BFB scale, consisting of BBF1, BBF2, BBF3, BBF4, and BBF5
- The SINF scale, consisting of SINF1, SINF2, SINF3, and SINF4
- The BTR scale, consisting of BTR1, BTR2, and BTR3
- The PEXP scale, consisting of PEXP1, PEXP2, PEXP3, and PEXP4
- The BINT scale, consisting of BINT1, BINT2, BINT3, and BINT4
- The BEXP scale, consisting of BEXP1, BEXP3, and BEXP2

The Cronbach's alpha coefficient was evaluated using the guidelines suggested by George and Mallery (2016) where > .9 excellent, > .8 good, > .7 acceptable, > .6 questionable, > .5 poor, and ≤ .5 unacceptable.

Results

The items for BFB, SINF, PEXP, and BEXP had a Cronbach's alpha coefficient of 0.90, 0.90, 0.91, and 0.92 respectively, and indicating excellent reliability. The items for BTR and BINT had a Cronbach's alpha coefficient of 0.80 and 0.88 respectively, indicating good reliability. Table 10 presents the results of the reliability analysis.

Table 10: Reliability Table

Scale	No. of Items	α	Lower Bound	Upper Bound
BFB	5	0.90	0.85	0.94
SINF	4	0.90	0.86	0.95
BTR	3	0.80	0.70	0.90
PEXP	4	0.91	0.86	0.95
BINT	4	0.88	0.83	0.93
BEXP	3	0.92	0.88	0.96

Note. The lower and upper bounds of Cronbach's α were calculated using a 95.00% confidence interval.

5.4.3 Hypotheses Testing

A Spearman correlation analysis was conducted to test the hypotheses.

Spearman Correlation Analysis

Introduction

A Spearman correlation analysis was conducted between PEXP, BTRU, SINF, BFB and BINT and between BINT and BEXP. Cohen's standard was used to evaluate the strength of the relationship, where coefficients between .10 and .29 represent a small effect size, coefficients between .30 and .49 represent a moderate effect size, and coefficients above .50 indicate a large effect size (Cohen, 1988).

Assumptions

Monotonic Relationship. A Spearman correlation requires that the relationship between each pair of variables does not change direction (Conover & Iman, 1981). This assumption is violated if the points on the scatterplot between any pair of variables appear to shift from a positive to negative or negative to positive relationship. Figure 7 presents the scatterplots of the correlations. A regression line has been added to assist the interpretation.

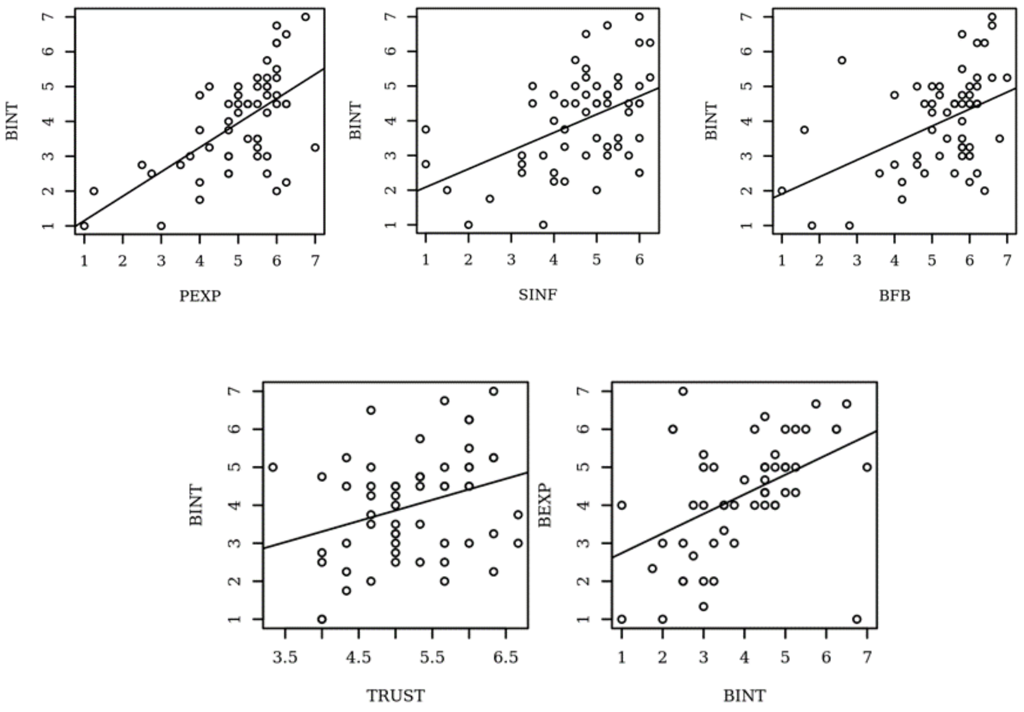

Figure 7: Scatterplots between each variable with the Regression Line Added

Results

The correlations were examined based on an alpha value of 0.05.

A significant positive correlation was observed between **PEXP and BINT** (H1) (rs = 0.55, p < .001). The correlation coefficient between PEXP and BINT was 0.55, indicating a large effect size.

A significant positive correlation was observed between **SINF and BINT** (H2) (r_s = 0.43, p < .001). The correlation coefficient between SINF and BINT was 0.43, indicating a moderate effect size. This correlation indicates that as SINF increases, BINT tends to increase.

A significant positive correlation was observed between **BTR and BINT** (H3) (r_s = 0.31, p = .003). The correlation coefficient between BTR and BINT was 0.31, indicating a moderate effect size. This correlation indicates that as BTR increases, BINT tends to increase.

A significant positive correlation was observed between **BFB and BINT** (H4) (r_s = 0.41, p = .002). The correlation coefficient between BFB and BINT was 0.41, indicating a moderate effect size. This correlation indicates that as BFB increases, BINT tends to increase.

A significant positive correlation was observed between **BINT and BEXP** (H5) (r_s = 0.50, p < .001). The correlation coefficient between BINT and BEXP was 0.50, indicating a moderate effect size. This correlation indicates that as BINT increases, BEXP tends to increase. Table 11 presents the results of the correlation.

Table 11: Spearman Correlation Results

	Combination	r_s	Lower	Upper	p
H1:	**PEXP-BINT**	0.55	0.33	0.71	< .001
H2:	**SINF-BINT**	0.43	0.19	0.62	< .001
H3:	**BTR-BINT**	0.31	0.05	0.53	.003
H4:	**BFB-BINT**	0.41	0.17	0.61	.002
H5:	**BINT-BEXP**	0.50	0.27	0.67	< .001

Note. The confidence intervals were computed using $\alpha = 0.05$; $n = 57$

Linear Regression Analysis

Introduction

A linear regression analysis was conducted to assess whether BFB, BTR, PEXP, BINT, and SINF significantly predicted BEXP. The 'Enter' variable selection method was chosen for the linear regression model, which includes all of the selected predictors.

Assumptions

Normality. The assumption of normality was assessed by plotting the quantiles of the model residuals against the quantiles of a Chi-square distribution, also called a Q-Q scatterplot (DeCarlo, 1997). For the assumption of normality to be met, the quantiles of the residuals must not strongly deviate from the theoretical quantiles. Strong deviations could indicate that the parameter estimates are unreliable. Figure 8 presents a Q-Q scatterplot of the model residuals.

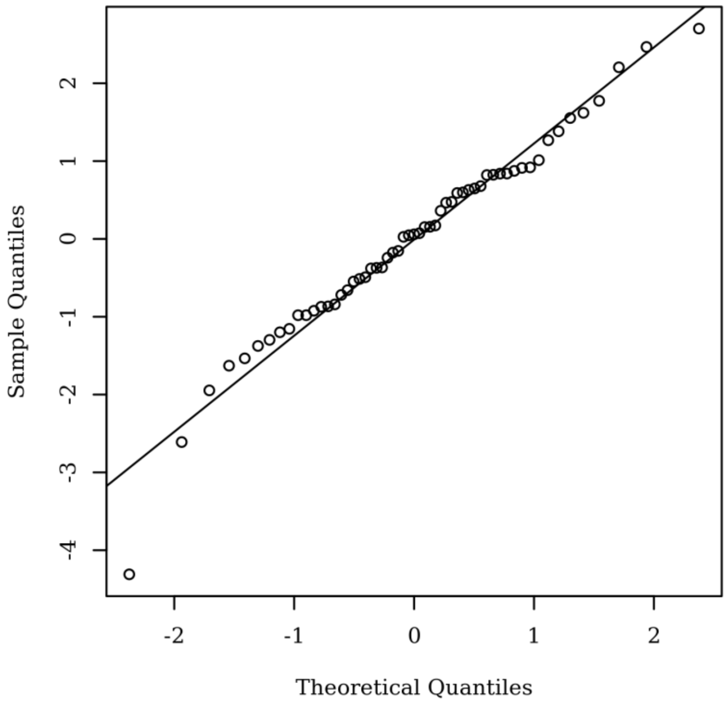

Figure 8: Q-Q scatterplot for normality of the residuals for the regression model.

Homoscedasticity. Homoscedasticity was evaluated by plotting the residuals against the predicted values (Bates et al., 2014; Field, 2013; Osborne & Walters, 2002). The assumption of homoscedasticity is met if the points appear randomly distributed with a mean of zero and no apparent curvature. Figure 9 presents a scatterplot of predicted values and model residuals.

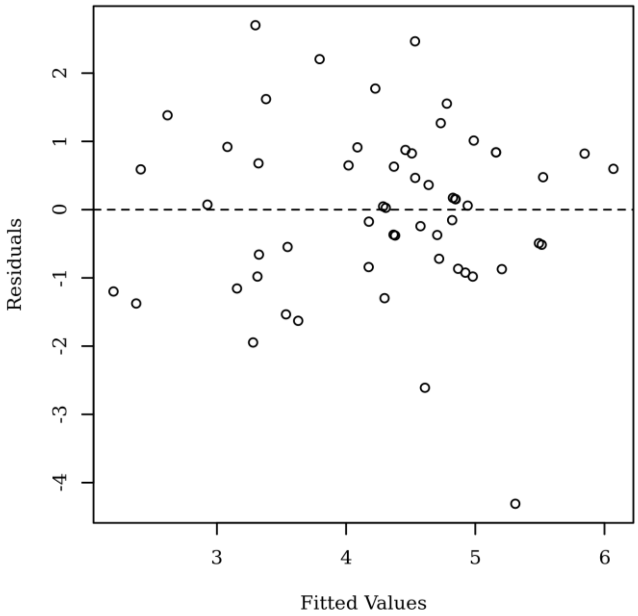

Figure 9: Residuals scatterplot testing homoscedasticity

Multicollinearity. Variance Inflation Factors (VIFs) were calculated to detect the presence of multicollinearity between predictors. High VIFs indicate increased effects of multicollinearity in the model. VIFs greater than 5 are cause for concern, whereas VIFs of 10 should be considered the maximum upper limit (Menard, 2009). All predictors in the regression model have VIFs less than 10. Table 12 presents the VIF for each predictor in the model.

Table 12: Variance Inflation Factors for BFB, BTR, PEXP, BINT, and SINF

Variable	VIF
BFB	3.07
BTR	1.39
PEXP	3.81
BINT	1.60
SINF	2.64

Outliers. To identify influential points, Studentized residuals were calculated and the absolute values were plotted against the observation numbers (Field, 2013; Stevens, 2009). Studentized residuals are calculated by dividing the model residuals by the estimated residual standard deviation. An observation with a Studentized residual greater than 3.24 in absolute value, the 0.999 quartile of a *t* distribution with 56 degrees of freedom, was considered to have significant influence on the results of the model. Figure 10 presents the Studentized residuals plot of the observations. Observation numbers are specified next to each point with a Studentized residual greater than 3.24.

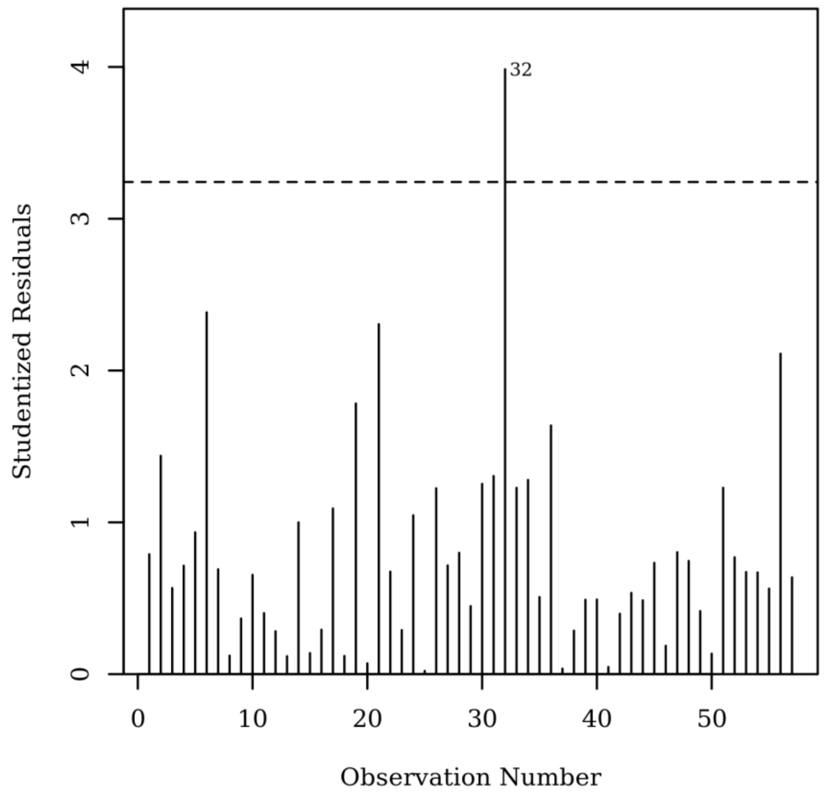

Figure 10: Studentized residuals plot for outlier detection

Results

The results of the linear regression model were significant, $F(5,51) = 5.26$, $p < .001$, $\boldsymbol{R^2 = 0.34}$, indicating that approximately 34% of the variance in BEXP is explainable by BFB, BTR, PEXP, BINT, and SINF. BFB did not significantly predict BEXP, $B = -0.24$, $t(51) = -1.03$, $p = .310$. Based on this sample, a one-unit increase in BFB does not have a significant effect on BEXP. BTR significantly predicted BEXP, $B = -0.63$, $t(51) = -2.39$, $p = .020$. This indicates that on average, a one-unit increase of BTR will decrease the value of BEXP by 0.63 units. PEXP did not significantly predict BEXP, $B = 0.51$, $t(51) = 1.82$, $p = .075$. Based on this sample, a one-unit increase in PEXP does not have a significant effect on BEXP. BINT significantly predicted BEXP, $B = 0.37$, $t(51) = 2.35$, $p = .023$. This indicates that on average, a one-unit increase of BINT will increase the value of BEXP by 0.37 units. SINF did not significantly predict BEXP, $B = 0.20$, $t(51) = 0.88$, $p = .382$. Based on this sample, a one-unit increase in SINF does not have a significant effect on BEXP. Table 13 summarizes the results of the regression model.

Table 13: Results for Linear Regression with BFB, BTR, PEXP, BINT, and SINF predicting BEXP

Variable	*B*	*SE*	CI	β	*t*	*p*
(Intercept)	3.87	1.24	[1.38, 6.37]	0.00	3.11	.003
BFB	-0.24	0.24	[-0.72, 0.23]	-0.20	-1.03	.310
BTR	-0.63	0.26	[-1.16, -0.10]	-0.32	-2.39	.020
PEXP	0.51	0.28	[-0.05, 1.07]	0.40	1.82	.075
BINT	0.37	0.16	[0.05, 0.69]	0.34	2.35	.023
SINF	0.20	0.22	[-0.25, 0.65]	0.16	0.88	.382

Note. CI is at the 95% confidence level. Results: $F(5,51) = 5.26$, $p < .001$, $\boldsymbol{R^2 = 0.34}$
Unstandardized Regression Equation:

BEXP = 3.87 - 0.24*BFB - 0.63* BTR + 0.51*PEXP + 0.37*BINT + 0.20*SINF

5.5 Discussion

Based on theories concerning technology acceptance models, with special focus on UTAUT (Venkatesh et al., 2003), a theoretical research model was developed and proposed to help understand the individual behavior on blockchain adoption and use in the Hellenic maritime industry. Prior literature does not include outstanding research on blockchain adoption from the Hellenic maritime industry using the UTAUT model or its variation on blockchain adoption. This is why our model presents new constructs that may help to predict behavioral intention and behavioral expectation. Thus, we incorporated BTRU as a predictor of BINT (H3), and BFB as a predictor of BINT (H4).

In line with the prior literature, PEXP (H1), SINF (H2), BTR (H3) and BFB (H4) had a significant positive correlation with BINT (Venkatesh et al., 2003, Liébana-Cabanillas et al., 2017; Lin, 2011; Riffai et al., 2012; Wu et al., 2011, DeLone & McLean, 2003), and BINT (H5) had a significant positive correlation with BEXP (Venkatesh et al., 2003).

Surprisingly, the Linear Regression Analysis indicated that BTR and BFB have a negative influence on BEXP. These non-predicted negative effects on adoption behavior can be explained by the fact that the responders do not have practical experience on the blockchain technology and they cannot estimate the benefits that they will gain from its usage.

The value of R^2 accounted in BEXP (34%) seems to be low. R^2 is typically higher, because it is easier to specify complete, well-specified models. But in the social sciences, where it is hard to specify such modes, low R^2 values are often expected. Studies that attempt to predict human behavior generally have R-squared values less than 50% because people are hard to predict (Frost J., n.d.). Also, the exclusion of two basic constructs of the UTAUT model (Facilitating conditions and Effort expectancy) may cause a lower R^2 value.

The results bring valuable contributions to the theory and for practice. The proposed model showed relationships with strong coefficients and although the adoption of blockchain in the maritime industry is quite recent, the shipping companies' managers which will involve in blockchain adoption projects, would be benefited from the offered findings.

In conclusion, the Hellenic Shipping Industry is willing to adopt the blockchain technology and Performance Expectancy, Social Influence, Trust and Blockchain Functional Benefits have a significant positive correlation with Behavioral Intention and Behavioral Intention has a significant positive correlation with the intention of the Hellenic’s shipping industry stakeholders to adopt and use this new.

6.0 Conclusions

To provide an insight into the research questions, this thesis, through the First Stage, recognized the shipping industry sectors which can be benefited from the blockchain implementation. Among them, Bill of Lading seems to be the most difficult case, but also the most promising. By adopting a blockchain-based platform for BoLs, the shipping industry will fill a giant gap between todays' paper-based procedures and the future digitalized ones. The chartering and brokering sectors, through the implementation of Smart and Ricardian Contracts, will gain a more efficient, transparent and cost effective shape, saving valuable time and funds for their users. Finally, all the sectors which handle documents and crucial characteristics such as authenticity and uniqueness will play a decisive role, as the implementation of the blockchain will enable them to eliminate fraud and drastically reduce their operating costs. Also, they will be able to upgrade the cyber security through the hack-proof capabilities of a DLT-based application.

At Stage Two, the demonstrated use cases of blockchain-based applications and platforms, give us a representative example of the new age in shipping industry transactions. New applications constantly appear and new alliances between shipping and IT companies are created. This proves the willingness of the shipping industry to adopt blockchain, in a general digital transformation framework. On the other hand, the blockchain and the DLTs in general, are still facing many challenges to overcome. Industry standards and operating regulations must be defined. For those reasons, governments and international regulators such as IMO must take the lead and steer the course of the digital evolution. Moreover, the Hellenic shipping industry participants need to be prepared for the new technology as it is coming and they need to be ready to be able to take advantage of this game-changing technology. Additionally, more steps have to be made on the technology development from the Hellenic Institutes and Universities and include this innovative technology in their curricular in order to prepare the students and man the IT companies with the appropriate professionals.

The Hellenic government can be also benefited from this technological revolution. As mentioned in Chapter 3, a legislative framework is crucial for the appliance of blockchain technology. Greece, by applying the following steps, combined with the influence that the Hellenic shipping companies exerts on the global ocean transports, can become the new global "Shipping Center". Firstly, it has to apply a framework based on international legislation like the UNCITRAL Model Law on Electronic Transferable Records and enact more blockchain-friendly laws. Secondly, a specialized blockchain shipping court, properly staffed by judges specialized in maritime law and with the appropriate technological know-how, needs to be created. The same strategy had been applied by Great Britain, when it enforced the English Law, using its 'shipping power' which it had during the 18^{th} and 19^{th} century in the maritime procedures and establishing London as the shipping center of the non-digital era.

Finally, at the Third Stage of this thesis, some light was shed on blockchain adoption behaviour by the Hellenic shipping industry, while taking into account the behaviour of the adopters from the most influential sectors. By analysing the collected data from the distributed questionnaire, **a willing behaviour to adopt blockchain from the Hellenic shipping has been proved**. Also, the investigation of the constructs "Performance Expectancy", "Social Influence", "Trust" and "Functional Benefits" have a significant positive correlation with the intention of the Hellenic's shipping industry stakeholders to adopt and use this new technology.

This conclusion, combined with the global shipping trend, is very important for the future strategic planning of the Hellenic shipping industry. In other words, the Hellenic shipping industry must be aware of the blockchain evolution in order to continue to play a preponderant and substantial part in the world's shipping activities.

6.1 Limitations and Future Research

Although this thesis' objectives were accomplished, several limitations have to be addressed in future research.

Firstly, the proposed model considers a limited number of constructs to explain and predict the blockchain adoption from the Hellenic shipping industry. Future researchers may consider extending the model by adding constructs, like the Effort Expectancy (EFEXP) and Facilitating Conditions (FCON).

Secondly, the research can be expanded to a greater sample or for a greater period of time in order to collect more data from respondents.

Thirdly, it would be interesting to conduct the same survey after presenting and explaining the blockchain benefits, in front of a high-seniority level audience (CEOs and General Managers) of the Hellenic shipping industry.

Finally, the fact that the proposed model was tested only in one of the greatest in shipping industry countries, does not give us the adequate leeway to generalize the results. Thus, it will open a research avenue that will consist of the application of comparative blockchain adoption models in other countries.

References

Akter, S., Fosso Wamba, S., & Dewan, S. (2017). *Why PLS-SEM is suitable for complex modelling? An empirical illustration in big data analytics quality. Production Planning and Control*, 28(11–12), 1011–1021. Available: https://doi.org/10.1080/09537287.2016.1267411.

Albrecht, C. (2018). *Blockchain Bills of Lading: The End of History*. *Overcoming Paper-Based Transport Documents in Sea Carriage through New Technologies*. Tul. Mar. LJ, 43, pp.251.

Ali, S., Wang, G., White, B., & Fatima, K. (2019). *Libra Critique Towards Global Decentralized Financial System*. In International Conference on Smart City and Informatization (pp. 661-672). Springer, Singapore.

Althobaiti M., Mayhew P., (2016) "*Assessing the Usability of Learning Management System: User Experience Study*," Int. Conference on E-Learning, E-Education, and Online Training, pp. 9-18.

Anwar, M. (2019). *"The feasibility of Blockchain solutions in the maritime industry*." In *The 31st Annual NOFOMA Conference*. The Nordic Logistics Research Network (NOFOMA).

Athanasiadis C., Lens C.Z., Koutsoukos D., Hortal E. and Asteriadis S., (2017) "*Personalized, affect and performance-driven Computer-based Learning,"* 9th Int. Conference on Computer Supported Education, Porto, Portugal. Available at: https://www.ibm.com/blogs/think/2017/03/trade-and-blockchain/

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). *Fitting linear mixed-effects models using lme4*: arXiv preprint arXiv, Journal of Statistical Software.

Biazetti, A., (2019) "*Setting Trade Free with Permissions*," TradeLens Blog.

Brunner R., (2007), *Electronic transport documents and shipping practice not yet a married couple*, LL.M. Shipping Law.

Cachin, C. (2016). *Architecture of the hyperledger blockchain fabric.* In Workshop on distributed cryptocurrencies and consensus ledgers (Vol. 310, p. 4).

Chang, Y., Iakovou, E., & Shi, W. (2019). *Blockchain in Global Supply Chains and Cross Border Trade: A Critical Synthesis of the State-of-the-Art, Challenges and Opportunities*. arXiv preprint arXiv:1901.02715.

Cohen, J. (1988). *Statistical power analysis for the behavior sciences* (2nd ed.). West Publishing Company.

Conover, W. J., & Iman, R. L. (1981). *Rank transformations as a bridge between parametric and nonparametric statistics.* The American Statistician, *35*(3), 124-129.

Crawford, S., Russignan, L., & Kumar, N. (2018). *Global insurance trends analysis*.

Czachorowski, K., Solesvik, M., & Kondratenko, Y. (2019). *"The Application of blockchain technology in the maritime industry",* in Green IT Engineering: Social, Business and Industrial Applications (pp. 561-577). Springer, Cham.

DeCarlo, L. T. (1997). *On the meaning and use of kurtosis. Psychological Methods*, 2(3), 292-307

DeLone H., McLeann E.R., (1992) *Information systems success: The quest for the dependent variable information Systems Research*, 3 (1), pp. 60-95.

Field, A. (2013). *Discovering statistics using SPSS (4th ed.)*. Sage Publications

Frost J., (n.d.), "*Introduction to Statistics: An Intuitive Guide", e-book.* Available: https://statisticsbyjim.com/

Grigg I., (2004). *The Ricardian Contract. In Proceedings of the First IEEE International Workshop on Electronic Contracting*, pages 25-31. IEEE, http://iang.org/papers/ricardian_contract.html

Gronholt-Pedersen, Jacob. (2019) "*MSC, CMA CGM to board Maersk's shipping blockchain platform*," Reuters.

Gupta, M. (2017), *Blockchain for Dummies, IBM Limited Edition.* Wiley, Hoboken NJ N. Szabo,(1994), *Smart Contracts*, Available: http://szabo.best.vwh.net/smart.contracts.html.

Harshvardhan. *Improving shipping contracts with the use of Blockchains*, MIT, Available:https://ctl.mit.edu/sites/ctl.mit.edu/files/theses/executive_summary_harshvardhan.pdf

Herd J., (n.d.), '*BLOCKS OF LADING' Distributed Ledger Technology and the Disruption of Sea Carriage Regulation*, QUT Law Review – Vol 18, No 2

Hughes, A., Park, A., Kietzmann, J., & Archer-Brown, C. (2019). *Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms.* Business Horizons, 62(3), 273-281.

Imeri, A., Khadraoui, D., & Agoulmine, N. (2019). *Blockchain Technology for the Improvement of SCM and Logistics Services: A Survey*. In Industrial Engineering in the Big Data Era (pp. 349-361). Springer, Cham.

Intellectus Statistics [Online computer software]. (2020). *Intellectus Statistics*. https://analyze.intellectusstatistics.com/

Jensen, T., Hedman, J., & Henningsson, S. (2019). *How TradeLens Delivers Business Value With Blockchain Technology*. MIS Quarterly Executive, 18(4).

Kosowatz, J. (2019). *Sailing Toward Autonomy*. *Mechanical Engineering*, *141*(09), 30-35.

Menard, S. (2009). *Logistic regression: From introductory to advanced concepts and applications*. Sage Publications.

Moreira, T. (2019). UNCTAD–*United Nations Conference for Trade and Development is the International Forum to Discuss Global Consumer*

Protection Issues. Journal of European Consumer and Market Law, *8*(4), 133-135.

Murray, D., (1983) *History, and Development of the Lading Bill*.

N. Szabo, *The Idea of Smart Contracts*, 1997, Available: http://szabo.best.vwh.net/smart_contracts_idea.html.

Nasaruddin, M. M., & Emad, G. R. (2019). *Preparing maritime professionals for their future roles in a digitalized era: bridging the blockchain skills gap in maritime education and training.* In The International Association of Maritime Universities (IAMU) Conference (pp. 87-97).

Osborne, J., & Waters, E. (2002). *Four assumptions of multiple regression that researchers should always test. Practical Assessment, Research & Evaluation*, 8(2), 1-9.

Petter S., McLean E.R., (2009), *A meta-analytic assessment of the DeLone and McLean IS success model: An examination of IS success at the individual level Information & Managemen*t, 46 (3), pp. 159-166

Petter S., William D., McLean E.P., (2008), *Measuring information systems success: Models, dimensions, measures, and interrelationships*, European Journal of Information Systems, 17 (3), pp. 236-263

Philipp, R., Prause, G., & Gerlitz, L. (2019). *Blockchain and Smart Contracts for Entrepreneurial Collaboration in Maritime Supply Chains*. Transport and Telecommunication Journal, *20*(4), 365-378.

Praetorius, G., Hult, C., & Sandberg, C. (2019, July). *Towards Autonomous Shipping–Exploring Potential Threats and Opportunities in Future Maritime Operations*. In International Conference on Applied Human Factors and Ergonomics (pp. 633-644). Springer, Cham.

Reni, A., Hidayat, S., Bhawika, G. W., Ratnawati, E., & Thanh, P. (2020). *Maritime Technology and the Industrial Revolution*. *Journal of Environmental Treatment Techniques*, *8*(1), 250-253.

Salimitari, Mehrdad and Chatterjee, (2019) "*A Survey on Consensus Protocols in Blockchain for IoT Networks,*" pp. 7-12. 23

Singular Point, *press release*, 2019, Available: https://www.singular-point.com/en/news/details/1/Blockchain-Technology-in-the-Shipping-Industry

Stellnberger M., (2020), *Document Certification Through the Blockchain*. Available: https://www.martinstellnberger.co/document-certification-through-the-blockchain

Stevens, J. P. (2009). *Applied multivariate statistics for the social sciences (5th ed.)*. Routledge Academic.

Stopford M., (2009). *Maritime economics*, London: Routledge.

Stopford, M. (2009). *Maritime economics 3e*. Routledge.

Suominen, K. (2018). *Closing in on the holy grail of world trade: Using blockchain to expand Southeast Asia's trade*. Retrieved from Geneva, Switzerland*:* https://www.ictsd.Org/sites/default/files/research/blockchain_ in_southeast_asia_- _suominen. pdf.

Svarc J., Dabic M., (2015) "*Evolution of the Knowledge Economy: a Historical Perspective with an Application to the Case of Europe*," Journal of the Knowledge Economy, vol.8, pp. 1-18.

Takahashi, Koji. (2019) *"Bahraini legislation based on the UNCITRAL MLETR"*. Blockchain, Cryptocurrency, Crypto-asset and the Law. Retrieved 12 February 2019.

Takahashi, Koji. (n.d.), *"Relevance of the blockchain technology to the draft Model Law on Electronic Transferable Recores (as acknowledged by the latest official document)"*. Blockchain, Cryptocurrency, Crypto-asset and the Law.

Teece, D. J., Pisano, G., & Shuen, A. (1997). "*Dynamic capabilities and strategic management*." Strategic management journal, *18*(7), p.509-533.

UNCITRAL (2017). *Model Law on Electronic Transferable Records and Explanatory Note.*

UNCTAD, (2013), *The Use Of Transport Documents In International Trade*.

UNCTAD, 2019, *Review of Maritime Transport*, Available at: https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

Van Kralingen, B., (2017). *Lowering the Barriers to Global Trade with Blockchain.*

Venkatesh, V., & Bala, H. (2008). *TAM3 technology acceptance model 3 and a research agenda on interventions*. Decision Sciences, 39(2), 273–315. https://doi.org/10.1111/

Venkatesh, V., & Brown, S. A. (2001). *A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges*. MIS Quarterly, 25(1), 71. https://doi.org/10.2307/3250959.

Venkatesh, V., & Davis, F. D. (2000). *A theoretical extension of the technology acceptance model: Four longitudinal field studies*. Management Science, 46(2), 186–204. https://doi.org/10.1287/mnsc.46.2.186.11926.

Venkatesh, Brown, Maruping, & Bala (2008). *Predicting different conceptualizations of system use: The competing roles of behavioral intention, facilitating conditions, and behavioral expectation*. MIS Quarterly, 32(3), 483. https://doi.org/10.2307/25148853.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). *User acceptance of information technology: Toward a unified view*. MIS Quarterly, 27(3), 425–478. https://doi.org/10.2307/30036540.

Venkatesh, V., Thong, J., & Xu, X. (2012). *Consumer acceptance and user of information technology: Extending the unified theory of acceptance and use of technology*. MIS Quarterly, 36(1), 157–178.https://doi.org/10.1111/j.1365-2729.2006.00163.x.

Wagner, N., & Wiśnicki, B. (2019). *Application of blockchain technology in maritime logistics*. In DIEM: Dubrovnik International Economic Meeting (Vol. 4, No. 1, pp. 155-164). Sveučilište u Dubrovniku.

Wood, G. (2014). *Ethereum: A secure decentralised generalised transaction ledger*. Ethereum project yellow paper, *151*(2014), 1-32.

Yang, C. S. (2019). *Maritime shipping digitalization: Blockchain-based technology applications, future improvements, and intention to use. Transportation Research Part E: Logistics and Transportation Review*, 131, pp108-117.

Yi, M. Y., Jackson, J. D., Park, J. S., & Probst, J. C. (2006). *Understanding information technology acceptance by individual professionals: Toward an integrative view*. Information & Management, 43, 350–363. Available at: https://doi.org/10.1016/j.im.2005.08.006.

Zhou S., Feng A. J., & Jiang, S. (2019). "*Dynamic capabilities and organizational performance: The mediating role of innovation*". Journal of Management & Organization, 25(5), p.731-747.

ZIM, (2019), *Press Releases*, Available: https://www.zim.com/news/press-releases/zim-s-blockchain-based-bl-s-initiative

Zin, M. I. M. (2019). *"Blockchain opportunities in the maritime industry liner industry."*

Internet References

https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Consultations/Consultation-Papers/Public-Consultation-on-the-Review-of-the-Electronic-Transactions-Act/Public-Consultation-Paper-on-the-Review-of-the-Electronic-Transactions-Act-27-Jun-2019.pdf) https://www.igpandi.org/article/international-group-circular-bills-lading-and-blockchain-based-system

http://www.bolero.net/

http://www.essdocs.com/

http://www.e-title.net/

https://www.globalshare.com.ar/

http://www.wavebl.com/

https://cargox.io/CargoX-Business-Overview-Technology-Bluepaper.pdf

https://cargox.io/

https://www.investopedia.com/terms/n/negotiable-bill-of-lading.asp

https://cointelegraph.com/news/what-is-the-difference-between-blockchain-and-dlt

https://www.hyperledger.org/projects/fabric

https://www.r3.com/corda-platform/

https://www.scidex.co/

https://blockchainhub.net/blockchains-and-distributed-ledger-technologies-in-general/

Appendix A. Survey instrument

Table 14: Indicators of the Research Model

Construct	Cod	Indicators	Adapted from
Blockchain Functional Benefits (BFB)	BFB1	I will use blockchain technology because I believe that it ensures the traceability of the information, and avoid false claims.	Authors' proposal based on DeLone and McLean IS model (2003).
	BFB2	I will use blockchain technology because I believe that it will speed up customs clearance and management, in general, of maritime transport.	
	BFB3	I will use blockchain technology because I believe that it will digitize and reduce paperwork in the maritime industry.	
	BFB4	I will use blockchain technology because I believe that it will reduce the running cost of my enterprise.	
	BFB5	I will use blockchain technology because I believe that it will eliminate cyber-attacks in essential maritime activities.	
Social Influence (SINF)	SINF1	Enterprises who are important to me think that I should use blockchain technologies	(Brown et al., 2010; Maruping et al., 2017)
	SINF2	Enterprises who influence my behavior think that I should use blockchain technologies	Venkatesh et al., 2003, 2012)
	SINF3	Other enterprises in the maritime industry use blockchain, so I also intend to use it.	
	SINF4	Organizations like IMO, P&I Clubs, BIMCO and the UN have supported the use of blockchain technologies, so I also intend to use them.	
Blockchain and trust	BTR1	I trust that blockchain protects personal information.	(Lee, Kriscenski, Lim , 2019)
(BTR)	BTR2	Maritime industry stakeholders can be trusted to carry out blockchain transactions faithfully	(Mayer et al., 1995; Svensson, 2001; Whipple et al.,
	BTR3	I think I can trust Maritime industry stakeholders more if they use blockchain applications.	2013)
Performance Expectancy	PEXP1	I would find blockchain technology useful in my job	(Brown et al., 2010; Maruping et al., 2017

(PEXP)	PEXP2	Using blockchain technology will allow me to accomplish tasks more quickly and efficiently.	Venkatesh et al., 2003, 2012)
	PEXP3	Using blockchain technology increases my productivity.	
	PEXP4	If I use blockchain technologies, I will increase my chances of getting a raise or a promotion.	
Behavioral Intention (BINT)	BINT1	I intend to use blockchain technology in the following months (12 to 24)	(Venkatesh et al., 2003, 2012, Brown et al., 2010; Maruping et al., 2017)
	BINT2	I predict I would use blockchain technology in the following months (12 to 24)	
	BINT3	I plan to use blockchain technology in the following months (12 to 24)	
	BINT4	I am willing to use a demo blockchain application in order to learn the benefits of this new technology.	
Behavioral Expectation (BEXP)	BEXP1	I expect to use blockchain technology in the following months (more than 24)	(Maruping et al., 2017)
	BEXP2	I will use blockchain technology in the following months (more than 24)	
	BEXP3	I am likely to use blockchain technology in the following months(more than 24)	

Appendix B. Paper