

DURBAN UNIVERSITY OF TECHNOLOGY

**ADOPTION OF BLOCKCHAIN TECHNOLOGY AMONG
EMERGING MARITIME BUSINESSES IN KWAZULU-NATAL**

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ABSTRACT

This dissertation considered Blockchain deployment across maritime cluster, with reference to the needs and preferences of the KwaZulu-Natal marine businesses and industry. Blockchain is a novel digital concept and technology that was first employed in the maritime trade at the beginning of the 21st century, with the emergence of smart contracts in the form of an electronic Bill of Lading (eBL) running on top of the Ethereum platform. The maritime Blockchain digital database or shared ledger has the capacity to be applied to tracking and tracing of trade documentation and cargo, sea traffic management, port automation, crew and assets' certifications, etc. Regardless of its great prospective, this technology is currently in its infancy, and it has yet to gain mainstream implementation and adoption in the maritime business and industry in general, and in the maritime sector in KwaZulu-Natal in particular. This study examined the barriers to wider adoption of the Blockchain technology, including their hierarchical structure in terms of impact and their interconnections. The Interpretative Structural Modelling (ISM) and Cross-Impact Matrix Multiplication Applied Classification (MICMAC) tools were applied for this purpose. The case study revealed that the lack of government regulation of Blockchain technology was found to have the highest impact as an impediment to wider adoption of Blockchain, while the lack of early adopters in the maritime industry was found to have the lowest impact on the wider deployment of this emerging concept and technology. Examination of the constructs such as the actors' reluctance to distribute business information, lack of knowledge and understanding how Blockchain functions, lack of stakeholders' support, and high investment costs, revealed that they were linked at the same hierarchical level in terms of how they hindered wider adoption of this technology and could have a domino effect on widespread adoption. Given the accelerating pace of digitalization in the maritime sector, it is expected that this technology will have a considerably greater impact on the maritime ecosystem in the coming decades.

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LIST OF ABBREVIATIONS

AI	: Artificial Intelligence
AISAs	: Autonomous Intelligent Software agents
APIs	: Application Programming Interfaces
4IR	: 4 th Industrial Revolution
BACTS	: Blockchain-based Automated Toll-Tax Collection System
BC	: Blockchain
BCT	: Blockchain Technology
BCO	: Beneficiary Cargo Owners
BIMCO	: Baltic and International Maritime Council
BL	: Bill of Lading
CORDIS	: Information Research and Development Information Service of the European Commission
CRM	: Customer Relationship Management
Crypto	: Cryptocurrencies
CTP	: Container Platform Tokens
DCSA	: Digital Container Shipping Association
DNP	: Dependence Power
DOGE	: Dogecoin
DRP	: Driving Power
EBL	: Electronic Bill of Lading
ECA	: Europe and Central Africa
EDI	: Electronic Data Interchange
EMC	: EThekwini Maritime Cluster
ERP	:Enterprise Resource System

ETC	: Electric Toll Collection
ETI	: Exploiting Technology Intelligently
GCT	: Global Container Terminal
GPS	: Global Positioning System
IBM	: International Business Machines
ICO	: Information Commissioner's Office
IMO	: International Maritime Organization
IoT	: Internet of Things
IPFS	: Inter Planetary File System
IS	: Information System
ISM	: Interpretative Structural Modelling
ISP	: Internet Service Provider
IT	: Information Technology
KZN	: KwaZulu-Natal Province
MICMAC	: Matrix Multiplication Applied Classification
MSA	: Classification & Types of Mobile Satellite Antennas
NFT	: Non-Fungible Token
OSAM	: Online Shopping Acceptance Model
PCS	: Port Community Systems
PoW	: Proof of Work
PoS	: Proof of Stake
PSF	: Prime Shipping Foundation
RFID	: Radio Frequency Identification
RMG	: Rail Mounted Gantry

RTG	: Rubber Tyred Gantry
SAMSA	: South African Maritime Safety Authority
SC	: Smart Contract
SCM	: Supply Chain Management
SHA	: Secure Hash Algorithm
SOL	: Solana
SW	: Single Window
SWIFT	: Society for Worldwide Interbank Financial Telecommunications
TA	: Toll-Tax Amount
TAM	: Technology Acceptance Model
TEU	: Twenty Equivalent Unit
TOE	: Technology Organization and Environment
UTAUT	: Unified Theory of Acceptance and Use of Technology
USA	: United States of America
WEF	: World Economic Forum
WHO	: World Health Organization
XMR	: Monero (cryptocurrency)

CHAPTER 1 INTRODUCTION

1.1 Introduction

Blockchain is an emerging technology with countless advantages in an increasingly digital world. It is a distributed ledger system that captures and safe data in digitally. The data is a distributed list of transactions that is updated and reviewed continuously. The technology is secure because it has encryption features, it is made up of a decentralized network of nodes, and there is no requirement for third parties or additional fees when executing a transaction. However, it needs sophisticated software, high-tech hardware, a strong network infrastructure, and energy on which to operate various types of consensus mechanisms efficiently and effectively.

At the beginning, this new, disruptive technology was predominantly associated with cryptocurrencies. Today, having evolved, it enables immutable digital transactions of digital assets, visible and invisible, with no intermediaries (like lawyers and bankers), through so-called smart contracts. The assets within Blockchain transactions might be: cryptocurrencies like Bitcoin, Ether, Doge, Tether, Litecoin, etc.; votes; carbon credits; educational degrees; rights to intellectual property (writings, music, art, or any other kind of creative work); locations of portable assets (containers in maritime transportation, e.g.); charitable donations; bills of lading; sea waybills; letters of credit; ownership titles; sensors' data collected for different purposes; satellite constellation communication data; and much more.

Blockchain can be described a distributed, decentralised, relational ledger of digital transactions that are arranged in blocks and shared among a computer network's nodes. Each block is protected, and it should be resistant to any kind of mutation. Blocks associated with headers (used to identify a particular block on an entire blockchain) and approved transactions enable digital assets' movements within the network of nodes through a consensus mechanism, without external supervision. Therefore, Blockchain technology could be of great use in any field that includes transactions. In fact, it may turn out to be the biggest technological development in internet history.

In the maritime industry, Blockchain technology draws together several logistics partners, who interchange numerous documents, like booking requests/confirmations; packing lists; export/import customs declarations; production certificates; vessel certificates; phytosanitary certificates; certificates of origin; arrival notices; letters of credit; commercial invoices; bills of lading; customs clearances; delivery orders, etc. Besides these, Blockchain also reduces the possibility of cargo delivery delays by enabling the tracking of freight containers along the whole supply chain. Despite the fact that the participants in the global supply chain frequently come from several organizations with different laws, regulations, standards, social norms, and organizational cultures, Blockchain is designed in such a way that it can overcome the majority of these obstacles.

This study investigates how Blockchain technology could improve South Africa's maritime businesses and industry as a whole. This new technology could reduce excessive paperwork, i.e. administration, and considerably reduce costs while ensuring efficient and effective business model. For example, the seaports and shipping companies cooperate with a plethora of different operations daily to realize successfully transport of goods worldwide. This includes things such as the network design, selection of transshipment nodes, routing and scheduling, fleet planning, and so on. Blockchain is capable to resolve issues in the maritime sector that previously seemed unmanageable. Positive effects of this advanced technology have become visible across food production and distribution chains, mining industry, international trade, unimodal and multimodal transportation, financial sector, health, education, administration, and other businesses. In the maritime sector, the aim is to digitalize global trade while improving visibility and efficiency across entire supply chains.

The maritime sector has the smallest innovation impact in comparison to other industries, since it is profit-driven and conservative. Since ports and shipping logistics play essential roles in global supply chains, successful technological innovation in the sector is vital and should include a larger number of stakeholders. The increased global demand for commodities increased the need for sea transportation of freight containers. The massification of maritime transport led to the evolution of business

clusters, but these are mostly separated into non-modular and centralized ones. Sea ports serve as central hubs for these clusters in the globally spread shipping market, and port community systems (PCSs) were introduced as integrated information systems to satisfy the needs of the numerous actors. PCSs make it easier to exchange data, streamlined conformity to global norms, and set the foundation for the digitalization of processes. The precise functions of PCSs are hard to generalise because they vary, depending on the community's players and their relevant metrics. Regardless of this, PCSs enable greater business integration; these systems enhance safety, security, and reduce frauds.

As stated, the PCSs set the foundation for digitization in the maritime industry. The next milestone was the introduction of the maritime single window (SW) environment. The SW is a single point of interaction between maritime affairs and authorities. The PCSs and SWs can bring great benefits on an individual organizational level, however, segregation and insufficient presence of close to real time data globally are still present.

The introduction of the Blockchain system signifies a big change for the maritime sector, since it has the potential to enable the exchange from segregated, centralized approaches to a global net of computers that are linked in a peer-to-peer nets without the necessity of consensus among the players. Transactions can be done through a spread, added-only ledger, which is constantly run via agreement mechanisms and protected by asymmetric cryptography algorithms. All records of transactions are maintained across the network. As a decentralized system, Blockchain eliminates a single point of malfunction and the need for the third parties. Blockchain can facilitate the improvement and growth of world trade, along with the reduction of transportation costs. Through smart contracts, personalized automated services can be increased, and delivery delays can be decreased. All this supports tentative statements that the Blockchain technology might be applied in the maritime business worldwide, including South Africa, for seamless operational processing that includes a higher level of digitization and efficiency.

CHAPTER 2 DETAILS OF THE STUDY

2.1 Problem statement

The primary objective of this dissertation is to eliminate the paucity of knowledge regarding the meaning, challenges, benefits, and prospective usage of Blockchain technology, with the intention of promoting widespread implementation of this advanced technology in the maritime sector in KwaZulu-Natal, South Africa (SA). Installing and maintaining Blockchain technology requires skilled human capital and robust infrastructure, which are currently underdeveloped. There is thus a need to develop an integrated, holistic model for smart implementation and adoption of Blockchain technology (BCT) in the maritime sector, with particular attention to its implementation and adoption in an emerging economy like that of KwaZulu-Natal. The proposed model should encompass:

- Blockchain technology's challenges such as governmental, legal, societal, privacy, and security challenges.
- Blockchain technology's opportunities such as improved efficiency, effectivity, security, business excellence, innovation, and development.
- Blockchain technology's applications such as smart contracts, reduction of operational costs, reduction of human errors, tracking and tracing of items, insurance within the supply chain, ports' state controls, ships' registries, and the like, with particular attention to the specific needs and preferences of KwaZulu-Natal's developing maritime business ecosystem.

2.2 Objectives

While the goal of this work is to provide a comprehensive model for intelligent, smart, or rational implementation and adoption of Blockchain in maritime across KwaZulu-Natal, the objectives of the study are as follows:

- Examine Blockchain technology as a disruptive technology or game changer in maritime businesses.

- Explore the transition from Bitcoin to Blockchain; interrogate the advantages of Blockchain technology in comparison to (real and virtual) relational databases and similar IT systems (enterprise resource planning, customer relationship management, the single window environment, the electronic logistic marketplace, etc.).
- Examine the relevance of Blockchain technology's implementation in the maritime sector in general and KwaZulu-Natal in particular, with reference to the TradeLens, CargoX, 300Cubits, and Blockshipping platforms.
- Make a distinction between the benefits and challenges of Blockchain technology's implementation in maritime businesses in emerging settings.
- Provide recommendations in the form of a model for the rational deployment of Blockchain technology in KwaZulu-Natal's maritime businesses.

Towards achieving these objectives, the thesis intends to:

- Explore the level of stakeholders' knowledge and experience regarding Blockchain technology's exploitation in the maritime sector.
- Collect relevant data/information/knowledge about the prospective implementation of Blockchain technology in the maritime sector in general, and specifically in KwaZulu-Natal.
- Develop a model for rational adoption and implementation of Blockchain technology in KwaZulu-Natal Province's maritime business and industry.

2.3 Research questions

The research questions are conceived to clarify the issue at hand:

- Why is Blockchain technology a game changer in the maritime sector?
- What is the difference between Bitcoin and Blockchain technology?
- What distinguishes Blockchain technology from ordinary databases, like ERP (Enterprise Resource Planning), CRM (Customer Relationship Management, the single window environment, and the electronic logistic marketplace?

- Why is Blockchain important in maritime, and in which way can this disruptive approach be applied across this industry?
- What are the benefits and challenges of Blockchain technology's implementation in the maritime sector?
- What are the elements and relationships between the beneficial and detrimental constructs identified in the proposed model?

These research questions specify what we intend to find out through the study. They translate the problem of Blockchain technology's successful implementation in the maritime sector in KwaZulu-Natal (KZN) into a specific need for data and information collection, coding, analysis, and then sketching out the data. The Table 1.1 summarizes this research problem, research objectives, and the research questions.

Table 2.1: Research statement, objectives, and questions

Problem statement		
	Objectives	Questions
The main goal of this dissertation is reduction of the paucity of knowledge regarding the meaning, challenges, benefits, and prospective applications of BCT, with the intention of promoting widespread adoption of this technology in the maritime sector in KZN, SA. Installing and maintaining BCT requires skilled human capital and powerful networks, which are scarce at present. This	<ul style="list-style-type: none"> - Examine BCT as a disruptive technology or game changer in maritime businesses. - Explore the transition from Bitcoin to Blockchain. - Interrogate the advantages of BCT in comparison to real and virtual relational databases and similar IT systems (enterprise resource planning, customer relationship 	<ul style="list-style-type: none"> - Why is BCT a game changer in the maritime sector? - What is the difference between Bitcoin and BCT? - What distinguishes BCT from classical databases, ERP, CRM, MSW, and the electronic logistic marketplace? - Why is BCT important in the maritime sector and how can this disruptive

<p>imposes the need to develop an integrated, holistic model for smart-implementation and adoption of BCT in the maritime industry, with particular attention required for emerging economies like that of KZN.</p>	<p>management, the single window environment, the electronic logistic marketplace, etc.).</p> <ul style="list-style-type: none"> - Explore the relevance of BCT's implementation in the maritime in general and KZN in particular, with an overview to the TradeLens, CargoX, 300Cubits, and Blockshipping platforms. - Make a distinction between the advantages and disadvantages of BCT's implementation in maritime businesses in emerging settings. - Provide recommendations in the form of a model for the rational deployment of BCT in KZN's maritime businesses. 	<p>technology be applied across this industry?</p> <ul style="list-style-type: none"> - What are the advantages and disadvantages of BCT implementation in the maritime industry? - What are the elements and relationships between the beneficial and detrimental constructs identified in the proposed model?
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Source: Researcher (2023)

The following section will provide environmental scan in terms of Blockchain principles and applications, including maritime ones. An extensive literature review will be provided, along with explanations of how Blockchain technology functions, using the example of Bitcoin. A brief introduction to cryptocurrencies and smart contracts will be

presented as well. This will be done at a rather high level of abstraction since Blockchain technology is relatively new, very complex, and sophisticated.

2.4 Limitations and delimitations

Time and financial resources are typically restricted in research studies, while the availability of respondents may also be an issue. Regarding the limitations of this study, it should be noted that we mostly dealt with descriptive and exploitative approaches, as Blockchain is an emerging technology and a 'game changer' in the maritime sector. The research focused on a case study with a rather small number of respondents. That is, a few individuals employed in the maritime sector in KwaZulu-Natal 'served' as the key data collection units. In terms of the time span over which this research project was conducted, it was a one-shot, cross-sectional study. In future research in this area, longitudinal studies should be conducted with larger numbers of respondents from different organizational levels in various maritime businesses in and administrative bodies in KwaZulu-Natal and further afield. Instead of descriptive and exploratory approaches, a causal approach should be used, while mixed quantitative and qualitative techniques should be deployed to test the tentative statements and justify the causal connections among the variables in the context of smart adoption of sophisticated and complex Blockchain applications in the maritime domain. In addition, experiments with dynamic programming and stochastic models could be included besides the analysis using Interpretative Structural Modelling (ISM) and Matrix Multiplication Applied Classification (MICMAC) techniques. However, within the present study, we did our best to collect, contextualize, analyse and present the obtained results in an acceptable way that is useful for researchers and information technology (IT) and maritime professionals at this moment. This study has the potential to be used as a foundation for further investigations in this area.

2.5 Significance of the study

This study covered a wide range of Blockchain prospective applications in the maritime sector. It acquainted readers with the key features and utilities of these systems, as well as with directions for their rational use in developing environments, with a focus

on KwaZulu-Natal, in South Africa. The study pointed to the advantages but also the challenges associated with implementation of the emerging Blockchain in maritime. Additionally, it established causal relationships among the key factors for Blockchain's successful implementation. This research work also opened the door for additional research work in this subject area and facilitated communication between IT architects (designers), managers and customers (end users) in the maritime sector.

2.6 Project contribution

This research study resulted in several research articles being published in journals and conference proceedings. These are attached as appendices and indexed in the bibliography. The list of publications resulting from this research project is as follows.

Journal paper (Scopus):

1. Bauk, S. and **Ntshangase, L. H.** 2023a. Blockchain implementation barriers in maritime: A case study based on ISM and MICMAC techniques. *Journal of Maritime Research*, 20(3): 72-80. Available: <https://www.jmr.unican.es/index.php/jmr/article/view/736/766>.

Conference papers (Scopus):

2. Bauk, S. and **Ntshangase, L. H.** 2023b. Maritime Blockchain constraints' analysis by ISM and MICMAC techniques. *Proceedings of the 12th Mediterranean Conference on Embedded Computing (MECO)*, Budva, Montenegro: 1-6. Available: <http://dx.doi.org/10.1109/MECO58584.2023.10155037>
3. Ntshangase, L. H. and Bauk, S. 2024. Blockchain applications and cybersecurity threats: A review. *Proceedings of the 28th International Conference on Information Technology (IT)*, Žabljak, Montenegro, 21 – 24 February 2024. (Accepted for publication).

CHAPTER 3 ENVIRONMENTAL SCAN

3.1 Environmental scan

Advanced digital technologies are permanently changing the outlook of numerous businesses in different aspects. Back to 1980s and early 1990s, it was almost impossible to foresee the influence of the Internet to our day-to-day living and working habits. The Internet assists us reading an online article, ordering goods online, interacting with friends and family, or business partners, etc. It has merged itself unequivocally into our lives. Concerning business issues, today's digital economy relies on a third trusted party. Most of online transactions depend on somebody to confirm the transactions are done. This might be a mail server confirming that our email has been delivered, or it can be a social network like Facebook, informing us that our trails have been distributed among our friends, or it can be a bank informing us our monetary assets has been transferred smoothly to the recipients abroad. Because we depend on outside parties to protect the security and privacy of our digital assets, the truth is that we live in a very unpredictable world in the digital age. These trustees are vulnerable and can be corrupted. In such cases Blockchain comes in handy.

Blockchain technology records every transaction, since the first one was made (Alharby and van Moorsel, 2017). Blockchain contains chains of digital transactions, stored on a digital ledger. Blockchain technology allows the transfer of funds and any other digital asset speedily and securely anywhere in the world. Blockchain technology enables trusted transactions among untrusted participants in an entire network (Horrocks et al., 2020). In other words, Blockchain is a distributed, dynamic, electronic ledger, which memorizes the transactions as they materialise among peers in a protected and intrusion-resistant manner (Wang, Han and Beynon-Davies, 2019).

With Blockchain, contracts are kept on an open, shared ledger and incorporated in digital code. These ledgers are secured from removal, damage, or unallowed change

of transactions information. All contracts, tasks, processes, and payments have a digital record and signature, which can be authorised, proved, memorized, and shared among the network participants. Brokers and other intermediaries such as lawyers and bankers might not be necessary. Corporations, companies, persons, computers, and programs can make transactions and communicate directly. This is the huge power and convenience of Blockchain.

However, Blockchain requires sophisticated software, high-tech hardware, powerful network infrastructure, and energy to run the different types of consensus mechanisms required efficiently and effectively. All this must be achieved while taking into consideration the need to reduce greenhouse gases and carbon footprints.

Over the past few years, interest in blockchain technology and its business applications has been rapidly growing in the academic community, and this has been confirmed by a series of literature reviews (Blossey, Eisenhardt and Hahn, 2019). This new, disruptive technology has predominantly been associated with cryptocurrencies. However, it has evolved over time and now enables immutable digital transactions regarding a variety of assets without the need for intermediaries via virtually smart contracts.

Some states are currently dealing with IT specialists to settle deed titles onto Blockchain. This will potentially create some of the conditions required for the prosperity of billions of people across the globe, as they will be able to plan for their future. This is because, as things stand currently, approximately 70 per cent of the world population have vulnerable title to their own properties. Additionally, Blockchain can replace the transfer of money in the form of workers' remittances from developed parts of the world into developing ones. The Blockchain-based Abra system might gradually replace the actual Western Union, and the costs of money transfers can be reduced significantly from about 10 per cent to 2 per cent per transaction (De Mijer, 2016). Airbnb can be replaced with Blockchain-based B-Airbnb, as this will be more efficient, and so on. Figure 3.1 shows different application domains of Blockchain technology that have the potential to expand.

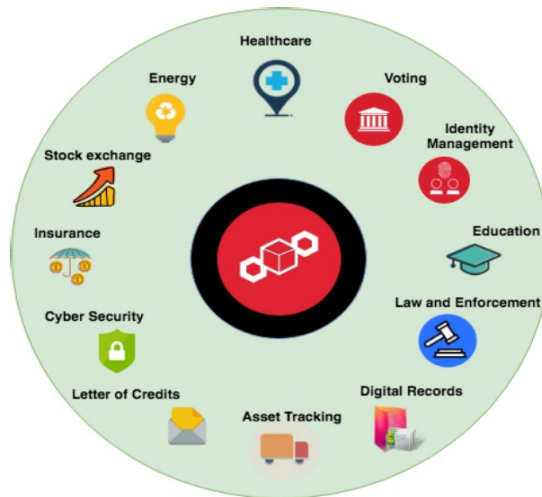


Figure 3.1: Application domains of Blockchain technology

Source: Monrat et al. (2019)

Blockchain has become central to various methods for solving problems in many different fields since its inception (Le et al., 2023). Gimerská, Šoltés and Mirdala (2023) highlight that the technology has been widely adopted by multiple companies across various sectors, since most of Blockchain's attention is centred around its use in cryptocurrency. Blockchain technology has already been used in a wide range of sectors, from banking to health (Monrat, 2021; Abdallah et al., 2023).

3.1.1 Financial sector

The first applications of Blockchain technology were closely associated with the financial sector, as Blockchain enables cheaper and faster money transfers than traditional money transfers.

The World Economic Forum (WEF) embarked on intensive research on the effects that Blockchain could have on financial services (De Meijer, 2016), and Wagner and Winsnicki (2019) confirmed that the financial market is the most promising for Blockchain adoption. Blockchain technology is already making a significant impact across the banking sector and promises long-term benefits (Farley and Williams, 2018). Reduction of transaction costs, speed, and efficiency are all easily noticeable

advantages, but Blockchain also serves to reduce counterparty risk as it is a more autonomous and transparent process.

Cross-border payments take place between at least two countries or regions, and if a certain product has been purchased from foreign manufacturers by a domestic consumer, a settlement tool and payment system have to be utilized to finish the cross-border payments involved (Wu and Duan, 2019). The authors argue that the most widely used payment method is foreign money, and the payment system most commonly used is a cross-border interbank payment system. Ordinary payment channels through VISA cards, Master cards, JCB cards, and so on, can be conveniently utilized by domestic consumers when purchasing imports overseas. The mainstream cross-border payments include bank telegraphic transfers, transfers by a remittance company, credit card payments and third-party payments. The bank telegraphic transfer is based on the payment network of the Society for Worldwide Interbank Financial Telecommunications (SWIFT). The local remitting bank at home sends a remittance message to the bank at the receiving end abroad, and the payment is then made by the receiving bank to the payee. This type of payment goes along with high level of fees and takes an unnecessarily long time to process. In such circumstances, Blockchain technology can be integrated into cross-border payments and reduce transaction risks (Guo et al., 2016).

Ibrahim (2018) adds that the advantages connected with the innovation of Blockchain for private investment fund strategies promise far-reaching positive changes for the industry. We can take as an example a recent study by Kaal (2017) showed how the utilization of block chain technology by private fund advisers resulted in significant benefits for their clients. Xu, Xiangxin and Zeng (2023) also pointed out that Blockchain technology offers a possible remedy for supply chain finance automation issues, such as inventory monitoring, transaction settlements, and knowing your customers.

Figure 3.2 shows Bitcoin's legacy across the world, and it is clear that 110 out of 251 countries worldwide have accepted this cryptocurrency as a means of payment.



Figure 3.2: The global Bitcoin legacy

Source: Monrat et al. (2019)

3.1.2 Legal sector

Every day, technology advances, yet the legal fraternity is sadly notorious for being slow to adapt to technological changes and for being slow to catch up with other sectors. Blockchain's ability to store and verify documents efficiently has changed this, however, and the legal industry has also begun utilising Blockchain, especially for some activities that were once regarded as exclusive to lawyers.

Sarmah (2018) claims that Blockchain can significantly reduce the time spent on court cases and legal battles as it provides a suitable, protected environment in which we can verify and confirm the veracity of legal documents. De Kock (2023) highlighted that Blockchain has capacity to influence many dimensions of legal services, particularly those related to virtually smart contracts, protecting intellectual properties and royalties, and storing transactions over land and real estate properties. By embracing Blockchain technology, legal services will be more accessible and transparent for clients. Additionally, blockchain will enhance data integrity, automation, and cost savings.

3.1.3 Education sector

Technological innovations have played a crucial role in redefining education of late (Garrison, 2016). From e-learning systems to data-driven methods, several institutions of learning have sought ways to incorporate technology to address problems such as content delivery and reach, recommendations, early interventions, assessments, and issuing and verifying of credentials.

The problems of security, vulnerability, and privacy in ubiquitous learning environments may be resolved by blockchain technology (Casino, Dasaklis and Patsakis, 2019). The education sector is beginning to embrace the emerging technology in numerous areas, and some schools are recording certification licences, graduation certificates, and more in the field of education using Blockchain (Jheng, 2018). Academic research, reputations, e-portfolios, and intellectual property are other aspects of education that Blockchain impacts with its innovative technology (Grech and Camilleri, 2017).

Thayer and Yanckello (2019) state that many of the bureaucratic systems in educational institutions manage well on learning processes, as well as many other aspects such as enrolment, retention, recruitment, and alumni advancement. These authors therefore suggest a combination of customer relationship management (CRM) technologies, big data analysis, and Blockchain to provide tailor made services to students throughout their entire academic cycle. (Steiu, 2020) highlights that by using Blockchain technology, employers can be guaranteed that prospective employees' have the necessary credentials to thrive in the workplace, as this emerging technology secures that students cannot change their grades, diplomas, or certifications.

3.1.4 Voting process

A democratic system's cornerstone is its elections, which allow the people to voice their opinions by casting ballots. However, enormous sections of society around the globe do not have confidence in their election systems, which is a huge concern for

democracy. According to Lahane et al. (2020), some of the world's massive democracies, like Japan and India, suffer from an impaired election system. Blockchain could be a potential solution to prevent criminality in elections, thanks to its additional inherent security mechanisms.

Election processes should be reliable and transparent due to their significance for countries, so it is important to ensure their credibility for the public casting their votes (Khan and Arshad Khan, 2018). Due to the importance of voting systems, continuous efforts have been made over time to improve the overall efficiency and durability of voting systems. Blockchain technology inherently ensures robust functioning, preserves anonymity, and maintains a decentralised and publicly distributed ledger of all transactions on all computer nodes, so it could be crucial in the area of computerised voting.

Conway (2020) agrees that voting on a blockchain can help modernise elections by reducing the possibility of election fraud and increasing voter turn around. A test was conducted in the November 2018 midterm elections in West Virginia to prove this point, and Conway (2020) asserts that "Using blockchain in this way would make it almost impossible to tamper with votes." The blockchain protocol would also maintain transparency in the electoral process, reducing the number of staff needed to run elections and providing officials with near-instantaneous results. The need for recounts would be eliminated, as would any real worry that fraud could corrupt the election. Benny (2020) also supports the use of blockchain technology in the electoral process and expands on this by stating that e-voting using this technology could solve and eliminate the current concerns with the e-voting system.

3.1.5 Supply chain

Supply chains have to be flexible, innovative, and transparent in order to keep up with cutting-edge technology and stay competitive in the marketplace (Awwad et al., 2018). The same authors state as well that it is important that technology be used to simplify

supply chains to make them more efficient. The traceability of products across a complex supply chain might be hugely improved by deploying Blockchain into the supply chain management. Gnimpieba et al. (2015) report that traceability, identification, and close to real time monitoring of goods in a supply chain have been a challenge, as the monitoring and controlling systems used by the different actors in the chain are diversified.

Order management in supply chain begins when an order is placed and concludes when the client receives the items (Varriale et al., 2021). The most common order management process problems are usually variability, inaccurate specifications, and frequent requests for changes (Ivanon, 2018). Such problems are often exacerbated by other concerns like human errors, or problems with management procedures, too many communication channels, and different information systems. All these challenges combined cause insufficient visibility for customers, insufficient traceability for supply chain players, and therefore, a low level of trust and efficiency (Niu, Shen and Xie, 2021). Automating manual supply chain processes can improve the processes, reduce costs, and increase gains significantly by alleviating errors (Fatorachian et al., 2021).

Transportation and logistics can benefit from the application of blockchain technology and tracking tools in conjunction with smart contracts. These smart contracts can facilitate payments to suppliers once tasks have been completed, such as the delivery of goods to a warehouse, and once predefined specifications have been met in terms of quality and quantity (Varriale et al., 2021). These authors advise that radio frequency identification (RFID) tracking devices at a buyer's warehouse can be connected directly to the blockchain. After the customer confirms that the agreed-upon quantity has been delivered and that no further requirements need to be met, the smart contract can automatically release the payment to the supplier once it has received goods from the supplier satisfactorily.

Stakeholders in the supply chain (ports, banks, customs, etc.) exchange and transfer all kinds of information with each other; consequently, reliance is a crucial component

of the supply chain (Cruz Cruz, 2019). Unfortunately, there is a possibility of fraud in supply chain systems, and falsification of documents regarding the originality and quality of products often takes place in the supply chain. Blockchain has become a technology, which can ensure significant benefits in global supply chains and eliminate opportunities for fraud. Queiroz, Telles and Bonilla (2020) explored the actual extent of Blockchain implementations in the supply management domain. They focused on the Blockchain–supply chain management (SCM) relationship within common SCM domains like distribution, intelligent transportation systems, product traceability, and anti-counterfeiting measures. Notwithstanding, there is the scarcity of literature on Blockchain–SCM integration in other areas of SCM, such as warehouse and inventory, network optimization, routing, production optimization, procurement, quality, etc.

Saberi et al. (2023) suggest that Blockchain technology is a pertinent solution to the inefficiencies of SCM, since it offers a productive management system capable of managing recalled items and recycle them by managing their placement in inventory, disposal, repair, or resale. According to Dhingra et al. (2023), the enhanced visibility enabled by BCT enhances the quality control of raw materials, supports inventory management, and minimises product recalls. It reduces data acquisition delays, supporting effective and effective decisions making processes and the like.

Several other authors have stated that ensuring chain of custody and traceability via Blockchain allows organizations to demonstrate their products' provenance, integrity, and compliance with quality standards.

Toll collection

Toll collection (toll tax) at toll plazas is considered an important way to generate more funding for transport infrastructure, because the development of transportation systems needs high investments. Manually managing the traffic at toll plazas has become a daunting task, however, given the increasing number of vehicles on highways (Tanveer and Javaid, 2019). Various scholars have suggested implementing an Electronic Toll System (ETC) system with enhanced security and Blockchain-provided interoperability. Toll collection systems, based on Blockchain, should prevent

toll evasion, especially when vehicles move together in groups (Ying, Ye and Ma, 2020). Such systems can also reduce vehicle theft, as all of the information relating to vehicles, like ownership history and registration information, can be stored by these systems and allow for stolen vehicles to be identified and potentially intercepted. Blockchain technology has the capacity to record and verify this vehicle information.

The FASTag system of tolling is currently being used in countries like India, but it does not really yield the desired results. Physical problems like traffic congestion, inaccurate revenue collection, fuel efficiency reduction, and electronic vehicle tags being damaged are among the problems that have become apparent since the adoption of the system. Thosar et al. (2023) proposed a virtual tolling system based on Blockchain, along with using GPS and image processing to solve the problem. Das et al. (2022) explained that the most suitable ETC system is one where the collection of the toll-tax amount (TA) does not slow down a vehicle's speed at the toll plazas on the national roads. These authors supported the introduction of the automated toll-tax collection system on Blockchain (BATCS), their preferred system for toll collection, as it can pick the appropriate toll amount without impeding the speed of a vehicle as it passes a toll plaza. A set amount of tax can be deducted automatically from the vehicle owner's account as their vehicle passes the toll plaza. A lot of countries are currently using RFID technology for their automated toll collection. With this method of toll collection, a transponder installed inside a vehicle is used to tap or connect to the vehicle owner's credit card/debit card to facilitate the automatic deduction of the toll fee as the vehicle passes the toll plaza (Singh et al., 2022).

3.1.6 Energy sector

In the energy industry, the development of sustainable energy sources and network technology has created challenges and opportunities. BCT has been earmarked as one of the potential solutions to overcome challenges such as management issues and inefficiency (Iliina et al., 2023). One of the primary applications of blockchain technology in the energy sector is microgrids. Monrat, Schelén and Anderson (2019) explain a microgrid as a set of localised electric power sources along with loads

integrated and managed with the objective of enhancing energy production and consumption. Distributed generation, renewable energy plants and energy storage components in facilities created and owned by different organisations or energy providers can all be sources of electricity. One of the most notable benefits of microgrid technology is that it cannot only provide homes and other power users, such as factories, with much-needed energy; it can also manage the production and sale of excess energy to the grid (Cohn, West and Parker, 2017). Blockchain can be used to facilitate, record, and validate power sales and purchases linked to microgrids, which includes electricity for the charging of electric vehicles (Cui et al., 2023). Similar to this, blockchain technology can be widely applied to allow energy exchange between smart grids. Pan, Zhu and Teng (2023) point out that Grid+ leverages the Ethereum Blockchain to give consumers direct access to wholesale energy markets. This system supplies energy and offers real-time metering and settlement services, enabling automatic payment and purchase of electricity by consumers using smart contracts.

In addition, blockchain can be applied to monitor, support and maintain secure and private energy consumption and supply in smart grids designed with bi-directional communication flow without the help or need for a central intermediary. (Aitzhan et al., 2018).

3.1.7 Health sector

Drug traceability and patient data management are two aspects in the health sector where Blockchain can be of good use. According to Bauk and Ntshangase (2023b), this emerging technology can be put to good use in protecting confidential data contained in health services users' files. Blockchain technology can also be used to control the accuracy, distribution, and price of medicines. Moreover, Blockchain is opening new possibilities for health insurance and the like.

Monrat et al. (2019) report drug counterfeiting as one of the main issues facing the pharmaceutical sector. According to (Radanovic and Likic, 2018), as much as 10 to 30 per cent of the drugs that are sold in developing countries are reported to involve counterfeiting. According to the estimates from the World Health Organization, 16 per

cent of counterfeit drugs include the incorrect ingredients, while about 17 per cent of them have inaccurate levels of essential ingredients. European pharmaceutical companies lose 10.2 billion Euros annually from an economic standpoint (ECA Academy, 2016). All transactions included into the distributed ledger in Blockchain are digitally timestamped and immutable, which makes it possible to monitor status of an asset and make the information tamper safe. Blockchain technology can therefore solve this problem, as purchasers can be guaranteed that their drugs are not counterfeit.

3.1.8 Satellite system

The introduction of Blockchain technology in satellite-as-a-service business models is inevitable. These models relate to advertising and subscriptions on different broadcast channels.

Torky et al. (2022) assert that it has become impossible to imagine modern living without satellite – based services like navigation, mobile communication, surveillance, and digital maps have become unimaginable. The communication among satellite constellations therefore needs to be secured, and this can be achieved through multi-secured Blockchain mechanisms. Numerous types of space technologies and satellite transactions are responsible for such services. The development of new generations of satellite systems has become heavily reliant on various types of emergent technologies, such as the Internet of things (IoT), artificial intelligence (AI), and quantum and edge computing. Blockchain technology has quickly emerged as another important tool that can be used to address issues facing the international space sector. Many applications, such as managing the space supply chain, satellite-as-a-service business models, and even how to build satellite payloads, can be created by Blockchain. Jing et al. (2023) suggest that the introduction of Blockchain technology within satellite launch supply chains recently has inspired hope as it is the answer to workflow inefficiency and enhances data sharing, thereby minimizing launch risks. Furthermore, major developments will be achieved in the space of financial

transactions because of Blockchain technology. For example, the Bitcoin Blockchain's satellite transfer will revolutionize international financial transactions.

3.1.9 Aquaculture management

Park (2021) emphasized that the deployment of Blockchain can add towards more sustainable and efficient management of the food supply chains. Authors have identified the benefits of incorporating block chain technology in supply chains' logistics. For example, Kshetri and DeFranco (2020) highlighted that it allows small farmers to be more visible, improves food safety, strengthens accountability, allows for greater transparency, and allows for the tracing of contamination. Aquaculture currently accounts for 53 per cent of the consumption of all fishery products, if non-food uses are excluded (Food and Agriculture Organization of the United Nations, 2018).

Several authors have suggested the adoption of Blockchain to implement traceability in the aquaculture industry's value chains. Howson (2020) discussed how Blockchain could be used to improve consumer confidence in the fish value chain and gave an example of how Blockchain technology could also help preserve marine life. Forsvoll and Andal (2019) explained how Blockchain may improve the aquaculture products supply chains visibility. Protected data can include the age of aqua products, feed conversion ratios, seed strains used, temperature, harvest circumstances, and so on.

3.1.10 Marketing and advertising

The incorporation of blockchain technology into marketing has the potential to breathe new life into the discipline, rejuvenating it from a state of saturation. (Wasiq et al., 2023). Access to a wide range of consumer data is essential for marketers to improve the positioning of their products and create effective products that meet the needs of their consumers.

As privacy becomes a global issue, many consumers are becoming more cautious about sharing their information online. Advertising fraud is becoming increasingly difficult for advertisers to detect, largely because of the inconsistency of pay-per-click,

cost-per-click and users' experiences and clicks marketing across the internet. The threat of ad vendors accessing users' personal data for their own benefit, in exchange for rewards, through illegal means and similar scenarios is a serious threat. Therefore, blockchain is being adopted in the advertising domain to ensure users ownership of their personal data. (Chokkasamudra, Pathak and Shawkat, 2023).

Kaur et al. (2022) state that the decentralization feature of Blockchain is pivotal in enabling advertisers and marketers to gain deeper insights into customers' reactions to advertisements, manage data effectively, and make sustainable customer relationships.

Adigüzel (2021) highlights several well-established brands like Unilever, Nestle, McDonald's, and Virgin Media have adopted Blockchain technology in order to enhance visibility across their digital marketing channels.

3.1.11 Cybersecurity domain

Cyberthreats and incidences of fraud have increased by more than 40 per cent over the past 5 years, according to CORDIS (2021). Cybersecurity is part of Blockchain technology, since it is a decentralised public or private network of digital ledgers built on the principles of privacy, security, and trust. Chin (2023) cautions that cybercriminals are constantly improving the sophistication of their cyber-attacks by gaining access to new knowledge and capitalizing on new technologies. AI, machine learning, and botnets have become their tools with which to perpetrate cybercrime more efficiently, and these tools are enabling them to commit more serious crimes. Modern cybersecurity challenges are very difficult to contain using traditional solutions alone.

A huge number of companies had to resort to allowing their employees to work from home via internet connectivity mainly because of recent coronavirus pandemic responsible for the COVID-19 pandemic, and this also created new data threats for companies (World Economic Forum, 2019). Different technologies, including IoT, Big Data, and AI have been developed and introduced to strengthen and secure business

processes in an effective manner. Of these, Blockchain technology sticks out as one among the technologies that have a vital role in providing data security and the smooth running of business processes in the online business environment during the pandemic (Sriram et al., 2023).

Demirkan and McKee (2020) pointed out that blockchain can uplift cybersecurity, since it is one of the most secure platforms to prevent insincere activity through its various encryption and consent mechanisms. Experts from various business sectors have indicated that this emerging technology offers high level of safety for customers' business data as it prevents unlawful access to their data and helps them avoid cyber-attacks. According to IBM (2022), Blockchain technology is one of the favourites to adopt in making sure that business processes are kept safely in a secured environment, as it enhances cybersecurity in almost all industries.

Some of the most common cyber-attacks in the context of Blockchain technology are outlined below (Ntshangase and Bauk, 2024). Of course, the scope of the possible attacks on Blockchain technology is much wider, and its boundaries are widening as the technology develops.

3.1.12 The 51 per cent attack

This is the type of attack that is primarily related to Bitcoin and the proof-of-work (PoW) consensus mechanism. It occurs when the majority of nodes mining Bitcoin hijack the blockchain network and gain control of over 50 per cent of the blockchain's hashing power. This allows them to take over the verification of transactions and create a new block in the chain. It also prevents other participants in the blockchain from competing equally to solve the new block's code or hash nonce and gain control of the block. Cryptocurrencies like Bitcoin, Hanacoin, Vertcoin, Verge, Expanse, and Lincon Cash are prone to 51 per cent attacks (Merchant, 2022), but this sort of attack can be avoided by using a proof of stake (PoS) consensus algorithm, and this algorithm is inherent to the Ethereum Blockchain network.

3.1.13 Sybil attack

In a Sybil attack, fake nodes are created by hackers. These fake nodes flood a blockchain's network, causing it to collapse. Using these fake nodes, hackers can take control of a network and disrupt the normal flow of transactions.

3.1.14 Malicious nodes

This type of attack emerges when a dishonest participant gains access to the network and attempts to reroute transactions or flood regular network traffic. This is a threat by only one malicious node in the network.

3.1.15 Phishing attack

Blockchain users receive deceptive emails from malicious hackers to trick them into disclosing their credentials and wallet details. Upon being successful in doing so, intruders enter the system and take full control of it.

3.1.16 Routing attack

In this type of attack, intruders intercept network traffic before it reaches the router connected to the internet service provider (ISP), gaining confidential information that they can use to break into and interrupt the blockchain network's regular operation.

3.1.17 Endpoint vulnerabilities

This is also a common type of cyber-attack on Blockchain networks. It is based on intruders 'sniffing' around users' end devices, such as mobile phones, laptops, and desktop computers for the purpose of stealing passwords to access these end devices. Once they get into these devices, they are halfway into the blockchain network and can cause serious problems.

3.1.18 Private key disclosure

Blockchain technology uses two keys: public and private keys. Hackers can guess the private key if it is simple or if it is not well protected by the users. It is, therefore, recommended that the private key be as complex and complicated as possible so that

it is almost impossible to guess it and that it be kept very safely as something extremely private.

These and other intrusions can block the operation of a network, cause irreversible damage to participants and to the system, reduce the value of cryptocurrencies on the financial market, and consequently threaten the reputation of the entire business and technical system in the eyes of current and potential participants.

3.2 Maritime applications

The shipping industry is a key driver of supply chains logistics. Everybody in the world needs shipping, but they are not always aware of this. The shipping industry is connected globally to suppliers, sellers, and buyers, as well as to the oceans, the land, and the air. However, we cannot speak about global commerce without considering the logistics and operations that empower it (TradeLens, 2021).

A lot of products that are ordered today, when a buyer orders them or goes to a local retailer, are delayed due to the difficulties that the supply chain can encounter. Additional dimensions, regionalisation, huge trade tensions and the like make supply chains very complex and robust. When moving a container from one country to another, it has to go through customs, ports, container terminals, and ultimately to the customer, and everyone in the supply chain needs access to the shipping information and to share the information with others along the journey. The shipping industry thus needs to be very well connected.

A typical transaction involves 20 to 30 stakeholders (parties or actors) worldwide who have to follow different processes that include data in different formats, fields, and timelines. The whole supply chain's workflow suffers from inefficiencies as a result of this, and these unfortunately get passed on to the customers at the end of the chain. From a digital standpoint, there are thousands and thousands of data connections between carriers, customers, and vendors, and there have to be predefined rules if we want them to work together and 'speak the same language'. Standardization is the only way to create that foundation, and all players in the maritime industry must do this

together. There is a need for 'a tide to lift all boats. And that is why Maersk, a lot of shipping lines, and the International Business Machines Corporation (IBM), operating in over 171 countries, have joined forces to create a platform called 'TradeLens'. This platform must solve the problems that have plagued the global supply chain for a long time.

TradeLens is a Blockchain platform that supports global supply chains. It has been developed with the aim of enabling all participants to collaborate more efficiently, to share data and control location and status of the assets along the supply chain. TradeLens provides the information that all the actors in the shipping industry need on a common platform. It enables the industry to operate more effectively on a global scale. It enhances customers' satisfaction, lowers operations' costs, and increases services to cargo owners everywhere. TradeLens has been in operation from 2018 to 2023, when it was terminated for predominantly commercial reasons (Litan, 2022). However, its advanced technology is sound, and it should be redeployed in the future.

Maritime application of Blockchain supports supply chain logistics, which encompasses the conceiving, producing, labelling, and delivering of goods or services from producers/providers to end-users (Muckstadt, 2001). In a blockchain-based maritime supply chain system, a variety of logistics players are brought together by the blockchain itself (Figure 3.3). To facilitate cargo tracking and tracing and to give access to information about the delivery of shipments, it includes producers, sellers, transporters, terminal operators, seaport and customs authorities, insurance offices, banks, cargo owners, and the like (Liu, Zhang and Zhen 2021).

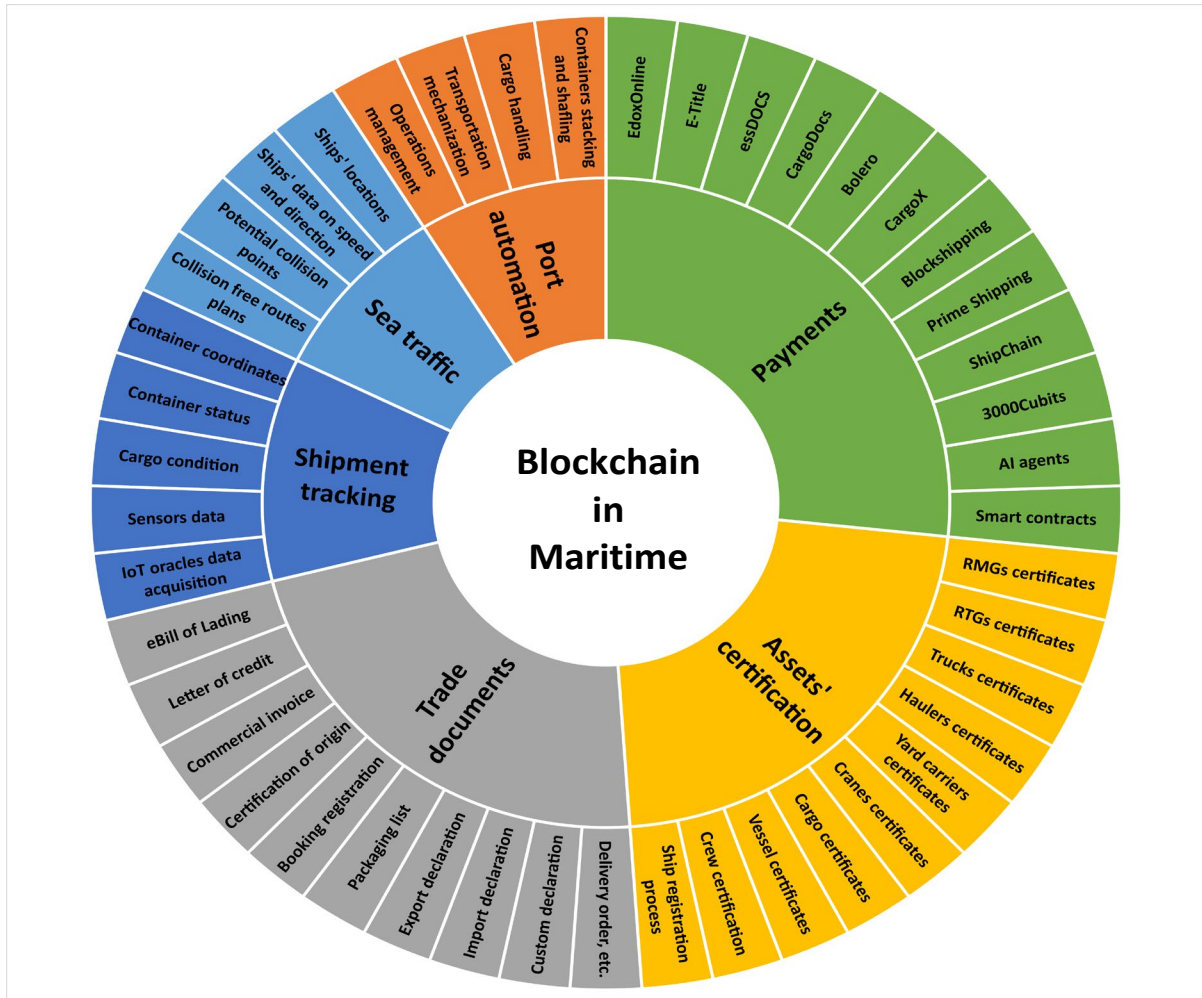


Figure 3.3: Blockchain’s maritime applications

Source: Researcher (2023)

The actors come from various departments in different states, so they all have different requirements, laws, regulations, business cultures, etc. The need for maritime application of Blockchain thus arises to reduce paperwork, inefficiencies, and limited data capture capacities.

Essentially, Blockchain is a distributed digital ledger enhanced by robust asymmetric (de)encryption algorithms, timestamps, hashes, mathematical puzzles or difficult tasks, and consensus mechanisms to enable data transfer instantaneously in safe and secure manner. Blockchain's primary benefit for the maritime industry is its ability to

organize and store enormous volumes of data, which makes it easily accessible to parties involved in international trade. When compared to labour-intensive and prone to error human-based work—which is still common in the maritime industry—this offers significant advantages.

3.3 Applications beyond cryptocurrencies

Maritime application of Blockchain increases productivity through virtually smart contracts, payments based on cryptocurrency, monitoring and controlling the location and condition of freight, and the placement of empty containers via UHF-RFID, GNSS, GSM and/or IoT/IoE. It also enables early risk assessment methods and opportunities for added-value service introducing on the consortium or open platforms (Figure 3.4).

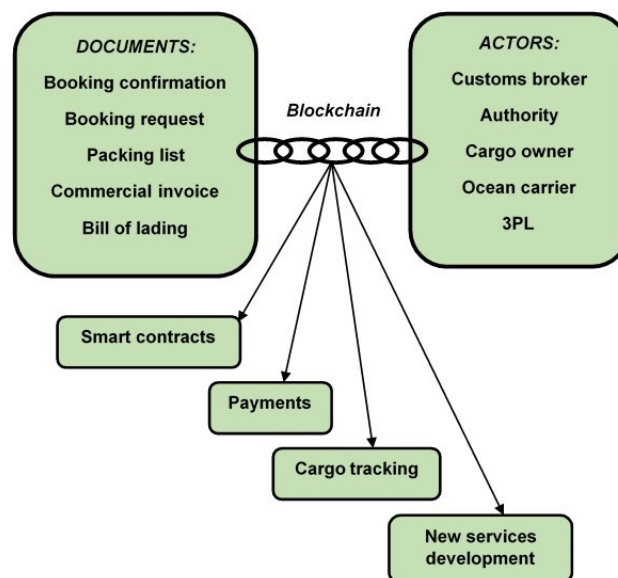


Figure 3.4: Key constructs of maritime application of Blockchain

Source: Bauk (2023c)

There are currently enough start-ups to introduce Blockchain technology in shipping and port logistics. Among the most complete options is TradeLens, which Maersk and IBM created in 2018 (TradeLens, 2019). There are numerous other advanced technology initiatives in the maritime sector that are comparable to TradeLens. For example, DP World Company began utilizing TradeLens integration. Additionally, TradeLens and the Port Authority of Algerica Bay inked a contract. At the Danish

Maritime University, work on integrating blockchain technology into customs clearance has started. The largest Chinese ports, including the Port of Shanghai and the Port of Guangdong, are served by the IT firm Ideanomics, which works with the Asia-Pacific Model Electronic Port Network on Blockchain. The Port of Rotterdam began investigating the use of blockchain technology to reduce vessel turnaround times, logistics trusts, transparency, etc. To address the declaration, tracking, tracing, online auditing, and processing of dangerous goods in order to raise their visibility and lower risks, Maritime Blockchain Labs developed a Blockchain prototype. Cargo Smart and IBM are collaborating to enhance the logistics trusts, transparency, and other aspects of the customs clearance process (Oracle Blockchain, 2018). Ship tracking is the focus of CargoLedger, a start-up founded by the Rotterdam Port Authority and Ditch Blockchain. CargoX also offers services related to other maritime documents and transactions, such as the first smart bill of lading. The key advancements in maritime Blockchain technology to date are shown in Table 3.1. (CargoLedger, n.d.; CargoX, 2021). Semi-private blockchains are widely used and secure, and the standing of consortium companies is frequently directly related to the security of this innovative technology and their novel business strategies.

Table 3.1: Blockchain suites in maritime

Suite	URL	Type
<i>Ethereum</i>	https://ethereum.org/en/	Open platform
<i>Ganache</i> (on Ethereum)	https://www.blockchain-council.org/blockchain/ganache-blockchain-all-you-need-to-know/	Private use for smart contracts
<i>Truffle</i> (on different BCT platforms)	https://archive.trufflesuite.com/	Open platform for smart contracts

Metamask	https://metamask.io/	Open platform for crypto wallets
Fabric	https://fabricmc.net/	Open platform for crypto mining
Besu (on Etheraum mainly)	https://www.hyperledger.org/projects/besu	Open or private depending on purpose
Quorum	https://www.quorumsoftware.com/	Private
Bolero	https://www.bolero.net/	Private for smart contracts
CargoX	https://cargox.io/	Private for document exchange

Source: Researcher (2024) / All URLs accessed on 20th March 2024

In the maritime industry, Blockchain is a complex, decentralized and digitalized ledger of transactions, which allows actors to communicate and exchange information instantaneously. This ledger enables goods monitoring and controlling across the whole supply chain. It is the basis for smart contracts in the maritime industry, like letters of credit and bills of lading. The maritime application of Blockchain incorporates virtually smart payments based on cryptocurrencies such as 300Cubits, Blockshipping, CargoLedger, Bolero, CargoX, etc. It allows early risk detection and optimization of supply chains when unplanned changes occurred. It is usually built on open platforms, so that new offers, suited to the customers' needs, can emerge on it as well.

3.3.1 Adoption impediments

The maritime industry is a conservative one that recognizes the importance of the quality of its operations over an extended period. Key actors in the maritime industry are thus not quick to adopt new technology, and confidence between network players is a huge concern than safety. Blockchain in the maritime industry is an unconventional technology and it includes cryptocurrencies, which are still in a flux. In such an

environment, key players in maritime sector are reluctant to divulge important information about their customers, suppliers, and cargoes. Numerous freight forwarders and agents gain the profits thanks to information asymmetry, so they will be reluctant to have closer scrutiny. Interoperability between stakeholders in the supply chain is not a significant problem concerning technology, as the technology has been standardized and developed extensively over time in comparison to the process flows carried out at inter-organizational levels (Bauk, 2022b).

Additionally, data on location of vessels can be (mis)used for disclosing ports, fuelling locations, and voyage plans. This can happen with dangerous goods and hazardous materials, drugs, proteins, etc. However, the deployment of blockchain in the maritime sector does not ensure the accuracy of the data recorded in the ledger or prevent data manipulation before it is entered into the ledger. Information about fuel type, testing, exhausted gases, and other related topics may be inaccurate. Blockchain requires a broadband channel like 5G or 6G, because of the large amount of data, traffic, and memory space requirements. Besides, the internet bandwidth and speed can be low when working at vast sea. Last but not least, the maritime applications of blockchain consume a lot of energy and produce a large carbon footprint.

3.3.2 Benefits and concerns

Information about fuel type, testing, combustion risks, and other related topics may be inaccurate. However, as was already mentioned, this does not account for the high total cost of investment or the costs related to the adoption and implementation of Blockchain, particularly in developing economies. At present, there is a dearth of awareness, knowledge, and expertise regarding Blockchain among supply chain stakeholders. Thus, at the administrative, operational, and regulatory levels, programs for education, training, or the development of human capacity are required. The global supply chain still requires a greater degree of standardization. In this regard, the Digital Container Shipping Association (DCSA) is working hard, but more needs to be done.

As blockchain technology requires technological integration and comes with operational, legal, and training costs, stakeholders are generally not as keen to invest

in it. Given that the maritime industry has historically depended on its legacy, this is especially true. Additionally, there seems to be a disconnect between the range of state-of-the-art approaches available in software engineering and information security research and practice, and what practitioners in the Blockchain sector suggest.

Aside from this, larger shipping companies are the ones most likely to gain from blockchain technology; however, to meet the demands of their wide range of players, their blockchains would need to be extremely complex, requiring substantial financial resources. This could work against other smaller participants in the global supply chain because they would be less likely to be able to afford the technology. Not to be overlooked is the belief that technology—in this case, blockchain, the cutting edge of international trade—should improve humankind rather than supplant it (Burgess, 2021). As a result, it is important to consider the ethical and human aspects of blockchain further growth.

3.3.3 The stakeholders' voices

I have provided quotes from a few maritime industry stakeholders to support the significance of this new technology. This could provide hope to individuals who may be sceptical about the widespread adoption of Blockchain technology in the maritime industry in the near future.

“We are all connected, only not to each other. I thought, in the beginning, it was funny, but actually, it is the case. We think we are connected, and we somehow are, but often what happens in shipping today, is that people are connected by fax, email, EDI, and all types of communication, that are really not up to speed with what is required today, which is real-time information. The value proposition at the beginning [of the TradeLens project] was simply to take out the function and remove the friction from the communication that goes on between the different parties in the supply chain, because it is a chain, so no actor can act independently anyway.”

A senior Maersk executive (Jovanovic et al., 2022).

“The benefit of TradeLens is that we only need to connect to the platform, and all the shippers need to connect to the platform versus us connecting to each of the 15 shippers directly, which costs a lot of money, takes a lot of time, and does not create a lot of value.”

The president and CEO of Global Container Terminals (Jovanovic et al., 2022).

“TradeLens was founded on the bold vision to make a leap in global supply chain digitization as an open and neutral industry platform. Unfortunately, while we successfully developed a viable platform, the need for full global industry collaboration has not been achieved. As a result, TradeLens has not reached the level of commercial viability necessary to continue work and meet the financial expectations as an independent business.”

Head of Business Platforms at Maersk (Litan, 2022).

“So, bylaws could help interoperability, but it’s not only for interoperability. Let’s imagine for a second a world in which interoperability never happens in terms of eBL solution providers; to us, it still makes sense to create standard bylaws.”

DCSA-Digital Container Shipping Association program director

(Jovanovic et al., 2022).

“This process knocked ten days off the usual document processing lead time for Syngenta, and helped avoid extra costs due to delayed paperwork, such as potential destination detention and demurrage costs.”

TradeLens (Wragg, 2022).

CHAPTER 4 THE PRINCIPLES OF BLOCKCHAIN

4.1 Blockchain principles

Now let us use Bitcoin as an example to explain the fundamentals of blockchain technology. Bitcoin is now the most well-known and widely used use of blockchain technology (Bauk, 2023a).

Blocks are the fundamental building elements of a blockchain. Every block consists of a transaction and a header. Number, timestamp, public and private key set, hash, nonce, previous hash, and Merkle's roots are all contained in headers. Hash, nonce, previous hash, and Merkle's root are connected to the transactions (Figure 4.1).

Header Element – Number. Blocks have numbers: 1,2,3, etc., connected with the number of blocks in the chain of before approved blocks.

Header Element – Timestamp. There is a timestamp for each block header. It provides data on the date and time when the block was approved and added to the chain of existing blocks.

Encryption Elements - Public and Private Keys. Block header contains a pair of keys, public and private ones. The purpose of these keys can be explained on the example on a bank account. The account number functions similarly to a public key. Everyone who needs to make a payment into the account can access it. Conversely, the password and private key serve as our credentials to access the electronic bank account so that we can view the statements, make transfers, and payments. All users on the network have insight into the public key in a blockchain, while the private one is known only to the sender, or initiator of a transaction. Private key has to be protected and known only to its owner. These two keys support an asymmetric cryptographic mechanism inherent to the blockchain. Two entities, who make transactions in the are, in fact, "sender" and the "receiver". The original transaction, on the sender's side, passes through a hash function (Secure Hash Algorithm SHA-256). It is then converted into a unidirectional hash function of a 256-bits. There is no way to convert hash

function directly into the original transaction. This function contains a combination of 64 numbers (0-9) and letters (A-Z). Each transaction on a Bitcoin platform has an original hash. Any simple change to the transaction will cause a radical change to the original transaction hash value. Thanks to SHA-256 algorithm, Blockchain prevents intrusions into regular transactions flow and quarantines blocks security.

After the hash and private key are run through a signature algorithm, a digitally signed document is produced. This document follows then across the network. On another, i.e. recipient's side, this document, and the public together are sent to so-called verification function that creates a hash. If this hash is equivalent to the hash of the original transaction, decryption will be done, and the recipient will see the original transaction. Through such asymmetric cryptography mechanism, authenticity and integrity of the transaction, sender, and recipient are ensured (Figure 4.2).

Explanation of Transaction. Each transaction must be registered on blockchain. Then, every node on the network must approve the block, and the public ledger miners must confirm it. Ultimately, the ledger needs to be synchronised and the validated block added to the main chain of transactions. A miner has to validate the transaction to receive bitcoin as reward for successfully accomplished mining job. What is the role of special nodes called miners? - Miners compete in resolving difficult mathematical puzzles to reach a target.

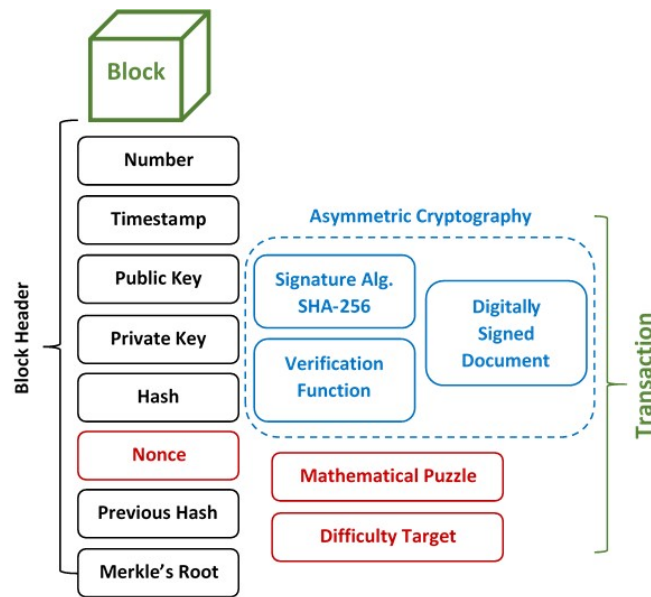


Figure 4.1: Bitcoin key elements: Blocks and transactions

Source: Bauk (2023a)

Role of the Nonce. The block number, timestamp, and Merkle's root of transactions - which functions as a kind of fingerprint for all the block's prior transactions, are contained in the header of each block in the chain of transactions. The header of each block also contains the hash of the previous block, or the 'previous hash'. This information cannot be changed. Additionally, there is a 32-bits sequence in a header that is reserved for so-called nonce. Nonce is a dedicated area in the block header in which miners put numbers randomly, aiming to solve mathematical puzzle and reach difficulty target. The winner, or the miner that first resolves the complex mathematical puzzle wins the reward, in a form of a Bitcoin. To ensure that the block is added to the blockchain, all miners must validate the block. This is accompanied by adding the guessed nonce to the block header (Antonop, 2022).

This process is known as a proof of work (PoW). It is inherent to Bitcoin. This time and energy consuming process, so other algorithms and Blockchain platforms will be discussed in the following paragraphs.

The miner requires huge computational power and time to guess the correct key, since the key is random. The miner repeatedly guesses keys until they reach the goal of solving the puzzle by matching the difficulty target.

Once the winning miner has published the nonce, all other nodes in the network have to add it into their latest block header to lock the new verified block to the chain of previous transactions. In other words, to put it into the ledger, and this then has to be synchronized at the network level.

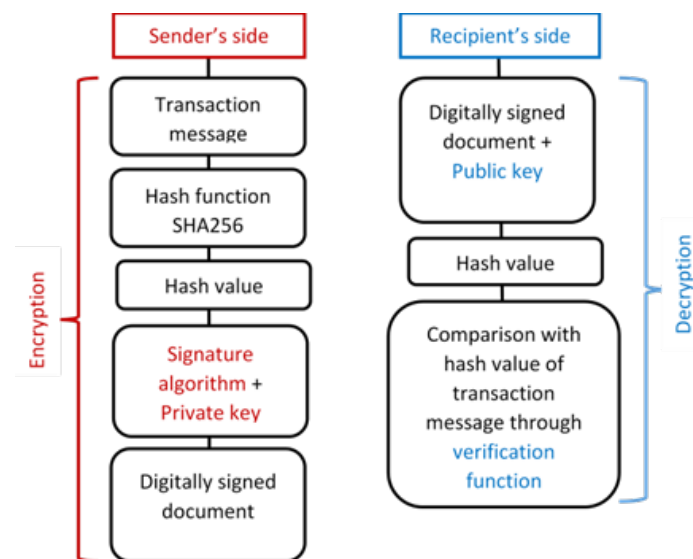


Figure 4.2: Transactions asymmetric encryption

Source: Bauk (2023a)

Meaning of Previous Hash: Blocks contain in their headers the hash of the previous block in the chain of transactions. This is referred to as a previous hash. The previous hash of the first block, it's always equal to all zero values (Brownworth, 2022).

Role of Merkle's Root: Changes to the proceeding blocks are prevented by the Merkle's root of transactions, which works as fingerprint of every transaction in the chain before. Therefore, making modifications to the chain's immutable blocks in the past is very challenging. Changes to the chain are only feasible by creating new

blocks. Thanks to these, blockchain ensures transparency, traceability, and immutability of transactions.

4.2 Cryptocurrencies

The idea of Blockchain technology first appeared in David Lee Chaum's doctoral thesis entitled "*Computer systems established, maintained, and trusted by mutually suspicious groups*", which was defended at the University of California in 1982. Then, in 1991, the paper on "*How to timestamp a digital domain*" was published by Haber & Stonett, in which they developed the concept of cryptographic time stamping of digital data. Later, in 1998, the idea of Bit Gold was developed by Nick Szabo to create a decentralized cryptocurrency system. Szabo's idea is considered as the basis of Satoshi Nakamoto's 2008 Bitcoin protocol, the principles of which are published in the paper "*Bitcoin: A peer-to-peer electronic cash system*" (Alqahtani and Algarni, 2023). The programmers, under the nick name Satoshi Nakamoto, established the Bitcoin platform and the Bitcoin as the first cryptocurrency (BTC), which is still the strongest cryptocurrency (Reiff, 2023), despite its high energy consumption issues (Bauk, 2023). In the Bitcoin network, miners' rewards halve on average every four years, i.e. after resolving 210 000 blocks. The number of Bitcoins is limited to at 21 million, and the mining rate is declining during the time. It is likely that circulation of the final bitcoin will take place in the year 2140. Only then when the Bitcoin miners will earn only from transaction fees (Hayes, 2023). A histogram of the historical development of the Bitcoin platform and its cryptocurrency is presented in Figure 4.3.

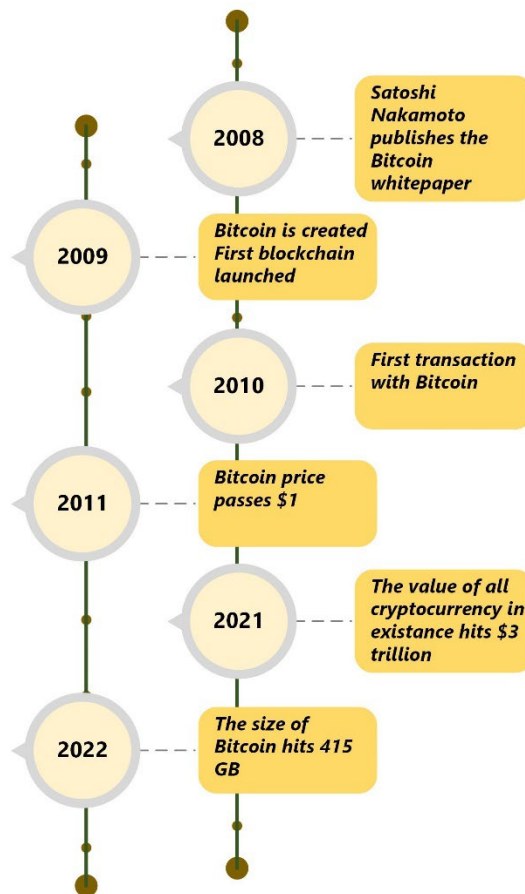


Figure 4.3: Bitcoin development histogram

Source: Researcher (2023)

Other Blockchain platforms and cryptocurrencies developed in the following chronological order: 2012 - Ripple (XRP) and Dogecoin (DOGE); 2013 - Ethereum (ETH); 2014 - Steller (XLM), Neo (NEO) and Monero (XMR); 2017 - Solana (SOL); 2018 - Tron (TRX); 2021 - Chia (XCH); 2022 - Eos (EOS), and so on. Some sources suggest that there are more than 1000 different Blockchain platforms (William, 2023) and some 9000 different cryptocurrencies in existence today (Howarth, 2023). It is thus obvious that the primary purpose of Blockchain technology is to work with cryptocurrencies.

4.2.1 Payment principles and examples

While Blockchain is a digital coin, it is also the technology that enables various transactions of digital assets between entities in a network. One of the assets that can be transferred via Blockchain is Bitcoin, which is a digital coin or simply digital money (Rubin, 2016). An open-source program was released to implement the Blockchain system shortly after the inception of Blockchain, but it was only in 2009 that the first Bitcoin network began (Sarmah, 2018). According to Ganne (2018), five years into the introduction of Bitcoin, the history of Blockchain remained nearly interchangeable with that of Bitcoin. Blockchain technology only began finding its feet in other cryptocurrencies, such as Ethereum in 2013.

An explanation of how Blockchain solves the problem of money transfers follows using simple terms: Money transfers generally include third parties, whereas Blockchain technology helps eliminate these third parties. Blockchain enables money transfers faster (immediately) and cheaper than an intermediary or third party would. The process is then dissected for the purposes of simplifying it, looking at the money transfer process between two parties (A and B) via Blockchain: An open ledger is introduced to a network. An open digital ledger is a chain of transactions carried out among the nodes of the blockchain network; it is public for the consortium members (Bauk, 2022c). All participants in the blockchain basically have access to all the information, i.e., the amount of money each party has and where the money is, and the next intended transaction can be deduced hypothetically by everyone, whether it is valid or not.

Payment example 1: Here is explained how an open digital ledger can be implemented in Blockchain. Let's suppose that "A" has \$15 and needs to transfer \$5 to "B". This transaction will be added to the open blockchain ledger. On the other side, "B" needs to send \$3 to "C" in the same way, and this is added to the open ledger. Remember, transactions can be seen and validated instantly by all the nodes in the open ledger network if they are valid, as the open ledger is public.

“C” can easily send \$1 to “D” (Figure 4.4). But, if “A” attempts to send \$15 to “D”, such transaction will not be allowed, as the remaining funds for “A” are only \$10. As a result, this transaction is not going to be validated, and it will not become a part of the chain of validated transactions. This is a case with a central, open ledger, and as such, it is simplified one. In the case of distributed ledger, each node would have a copy of the previously validated transactions. This scenario is more robust, and it is demonstrated on the next example.

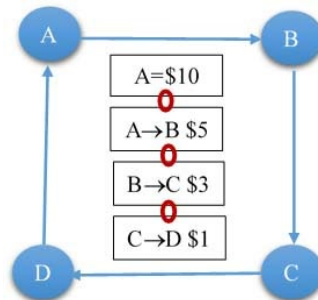


Figure 4.4: Centralized ledger scheme

Source: Rubin (2016)

Payment example 2: The centralized ledger is superfluous if each node holds a copy of the transactions. The next step is to ensure that the same version of validated transactions is seen by each node in real time. An example will clarify the point: “B” needs to send \$5 to “C” (Figure 4.5). “B” communicates its plan to the blockchain, and all nodes on the blockchain will be informed about this intention. This is an unvalidated transaction that then needs to be validated, and this is where “miners” come in. Miners are special nodes in the network that compete, and the first one to guess the difficulty puzzle to declare is the winner and receives the financial reward of bitcoin.

The winner has to satisfy the following requirements:

1. To determine whether “B” has enough money to make the transaction.
2. To reveal a key that enables the miner to lock the new transaction to a previous validated transaction in the chain. As the key is random, it takes computational power and time to find it. It is a guessing game until the key is found.

Going back to the example – if we assume that “D” has found the key and publishes it, other participants become aware that it is now public, while the ledger contains a new transaction, which is validated, i.e. moved \$5 to C’. This transaction will automatically be distributed to the ledger copies of “A” “B” and “C” in a synchronized way.

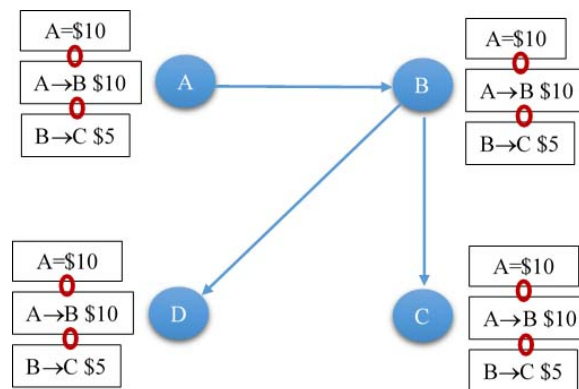


Figure 4.5: Distributed ledger scheme

Source: Rubin (2016)

This payment mechanism can be used in maritime supply chains. Examples of such platforms are Prime Shipping Foundation, 300Cubits, ShipChain, etc. However, we must be aware that there are currently many obstacles on the way to greater use of this payment principle in shipping. The reasons are numerous. The maritime industry is conservative and not an early adopter of new technologies. Shipping operators are often opportunistic and reluctant to share their business information. The lack of regulations and standards is also a problem. Then, there is the growing threat of cyber-attacks. One example is the NetPetya cyber-attack in 2017, which cost Maersk 200 million USD in cryptocurrency.

4.3 Smart Contracts

Traditional paperwork is normally time-consuming, involves third parties, and is prone to human error. Smart contracts make use of Blockchain technology to rectify these impediments by negating ‘third parties’ and digitalizing the flow of information, which

results with environmental protection and minimises delays (Rana et al., 2023). Programs called 'smart contracts' are kept on a blockchain that runs when preset requirements are satisfied. The realisation of a consensus is automated by smart contracts so that every participant can immediately be certain of the outcome of a transaction without intervention by intermediaries or time loss.

Smart contracts, which initiates the subsequent action upon the fulfilment of predetermined circumstances, can also automate workflows (IBM, 2022). Blockchain contains a program that is presented by a smart contract, which is automatically executed when the preset requirements are fulfilled (Jensen, Henningsson and Hedman 2019). In other words, the actions are executed by the computers when the preset requirements have been fulfilled and approved. This enables automatic payments.

Upon completion of a transaction, the blockchain is updated. This essentially means that only those who have been granted authorisation may view the results, and that the transaction cannot be altered or interfered with. For a task to be completed correctly, there may be as many conditions as needed to satisfy the parties in a smart contract (Bauk, 2021). The participants have to decide how transactions and their data will be transferred into a smart contract on a blockchain. Before executing the contract, the parties must agree on all terms and conditions. All if then rules must be in place. This is a prerequisite for executing the contract.

A developer can then program the smart contract, although there are organizations that offer forms, online interfaces, and additional services for the purposes of simplifying the process of setting smart contracts. The benefits of smart contracts include efficiency, speed, accuracy, security, and transparency. Because blockchain transaction records are encrypted and linked together in a distributed ledger, hackers would have to change the entire chain to change a single record. This makes blockchain transaction records almost impossible to crack.

A bill of lading or sea waybill can be transformed into a smart contract in the maritime supply chain. An agreement is required between the owner, transporter, and any other

involved parties to view the consignment, the transport device features, accompanied documents, and the like (IBM and Maersk, 2020).

Additional benefits of smart contracts include fast sharing of files with all involved actors; in safe and secure manner ; including issuing electronic bill of lading; management of accompanied files' statuses and their different versions(Green et al., 2020).

4.4 Electronic Bill of Lading (EBL)

Programmes that are automatically carried out if both parties to a contract agree are known as smart contracts. Blockchain technology is presently used to carry out smart contracts, however, this cutting- edge technology was developed later (Pertoniho, 2022). In fact, the concept of the smart contract came into being through a gentleman by the name of Nick Szabo in 1994, while Ethereum, the Blockchain platform that smart contracts usually run on, was only introduced 20 years later by Vitalik Buterin in 2014 (Bauk, 2023b). Smart contracts are sets of "if-then" rules that are applicable to the delivery of funds, goods, confirmations, and receipts in general, including in the maritime trade. The electronic bill of lading (EBL) is a kind of smart contract in the maritime domain.

The EBL's two main duties are to issue a receipt for the transportation of goods and a document of title. An EBL requires agreement between the owner, shipper, carrier, and any other relevant and authorized party for the inspection of consignments, transport equipment, and the following documents. An EBL also provides evidence of a contract of carriage between the cargo owner and the carrier. An EBL has several advantages over a traditional paper-based bill of lading (BL), as it provides efficiency, effectiveness, and stringent security. It seeks to eliminate risks such as the loss, damage, or miss delivery of documents, enables automatic execution, eliminates intermediaries, ensures distributed backups, and the like. High levels of accountability, transparency, and legal and technical interoperability are of paramount importance for the EBL, as it aims to increase confidence among the various stakeholders in maritime trade and transport.

Some of the platforms for the EBL are essDOCS, CargoDocs, Bolero, CargoX, EdoxOnline, and E-Title. Some of the EBLs on these platforms are correlated with public or open-access Blockchain platforms, like CargoX, whereas others are linked with private Blockchain platforms, such as Bolero. Brief descriptions of these two types of EBLs are provided below to highlight the pros and cons of each. In both cases, it is a matter of tokenizing ownership, but it is also a matter of who has access, and under what conditions, to the nodes of the network and ledger copies that hold information about transactions, including the parties involved and the ownership of goods.

4.4.1 Bolero EBL

At the close of 1990s, the Bolero EBL transfer platform made its debut. Since then, this system has been enhanced and is currently built on blockchain technology. At the core of the system is Galileo’s scalable, available, and reliable cloud platform. The Galileo platform is linked to financial institutions such as banks, the Treasury, the enterprise resource planning (ERP) systems of various third parties and carriers, as well as the Blockchain system. The establishment of this connection is through application programming interfaces (APIs) and the SWIFT Net MT798 standard format for sending Society for Worldwide Interbank Financial Telecommunication (SWIFT) messages. The Galileo platform is also connected via a secure web application to freight sellers and buyers, customs, logistics service providers, insurance companies, banks, forwarders, carriers, and the like (Figure 4.6).



Figure 4.6: Bolero EBL platform conceptual scheme

Source: Bolero International Ltd. (n.d.)

Users can agree to a shared set of rules using Bolero's multilateral contracts, which eliminates the need for individual bilateral agreements. The Bolero rule book contains the rules and conditions that apply to both the traditional BL and the EBL. This system also encompasses an IT management and control system called Title Registry that keeps track of all the parties involved in creating and transferring EBL documents. Being a closed network, Bolero is based on Blockchain technology. Therefore, there is a need for user registration and authentication to access the system. This closed network is associated with a higher level of transparency and privacy than open access or public platforms of the same type. A situation where the EBL needs to be exchanged with a party that is not a member of the consortium is the only time when a problem appears. In this instance, the traditional paper BL will have to be issued. However, the system will substitute the classic ancient system of issuing and transferring paper BLs in international maritime trade if proven to be faster and cheaper over time.

4.4.2 CargoX EBL

.In order to facilitate the electronic preparation and exchange of papers between various parties involved in maritime shipping, the CargoX platform was introduced in 2008. The electronic bill of lading is one of key documents that the platform supports. The CargoX platform communicates via APIs with three key segments of the system: (1) the latest generation Ethereum application for implementing smart contracts; (2) a database containing customer contacts and other background off-chain information; and (3) a secure distributed encrypted repository hosted by the InterPlanetary File System (IPFS). Documents on the CargoX platform are tokenised with ERC-721 NFT non-fungible token technology and kept with the highest level of encryption security on a distributed IPFS (Figure 4.7). The CargoX platform is a public blockchain suitable for cases where goods in transit may change hands several times. As an open-access platform, it opens up the possibility of deliberate market price changes for certain commodities. Additionally, information about the participants in the maritime transport chain can be disclosed in this public blockchain. This is definitely undesirable for some

of the actors; therefore, public blockchain platforms such as CargoX can be problematic.

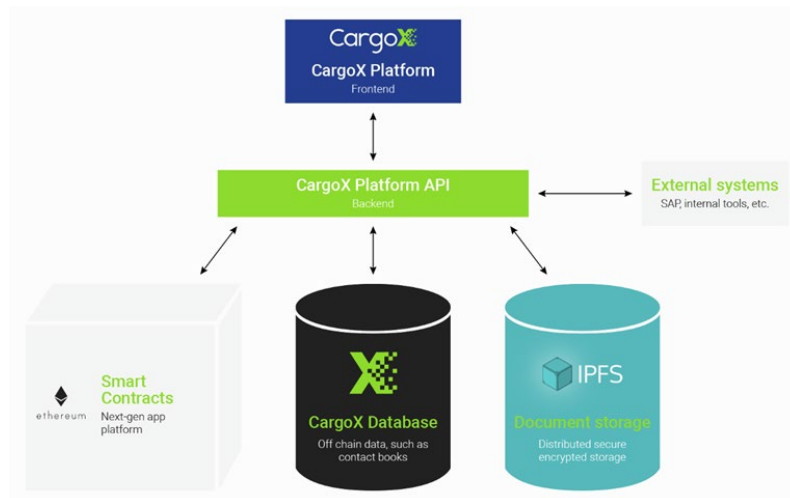


Figure 4.7: CargoX EBL platform conceptual scheme

Source: CargoX (2023)

Despite the potential advantages of EBL, according to BIMCO data, just 2% of the BL's are completely electronically. (BIMCO, 2023). Given the traditional nature of shipping, private blockchain platforms are preferred, as these require all contracting parties to be members of the network. Privacy and confidentiality risks may be the main reason why the current blockchain EBLs are limited to private systems. It is thus unlikely that public blockchain EBLs will be widely utilised in the near future. In a blockchain system, there is no trusted third party who is responsible for validating a transaction. Instead, participants in the maritime supply chain would rather be a part of a more exclusive, private blockchain since they validate it as a group.

CHAPTER 5 THEORETICAL FRAMEWORK

5.1 Theoretical Framework

The blueprint for an entire study is the theoretical framework. It plays a crucial role in giving guidance on how to build and support the study (Grant and Osanloo, 2013). It defines the research approach philosophically, epistemologically, and methodologically. It is a structure that relies on various formal theories to guide research, put together by applying a well-established, consistent description of particular phenomena and relations (Adom, Hussein and Agyem, 2018).

The necessity of introducing information system (IS) and information technology (IT) applied solutions to organizations has proven to be unavoidable to reach better organizational performance (Ayaz and Yanartas, 2020). The existence of computers and IT in contemporary organizations has risen significantly. These technologies must be utilised by employees to improve their productivity and well-being in the workplace. Studies in this domain has led to a number of theoretical models with basis in IT and IS , management science, psychology, and sociology (Venkatesh et al., 2003). Scientists are faced with a choice of several different proposed approaches, and they have to find the constructs across the models that best serve their particular study of new technology implementation and adoption.

Having the presence of several comprehensive theories on technology adoption in the digital era in mind, our theoretical framework is derived from triangulation of the following theories: the Technology Acceptance Model (TAM); the Technology Organization and Environment (TOE); the Unified Theory of Acceptance and Use of Technology (UTAUT); and the Exploiting Technology Intelligently (ETI). Table 5.1 gives an overview of these theories, including the paradigms, perspectives, and basic assumptions for each of them.

Table 5.1: Theoretical framework

Theory	TAM	TOE	UTAUT	ETI
Paradigm	New technology adoption approach	New technology adoption approach	New technology adoption approach	New technology adoption approach
Perspective	Customers' perceptions and impact of external factors	Customers' behavioural attitudes and implementation of innovation at firm level	Customers' perceptions of technology usage in the working environment	Managers' mindsets towards adopting new technology and organizational culture
Basic assumptions	<ul style="list-style-type: none"> • TAM thought to be beneficial • TAM simplicity of use • TAM perspective on utilizing it • TAM behavioural intent to make use of it • TAM real-world application of the system 	<ul style="list-style-type: none"> • TOE technological setting • TOE contextual organization • TOE surroundings • TOE Innovation in technology and decision-making 	<ul style="list-style-type: none"> • UTAUT expectations for performance • UTAUT expectancy of effort • UTAUT social impact • UTAUT enabling circumstances • UTAUT hedonistic incentive 	<ul style="list-style-type: none"> • ETI effective system as a prerequisite • ETI knowledge about technology • ETI strategy • ETI management

Source: Researcher (2023)

5.1.1 Technology Acceptance Model (TAM)

One of the most well-known theories to predict how end users will use and accept technology and information systems is the Technology Acceptance Model (TAM). It was developed by Davis (Davis, 1989). Numerous studies that looked at how users behaved in various settings have confirmed this widely researched theory. The perceived usefulness along with the prospective user's ease of use of information technology are the two constructs that form the basis of the TAM model. Perceived usefulness is described as the customer's individual assessment that employing a particular digital system will greatly impact both his or her working and/or private life conditions. The degree to which a potential user anticipates that using the system will be effortless can be attributed to perceived ease of use. These two crucial elements are, nevertheless, impacted by external factors. Among these are cultural, social, and political factors. Social factors include language, basic skills, and supportive environments. The impact of technology on politics and a political crisis are major political factors. The intention to use is associated with how the user evaluates their experience utilizing a specific IS and/or IT tools. Behavioural intention expresses the likelihood of a user deploying the IS/IT asset, and it is consequently directly connected with perceived usefulness (Surendran, n.d.). Figure 5.1. shows the conceptual scheme of TAM theory.

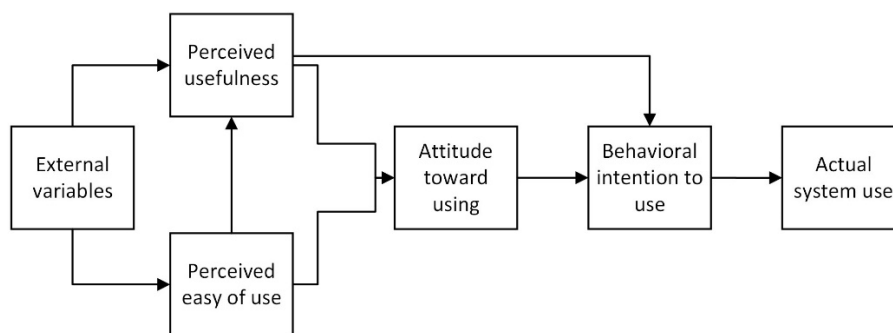


Figure 5.1: TAM - Technology Acceptance Model: Conceptual scheme

Source: Davis (1989)

TAM has been used by researchers all over the world to learn about the acceptance of various IS/IT system types. For example, Shafeek (2011) carried out a study to appraise the adoption of eLearning teaching and learning systems by instructors using the TAM. To investigate online shopping behaviour, Zhou, Dai, and Zhang (2007) developed a brand-new TAM-based model known as the Online Shopping Acceptance Model (OSAM). To project the acceptance of e-commerce, Pavlou (2003) developed a predictive modelling technique that included additional variables for perceived risk and trust. Pikkarainen et al. (2004) in their research explained the acceptance of online banking in Finland, because of perceived usefulness of this type of banking. A model was proposed by Chiu et al. (2009) that lists the important roles that internet self-efficacy and acceptance pattern play in the adoption of e-services. A TAM-based explanation of mobile service usage was put forth by Ervasti and Helaakoski (2010), and the results show that perceived utility is the main factor influencing people's acceptance of new technology. The TAM was used by Muller-Seitz et al. (2009) to elaborate on the adoption of RFID technology in relation to security issues. This study will try to expand the TAM for deeper understanding of end-users' adoption of technology in the maritime environment.

While conceiving our research model, we had in mind the key constructs of the TAM theory and its influence on the IS/IT systems' actual and effective use in maritime businesses in KZN. However, we did not strictly adhere to any of the models presented in this section and instead tried to develop a new one, based on our own desktop and practical research work.

5.1.2 Technology Organization Environment (TOE)

The Technology, Organization, and Environment (TOE) Framework has been proposed by Tornatzky and Fleischer (1990) and is in coherence with the Diffusion of Innovations Theory, developed by Rogers (1983). The TOE would be valuable for examining the embracing and assimilation of various IT innovative approaches (Oliveira and Martins, 2010). The TOE is a practical and flexible framework to understand adoption behaviour in accordance to three types of IT innovations. These

are applied innovations for technical tasks, innovations for business administration, and innovations embedded into the key business processes of a business entity (Swanson, 1994; Ramdani and Kawalek, 2007). Three context-related elements of a business entity are introduced by the TOE framework, and they have an impact on the adoption and implementation of technological innovations. They are the contexts of technology *per se*, organizations' culture, and the outside conditions.

All the pertinent technologies used by the company are included in the technological context, including both those that are currently in use within the organization and those that are available in the market but not being used. The current technologies employed by the business are crucial to the adoption process because they place significant restrictions on the scope and rate of technological innovation that the organization can pursue. Existing innovations that the company hasn't yet embraced have an impact on innovation as well, as they define the boundaries of what is feasible and demonstrate to them how technology can help them adapt and change (Baker, 2012). The term "business entities" refers to the features and assets of the organization, such as the number of spare resources, internal communication channels, employee linkages, and firm size, e.g. (Figure 5.2).

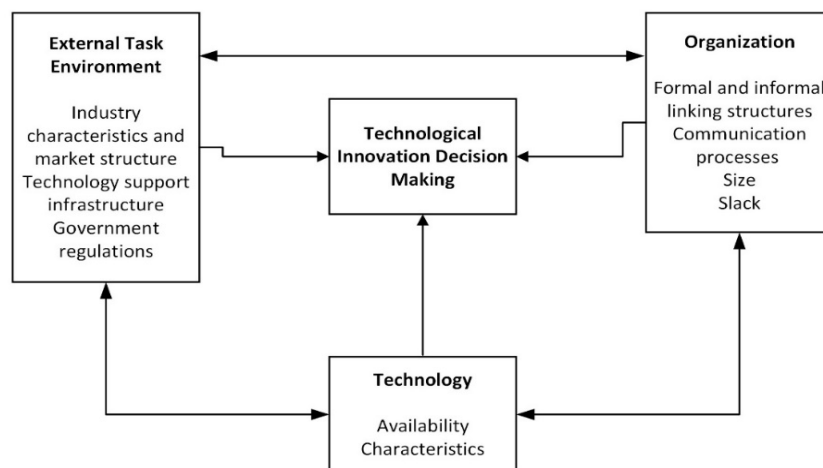


Figure 5.2: TOE - Technology Organization Environment model: Concept

Source: Baker (2012)

Depending on the nature of their studies, the researchers used slightly different parameters for the technological, organizational, and environmental contexts when testing the TOE framework. Additionally, there are a variety of factors linked to innovations that affect their adoption. In a similar vein, distinct industries, as well as various national and cultural contexts, have unique factors influencing the adoption of new technologies. Much of the theoretical work that has been done on the TOE framework has been restricted to listing the various elements that matter in different adoption scenarios. As a result, not much has changed about the TOE framework since it was first developed. Further experiments with the TOE model, can go into several different directions. One of the most anticipated is that the TOE model will continue to be applicable to empirical studies in the future.

Later, we will discuss in more detail the Exploiting Technology Intelligently (ETI) model, which has certain similarities to the TOE regarding internal and external organizational links with the outside world and business environment and communications between the company's employees within the company. Familiarity with the TOE framework helped us to a certain extent in designing our Blockchain technology implementation model for the maritime sector in KZN.

5.1.3 Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003) developed this theory of technology acceptance. Its foundation consists of seven elements: behavioural intention, voluntariness of use, social influence, performance expectancy, effort expectancy, and use behaviour.

The concept of performance expectancy refers to an individual's belief in the ability of a system to help them achieve improvements in their job performance. Conversely, the construct known as effort expectancy denotes the level of convenience associated with using technology. Moreover, the concept of social influence is acknowledged as the extent to which a person feels that significant others think they ought to adopt the new system. It is a direct consequence of behavioural intention. The degree to which a person believes that an organizational and technical infrastructure exists to support

the use of the system is known as the constructs - facilitating conditions. Compatibility, enabling circumstances, and perceived behavioural control are the cornerstones of each of these requirements. Perceived behavioural control includes self-efficacy, resource-facilitating conditions, and technology-facilitating conditions. It reflects perceptions of internal and external behavioural constraints (Ajzen 1991; Taylor and Todd 1995a; 1995b). The most important elements of the computer-supported environment are the facilitating conditions. They are provided to users to facilitate their actions (Thompson, Higgins and Howell, 1991).

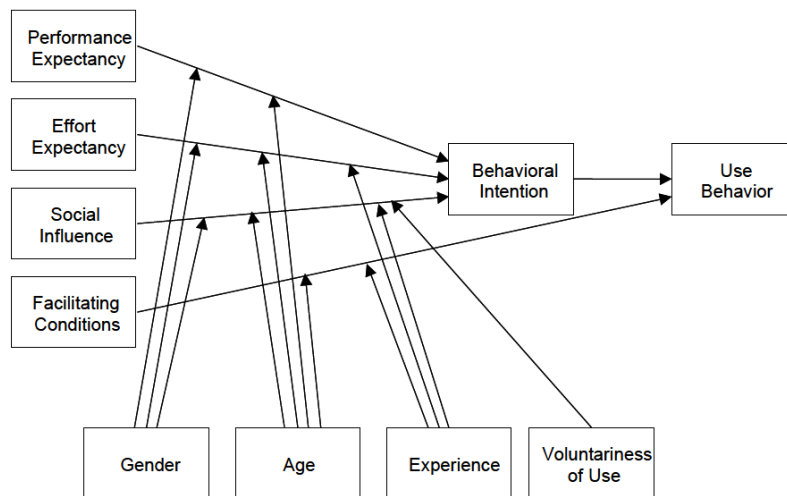


Figure 5.3: UTAUT - Unified Theory of Acceptance and Use of Technology model: Concept

Source: Venkatesh et al. (2003)

The concept of compatibility indicates how well an invention is perceived to fit in with the needs, experiences, and values of potential adopters (Moore and Benbasat, 1991). A cardinal construct within the UTAUT framework is behavioural intention. This construct quantifies the degree to which an individual intends to participate in a specific behaviour. The moderating variables in this theoretical model include age, gender, experience, and users' willingness or attitude toward using technology. These perspectives are explained by several theoretical frameworks, including intrinsic motivation (Davis, Bagozzi and Warshaw, 1992; Thompson et al., 1991; Compeau et

al., 1999). The use behaviour is the dependent construct in the model, and this is given in Figure 5.3.

The UTAUT model seeks to clarify how users intend to use and intend to use information systems (Foon and Fah, 2011). It suggests that there is a direct correlation between behavioural intention and the actual use of technology. Four major constructs - performance expectancy, effort expectancy, social influence, and facilitating conditions - have a direct impact on the adoption of technology. To take advantage of the system, age, gender, experience, and voluntariness can all be used to mediate these constructs (Marikyan and Papagiannidis, 2023).

Familiarity with this theory assisted us in designing a research plan and a model for the rational implementation of BCT in the maritime sector in KZN.

5.1.4 Exploiting Technology Intelligently (ETI)

The four main components of this theoretical approach are knowledge, IT strategy, system effectiveness, and IT management. Organizational culture and the top managers' mindsets contribute to these dimensions (Figure 5.4).

The concept of knowledge can be defined as the understanding of a subject acquired through education or experience and that is typically held by one or more people. An additional way to define it is as the knowledge or awareness of something (Cambridge Dictionary, n.d.). According to the Cambridge Dictionary, knowledge can also be defined as awareness, comprehension, or possession of information about something, or as the ability to understand information about something. These are all attributes that can only be acquired via study or experience, and they can be shared by an individual or the public. Knowledge is represented metaphorically as one of the rungs on the so-called ladder of knowledge. Data, information, knowledge itself, and wisdom make up the knowledge ladder. The ideas of knowledge and wisdom are more difficult to explain than the stairs, which represent data and information. Here, the knowledge step will be highlighted as the essential to comprehending contemporary IT and its astute application in maritime enterprises. Understanding the existence of advanced

IT applications on the market and their usefulness for business strategies, procedures, and operations is referred to as knowledge.

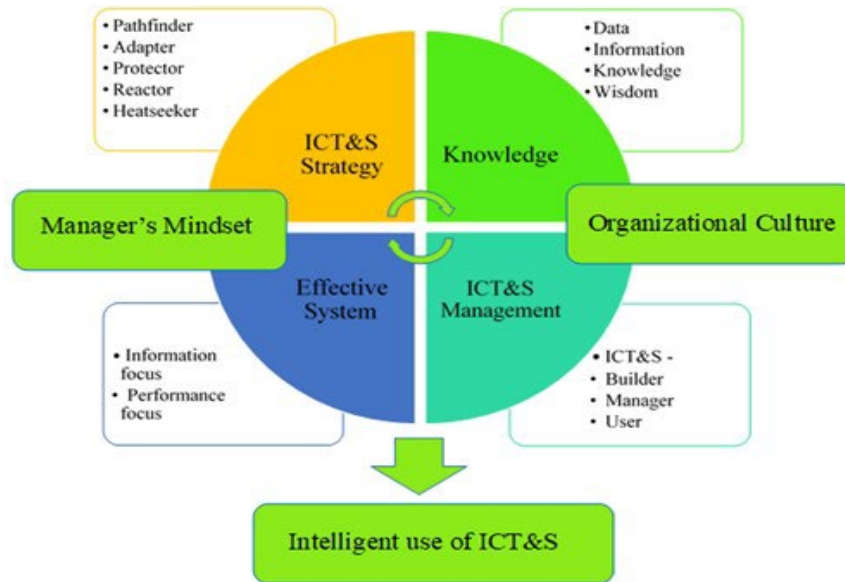


Figure 5.4: Adapted Exploiting Technology Intelligently (ETI) model

Source: Bauk (2022a)

Business and technology are combined in an IT strategy. The ETI, also known as Holtham and Courtney's model (Bauk, 2022c), consists of five distinct organizational strategic orientations.

Pathfinder: continuously investigates and carefully chooses from pertinent IT trends to obtain a competitive edge and break into new markets. The pathfinder is open to trying out cutting-edge, new IT. The pathfinder constantly looks for ways to gain a competitive edge by spotting or feeling new developments in IT.

Adapter: operates in two distinct markets: one is more stable and efficiency-focused, while the other is one where IT is becoming more and more significant. Different technological uptake scales are used by adapters for each. This divided characteristic is typical of companies with differing degrees of technology adoption, where standard solutions are not as important as adaptability.

Protector: carefully assesses an IT investment for its focus and efficiency; instead of generating new business opportunities, technology is applied primarily to lower investment costs and improve communication processes. A protector is slow to innovate and control-oriented. These companies operate in industries where basic IT is widely accessible and reproducible.

Reactor: is a part of the company where technology is not considered a strategic advantage. It tends to see IT applications as stand-alone tools and is not very flexible. This strategic orientation typically makes the IT platforms look outdated or feeble. Because of its inability to satisfy the needs of its clients, this puts the company's competitiveness at risk.

Heat seeker: searches for the most in-demand IT rather than carefully evaluating which IT is most appropriate for its operational procedures. An organization that is always changing its structure and trying out new ideas before achieving consistent business performance is likely to have a heat seeker orientation. An organization of this type responds to IT expenditures and subsequently makes partial withdrawals when the anticipated benefits take time to materialize.

By establishing, articulating, and continuously developing critical success factors (CSF) (Rockart, 1982), the effectiveness of the IT system can be reached. Using technology, the first step is to build an efficient operating platform that is based mostly on internal data. The CSFs can then be expanded to support enhanced technological proficiency. Employees are the first to experience this, followed by suppliers and customers. When these two processes are functioning effectively, the CSFs can be expanded to incorporate outside data about competitors, customers, and markets. Business intelligence comes next, allowing organizations to manage risks and identify opportunities as they develop new goods, services, and markets to secure a prosperous future.

IT managers, IT builders, and IT users are all involved in the administration of the IT system. As a knowledge navigator or information resource manager, they should be part of the team or individual within the organization that conveys the needs of IT users

to IT builders or designers. Some organizations have acknowledged this triangle and are making efforts to close any gaps and enhance employee competencies to accomplish the objective of efficiently utilizing and managing IT systems (Earl, 1989; Earl, 1998).

The organizational culture and the mindset of the top manager support the four constructs that make up Holtham and Courtney's model.

It is widely acknowledged that organizational culture exists and has a significant influence on how people behave within them. As for the general definition of organizational culture, there isn't much agreement. Since a consensus explanation is lacking, the following ones (Weil and Ross, 2009) can be employed: Organizational culture can be defined as the way that organizations operate, as well as the culmination of rituals and values that act as a unifying factor among its members and as a form of workplace civilization.

The job of the top manager or top management team is to create a web of interconnected vertical (direction, knowledge, process, and climate) and horizontal (information, technology, people, and the organization) threads. Managers have frequently identified people's skills as the primary influence, along with the organizational climate, in organizations where knowledge is a core dimension. According to Kadiri et al. (2016), for today's businesses, transitioning from an information-based to a knowledge-based enterprise is a crucial challenge. As a result, managers need to properly integrate concepts from a variety of fields, including artificial intelligence, big data, analytics, organizational behavior, and human resource management. Although a major enabler, technology is typically not as important as climate and skills. The team mentality of top managers encompasses all taken into account constructs and influences the wise or prudent use of IT (Kapidani, Bauk and Davidson, 2020).

Besides presenting theories and models, we considered the studies of Holtham et al. (2004; 2006); Holtham and Courtney (2010); Stace et al. (2012); Roztocki (2014); Sabi et al. (2016); Keszey (2017); and Sislian and Jaegler (2020). These helped us in

conceiving our own study of the rational adoption of Blockchain technology in the maritime industry in KZN. In fact, we triangulated all these approaches in conceiving the structure of our research.

The research methodology used to enable a quantitative analysis of the data collected from questionnaires given to experts working at three major maritime companies in KwaZulu-Natal (KZN) is described in the next chapter. These companies are the South African Maritime Safety Agency (SAMSA), the Ethekewini Maritime Cluster (EMC), and Integral, Ltd., an integral logistics company. The gathered data were subjected to a traditional statistical analysis, as well as specialized Interpretative Structural Modelling (ISM) and a Matrix Multiplication Applied Classification (MICMAC) tool analysis. The following chapter will go into further detail about these.

CHAPTER 6 RESEARCH METHODOLOGY

6.1 Research Methodology

Within the business domain, research can be characterized as a systematic and organized effort to investigate a particular problem that needs to be fixed at work. It consists of a few steps designed and carried out with the intention of resolving the problems that the workplace manager (or researcher) is concerned about. This suggests that the first step in conducting research (in this case, maritime research) is to identify the problem areas within the company or industry and to as precisely and clearly identify the issues that require investigation and resolution. Following a clear definition of the issue, actions can be taken to determine its contributing factors, collect data, analyse it, and create an explanation before implementing the required corrective measures to resolve it.

The term "research process" refers to the entire endeavour to find solutions to issues. Therefore, research consists of several carefully planned and carried out tasks that help managers and researchers understand how to solve or at least greatly reduce business and research problems. Inquiry, investigation, testing, and experimentation are all included in research. These tasks need to be carried out methodically, cautiously, critically, impartially, and logically. Findings that help stakeholders address the issue situation would be the desired result.

Understanding business research is essential for managing the following tasks: identifying the important issues, gathering pertinent data, analysing the data to support decision-making, and implementing the best course of action. After all, selecting from a range of potential solutions to an issue is the essence of decision-making. Understanding research empowers us to conduct our own research to address both minor and major issues. It facilitates better communication with researchers and consultants and helps us distinguish between strong and weak research works published in (professional) journals, between strong and weak studies carried out by research agencies, and between notable and subpar research proposals by research agencies.

An organized, methodical, data-driven, critical, and exhaustive questioning or investigation into a specific problem with the goal of finding solutions is what is known as a business study. Fundamentally, research provides the information and data needed to help stakeholders make more informed decisions. This is typically the outcome of a thorough examination of primary data obtained through in-person or online first-hand research. These may be quantitative (quantitative data are data in the form of numbers and are typically gathered through questionnaires) or qualitative (qualitative data are words gathered through interviews).

Secondary and primary research methods were used to gather data for this business research project. Relevant books, articles, theses, dissertations, statistical reports, bulletins, government publications, conference proceedings, social media, unpublished manuscripts, etc. were used as secondary sources of information. The type and utility of the secondary data were carefully evaluated. Timeliness, accuracy, relevance, and the cost or parsimony of the data were the evaluation's criteria. We used our knowledge and experience, as well as the outcomes of a thorough analysis of secondary literature resources found on the databases of EBSCO, ProQuest, Science Direct, Web of Science, IMarEST, Google Scholar, and IEEE Explore, to inform the interviews and questionnaires for the case study. A comprehensive desktop search was performed to locate pertinent data sources. When collecting the primary data, a mixed, sequential method was applied (Table 6.1).

Table 6.1: Mixed research method applied to collect primary data

Target	Mixed research method	Data collection method	Type of data
Employees at SAMSA, the EMC, and Ltd. Integral, maritime firms in KZN	Qualitative	Structured interview composed of open-ended questions	Text (Work)
	Quantitative	Questionnaire composed of close-ended questions	Numbers (Likert scale)

Source: Researcher (2023)

Primary data were collected through structured interviews, using open-ended questions and questionnaires made of closed-ended questions populated according to a Likert's scale (1-5). The respondents were employees of the South African Maritime Safety Agency (SAMSA) office located in Durban, the eThekweni Maritime Cluster (EMC) based in Durban, and the branch of the Integral, Ltd. Integral logistics company located in Durban.

6.1.1 Research approach and data collection method

As our research methodology, we conducted a single, cross-sectional case study. The unit of analysis was an employee, employed at one of three selected maritime firms in KZN (SAMSA, EMC, and Integral Ltd.). The primary data collection methods were a structured interview and a questionnaire. The instruments used in these methods collected data from people to explore their knowledge and attitudes regarding Blockchain deployment in the maritime shipping industry and port management. This approach allowed us to acquire both qualitative and quantitative data.

Structured interviews were carried out with the aim to get feedback, which helped us to design the questionnaire. The interview data were used to establish the validity of the questionnaire, which comprised of a set of closed-ended questions answered by

means of well-known Likert scale (with scores of 1-5). The interviews and questionnaires were self-administrated, and the respondents completed them on their own on their computers. The data collected from the respondents' feedback were captured on a computer, coded, edited, and presented in an easy-to-understand form.

The questions for the survey and interview were created after carefully examining Upadhyay's (2020) research on the revealing blockchain technology in the maritime industry. We also used triangulation of the different methods of intelligent or reasonable IT adoption (see Chapter 3 for more details) and identified the main constructs for the interview and questionnaire. The key constructs around which the interview and survey questions were conceived are presented in Figure 6.1.

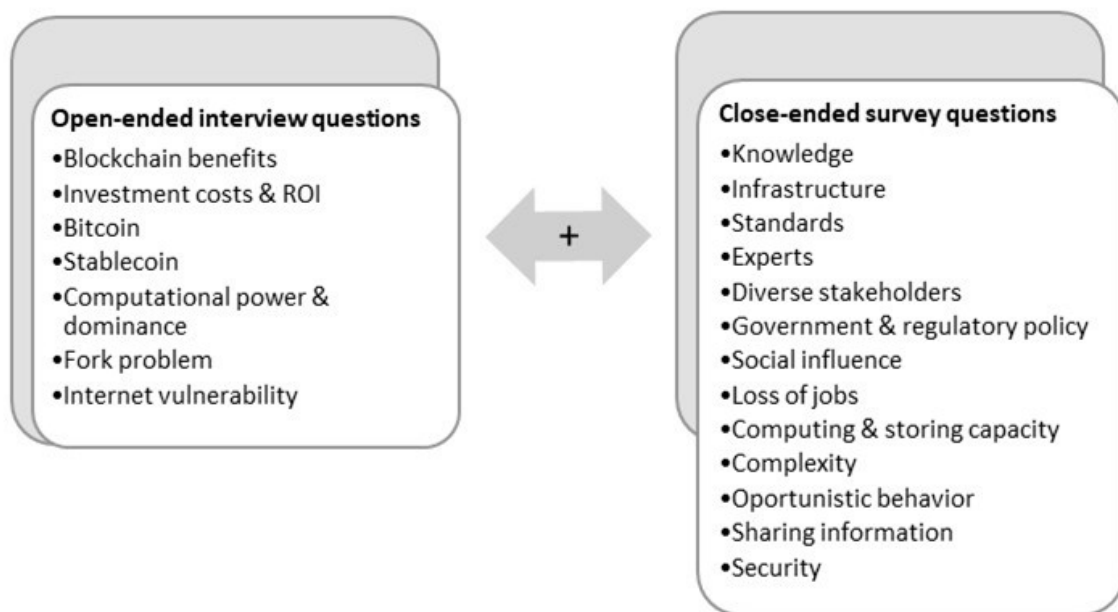


Figure 6.1: The constructs for the interview and survey questions

Source: Researcher (2023)

6.1.2 The interview as a data collection method

Conducting interviews with respondents is a method used in business research to gather data on a specific topic. Typically, an interview involves a purposeful exchange

between multiple individuals. There are several kinds of interviews. Structured or unstructured. Interviews can be done individually or in groups, and can take place face-to-face, through phone calls, or via mail. In structured interviews, the desired information is known in advance. It is feasible to get ready beforehand, and a structured interview generally consists of:

- The introductory section, in which the interviewer provides a brief introduction, explains the reason for the meeting, guarantees confidentiality, and requests authorization to record the conversation.
- A series of questions covering the study's purpose, followed by "warm-up" questions that are simple to respond to and "non-threatening".
- Follow-up questions known as probing questions are used when the interviewer needs more specific or detailed information, when the first response is ambiguous or incomplete, or in other similar situations (Sekaran and Bougie, 2016).

In the structured interview, which we used for our study, we introduced ourselves as researchers (the PhD student and the supervisor), and we introduced our study by means of a consent letter, which was a prerequisite for obtaining ethical clearance at the beginning of the study process. The consent letter was sent to the participants prior to the interview questions. The interview was structured in such a way that the first questions were more general and the following ones more specific. These had to do with their familiarity with the fundamentals of blockchain technology and its uses in the maritime industry and business domains. Since the individual, structured interviews we used were computer-assisted, we did not use probing questions and instead did our best to formulate the questions so that they were short and clear to avoid any misunderstanding of the questions and misinterpretation of the answers.

The interviews were composed of seven open-ended questions. These open-ended questions allowed the respondents to answer in the way they chose. An example of an open-ended question we asked is: "What are the potential benefits of introducing Blockchain solutions in the maritime businesses in KwaZulu-Natal, more precisely, in

the shipping industry and port management?” Another example relates to one of the key challenges of Blockchain technology: “Even though it is an advanced technology, Blockchain still struggles with some security issues. For instance, if someone has more than 51 per cent of the computing power on the network, their node can find the nonce (the number that Blockchain miners are trying to solve) quicker than others on the network can. This means that their one node has the authority to decide which block is permissible, and which is not, which influences the processes in the blockchain and has financial implications for the organization. What is your standpoint regarding this challenge?” We did not want to overwhelm the respondents with too many questions, as we wanted them to remain focused on the questions and their related answers.

We did not set limitations in terms of the number of characters or words the respondents could use. We just wanted them to address each topic covered by the questions freely and to the best of their knowledge and experience. All 20 sets of feedback received revealed that the questions were answered in a conscientious and meaningful manner. Based on the answers received, we concluded (once again) that the respondents were experts in their field and that they were very interested in Blockchain technology and its wider application and implementation in the maritime sector.

The interviews were computer-assisted, as we sent them via email to the respondents in the three selected maritime companies in KZN. The interview questions were sent as a Word document attached to their email, with a request for their participation. We sent emails to 30 prospective respondents but only received 20 responses within the period of 3 weeks allocated for response time. During this period, we sent gentle reminders about the deadline for responses to some of the respondents via email and phone calls. The results obtained from their responses will be presented in the following chapter, which deals with the qualitative data analysis. The interview questions are provided in Appendix 3 of this dissertation.

6.1.3 Qualitative data analysis

Qualitative data are those that are word-based. A variety of information sources, including interview notes and responses, focus group transcripts, responses to open-ended questions, transcribed video recordings, online product reviews, and news articles, are considered forms of qualitative data. Qualitative data can be obtained from a wide range of primary and/or secondary sources, such as individuals, focus groups, company records, government publications, and the Internet. Valid conclusions can be drawn from study data through the analysis of qualitative data (Sekaran and Bougie, 2016).

Analysing qualitative data is a challenging task. The problem is that there are relatively few well-established and generally accepted guidelines for the analysis of qualitative data, in contrast to the rules and guidelines available for the analysis of quantitative data. For the analysis of qualitative data, numerous general approaches have been developed over time; the most popular approach is based on Miles and Huberman's (1994) research. They stated that the three stages of qualitative data analysis are data reduction, data display, and conclusion drawing.

The first step in the analysis of qualitative data is data reduction. Data reduction is the act of choosing, classifying, and coding the data. Methods of presenting the data are referred to as data display. If the researcher (and eventually the reader) has access to a collection of quotes, a matrix, a graph, or a chart that illustrates patterns in the data, they might find it easier to understand the data. These data displays can be used to draw conclusions about the trends identified in the smaller dataset.

Analysing qualitative data is a continuous, iterative process as opposed to a sequential, linear one. For example, data coding might assist us in coming up with concepts for how the data might be presented as well as in making some initial conclusions. Preliminary findings could then influence how the raw data are sorted, coded, and presented.

In our study, we edited and analysed the qualitative data by grouping the answers around the key constructs like Blockchain technology's benefits, investment costs,

revenue from the investment period, Bitcoin, Stablecoin, computational power and dominance on the network, the fork effect, and Internet vulnerability. We also selected and quoted some of the answers we considered important or indicative of a theme. We believe that the best way to interpret certain answers is to quote them, so we did this in several instances. Our pool of respondents was relatively small, so we could easily select and present some of the most convincing answers. The findings were published in the journal and conference papers (Chapter 2 and Appendices 5, 6, and 7) and these publications were a testament to the quality of our research.

6.1.4 The questionnaire as a data collection method

A questionnaire consists of a prewritten set of questions to which respondents must write or record their answers, which must typically fall into one of several narrowly defined categories. Questionnaires are typically used to collect quantitative data. They can be distributed electronically, delivered in person, or mailed to the responders. Questionnaires are generally less expensive and time-consuming than observations and interviews, but there is a noticeably higher chance of non-responses when using them. We employed Word documents with questionnaires for our study, which we emailed to possible respondents. We made every effort to avoid asking loaded, confusing, misleading, or double-barrelled questions when we were creating the questions. We made an effort to keep the number of questions to a minimum and to phrase them clearly and succinctly. The questionnaire consisted of closed-ended questions that required respondents to provide a single response on a Likert (1–5) scale. More specifically, the statements and questions were constructed in a way that allowed participants to weigh the benefits and drawbacks of various blockchain dimensions before selecting a number from a range of 1, 2, 3, 4, or 5 to correspond with that statement or question. Number 1 indicated the least amount of agreement or disagreement, and number 5 the most amount of agreement.

To collect the qualitative data, we sent questionnaires with close-ended questions/statements via email to the respondents in three selected maritime firms in KZN. We sent the questionnaire as a Word document attached to the email to each of

the prospective respondents, together with the request for their participation. We sent 30 questionnaires in total and received 20 completed questionnaires in response within the designated response period of 3 weeks, as was the case with the open-ended interview questions. Emails and phone calls were used to provide gentle reminders for the respondents to complete the questionnaires. The results obtained will be presented in the next chapter, which deals with the quantitative data analysis.

6.1.5 Quantitative data analysis

The next stage in research is to analyse the quantitative data to find the answers to our research questions after they were gathered from the population representative sample. However, before we could begin analysing the data, there were a few things we needed to finish. By taking these actions, the data were made more accurate, comprehensive, and ready for analysis. Data coding was the first stage of data preparation. Data coding was the process of giving each participant's response a number so that it could be recorded in a database. After checking the validity of the data and entering them into an Excel spreadsheet, we did a basic statistical analysis of the dataset. We calculated the mean values and standard deviations. This method of quantitative data analysis was applied to 13 questions in the survey. We then conducted a deeper analysis of the qualitative data using Interpretative Structural Modelling (ISM) and Cross-Impact Matrix Multiplication Applied Classification (MICMAC) tools, which we applied to the 14th question in the survey. In the 14th question, the respondents were asked to compare the set of barriers to Blockchain technology's mainstream adoption in the maritime industry. The survey questions are provided in Appendix 4, and the data analysis is presented in the following chapter of the dissertation. The appropriate numerical and graphical presentations are provided. The ISM and MICMAC tools are described in the following paragraphs.

The structure of the primary data collection methods and qualitative and quantitative data analyses are given in Figure 6.2.

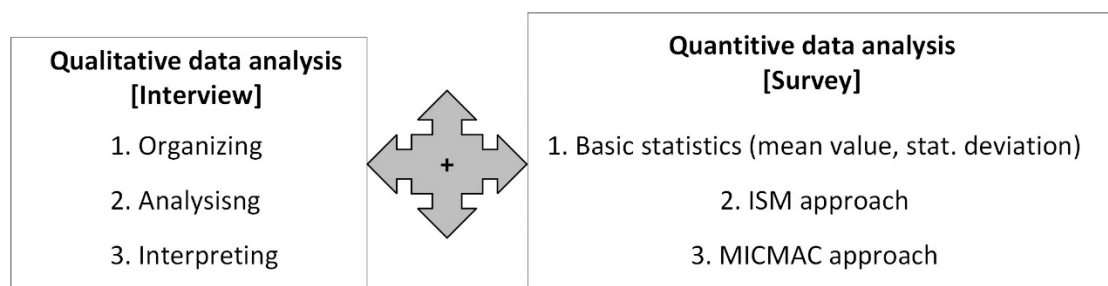


Figure 6.2: Data collection and analysis scheme

Source: Researcher (2023)

6.1.6 The ISM Approach

Interpretative Structural Modelling is a well-structured, collaborative technique used to reveal the relationships and hierarchy between the barriers considered in a model (Chandramowli, Transue and Felder, 2011; Poduval, Pramod and Jagathy Raj, 2015; Digalwa and Giridhar, 2015; Ahmash, 2021). It transforms initially unclear and poorly articulated interpretations into a visible and well-defined structural scheme. In this instance, a set of maritime Blockchain implementation barriers were first identified. An aspect is then added to the contextual relationships, for instance: did barrier B1 affect barrier B2, or vice versa; did they affect each other; or was there no relationship between them? After the barriers and contextual framework are determined, each respondent must perform pairwise comparisons. The transitivity of the contextual relationship is a fundamental assumption in the ISM. It states that if barrier B1 is related to B2, and B2 is related to B3, then B1 is necessarily related to B3. This enables the creation of a final reachability matrix and a hierarchical structural model. This method will be explained in the data analysis chapter.

6.1.7 The MICMAC Approach

A graph is produced by Matrix Multiplication Applied Classification, which categorizes the barriers in a model based on their driving and dependent powers (Saxena and Vrat, 1990; Dubey and Ali, 2014; Ahmad and Qahmash, 2019; Bashir and Ojiako,

2020). It enables the study of indirect relationships, and it is known as grey area exploration. More precisely, it complements the ISM approach, which explores the relationships yes/1 or no/0 and neglects the grey area between these two. This is where the MICMAC assists by establishing a clearer picture of the barriers' relationships to one another, including their driving and dependence levels, and the relationships are presented in the form of a graph. The data analysis section will provide an explanation of this procedure. This dissertation used the ISM and MICMAC tools to analyse the hierarchical structure and dependencies of the barriers preventing blockchain technology from being widely adopted in the maritime industry. These techniques, which make use of specialists' contextual knowledge of the elements, are widely used across many domains. Numerous fields, including supply chain and logistics management, manufacturing systems, information management, quality assurance, safety, health, and environmental management, financial management, governance, energy management, and marketing, have used these techniques.

CHAPTER 7 DATA ANALYSIS

7.1 Data analysis

Personal values and viewpoints have the potential to easily skew data in both qualitative and quantitative investigations. For the user to make an informed decision about the quality of the data later, it is imperative that the researcher be clear about their expectations and assumptions. There should be zero tolerance for falsification or manipulation when disseminating the study's data. After making the decision to take part in the study, the respondent must cooperate completely and give their full attention to the tasks at hand, which may include answering questions during an interview or survey. In addition, the respondent is required to give accurate and sincere answers. Giving information that is known to be false or making false representations should be avoided. Within the framework of this study, we did our best to ensure objectivity on our part as researchers, as well as on the part of the respondents by choosing them carefully. In the following text, we will present the results of the qualitative and quantitative analyses we carried out on rational blockchain adoption across KZN's maritime sector. There were 20 respondents from the 30 employees initially selected from SAMSA, the EMC, and Ltd. Integral maritime business entities.

7.1.1 The qualitative data analysis

Our qualitative analysis was designed around constructs like the prospective benefits of Blockchain's implementation and adoption, the investment costs associated with this, the return on investment, Bitcoin, Stablecoin, and the Internet's vulnerability since it is used as the platform for Blockchain's transactions of digital assets. The issues considered were encompassed by the following **interview questions**:

- 1) What are the potential benefits of introducing Blockchain solutions in the maritime businesses in KwaZulu-Natal, more precisely, in the shipping industry and port management?
- 2) Changing the current system will be very expensive and time-consuming, especially because it is infrastructure. We must make sure that this cutting-edge

technology not only generates economic benefits and complies with regulatory requirements, but also fosters positive relationships with traditional maritime business organizations, as these groups are resistant to change. Could you please share your thoughts on the matter of the logical integration of this new technology into KwaZulu-Natal's well-established maritime business practices?

- 3) Using Bitcoin as an example, the government is wary of Blockchain technologies because of the decentralized system's potential to undermine the central bank's authority over monetary policy and quantity. If authorities don't investigate this matter and quickly develop new regulations, the market will be vulnerable. What are your thoughts on this challenge related to the use of cryptocurrencies in the maritime industry?
- 4) Do you know what "Stablecoin" is? In what way can it help with the problem that was previously discussed?
- 5) Blockchain is a sophisticated technology, but it still has some security problems. The nonce, which Blockchain miners are trying to solve, can be found quicker by a node with more than 51% of the network's processing power. This implies that their single node has the power to determine which blocks are acceptable and which are not, which affects the blockchain's operations and has an impact on the company's finances. What are your thoughts on this challenge?
- 6) The "fork" problem is an additional concern. It has to do with a version agreement for decentralized nodes that occurs when the Blockchain software is updated. The nodes are divided into old and new ones during the upgrade, and problems could occur when they attempt to connect to the network simultaneously. In general, how do you think this issue can be resolved in the maritime industry?

The Internet is used by blockchain. Does this imply that it is vulnerable to widespread online threats like "botnets," for example? What safety and security precautions are necessary, and how can this be avoided?

The following dimensions or elements were selected after careful reading and analysis of the comments and answers provided by the selected specialists in the maritime businesses:

- 1) For example, the experts saw advantages in using BCT in the cruise industry. According to their opinions, it would facilitate payments, draw tourists, boost income, advance cruise tourism, etc. They believed that BCT could be used to control passenger flows, carry out market research, offer solutions for the shipping requirements of cruisers, etc. The experts were also in favour of the idea that BCT could assist by centralizing all relevant data and establishing a special platform for IT solution providers, ports, and agents that work along the supply chain. Because BCT made it possible to track cargo in real time, ports and shipping companies were able to plan land procedures in advance, which sped up terminal work and reduced operating costs. The experts expressed their opinion that trading safety and transparency were enhanced by the maritime application of BCT. The industry would become even more efficient and there would be a decrease in human error if BCT was implemented.
- 2) The second statement/question focused on the expenses associated with implementing BCT infrastructure and the challenges associated with altering organizational practices. Although the experts had differing views, they all agreed that this should be a part of the inevitable digitalization of the marine industry. Although switching from the old to the new system would cost the organizations a lot of money, there would be many advantages in the end. One of the experts expressed their opinion as follows: *“The BCT will transform the maritime industry, as it is still struggling with high costs and high level of pollution. This technology can help with both issues, by cutting down administrative costs and providing environmental-friendly solutions”*. We selected two additional answers regarding this issue. One of the experts stated: *“We need a law, which would regulate digital assets, together with crypto exchange and Information Commissioner's Office (ICO) regulation. Tokenizing big tourist investment via crypto would allow the crypto community worldwide*

to invest in future South African projects". We also selected the following expert's opinion as one to be kept in mind as well: *"Technology is advancing faster than human habits. Are our brains ready for all technological changes, and all that information delivered every day? Adoption is very slow; most of the people do not even use credit cards or e-banking services. It just needs decades for new digital generations to come"*.

- 3) The experts acknowledged that it could be beneficial for the central bank to act as a regulatory body; however, the general agreement was that South Africa's central bank was primarily the regulatory body for the country's commercial banks. South Africa has its own currency, so decentralized cryptocurrencies would ultimately create competition for the country's primary monetary flows. Some experts agreed that South Africa needed more digital assets, crypto exchanges, and ICO regulations, as these would prevent money laundering, fraud, and financial terrorist attacks. One of the experts stated: *"Bitcoin is unstoppable; its network is not censorable. There are no sanctions, no age, gender, or any other restrictions. It is free for the whole world to use it, with the same rules for all. Banks will embrace Bitcoin. It will become exchangeable in every bank... as the US dollar is today. Bitcoin is a safeguard against limitless money printing. It would not replace the US dollar or Euro, but it could be complementary to gold, something as digital gold"*. On the other hand, some of the experts were indecisive, and one of them said: *"Government will have to look at this system from all different angles in an attempt to find any serious loophole that might come with the system, especially in institutions like banks"*.
- 4) Most of the respondents said that they were not familiar with Stablecoin. One of them said: *"Yes, I am familiar. It can assist as a means of exchange of value, i.e., a proxy digital currency, linked with cryptocurrencies and regular financial systems"*. However, one of the experts expressed doubt about whether Stablecoin was fit-for-purpose: *"Major central banks are running pilot projects with Stablecoins. Key question is how money laundering, tax havens, and corruption will work with Stablecoins that are more transparent than current"*

financial systems. I guess, we shall have transparency for ordinary people, while big players will continue to hide their wealth”.

- 5) In response to the statement and question about the security of BCT and the ability of one player to attain 51 per cent of the computational power in a blockchain, one expert replied: *“This is very hard to achieve as it stands”.* Another expert stated: *“There are several technologies developed... ATMs, which practically make the 51 per cent attack almost impossible to happen if applied correctly. Still, I always suggest using strong blockchain projects with huge hash power mining community, PoW Blockchain networks like Ravencoin, BitcoinCash, etc., or some reputable Blockchain Proof of Stake networks like Ethereum, Ripple, etc.”* One of the experts said: *“The 51 per cent is really for smaller coins, but not for Bitcoin. This is only a theoretical threat for the Bitcoin network, and here is why. Firstly, it will cost billions in equipment to achieve that big hash rate, with dubious benefits. Price of Bitcoin will go sharply down. Bitcoin mining system is made that way to be more profitable to the honest miner. If attacker could control the network for longer period, value of Bitcoin would go to zero, because trust in Bitcoin network would be zero. So, they would manage to get control of lots of Bitcoins that would be worthless. Not to mention worldwide storage of chips. Such attack is not even possible right now”.*
- 6) When addressing the ‘fork’ problem, one of the experts said: *“Its democracy; whoever has 51 per cent or more votes, it’s a legit version of BC. There will always be one Bitcoin, no matter how many times they fork it”.* Another expert commented: *“Some argue that while no technology is completely secure, no one has yet managed to break the encryption and decentralized architecture of BC. Decentralized networks can be much or less resilient to shocks, which can affect participants directly, unless careful thought is given to their design”.* Of note was the fact that the majority of the maritime professionals interviewed were not familiar with this issue.
- 7) When asked about the security on the Internet, i.e., botnet attacks in the context of BCT implementation, some experts’ responses were very short: *“Something*

we live with for all Internet services". "Yes, to a certain extent". "All solid BC networks are worldwide decentralized, and this cannot be an issue". "With proper implementation, monitoring and improvement that would be made on the BC system over time, it would not be prone to any Internet related attacks". Only one of the experts gave a more comprehensive answer: "The BC is not prone to classical botnet attacks, but there are similar ones. Especially when fees for transactions are low, multiple spam attacks aimed to slowdown transactions and increase fees. Nevertheless, those people are just 'burning' their money, with increased fees; they increase cost of the spam transactions also".

However, most of the professionals consulted had no idea how botnets could impact BCT or how to stop attacks of that nature. Therefore, more study as well as the production and sharing of knowledge on the subject were needed.

Following a thorough examination of the responses, we concluded that there were disparities in the respondents' awareness and comprehension of the challenges associated with implementing BCT as well as the potential advantages this cutting-edge technology could offer the maritime industry. While some of the experts in the maritime sector who were interviewed knew a lot about this new technology, others did not. It is necessary to create new knowledge on this subject, and we think that our study can help to do so by piquing interest in the subject and producing fresh insights in this field. An additional It is necessary to create new knowledge on this subject, and we think that our study can help to do so by piquing interest in the subject and producing fresh insights in this field. Figure 7.1 presents an overview of the results from the study's qualitative portion.

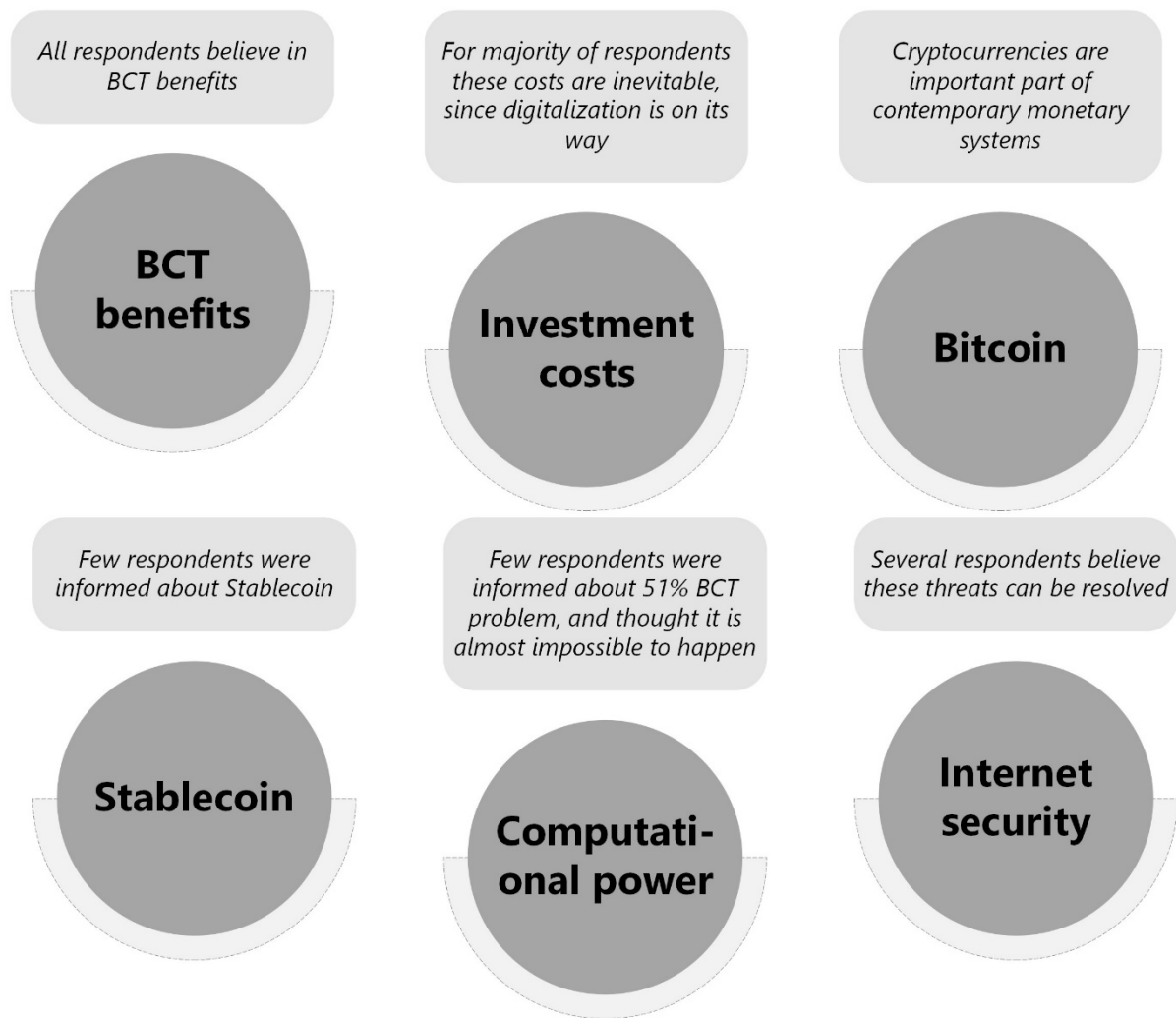


Figure 7.1: BCT dimensions investigated and the respondents' views

Source: Researcher (2023)

7.1.2 The quantitative data analysis

Quantitative data were collected from a representative sample from the maritime community in KwaZulu-Natal (Slovin formula, Chapter 6). The data then had to be analysed in order to answer the research questions. The first step in the process of analysis was the identification and elimination of inconsistent data. We then coded, edited, and analysed the data using basic statistical methods and the ISM and MICMAC tools that were described in Chapter 6.

7.1.3 The measure of central tendency

A measure of central tendency that provides an overall impression of a data set is the mean, or average value. The total number of observations (i.e., assessments or appraisals in this study) divided by 20 yields the mean or average of a set of 20 assessments. To obtain the quantitative data for this study, we asked thirty experts in KwaZulu-Natal maritime sector to rate their agreement or disagreement with a set of statements. For the convenience of the reader, these statements are reproduced here from the questionnaire found in the Appendix. The quantitative component of the study was composed of the following statements: The degree of knowledge and awareness surrounding Blockchain technology (BCT) influences the technology's uptake.

- 1) The availability of infrastructure with the necessary functionality and interoperability to integrate and function successfully within and across the industry and business sectors has an impact on the adoption of BCT.
- 2) Standardization and seamless interoperability are essential; without them, BCT may make things more challenging.
- 3) The adoption of BCT is contingent upon the accessibility of knowledgeable and proficient resources.
- 4) Many stakeholders are involved in the adoption of BCT, and modifying ingrained beliefs, corporate cultures, and work practices are significant challenges.
- 5) Adoption of BCT is boosted by supportive legislative and regulatory measures.
- 6) 6) When it comes to BCT use, social influence has a favourable effect on behaviour intention.
- 7) One barrier to BCT adoption may be the belief that implementing it would result in job losses.
- 8) Advances in cloud computing, data storage, and computing power will influence BCT adoption and enhance data-intensive procedures and practices.

- 9) Due to its significantly higher relative advantage, compatibility, trialability, observability, traceability, and resulting complexity, BCT adoption is likely to be impacted either positively or negatively.
- 10) Adopting BCT will lessen opportunistic behaviour, which maximizes one's own financial gain at the expense of other partners' losses.
- 11) If partners don't share information, blockchain adoption is decreased. More specifically, the adoption of BCT is hampered by some stakeholders' reluctance to divulge information because they see it as a competitive advantage.
- 12) Since BCT is still in its infancy and vulnerable, it is imperative that the privacy and security of models and data be guaranteed.

The experts in question were required to indicate their level of agreement or disagreement with the statements regarding the rational implementation and adoption of BCT in the maritime sector by selecting a grade ranging from 1 to 5. A grade of 1 meant the lowest level of agreement or disagreement, while 5 meant the highest level of agreement or disagreement with the statement. Twenty out of the thirty experts initially selected sent timely responses, so they were involved in the study.

The results obtained are presented in Figures 7.2 and 7.3. The average value of the respondents' agreements was 4.25, while the average value of their disagreements was 2.80. This means that the experts generally agreed with the statements we presented to them. The respondents expressed the lowest level of agreement (3.80) with statement 11 (S11): *BCT's adoption will reduce opportunistic behaviour (maximisation of economic self-interest and occasioned loss by other partners)*. This means that the experts engaged believed the introduction of BCT could result in a win-win situation for all stakeholders involved. On the other hand, the highest level of disagreement (4.20) was associated with statement S4: *BCT's adoption is affected by the availability of skilled and expert resources*. This means that the respondents were counting on outsourcing the expertise, knowledge, and skills required to manage and maintain the BCT if it were adopted in the maritime industry. This standpoint requires

further interrogation, and this could be achieved by conducting in-depth interviews or focus groups with the experts in the field.

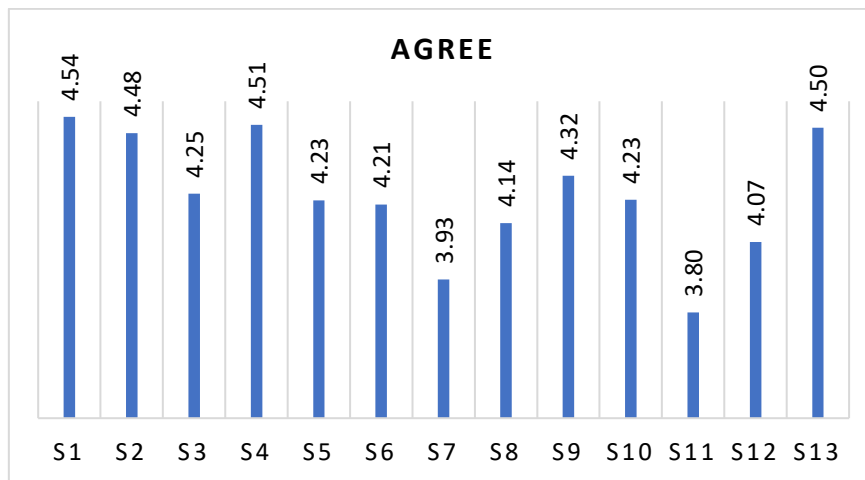


Figure 7.2: Agreement with the statements on smart BCT adoption

Source: Researcher (2023)

The highest level of agreement (4.54) was connected to statement S1: *The level of awareness and knowledge of Blockchain technology (BCT) affects its adoption*. This contradicts the previous observation, but it could mean that the experts had general awareness and knowledge about BCT in mind when they answered, rather than specific, expert knowledge of this very complex domain. The lowest level of disagreement (1.33) was observed in response to statement S13: *Privacy and security of models and data need to be ensured, as BCT is still new and vulnerable*. This means that the respondents believed that BCT's security and safety mechanisms were very good. This may be true, but we should not neglect the fact that cyberattacks are a reality in the maritime industry. Evidence of this is the Petya attack on Maersk when the company lost hundreds of millions of US dollars as a result of ransomware.

The data collected through the survey could be an indicator of further research required in this area.

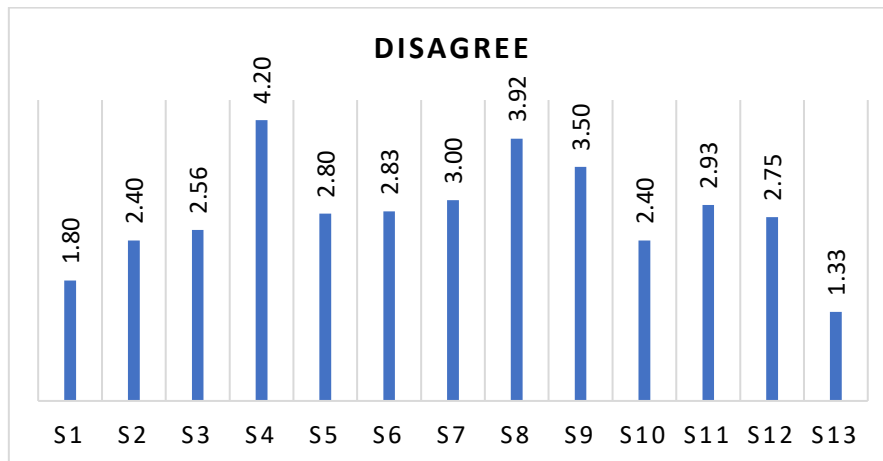


Figure 7.3: Disagreement with the statements on smart BCT adoption

Source: Researcher (2023)

7.1.4 The ISM and MICMAC analyses

We used ISM and MICMAC tools for the second part of the quantitative data analysis. These techniques were applied to the 14th survey question (Appendix 4). Here, we asked the experts to perform pairwise assessments of the following barriers to the implementation of Blockchain technology in the maritime industry:

- 1) Barrier 1: Lack of BCT regulations by the government.
- 2) Barrier 2: Lack of trust in BCT.
- 3) Barrier 3: Actors' reluctance to share business information.
- 4) Barrier 4: Lack of knowledge and understanding of BCT.
- 5) Barrier 5: Lack of support from stakeholders.
- 6) Barrier 6: Stakeholders' reluctance to adopt BCT.
- 7) Barrier 7: High investment costs.
- 8) Barrier 8: Lack of early adopters in the maritime industry.

The barriers' indexes 1 to 8 corresponded with both *i* and *j*, and *i* always preceded *j* in the pairwise comparisons of the barriers. Pairs of identified barriers were compared by means of the following denominators:

- F: barrier i led to barrier j ($i \rightarrow j$).
- R: barrier j led to barrier i ($j \rightarrow i$).
- FR: barrier i led to barrier j, and vice versa ($i \leftrightarrow j$). And
- X: barriers i and j were unrelated ($i \neq j$).

The respondents were asked to individually compare the paired barriers in the model. The value F, R, FR, or X with the highest frequency of appearances (Max. Freq.) in the individual experts' matrices (Table 7.1) was selected and inserted into the appropriate field of the structural self-interaction matrix (Table 7.2).

Table 7.1: The respondents' pairwise assessments of the barriers

	F	R	FR	X	Max. Freq.
B1-B2	41	0	4	5	F
B1-B3	25	6	0	19	F
B1-B4	9	6	3	32	X
B1-B5	27	8	8	7	F
B1-B6	24	7	4	15	F
B1-B7	14	5	4	27	X
B1-B8	16	14	6	14	F
B2-B3	21	12	13	4	F
B2-B4	11	14	19	6	FR
B2-B5	19	13	8	10	F
B2-B6	22	4	8	16	F

B2-B7	20	5	1	24	X
B2-B8	19	10	6	15	F
B3-B4	18	13	4	15	F
B3-B5	14	12	8	16	X
B3-B6	15	10	11	14	F
B3-B7	3	11	4	32	X
B3-B8	12	14	9	15	X
B4-B5	25	6	13	6	F
B4-B6	14	11	14	11	FR
B4-B7	14	7	2	27	X
B4-B8	17	8	12	13	F
B5-B6	23	11	12	4	F
B5-B7	19	11	6	14	X
B5-B8	15	12	9	14	F
B6-B7	12	9	16	13	FR
B6-B8	19	9	15	7	F
B7-B8	16	4	7	23	X

Source: Researcher (2023)

Table 7.2: Structural self-interaction matrix

	B1	B2	B3	B4	B5	B6	B7	B8
B1	FR	F	F	X	F	F	X	F
B2	R	FR	F	FR	F	F	X	F
B3	R	R	FR	F	X	F	X	X
B4	X	FR	R	FR	F	FR	X	F
B5	R	R	X	R	FR	F	X	F
B6	R	R	R	FR	R	FR	FR	F
B7	X	X	X	X	X	FR	FR	X
B8	R	R	X	R	R	R	X	FR

Source: Researcher (2023)

The structural self-interaction matrix (Table 7.2) was converted into a binary one, called the initial reachability matrix, by substituting F, R, FR, and X with 0 and 1 in correspondence with the scheme given in Table 7.3.

Table 7.3: Conversion scheme

	(i, j)	(j, i)
F	1	0
R	0	1
FR	1	1
X	0	0

Source: Researcher (2023)

The initial reachability matrix (Table 7.4) was formed in accordance with the data presented in Table 7.2 and the scheme given in Table 7.3.

Table 7.4: Initial reachability matrix

	B1	B2	B3	B4	B5	B6	B7	B8
B1	1	1	1	0	1	1	0	1
B2	0	1	1	1	1	1	0	1
B3	0	0	1	1	0	1	0	0
B4	0	1	0	1	1	1	0	1
B5	0	0	0	0	1	1	0	1
B6	0	0	0	1	0	1	1	1
B7	0	0	0	0	0	1	1	0
B8	0	0	0	0	0	0	0	1

Source: Researcher (2023)

This initial reachability matrix only showed the direct relationships among the barriers. The transitivity principle was then applied to include the indirect relationships. Transitivity means that when B1 was related to B2, and B2 was related to B3, then B1 was related to B3. This was obtained by multiplying the initial reachability matrix by itself until it became stabilized. The multiplication was performed using the Boolean matrix multiplication defined by the equation (1):

$$(AB)_{ij} = \bigcup_{k=1}^n (A_{ik} \cap B_{kj}) \quad (1)$$

The process of multiplying the initial reachability matrix twice by itself is presented in the following steps (Steps 1 & 2):

Step 1

$$\begin{array}{c}
 \left| \begin{array}{cccccccccc}
 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\
 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\
 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\
 +0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
 \end{array} \right| \cap \left| \begin{array}{cccccccccc}
 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\
 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\
 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\
 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0
 \end{array} \right| =
 \end{array}$$

Step 2

$$= \left| \begin{array}{cccccccccc}
 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0
 \end{array} \right| \cap \left| \begin{array}{cccccccccc}
 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\
 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\
 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\
 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0
 \end{array} \right| =$$

$$\begin{vmatrix} 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{vmatrix} \quad \begin{vmatrix} 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{vmatrix}$$

$$= \begin{vmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{vmatrix} .$$

The final reachability matrix is given in Table 7.5, along with the values of the driving power (DRP) and the dependence power (DNP), which were calculated by equations (2) and (3):

$$\text{Driving power (DRP): } \sum_{j=1}^8 b_{1j} \quad (2)$$

$$\text{Dependence power (DNP): } \sum_{i=1}^8 b_{i1} \quad (3)$$

Table 7.5: The final reachability matrix

	B1	B2	B3	B4	B5	B6	B7	B8	[DRP]
B1	1	1	1	1	1	1	1	1	8
B2	0	1	1	1	1	1	1	1	7
B3	0	1	1	1	1	1	1	1	7
B4	0	1	1	1	1	1	1	1	7
B5	0	1	0	1	1	1	1	1	6
B6	0	1	1	1	1	1	1	1	7
B7	0	1	0	1	1	1	1	1	6
B8	0	0	0	0	0	0	0	1	1
[DNP]	1	7	5	7	7	7	7	8	

Legend: [DNP] – dependence power & [DRP] driving power

Source: Researcher (2023)

The final reachability matrix, the set of ascendant nodes, and the intersection sets could all be used to determine the reachability set of nodes for each barrier (Table 7.6). The equality of the ascendant and intersection sets was checked iteratively, and the two equal sets were removed. Until every barrier was covered and connected to the proper level of the hierarchical structure, this process was repeated. The barriers for which the ascendant and intersection elements were the same were the first in the iterative process.

Table 7.6: Identification of each barrier’s hierarchical level

	Reachability set	Antecedent set	Intersection set	Iteration	Level
B1	1,2,3,4,5,6,7,8	1	1	1	I
B2	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B3	2,3,4,5,6,7,8	1,2,3,4,6	2,3,4,6	2	II
B4	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B5	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B6	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B7	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B8	8	1,2,3,4,5,6,7,8	8	3	III

Source: Researcher (2023)

The results provided in Table 7.6 enabled the creation of the ISM hierarchical scheme depicted in Figure 7.4.

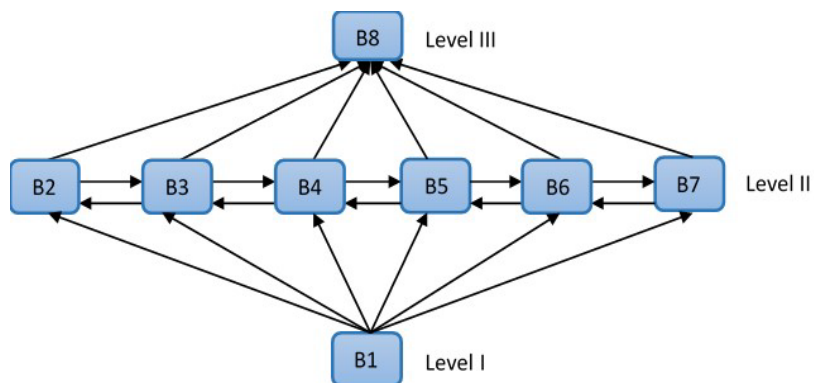


Figure 7.4: The ISM hierarchical scheme of the barriers to adoption of BCT in the maritime industry

Source: Researcher (2023)

- The ISM analysis was combined with the MICMAC analysis. Finding the driving power (DRP) and dependence power (DNP) of each barrier under consideration was the first stage in performing the MICMAC analysis (Table 7.5). The dependence power was calculated by summing the values in the final reachability matrix's column j. In the meantime, by adding each value in row i of the final reachability matrix, the driving power of each variable was calculated. Table 7.5 presents the findings from this analysis. The X-axis indicates the dependency power, and the Y-axis displays the driving power in the four quadrants that make up the driver-dependency diagram. As can be seen from the diagram (Figure 7.5), the following: Quadrant I contains no barriers.
- Quadrant II contains barrier B8, which means that it depends on other barriers, which confirms the ISM hierarchical scheme.
- The six barriers in Quadrant III are B2, B3, B4, B5, B6, and B7. These obstacles are referred to as linkage barriers. Because of their numerous interconnections, these call for careful analysis because they have the potential to cause a domino effect and the collapse of other barriers.
- Barrier B1 is in Quadrant IV. Since this independent barrier is the source of all other barriers in the model, it needs to be carefully considered. Eliminating further obstacles could be beneficial. It is positioned at the ISM hierarchical diagram's lowest levels.

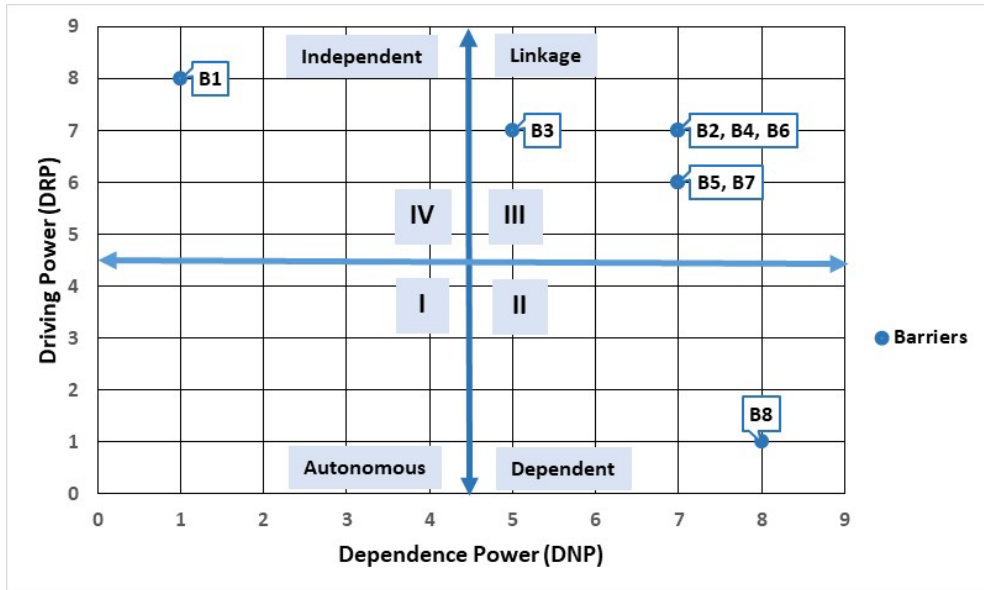


Figure 7.5: The MICMAC diagram of the barriers to adoption of BCT in the maritime industry

Source: Researcher (2023)

The results of the ISM and MICMAC analyses provided better insight into the connections among the barriers to the implementation of Blockchain technology in the maritime industry. However, it should be emphasized that the results obtained depended largely on the knowledge, experience, and perceptions of the respondents and that they could be significantly different if the structure of the expert panel changed. This is a limitation of this methodology, but it did at least provide an idea of the interdependence among the factors that inhibited faster implementation of the groundbreaking Blockchain technology and its key principles.

The approach applied could assist professionals in developing strategies to mitigate the constraints inherent to the complex and intertwined maritime environment and the deployment of new technology in this environment. The task of the group utilised for the analysis of the decision-making model in this study is to give the highest priority to the barrier at the bottom of the ISM hierarchical scheme, since it drives the other barriers in the model. In the case analysed, this was the lack of government regulations regarding Blockchain technology and its implementation. According to the MICMAC

analysis, the lack of government regulations was the independent barrier with a high driving power and a low dependency power. The following barriers appeared on the second level of the ISM hierarchical scheme: the reluctance of stakeholders to share business information; the lack of knowledge and understanding about Blockchain technology; the lack of support from stakeholders; the stakeholders' reluctance to adopt Blockchain technology; and the relatively high investment costs. In the MICMAC analysis, these barriers were linkage ones. They were linked mutually and linked all the other barriers in the model. This gave them the ability to cause a so-called domino effect. At the top of the ISM hierarchical scheme was the lack of early adopters of new technology in the maritime industry. This means that all other barriers in the model considered affected this constraint. The lack of early adopters in the maritime industry was therefore the dependent variable in the case considered, with high dependency and low driving power.

Lastly, we must emphasize that researchers need to be cognizant of the subjectivity of the experts' individual pairwise comparison assessments of the barriers to a more widespread application of BCT in the maritime sector. This consequently requires careful selection of the experts who are supposed to make assessments regarding technology adoption in the maritime sector in KZN. They should have long-standing experience in the maritime industry and have excellent logic and critical thinking skills to ensure their credibility in decision-making processes. The number of interviewees involved in future studies of this topic should be larger, so that we can better explain the aspects of Blockchain technology's integration into shipping and port logistics.

CHAPTER 8 DISCUSSION OF THE FINDINGS

8.1 Discussion

The discussion section's goals are to explain any new knowledge or insights that resulted from this study as well as to interpret and characterize the findings' significance in light of what is already known about the research problem under investigation. We revealed some of the mysteries about Blockchain technology using an environmental scan. We explained the principles of how this technology works, with an emphasis on cryptocurrencies and smart contracts. After an extensive desktop search of the secondary data resources available, we became aware of the numerous applications of Blockchain technology in different fields like finance, legislation, education, voting, supply chain management, toll collection, the energy sector, carbon footprint monitoring, satellite constellation communications, cybersecurity, to name a few, and a brief description of these was provided in Chapter 3. We placed our emphasis on the maritime sector and found out where Blockchain technology could be implemented in this sector. We then developed a model of Blockchain's applications in the shipping industry and port management, and this is presented in Figure 8.1.

First, Blockchain technology in the maritime sector encompasses numerous players, and we named them as cargo owners, agents, financial institutions, insurance companies, freight forwarders, inland transportation providers (both rail and trucking), ports, shipping terminals, shippers, ocean carriers, customs, flag states, government institutions, etc. The activities that can be supported and improved on in terms of their efficiency and safety are the tracking and tracing of shipments, administration of port operations, trade documentation protection, assets' certifications, vessels' traffic management, payments based on artificially intelligent agents, smart contracts, and the like.

Tracking and tracing of shipments is connected in the context of Blockchain technology with container coordinates and statuses, the condition of cargo, sensors' data (tilt, temperature, humidity, lighting, etc.) acquisition via IoT and Oracle, to name

a few. Regarding the administration of port operations, Blockchain technology can assist with container stacking, staffing, cargo handling, transportation mechanization, and mechanization operations' management in terms of speed, fuel consumption, operator misbehaviour, and so on. When it comes to the protection of trade documentation, Blockchain technology can facilitate bills of lading or waybills, commercial invoices, credit letters, certificates of origin, booking registrations, booking confirmations, packing lists, export/import declarations, customs declarations, delivery orders, etc.

Concerning assets' certifications, maritime Blockchain can safeguard ship registration processes, crew members' certificates of competence, vessel and cargo certificates, cranes, yard carriers, haulers, tracks, ports' rubber-tyred gantry (RTG) cranes and rail-mounted gantry (RMG) cranes' certificates, etc. On the other hand, vessel traffic management can be enhanced by the secure transfer of a ship's location data, speed, direction, potential collision points, collision free-route plans, etc. If we take payments in the maritime sector into account, these can be done via fast payment mechanisms like 300Cubits, ShipChain, Prime Shipping Foundation (PSF), Blockshipping, etc., based on smart agents and contracts and using cryptocurrencies and tokens.

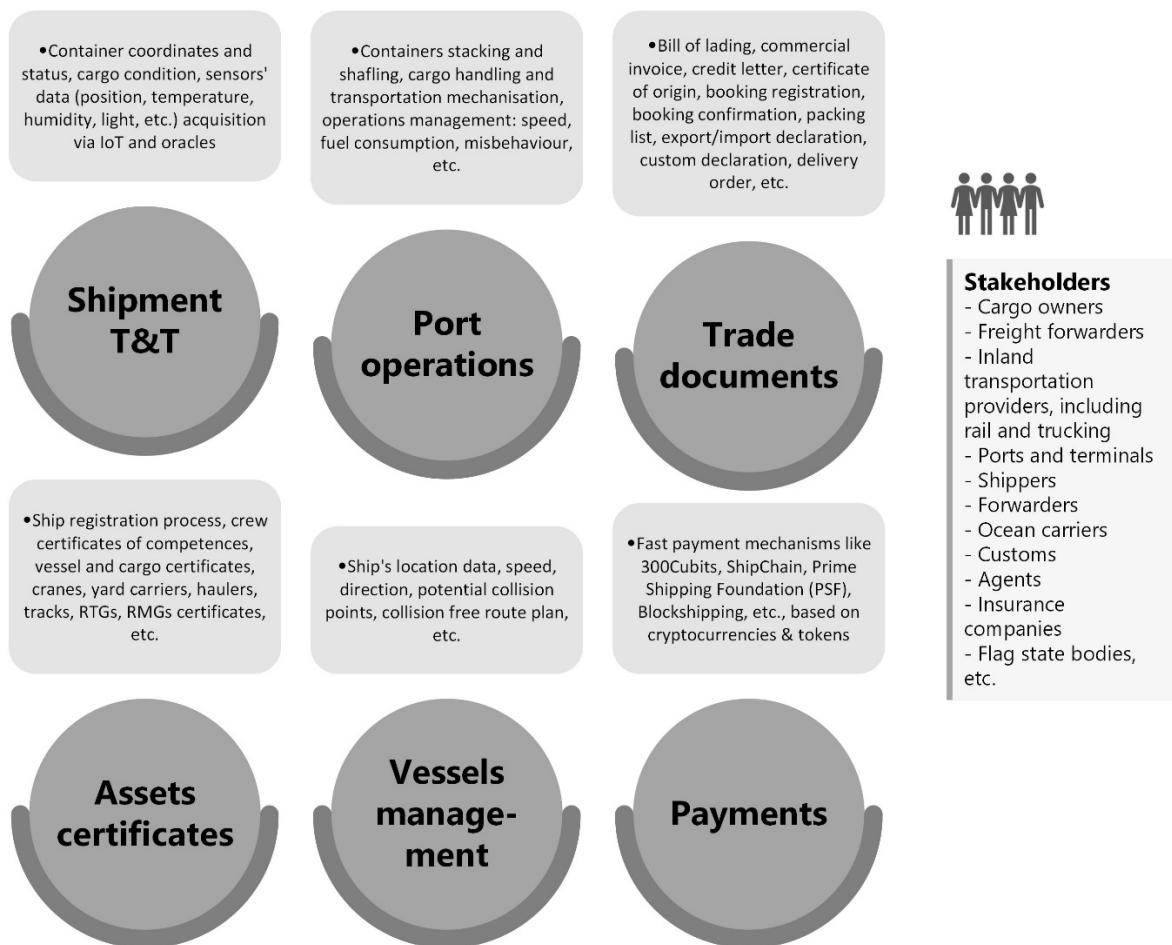


Figure 8.1: Maritime Blockchain's players and applications

Source: Researcher (2023)

Besides the desktop search of the resources available on Blockchain technology's applications in the maritime field, we also realized interviews and surveys among specialists from maritime business in KwaZulu-Natal (SAMSA, the EMC, and Integral Ltd.). We scanned the level of their awareness about Blockchain technology's mainstream adoption in the maritime industry and about its benefits and challenges. We determined the following, based on the interviews and the qualitative data collected from the survey:

- Every respondent expressed confidence in the advantages of BCT, which include centralizing critical data and establishing a distinct platform for ports, agents, and IT solution providers operating along the supply chain; tracking cargo in real time; facilitating early planning of land procedures by shipping companies and ports; and expediting terminal operations while reducing expenses. According to the experts, BCT improved trading safety and transparency in the maritime sector. Experts believe that implementing BCT will push the industry's efficiency to the next level and have a positive impact on lowering the rate of human error. Most of the respondents were of the opinion that investment costs in BCT and digitalization in general were inevitable since such investment is imperative in the digital era.
- Because they have the potential to produce new products, services, applications, or business models that have a positive and tangible influence on maritime institutions, cryptocurrencies were seen as an essential component of modern monetary systems. Only a few respondents were informed about Stablecoin. This means that further investigation, knowledge-building and knowledge-dissemination about cryptocurrencies are advisable across the maritime sector.
- Similarly, just a few of the respondents were informed about the problem of a potential 51 per cent attack when using BCT, and they thought that it was almost impossible for such an attack to happen. The potential for such an attack in the maritime sector requires further in-depth exploration by IT specialists.
- Several respondents believed that cyberthreats and cyberattacks are inherent to the Internet. Blockchain technology operates on the Internet and such threats and attacks can be resolved and prevented for the most part, so they should not be a barrier to wider implementation of BCT.

We used a questionnaire consisting of 14 statements/questions to conduct a survey in addition to the analysis of the qualitative data. Based on the evaluations provided by the respondents, we have deduced that the statements put forth to the experts were

largely accepted by them. The statement that the adoption of blockchain technology would lessen opportunistic behaviour - the maximization of one's own economic self-interest and the resulting loss by other partners—was met with the least amount of agreement from the respondents. On the other hand, the claim that the availability of knowledgeable and experienced personnel had an impact on the adoption of Blockchain technology was met with the greatest degree of disagreement. This indicated that, should the BCT be implemented in the maritime sector, the respondents were depending on outsourcing the knowledge, expertise, and skills necessary to manage and maintain it. The claim that the adoption of Blockchain technology was influenced by people's awareness and knowledge of it received the greatest degree of agreement. It was possible that the experts took this statement to mean that people were aware of Blockchain technology in general rather than having in-depth knowledge of how it operated. Given that blockchain technology was still in its infancy and thus vulnerable, the statement that the privacy and security of models and data needed to be ensured received the least amount of disagreement. This indicated that the respondents thought the security and safety features of blockchain technology were excellent. Despite the excellent security measures on the Blockchain platform, there have been a few noteworthy breaches, like the ransomware attack that Maersk experienced in 2017 that cost the company almost \$200 million USD.

The respondents also conducted pairwise comparisons of the barriers to BCT's wider implementation. The data generated here was analysed using well established ISM and MICMAC techniques (described in Chapter 4). We were able to establish the relationships among the barriers and determine their driving and dependency powers, and this helped us to establish a hierarchical model of the barriers influencing the widespread adoption of this new technology.

The absence of governmental oversight over the BCT has surfaced as a stand-alone obstacle with strong motivation and minimal reliance. This put it in the upper echelon of obstacles preventing the widespread use of this novel technology. The reluctance of stakeholders to share business information, their ignorance of and lack of understanding of Blockchain technology, their lack of support, their reluctance to adopt

this technology, and the comparatively high investment costs necessary to adopt and install the technology made up the second level of the hierarchical scheme of barriers. These barriers on this level were linked to all of the other barriers in the model and could thus have a domino effect on the implementation of the BCT. The top barrier in the hierarchy of barriers was the lack of early adopters of new technology in the maritime sector. All of the other barriers in the proposed model thus affected this one. The lack of early technology adopters in the maritime sector was thus established as the dependent variable in the case study, as it had low driving power.

We cautioned that researchers have to be aware of the subjectivity of “so-called” experts when conducting a study and interpreting data obtained from said experts. Researchers must select their experts very carefully and be sure that they have sufficient, rich experience in their field, in this case, the maritime sector. The experts must also be very logical and skilled in their fields as this will help ensure the credibility of their study.

CHAPTER 9 CONCLUSION

9.1 Conclusion

In the maritime industry, information sharing amongst various players can be difficult, so transparency and trust are essential. With safe, unchangeable records that can be shared amongst several parties, blockchain technology offers an alternative to conventional centralized information systems and the potential to completely reimagine maritime business operations. It enables participants to maintain cryptographically secured ledgers that can be reliably shared by chosen participants. Costs and profits are the primary motivators in the maritime sector, and BCT investment is highly expensive. As a result, Blockchain technology adoption in this sector is still going slowly. Another reason for the slow adoption could be a lack of awareness and comprehension of the advantages this technology can offer the industry. Smaller maritime businesses that work in developing nations typically struggle with a lack of resources and an ignorance of new technologies, making it difficult for them to switch to new operating systems like Blockchain. One of the main concerns was the implementation of international regulations to control the use of Blockchain technology in the maritime industry. For this technology to cross international borders with the least amount of resistance, a more accommodating regulatory framework that considers national boundaries must be offered. It's important to consider asymmetric information sharing in both upstream and downstream global supply chains. Both larger and smaller players in the maritime industry that are situated further down the supply chain are concerned about all of these issues. Considering all of this, it will take time for the global maritime industry to adopt Blockchain technology. Time, a more advanced degree of maritime education, sophisticated corporate and organizational cultures, and the combined efforts of all stakeholders are needed for the shift.

Fintech, or blockchain technology, encompasses cryptocurrencies. Fintech is a catch-all word for cutting-edge financial services supported by technology. New marine business models, applications, procedures, and products may arise from this,

benefiting all parties involved. By providing financial services to historically underserved segments of society, fintech can increase financial inclusion and accelerate inclusive economic growth. It is necessary to debunk the myths that BCT's innovation compromises security, safety, and responsible data handling. The fintech potential of blockchain technology allows for the hybrid coexistence of humans and machines through, for example, the best possible deployment of robo-advice services in idle computer allocations. This represents a significant benefit of blockchain technology for the maritime industry, and it merits more thorough research in the field.

With an emphasis on KwaZulu-Natal, this study outlined the possible advantages and difficulties of broader Blockchain technology adoption in the maritime industry. The structure or hierarchy of the obstacles to the adoption of blockchain technology in a developing maritime environment such as KwaZulu-Natal was examined in this study. This case study research carried out among experts in three maritime companies could equip decision-makers with an understanding of how basic statistics and ISM and MICMAC quantitative techniques could be used to assist with interpreting the relationships among the barriers to Blockchain technology's wider implementation. The methodology that was applied could assist professionals to develop strategies to mitigate the constraints inherent to the complex and intertwined maritime environment and its use of hi-tech.

The task of the group decision-making model provided and analysed in this study was to highlight that the highest priority has to be given to the barrier at the bottom of the ISM hierarchical scheme, since it drives the other barriers in the model. In the case analysed in this study, this proved to be the lack of government regulations regarding Blockchain technology and its implementation. The absence of governmental regulations was an independent barrier with strong driving power and low dependency power, according to the MICMAC technique that was used. The unwillingness of stakeholders to share business information, their ignorance of and lack of comprehension of Blockchain technology, the lack of support from stakeholders in the maritime industry, their reluctance to adopt Blockchain technology, and the comparatively high investment costs were the barriers on the second level of the ISM

hierarchical scheme. These barriers were identified as linkage barriers by the MICMAC analysis. They linked with the barriers on their level of the model, as well as with all the other barriers in the model, and they could therefore have a domino effect on each other. They could break the other barriers in the model down due to their high level of inter-connectedness.

At the top of the ISM pyramidal scheme was the lack of early adopters of new technology in the maritime industry. This means that all other barriers in the considered model affected this constraint. The lack of these early adopters in the maritime industry was therefore the dependent variable in the considered case, with high dependency and low driving power.

In order to get the expert opinions of those working in the maritime sector, this study asked them to compare the obstacles to the wider application of blockchain technology in the maritime sector in pairs. As researchers, we were aware that the subjective nature of their responses could pose a problem and skew the data, so we took the precaution of ensuring that we sampled highly skilled, knowledgeable, and experienced respondents with the ability to apply logic and critical thinking skills. This ensured the credibility of our findings. The maritime industry must utilise similarly skilled individuals when looking to introduce this technology throughout the supply chain. To maintain the validity of their research, scholars aiming to investigate the phenomenon of Blockchain technology's application in the maritime sector further must also take this into account. For their conclusions to be successfully applied to the integration of Blockchain technology in the broader shipping industry, port logistics, global supply chains, and beyond, the researchers should also think about using a larger sample of experts.

CHAPTER 10 LIMITATIONS

10.1 Limitations of the study

This study gave insight into the highly sophisticated Blockchain technology and its applications in developing maritime businesses in KwaZulu-Natal Province, South Africa. It not only highlighted the potential of this advanced technology but also identified key impediments to its mainstream implementation. Well-established methods were used to determine the hierarchical structure of these impediments and to explore the relationships between the barriers at the same hierarchical level. Despite its rigorous methodology, this study was not without limitations. The case study was used as the research design, and the number of experts in maritime businesses that were interviewed was limited. In the future, a similar study should be applied to a larger sample and be conducted longitudinally over time and over a wider geo-political area, beyond the borders of KZN. It is also recommended that comparisons be made with more developed maritime environments so as to learn from those cases to develop and implement a policy of rational adoption of new technological solutions in the maritime sector. The extent to which the maritime education curriculum should be upgraded with respect to Blockchain technology, and its successful applications could also be explored. The present scope and content of this study have provided a strong foundation for such research, thanks to the objective, experimental, and experiential knowledge embedded in it. The limitations of this research work study allow for more in-depth research. This dissertation, with its environmental scan, analyses, discussions, conclusions, and limitations, has provided fertile ground for further fruitful research and innovations in maritime affairs.

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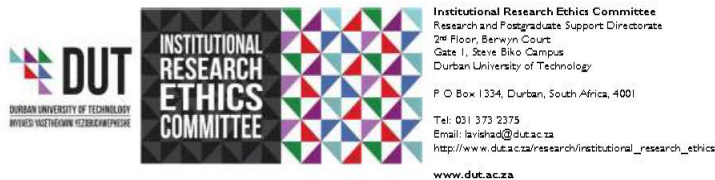
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APPENDICES

APPENDIX 1: ETHICAL CLEARANCE



16 March 2023

Mr L H Ntshangase
25 Victory Gardens
19 Victory Drive
Ashley
Pinetown

Dear Mr Ntshangase

Adoption of blockchain technology among emerging maritime businesses in Kwazulu-Natal

Ethics Clearance Number: IREC 159/22

The DUT-Institutional Research Ethics Committee acknowledges receipt of your notification regarding the piloting of your data collection tool.

Kindly ensure that participants used for the pilot study are not part of the main study.

In addition, the DUT-IREC acknowledges receipt of your gatekeeper permission letters.

Please note that **FULL APPROVAL** is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the DUT-IREC according to the DUT-IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the DUT-IREC as outlined in the DUT-IREC SOP's.

It is compulsory for a student or researcher to apply for recertification on an annual basis. The failure to do so will result in withdrawal of ethics clearance. It is the responsibility of the researcher and the supervisor to apply for recertification.

Please note that you are required to submit a Notification of Completion of Study form together with an abstract to the DUT-IREC office on completion of your study.

Yours Sincerely

Professor J K Adam
Chairperson: DUT-IREC

APPENDIX 2: INFORMED CONSENT, P.1

Appendix B



LETTER OF INFORMATION

Title of the Research Study:

Adoption of blockchain technology among emerging maritime businesses in Kwazulu-Natal

Researcher:

Mr Lindani Handsome Ntshangase

(Ndip: Maritime Studies, Btech: Operations Management, MSc in International Trade)

Supervisor:

Prof Sanja Bauk (D.Sc.)

Warm greetings,

My name is **Lindani Handsome Ntshangase**. I am currently the 2nd year PhD student at Durban University of Technology (DUT), Faculty of Management Sciences, doing research for my Doctoral degree in Business Administration. Therefore, I would like to invite you to participate in the research:

Adoption of blockchain technology among emerging maritime businesses in Kwazulu-Natal

Brief introduction and Purpose of the Study:

Blockchain is a new, transformative technology and business model based on digitalized, shared, distributed, and synchronized ledger. A ledger is comprised of unchangeable, digitally recorded data in blocks. It enables dealing with smart contracts, cryptocurrency, recording transactions, tracking and tracing assets, insurance, ship registry activities, reducing environmental impacts, and the like. Blockchain allows untampered record of transactions over physical and virtual assets. The network nodes within blockchain must validate and approve transactions before packing these into timestamped blocks, which form chains. This requires complex internodes communication and consensus mechanisms.

~1~

APPENDIX 2: INFORMED CONSENT, P.2

Blockchain transforms business from centralized, human-based to shared, algorithm-based system, which implies a new management paradigm.

In maritime, Blockchain technology can offer the oversight control and management to each stakeholder in the supply chain, including: ocean carriers, ports, terminal operators, inland carriers, shippers, freight forwarders, custom authorities, financial service providers, agents, insurance providers, port state control, and ship registry officials. It is open platform with powerful application programming interface model, but still in its nascent stage of development.

Aim of the Study:

The aim of the study is to provide a model for intelligent (smart or rational) implementation and adoption of Blockchain technology in maritime sector in KwaZulu Natal. Specific needs and preferences at the KwaZulu Natal developing maritime business ecosystem, will be in the focus.

Risk or Discomforts to the Participants:

There are no foreseeable risks or discomfort if you participate into this study.

The Reasons You may withdraw from the Study:

You can withdraw from the study if any of the questions make you feel uncomfortable. There will be no adverse consequences if you choose to withdraw from the study.

Benefits:

You may stand gain from this survey, in a sense that the quality of your working environment in maritime business can be improved in the future, thanks to the findings of the study.

Remuneration:

No remuneration will be offered for participating in this study.

Costs of the Study:

There are no costs associated with participating in this study.

Confidentiality:

All information gathered by this study is confidential. The questionnaire will be analyzed by the researcher and all information will only be used for research purposes. No personal information will be published in the final dissertation of this study. All information that relates to your participation in this study will be treated confidentially and answers to the questionnaire will be

~2~

APPENDIX 2: INFORMED CONSENT, P.3

processed anonymously.

Storage of All Electronic and Hard Copies including Tape Recordings:

This will be kept for five years and discarded afterwards.

Contacts in the Event of Any Problem or Queries:

Researcher: **Lindani Handsome Ntshangase** (Cell: 068-010-3817; Tel.: 031-373-2145; Email: Lindanin3@dut.ac.za)

Supervisor: **Prof Sanja Bauk** (Email: sanjab@dut.ac.za)

or

DUT-Institutional Research Ethics Administrator on 031 373 2375.

Complaints can be reported to the **Acting Director: Research and Postgraduate Support** on researchdirector@dut.ac.za

Yours assistance is greatly appreciated

Lindani Handsome Ntshangase

~3~

APPENDIX 2: INFORMED CONSENT, P.4



CONSENT

Title of the Study:
Adoption of blockchain technology among emerging maritime businesses in Kwazulu-Natal

Researcher:
Lindani Handsome Ntshangase

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Mr **Lindani Handsome Ntshangase**, about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number:
- I have also received, read and understood the above written information regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

_____	_____	_____	_____
Full Name of Participant	Date	Time	Signature

I, **Lindani Handsome Ntshangase** (name of researcher) herewith confirm that the above participant has been **fully informed about the nature, conduct and risks of the above study.**

_____	_____	_____
Full Name of Researcher	Date	Signature

~4~

APPENDIX 3: INTERVIEW QUESTIONS

Research Study:

“Adoption of blockchain technology among emerging maritime businesses in Kwazulu-Natal”

(2023)

Thank you in advance for your time and willingness to give viable contribution to this research! – We highly appreciated it.

Name and surname:	
Your organization:	
Scope of your activities:	
E-mail:	
Place:	
Date:	
Consent (Signature):	

Interview:

Q1	Which benefits South Africa might have of introducing blockchain solutions in maritime (shipping) industry?
	<i>Comment:</i>
Q2	It will have lot of cost in terms of time and money to change existing system, especially when it is an infrastructure. We have to make sure this innovative technology not only creates economic benefits and meet the requirements of supervision, but also bridges with traditional organization, and it always encounters difficulties from internal organization, which is existing now. What do you think accordingly?
	<i>Comment:</i>
Q3	Use of Bitcoin will weak the central bank's ability to control the economic policy and the amount of money that makes government be cautious of blockchain technologies. Authorities have to research this issue, accelerate formulating new policy, otherwise it will have risk on the financial market. What is your opinion in this regard?
	<i>Comment:</i>
Q4	Are you familiar with 'stablecoin'? – Can it assist regarding the previous challenge and in which way?
	<i>Comment:</i>
Q5	Even though it is an advanced technology, blockchain still struggle with some security issues. For instance, if someone has more than 51%

	computing power, then this entity can find nonce (number blockchain miners are solving for) quicker than others can, which means that it has authority to decide which block is permissible. How do you see this issue?
	<i>Comment:</i>
Q6	Another issue is ‘fork’ problem. It is related to decentralized node version agreement when the software upgrade. Then, nodes are divided into old and new ones, and different problems of their mutual communication can appear. How this can be alleviated?
	<i>Comment:</i>
Q7	At some points, blockchain uses Internet. Does it mean that it is prone at this instance to common internet attacks like ‘botnets’ or the like? Thanks for your opinion accordingly.
	<i>Comment:</i>

Thank you!

APPENDIX 4: QUESTIONNAIRE

Research Study:

**“Adoption of blockchain technology among emerging
maritime businesses in Kwazulu-Natal”**

(2023)

**Thank you in advance for your time and willingness to give viable
contribution to this research! – We highly appreciated it.**

Name and surname:	
Your organization:	
Scope of your activities:	
E-mail:	
Place:	
Date:	
Consent (Signature):	

Survey:

Q1. The level of awareness and knowledge of blockchain affects its adoption¹.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q2. Blockchain adoption is affected by the availability of the infrastructure and functionality to integrate and interoperate within and across the business ecosystem.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q3. Standardization and ensuring smooth interoperability is necessary, otherwise blockchain can make things difficult instead of making them easier.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q4. Blockchain adoption is affected by the availability of skilled and expert resources.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

¹ 1 - the lowest level of Agreement or Disagreement / 5 – the highest level of Agreement or Disagreement

Q5. Blockchain adoption is affected by large number of stakeholders, while changing age-old mind-sets, culture, and work methodologies are big issues.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q6. Blockchain adoption is increased by favorable government and regulatory policies.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q7. Social influence positively affects the behavioral intention of using blockchain.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q8. A perception that blockchain implementation might lead to loss of jobs can be an obstacle in its adoption.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q9. Development in storage, computing, and cloud infrastructure will affect the blockchain adoption and positively improve data-intensive processes and practices.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q10. Blockchain offering great levels of relative advantage, compatibility, simplicity in terms of using it, trialability, observability, traceability, and consequently complexity, are likely to have positive/negative impact on blockchain adoption.

Positive effect					Negative effect				
1	2	3	4	5	1	2	3	4	5

Comment (Please explain why you chose 'positive' or 'negative' effect):

.....

Q11. Blockchain adoption reduces opportunistic behavior (opportunistic behavior means maximization of economic self-interest and occasioned loss of the other partners).

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q12. Block change adoption is reduced if the information is not shared by the partners. More precisely, some stakeholders are hesitant to share information considering it is a competitive advantage thereby limiting the adoption of blockchain.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q13. Privacy and security of models and data need to be ensured, as blockchain technology is still immature and vulnerable.

Agree					Disagree				
1	2	3	4	5	1	2	3	4	5

Q14. Let us take into the consideration the following barriers in implementing blockchain technology in maritime:

- B1 – Lack of government regulations**
- B2 – Lack of trust towards blockchain technology**
- B3 – Privacy/business information sharing concern in blockchain platforms**
- B4 – Lack of knowledge/understanding of blockchain technology**
- B5 – Lack of support from influencing stakeholders**
- B6 – Resistance of some stakeholders to adopt**
- B7 – Initial capital requirements**
- B8 – Lack of early adopters in maritime**

Indexes 1 to 8 refer to i and j , while i always precedes j in mutual comparison of two criteria.

Mutually compare the set of barriers to blockchain technology adoption in maritime. Please enter the right letter due to your assessment in each empty cell in the table below:

- F means that barrier i leads to barrier j**
- R means that barrier j lead to barrier i**
- FR means that barrier i leads to barrier j and vice versa**
- X means that barrier i and j are unrelated**

Fill in only right side of the table, which is up of the diagonal (white cells).

	B1	B2	B3	B4	B5	B6	B7	B8
B1	FR							
B2		FR						
B3			FR					
B4				FR				
B5					FR			
B6						FR		
B7							FR	
B8								FR

Thank you!

APPENDIX 5: JOURNAL ARTICLE



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Blockchain Implementation Barriers in Maritime: A Case Study based on ISM and MICMAC Techniques

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ABSTRACT

This article considers blockchain implementation and adoption in maritime sector, including its benefits and challenges. In addition to a review of existing literature sources in this domain, through a case study the impediments of deploying blockchain in a developing maritime environment are examined. The analysis are based on the Interpretative Structural Modeling (ISM) and Cross-Impact Matrix Multiplication Applied Classification (MICMAC) methods. In this context, it is to be pointed out that the constraints in blockchain mainstream adoption in maritime are explored in several comprehensive academic papers so far. The same applies for ISM and MICMAC approaches. Therefore, in the focus of this work is a case study conducted among the specialists in maritime industry, business and higher education in South Africa as an emerging maritime ecosystem. The subjectivity inherent to the applied methodology is highlighted, since different specialist can differently evaluate pairwise relationships among the considered constraints..

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1. Introduction.

Maritime sector has the smallest innovation impact in comparison to other industries, since it is profit-driven and conservative [1]. Even though ports and shipping logistics play an essential role in global supply chains, the successful innovation path should include larger number of stakeholders intertwined into maritime. The increased global demand for commodities, increased the need for sea transportation of freight containers. The massification of maritime transport led to evolved business clusters, but these are mostly fragmented into modular centralized systems [2]. Sea ports serve as central hubs for these clusters at a globally spread shipping market. Consequently, port community systems (PCSs) were introduced as unifying platforms to facilitate needs of numerous actors. Commonly,

PCSs enable streamlined data exchange and trading processes, simplified alignment with international standards, and set the founding stone for processes automation. It is difficult to generalize the exact functionalities of PCSs because they vary depending on the community's players and their relevant metrics [3]. Regardless of this, PCSs allow better business compliance, improved security, and decrease in fraudulent activities [4]. PCSs were a setting stone in the digitization in maritime. Next milestone was the introduction of maritime single window (SW) environment [5]. SW is a synonym for a single point interaction between maritime affairs and authorities. PCSs and SWs can bring great benefits on a local scale, while fragmentation and the lack of reliable real-time data on a global scale are still present [6]. Therefore, blockchain brings a quantum leap for the maritime sector with the potential to enable transition from globally fragmented centralized systems to a peer-to-peer network, without the need for complete trust between actors. Transactions can be done through the distributed, append-only digital registry or ledger that is constantly maintained through consensus mechanisms and protected by asymmetric cryptography algorithms. As a decentralized system, blockchain eliminates a single point of failure and the need for trusted inter-

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mediaries. Due to some predictions, it can facilitate the improvement and growth in world trade of 15% [7], along with the reduction of transportation costs of 20% [8]. Through smart contracts, as a part of blockchain technology, personalized automated services can increase, along with an achievable 40% decrease in delivery delays [9]. This supports the hypothesis that blockchain can be used in maritime sector for seamless operational processing including higher level of digitization and efficiency.

Having in mind still unrelieved maritime blockchain integration potentials, *Section 2* gives its overview, including its pros and cons; *Section 3* deals with the case study based on ISM and MICMAC techniques for establishing hierarchy and determining the nature of relations among the considered barriers in its wider adoption; *Section 4* gives data analysis results; while *Section 5* contains conclusion, along with the recommendations for further research. This paper is a follow up of the papers [10;11] and it includes extended literature review and the analysis carried out on the larger group of interviewed specialists.

2. Blockchain in maritime.

Maritime blockchain serves ports and shipping logistics. It includes cargo tracking and tracing, automation of port terminal operations, protection of trade documentation, assets certification, crew certificates of competences, fleet operation management, empty containers optimal placement, payments, and the like [12]. It offers a foundation for faster, easier, more efficient, and lower-cost trade-related operations. It supports collaborative commerce by allowing licensed parties to access the trusted data in real time [13]. Albeit, maritime blockchain can be organized as a hybrid network that includes clusters of public, private and consortium bodies [14;15;16].

Shipping and port management involve several organizations, which have to ensure efficient flow of shipments from exporter to consignee. As complex and dynamic systems, maritime supply chains generate large amount of data on shipments, port operations, finance, and law regulations. Blockchain technology can play a key role in ensuring trust, security, traceability, and transparency to maritime operations [17]. It has a potential to eliminate frauds related to documentation involved in data and fleet management, trade documentation, crew certification, and shipment tracking. This can increase transaction efficiency and trust among the stakeholders. Blockchain requires every stakeholder involved to register on the permissioned platform. The authorized stakeholders can access the ledger in real time to view the records on the location of the shipment and state of the freight to efficiently plan for cargo handling and terminal operations. After containers are successfully loaded on the shipment vessel, smart contracts can inform the shipment details to various entities such as agents, ship owner, custom officers, and sea traffic police for higher coordination and security. The sensors attached to the containers can assist to identify any illegal attempts that may disrupt the state of cargo inside the container. Such acts will be recorded, audited, and notified to

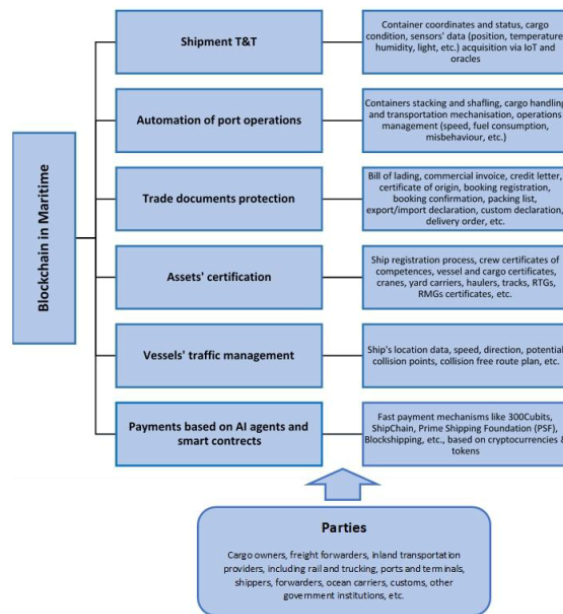
the exporter, port authority, and custom agency through suitable functions within the smart contracts. Furthermore, smart contracts can be programmed to compare the internal state of the container in terms of temperature, humidity, pressure, light and other relevant parameters with preset values, and to trigger alarms in the case of need. This is very useful when it comes to shipments as dangerous cargo, food, pharmaceuticals, etc.

Tracking the location of a vessel can help the port terminal authorities to prepare an optimal stowage plan and to increase the productivity. By using smart contracts, blockchain can efficiently shuffle the containers at the yard terminal and increase resource usage [18]. Additionally, smart contracts can optimize routes of vehicles like straddle carriers' via the agents installed at container yards, by controlling speed, reducing congestion and eventual misbehaving. Consequently, the accidents can be prevented. Besides its roles in cargo tracking and tracing and fleet management, blockchain is a ledger that assures a real-time accessing of trade documents by the participating stakeholders. For instance, it is mandatory for shipping carriers' to retain the declaration form during the shipment of hazardous goods. Similarly, the certificate of fitness has to state whether a ship is worthy to perform a journey or not [19]. These documents can be secured on a permissioned blockchain platform (Figure 1).

Maritime blockchain can incorporate smart payment mechanisms as 300Cubits, ShipChain, and Prime Shipping Foundation (PSF), e.g., which are based on crypto-currencies [20]. However, there are still significant barriers and challenges to use blockchain and smart contracts in validating shipments and payments in maritime. The port and shipping industry increasingly faces cybersecurity threats, such as, for instance, the Net-Petya ransomware attack that affected Maersk in 2017, at an estimated cost of \$200 million in bitcoins [21].

How blockchain based payment practically works in maritime, it can be easily explained at the example of Blockshipping platform, which is developed for empty containers optimal placement [22]. The processes flow within Blockshipping is based on several simple and fully automated steps. The easiest way to make an explanation is to follow an example [23]. Let us assume that shipping line needs to rent a container to transport goods from Nairobi (Kenya) to Rotterdam (Netherlands). Blockshipping empty container repository engine identifies the best-positioned empty container in Nairobi and informs the shipping line about the options. The shipping line informs its autonomous intelligent software agents (AISAs) about the containers. The rental negotiations then happen unsupervised between the shipping line and the container owner through the AISAs. The agreements established are persisted on blockchain in smart contracts that govern the rental. Blockshipping container platform tokens (CPTs) are used to pay rental fees, while the fees are transferred from the shipping line wallet, in accordance to the smart contract and reserved payment. When the container reaches its final destination in Rotterdam, then blockchain enforces the smart contract. The rental ends and releases CPTs to the container owner wallet. The smart contracts can be smoothly changed if conditions change.

Figure 1: Blockchain in maritime: Prospective applications and key parties.



Source: Authors.

Since maritime blockchain generates huge number of transactions, public Bitcoin and Ethereum blockchain platforms are not recommendable as suitable. Bitcoin can provide seven transactions per second [24], while Ethereum performs about twenty transactions per second [25]. Therefore, private Hyperledger Fabric, Besu, and Quorum platforms are more convenient. These platforms can process several hundred transactions per second [26]. Nevertheless, the entire process of maritime blockchain wider adoption is risky and requires a great deal of capital investment [27]. Maritime blockchain rational deployment is still in its infancy, and requires systematic technology testing, standardization and promotion. Stakeholders' awareness and knowledge about this groundbreaking technology should be uplifted, assuming their readiness to share business information and ultimately allow wider blockchain adoption.

2.1. Classification & Types of Mobile Satellite Antennas (MSA).

Even though blockchain has a potential for increasing efficiency and safety of maritime business, there are still numerous barriers in its mainstream implementation. Maritime sector is generally risk averse, tending not to be an early adapter in terms of new technology [28]. Some stakeholders like to preserve their data secret, since competition is fierce and numerous players compete with the same service [29]. Therefore, they consider information as a competitive advantage and do not want to share it along the supply chain. Furthermore, the use of blockchain in maritime does not guarantee that the information recorded into the ledger is correct. For instance, the content of a container, type of fuel used for ship propulsion, data on

exhausted gases emission, and the like, might be incorrectly entered into the ledger. In other words, if blockchain-based application record sensors' entry, and the sensors are compromised, the wrong data will be recorded into the ledger [30].

Large amount of data and traffic generated in blockchain need wideband channels like 5G or 6G [31], while the internet speed and stability at sea are usually lower than ashore. Additionally, blockchain technology is high-energy consuming and causes a high carbon footprint [32].

Regardless of maritime blockchain huge potential to reduce administrative and transaction costs of intermediaries such as banks, brokers and courier services, the investment costs are high, especially for developing countries [33;34]. Present level of awareness, knowledge, and expertise on blockchain is scarce among the stakeholders. Therefore, special educational, training and capacity building programs are required at regulatory, administrative and operational levels. Additionally, the major ports and shipping companies are the most likely actors to benefit from blockchain that can put other potential players at a disadvantage [35].

Different attitudes toward cryptocurrency and the absence of a worldwide regulation are the challenges for blockchain more intensive implementation. Cryptocurrencies have been the subject of hacking attacks based on vulnerabilities in apps, software, protocols, smart contracts, and other points of failure where considerable amounts of money were stolen [36].

The last but not the least, the basic attitude should be that blockchain improve the human condition, not replace humans [37]. Therefore, human and ethical dimensions of blockchain technology implementation need further investigation..

3. Methodology.

The case study for collecting information on blockchain adoption in maritime environment has been used as a research design strategy. As a data gathering method, an expert panel was arranged. The criteria for a qualification as an expert are many and varied, but commonly the expert panel comprises independent specialists [38], recognized in maritime sector and its digital transformation. The experts involved into this case study came from maritime industry, business, and higher maritime education and training institutions in South Africa (more precisely, from Cape Town, Durban, Port Elisabeth, Richards Bay, and Saldanha). The assessments of fifty selected experts are taken into consideration. The final matrix of barriers' pairwise comparisons is obtained by taking into account the frequency of certain denominators appearances in the individual experts' assessments. This was one-time study, since the data are gathered only once. Collected experts' individual evaluations are edited, coded and analyzed through ISM and MIC-MAC techniques, which are described in the following two subsections.

3.1. The ISM technique.

The ISM is a well-structured, collaborative technique to reveal the relationships and hierarchy between considered barriers in the model [39;40;41;42]. It transforms initially unclear

and poorly articulated interpretations into a visible and well-defined structural scheme. Firstly, a set of maritime blockchain implementation barriers has to be identified. Then, an aspect has to be added to the contextual relationships, for instance, does barrier B1 affect barrier B2, or vice versa, or they mutually affect each other, or there is no relationship between them. After the barriers and contextual framework are determined, each member of the experts' panel has to perform pairwise comparisons. The transitivity of the contextual relationship is a fundamental assumption in the ISM. It states that if barrier B1 is related to B2, and B2 is related to B3, than B1 is necessarily related to B3. This enables creation of a final reachability matrix and a hierarchical structural model.

3.2. The MICMAC technique.

The MICMAC means creating a graph that classifies barriers in the model according to their driving and dependence powers [43;44;45;46]. It enables the study of indirect relationships, and it is known as a gray area exploration. More precisely, it complements the ISM approach, which explores the relationships yes/1 or no/0, and neglects the gray area between these two. This is where the MICMAC can assist in establishing clearer picture of the barriers relations, including driving and dependence levels presented into the form of a graph.

4. The analysis.

The extensive research on barriers in blockchain implementation in maritime presented in [47], along with our previous studies [10;11], are used as a base for the extended analysis presented in this article, while a large group of fifty specialist in maritime (from South Africa) assessed the following maritime blockchain implementation barriers:

- Barrier 1: Lack of government blockchain regulations;
- Barrier 2: Lack of trust in blockchain;
- Barrier 3: Actors' reluctance to share business information;
- Barrier 4: Lack of knowledge and understanding of blockchain;
- Barrier 5: Lack of support from stakeholders;
- Barrier 6: Stakeholders' reluctance to adopt blockchain;
- Barrier 7: High investment costs;
- Barrier 8: Lack of early adopters in maritime.

Barriers' indexes 1 to 8 correspond to both i and j, while i always precedes j in pairwise comparisons of the barriers. Pairs of identified barriers are compared by means of the following denominators:

- F: barrier i leads to barrier j ($i \rightarrow j$);
- R: barrier j lead to barrier i ($j \rightarrow i$);

- FR: barrier i leads to barrier j, and vice versa ($i \leftrightarrow j$); and
- X: barrier i and j are unrelated ($i \neq j$).

Respondents were asked, individually, to compare pair-by-pair barriers in the model. The value F, R, FR, or X with the highest frequency of appearances (Max. Freq.) in the individual experts' matrixes (Table 1) is selected and inserted into the appropriate field of the structural self-interaction matrix (Table 2).

Table 1: The respondents' barriers pairwise assessments.

	F	R	FR	X	Max. Freq.
B1-B2	41	0	4	5	F
B1-B3	25	6	0	19	F
B1-B4	9	6	3	32	X
B1-B5	27	8	8	7	F
B1-B6	24	7	4	15	F
B1-B7	14	5	4	27	X
B1-B8	16	14	6	14	F
B2-B3	21	12	13	4	F
B2-B4	11	14	19	6	FR
B2-B5	19	13	8	10	F
B2-B6	22	4	8	16	F
B2-B7	20	5	1	24	X
B2-B8	19	10	6	15	F
B3-B4	18	13	4	15	F
B3-B5	14	12	8	16	X
B3-B6	15	10	11	14	F
B3-B7	3	11	4	32	X
B3-B8	12	14	9	15	X
B4-B5	25	6	13	6	F
B4-B6	14	11	14	11	FR
B4-B7	14	7	2	27	X
B4-B8	17	8	12	13	F
B5-B6	23	11	12	4	F
B5-B7	19	11	6	14	X
B5-B8	15	12	9	14	F
B6-B7	12	9	16	13	FR
B6-B8	19	9	15	7	F
B7-B8	16	4	7	23	X

Source: Authors.

The structural self-interaction matrix (Table 2) is converted into a binary one, called the initial reachability matrix by sub-

Table 2: Structural self-interaction matrix.

	B1	B2	B3	B4	B5	B6	B7	B8
B1	FR	F	F	X	F	F	X	F
B2	R	FR	F	FR	F	F	X	F
B3	R	R	FR	F	X	F	X	X
B4	X	FR	R	FR	F	FR	X	F
B5	R	R	X	R	FR	F	X	F
B6	R	R	R	FR	R	FR	FR	F
B7	X	X	X	X	X	FR	FR	X
B8	R	R	X	R	R	R	X	FR

Source: Authors.

stituting F, R, FR, and X with 0 and 1 in correspondence to the scheme given in Table 3.

Table 3: Conversion scheme.

	(i, j)	(j, i)
F	1	0
R	0	1
FR	1	1
X	0	0

Source: Authors.

In accordance with the data presented in Table 2 and the scheme given in Table 3, the initial reachability matrix is formed (Table 4).

This initial reachability matrix shows only the direct relationships among the barriers. To include indirect relationships, the transitivity principle is applied. Transitivity means that when B1 is related to B2, and B2 is related to B3, then definitely B1 is related to B3. This is obtained by multiplying the initial reachability matrix by itself until it became stabilized. The multiplication is performed using Boolean matrix multiplication defined by the equation (1):

$$(AB)_{ij} = \cup_{k=1}^n (A_{ik} \cap B_{kj}) \quad (1)$$

The process of multiplying the initial reachability matrix twice by itself is presented through the following steps (Step 1 & 2):

Table 4: Initial reachability matrix .

	B1	B2	B3	B4	B5	B6	B7	B8
B1	1	1	1	0	1	1	0	1
B2	0	1	1	1	1	1	0	1
B3	0	0	1	1	0	1	0	0
B4	0	1	0	1	1	1	0	1
B5	0	0	0	0	1	1	0	1
B6	0	0	0	1	0	1	1	1
B7	0	0	0	0	0	1	1	0
B8	0	0	0	0	0	0	0	1

Source: Authors.

Step 1

$$\begin{pmatrix} 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ +0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \cap \begin{pmatrix} 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} =$$

Step 2

$$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} \cap \begin{pmatrix} 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix} =$$

$$\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{pmatrix}$$

The final reachability matrix is given in Table 5, along with the values of the driving power (DRP) and dependence power (DNP), which are calculated by equations (2) and (3):

$$Driving_power(DRP) : \sum_{j=1}^8 b1_j \quad (2)$$

$$Dependence_power(DNP) : \sum_{i=1}^8 bi1 \quad (3)$$

Based on the final reachability matrix, reachability set of nodes for each barrier can be identified, as well as the set of ascendant nodes and the intersection sets (Table 6). Through the iterative process, equality of ascendant and intersections sets is examined, by eliminated elements from these two sets that are equal and continuing the process until all barriers are covered and associated with the appropriate level of hierarchical structure. The iterative process starts with the barriers for which ascendant and intersection elements are the same.

Table 5: The final reachability matrix.

Author (s)	H-Index	TC	NA	TC/NA
Avey JB and Luthans F	2	1214	2	607.00
Mhatre KH and Reichard RJ	1	738	1	738.00
Shuck B	11	618	18	34.33
Avolio BJ and Peterson SJ	1	476	1	476.00
Reio TG	5	451	7	64.43
Boerstler H, Carman JM, Foster RW, Hughes EFX, O'Brien JL, O'Connor EJ and Shortell SM	1	433	1	433.00
Ghosh R	6	271	6	45.17
Arthur MB, Barry S, Inkson K and Pringle J	1	244	1	244.00
Bland CJ, Henry R, Moorhead-Rosenberg L, Starnaman S, Wersal L and Zonia S	1	209	1	209.00
Dennis R and Lansang MA	1	202	1	202.00

Legend: [DNP] – dependence power & [DRP] driving power.
Source: Authors.

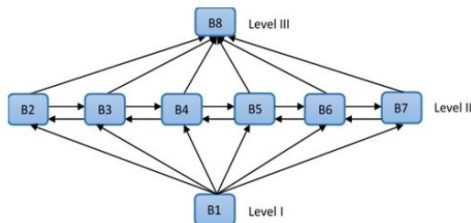
Table 6: The barriers hierarchical level identification.

	Reachability set	Antecedent set	Intersection set	Iteration	Level
B1	1,2,3,4,5,6,7,8	1	1	1	I
B2	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B3	2,3,4,5,6,7,8	1,2,3,4,6	2,3,4,6	2	II
B4	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,3,4,5,6,7	2	II
B5	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B6	2,3,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B7	2,4,5,6,7,8	1,2,3,4,5,6,7	2,4,5,6,7	2	II
B8	8	1,2,3,4,5,6,7,8	8	3	III

Source: Authors.

The results given in Table 6 enabled creation of the ISM hierarchical scheme (Figure 2).

Figure 2: The ISM hierarchical scheme of the maritime blockchain adoption barriers.



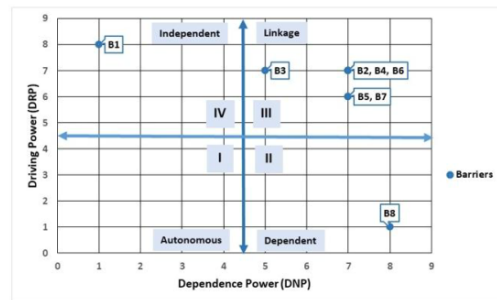
Source: Authors.

In addition to the ISM analysis, MICMAC approach has been applied. The first step in conducting MICMAC technique is to determine the dependence power (DNP) and driving power (DRP) of each considered barrier (Table 5). The dependence power is determined by adding all the values in column j of the final reachability matrix. Meanwhile, the driving power of a variable is determined by adding all the values in row i of the final reachability matrix. The results of this examination are given in Figure 3. The driver – dependency diagram is divided

into four quadrants, while X-axis presents dependency power, and Y-axis shows driving power. From the diagram, the following can be observed:

- Quadrant I contains no barriers.
- Quadrant II contains B8 barrier, which means that it depends on other barriers, what confirms the ISM hierarchical scheme.
- Quadrant III contains six barriers B2, B3, B4, B5, B6 and B7. These barriers are so-called linkage barriers. These require careful analysis, since they can cause domino effect and breakdown of other barriers due to the high number of interconnections.
- Quadrant IV contains B1 barrier. This independent barrier requires careful consideration, since it is the root cause of all other barriers in the model. It may help to remove other barriers. It is placed at the bottom levels of ISM hierarchical diagram.

Figure 3: The MICMAC diagram of the maritime blockchain wider adoption barriers.



Source: Authors.

The results of ISM and MICMAC give a better insight into the connections among the limitations while implementing blockchain in maritime. However, it should be emphasized that the obtained results largely depend on the knowledge, experience, and perception of the respondents and that they can be significantly different if the structure of the experts' panel changes. Besides, the statistical generalizability is very restricted in the case study approach, in general [48]. This is the limitation of the applied methodology, but it can provide at least an idea of interdependence of the factors that inhibit faster implementation of a groundbreaking blockchain technology and its principles.

Conclusions

This work points to the potential benefits and challenges of wider application of blockchain in maritime sector. Beside, its

focus is structuring of the barriers in blockchain implementation in an emerging maritime environment. Namely, through the case study conducted among the experts in maritime industry, business and education in South Africa, the paper equips decision makers with understanding of how ISM and MICMAC techniques can assist in interpreting relationships among the barriers in blockchain wider adoption. The applied methodology can assist professionals to develop strategies to mitigate the constraints inherent to the complex and intertwined maritime environment and new technology deployment. The task of the analyzed group decision-making model is to give the highest priority to the barrier at the bottom of the ISM hierarchical scheme, since it drives other barriers in the model. In the analyzed case this is the lack of government regulations regarding blockchain technology and its implementation. According to the applied MICMAC technique, the lack of government regulations is the independent barrier with a high driving power and low dependent one. At the second level of the ISM hierarchical scheme are the following barriers: the reluctance of stakeholders to share business information, the lack of knowledge and understanding of blockchain technology, the lack of support from stakeholders, the stakeholders' reluctance to adopt blockchain, and relatively high investment costs. In relation to the MICMAC, these barriers are linkage ones. They are linked mutually and link all other barriers in the model, and as such, they can cause so-called domino effect. At the top of the ISM pyramidal scheme, there is the lack of early new technology adopters in maritime. This means that all other barriers in the considered model affect this constraint. The lack of early adopters in maritime is therefore the dependent variable in the considered case, with high dependent and low driving power. Finally, we have to highlight that researchers have to be aware of the subjectivity of the assessments of the experts' individual pairwise comparisons of maritime blockchain wide deployment impediments. This consequently requires a careful selection of the experts who are supposed to make assessments. They should have long lasting experience in maritime, as well as a high level of logical and critical thinking skills in order to ensure credibility of such a group decision-making process. In future studies, the number of involved interviewees should be larger, so that we can better explain the aspects of blockchain better integration into shipping and port logistics.

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APPENDIX 6: PRESENTED AT THE MEDITERRANEAN CONFERENCE ON EMBEDDED COMPUTING

2023 12th MEDITERRANEAN CONFERENCE ON EMBEDDED COMPUTING (MECO), 6-10 JUNE 2023, BUDVA, MONTENEGRO

Maritime Blockchain Constraints' Analysis by ISM and MICMAC Techniques

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Abstract—This article considers blockchain technology (BCT) applications, including maritime ones, along with the impediments in this groundbreaking technology wider adoption across maritime cluster. More precisely, the Interpretive Structural Modeling (ISM) accompanied with Cross-Impact Matrix Multiplication Applied Classification (MICMAC) technique are used for assessing the barriers in BCT deployment in shipping and port management. Considered barriers are identified through previous research studies in the field. Subjectivity inherent to the applied methodology, along with the need for careful selection of the experts involved in the analysis, are highlighted.

Keywords—maritime; blockchain; constraints; ISM; MICMAC.

I. INTRODUCTION

The blockchain technology interest has been captured across various sectors [1]. The elimination of third parties in order to manage workflow is the main purpose of blockchain ecosystem [2]. These systems have been in widespread use and have been furnished in many different areas. The key domains in which blockchains are implemented include finances, pharmaceutical and automotive industries, and global supply chain management system, where maritime is its dominant component. The invention and implementation of blockchain came by 'Satoshi Sakamoto' (a pseudonym for a group of programmers) back in 2008. They issued an article "Bitcoin: A Peer to Peer Electronic Cash System" [3]. This article describes peer-to-peer electronic cash online payments made from one entity to another on the network without going through a bank. A few months later after the introduction of blockchain an open source programme to implement this system was released and the first bitcoin network was begun in 2009 [4]. During the first five years after the invention of bitcoin, it was used interchangeably with blockchain [5], what is not precise. In 2013, blockchain technology became a platform for using other cryptocurrencies, such as Ether, which is run on Ethereum platform. The invention of Ethereum was the second core stone in the development of blockchain. More precisely, in 2013,

Vitalik Buterin, issued an article that explains how blockchain system can be used for decentralized applications [6]. Smart contracts are part of these applications. They are part of shared ledger, in which they are protected from changes, tampering and removal from the ledger. All documents and transactions have digital signatures, which insure immutability of records. In fact, blockchain technology reduces or almost eliminates the need for the third parties like attorneys and bankers. People, companies, computers, smart phones, and algorithms can freely transact and interact with one another with little friction. This is a sound advantage of blockchain technology and makes it an enabler of digital assets transactions among network participants. The assets encompassed by blockchain technology are, but not limited to: votes; carbon credits; educational degrees; rights of intellectual property (manuscripts, films, videos, music, art, or other forms of creative artefacts); location of portable assets (containers in maritime transportation, e.g.); charitable donations; bill of lading; sea waybill; letter of credit; ownership titles; cryptocurrencies (bitcoin, ether, doge, tether, etc.); sensors' data collected for different purposes, and much more. Therefore, blockchain might be of a greater use to any field that includes transactions. It could turn out to be the largest technological expansion of the Internet so far.

Blockchain is an emerging technology with numerous advantages in an increasingly digital world, which should be highly secured, effective, decentralized, and with a strong automation capability [7]. It is always secured due to its encryption features; also, as it is a decentralized system, and no additional fee is required when executing a transaction. However, it needs complex software, high-tech hardware, powerful network infrastructure, and energy on which it will efficiently and effectively run different types of consensus mechanisms [8], whilst taking into the account need for reducing greenhouse effect and carbon footprint.

II. BLOCKCHAIN IN MARITIME

Blockchain systems have been in widespread use in many different areas. The primary areas in which this system has been applied are finance, pharmaceutical and automotive

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industries, along with global supply chain system. The latest is where maritime blockchain applications came onboard, since maritime transport is a key component of global supply chains as the most massive and the cheapest mode of transporting raw materials and goods worldwide.

Blockchain in maritime industry brings together numerous logistics partners, who exchange numerous documents like: booking request; booking confirmation; packing list; export/import customs declaration; production certificate; vessel certificate; phytosanitary certificate; certificate of origin; arrival notice; letter of credit; commercial invoice; bill of lading; custom clearance; delivery order, etc. These documents are connected mutually with dynamic events and numerous stakeholders in shipping and port management. Blockchain supports tracking freight containers along the whole supply chain and alleviates risks of delays in cargo delivery. The actors in the supply chain are often from several organizations with different laws and regulations, organizational cultures, and so on, but blockchain is conceived in a way that it can overcome majority of these impediments.

Like any blockchain, maritime one reduces paper and manual work, which are usually connected with latency and errors. Maritime blockchain encompasses complex (asymmetric) cryptography algorithms, time-stamps, digitally signed documents, difficulty puzzles, consensus mechanisms, and synchronization processes. It supports maritime transactions in real-time in traceable, transparent, verifiable, audible, and immutable manner. It deals with big data being accessible to all relevant actors in maritime, along the entire global supply chain. Blockchain in maritime enables [9]:

- Use of cryptocurrencies and related payment platforms;
- Smart contracts;
- Tracking and tracing (T&T) cargo in assistance with Radio Frequency Identification (RFID) system, Global Positioning System (GPS), Internet of Things (IoT) or Internet of Everything (IoE), Physical Internet (PI), etc.;
- Empty containers (re)placement via Blockshipping, e.g.;
- Early risk assessment and logistics adjustments;
- Added-value services built upon open blockchain platforms, etc.

Blockchain is an enabler of smart contracts in maritime, including bill of lading, or sea waybill, letter of credit, commercial invoice, packing list, arrival notice, custom clearance, delivery order, and so on. It allows instant payments through 300Cubits, ShipChain, Prime Shipping Foundation (PSF) platforms, and others. It allows revealing the risk and proposes the counter measures, when unplanned events occurred along the supply chain. Maritime blockchain enables adjustments, in order to prevent cargo delivery delays and unexpected expenditures. Besides, thanks to maritime

blockchain, the administrative expenditures in shipping goods and raw materials can be reduced approximately for 15% [10].

III. IMPLEMENTATION IMPEDIMENTS

Despite maritime blockchain potential for increasing business efficiency, there are still some impediments in its wider adoption, like:

- Maritime business is risk averse and dominantly relies on its legacy [11];
- Some parties are not willing to unveil their data as an competitive asset [12];
- Blockchain cannot guarantee accuracy of the data initially entered into the system;
- It needs stable and fast data transmission links due to the large amount of data exchange and communication traffic [13];
- Initial investments in blockchain technology are high, in particular when it comes to developing and emerging maritime ecosystems [14;15];
- Current knowledge about blockchain is scarce in maritime and requires its uplifting through proper education and training;
- Harmonizing regulation and standards in global supply chains is something that requires higher attention;
- The biggest shipping companies are the players that benefit mostly from this disruptive technology, whilst other actors can be put at a disadvantage;
- Blockchain should assist people employed in maritime, but not replace them. Consequently, human factor should be taken into consideration, as well.

In accordance with the above stated, the influence of several key obstacles in the implementation of blockchain in shipping and port management is examined in the following section.

III. RESEARCH PROBLEM AND APPLIED METHODOLOGY

Here, our task is to examine the interrelationships of some barriers inherent to blockchain adoption in maritime business. Two techniques were used for this purpose: Interpretive Structural Modeling (ISM), along with Cross-Impact Matrix Multiplication Applied Classification (MICMAC). As the research strategy, a case study is applied, while as a data gathering method, an expert panel is organized. Even though there is no unique definition of an expert, commonly the expert panel brings together specialists, who are recognized in the research domain, in this case – maritime business, industry, and education and training. For the purpose of this case study, the experts came from maritime industry, business, and higher education and training in KwaZulu-Natal Province in South Africa. The assessments of ten experts have been taken into consideration and final matrix of barriers' pairwise comparisons are performed by taking into account the

frequency of certain denominators appearances across the individual experts' assessments. Namely, the data obtained are edited, coded and analyzed through ISM and MICMAC techniques that are briefly presented in the following two subsections.

A. The ISM Technique

The ISM technique is a well-structured, collaborative method to reveal the relationships between the constructs in the research problem [16]. According to the experts' opinions, the ISM transforms unclear relationships between the constructs into a clear hierarchical structure of the interrelations [17]. Initially, the constructs related to a problem has to be specified. Then, an aspect has to be associated with each contextual relationship in the model. This aspect has to specify: (i) does the construct C1 affect construct C2, (ii) or vice versa, (iii) or they mutually affect each other, (iv) or there is no relationship between them. After the constructs and the structural framework are determined, each member of the experts' panel has to make pairwise comparisons of the constructs involved into the problem statement. The transitivity of the relationships is a key assumption of the ISM technique. It assumes that if construct C1 is connected to C2, and C2 is connected to C3, then C1 is consequently in relation to C3. This enables creation of a final reachability matrix and a hierarchical structural model of the relationships among the constructs. Once, when the input data is in place, then a final reachability matrix or a hypothetical graph of the relationships among the constructs can be created to support collective decision-making process by the specialists (professionals), who are engaged in a problem consideration. The whole process will be demonstrated on an example in Section IV.

B. The MICMAC Technique

The MICMAC technique assumes creating a graph that classifies factors-variables in the model concerning the driving and dependence levels [18]. It enables classification and structural prospective analysis of indirect relationships of the variables [19]. When it comes to an indirect relationship, we can take into consideration three constructs and their interrelations, e.g., construct C1 impacts C2, construct C2 impacts C3, C1 and C3 have no direct impact, but their relationship with C2 is a cross-relation, where any change in C1 has impact on C3. This approach is defined as a *gray area exploration* [20]. The MICMAC technique supports the ISM scheme by further examination of the relationships among the constructs in the ISM hierarchical model. Namely, the ISM scheme explores the relations "yes"(1) or "no" (0) and ignores the so-called *gray area* in-between "yes" (1) and "no" (0). This additional test leads us to a graph that classifies constructs due to their driving and dependence powers examined through the interconnections and mutual effects [21;22].

C. Some ISM and MICMAC Applications

In this article, we used ISM and MICMAC techniques for benchmarking barriers in maritime blockchain implementation.

However, these techniques can be applied in different domains in which the researchers and practitioners intend to establish clear relationships between the variables involved into the methodological framework. Therefore, we shall mentioned some issues which were considered by the complementary ISM and MICMAC methods so far, such as: particular supply chains [16], the landfill communities [18], energy conservation [20], seismic soil liquefaction [21], risk management process in SMEs [23], total productive maintenance (TPM) [24], the electronic vehicle market [25], enables of digital empowerment in technology [26], etc.

IV. THE EXPERIMENT AND RESULTS

Let us go back to our problem of assessing barriers in maritime blockchain mainstream deployment in port and shipping logistics.

Namely, several research works have considered barriers in blockchain adoption in maritime, while for the purpose of this study, we use as a reference barriers identified in [17]:

- Insufficient level of government regulations (C1);
- Low level of trust in blockchain technology (C2);
- Unwillingness to share business information (C3);
- Insufficient level of knowledge and understanding of blockchain technology and its applications (C4);
- Insufficient stakeholders' support in BCT adoption (C5);
- Some stakeholders reluctance to implement BCT (C6);
- High initial capital investment in BCT (C7); and
- Rarity of early new technology adopters in maritime (C8).

As a research strategy, we used a case study for collecting information on blockchain adoption in the developing maritime environment, i.e. in KwaZulu Natal Province (South Africa). For data gathering, the expert panel was organized. The experts engaged into the study were from maritime industry, business, and higher education and training institutions in KwaZulu-Natal.

The assessments of ten experts with rich experience in maritime, highly qualified, and with high level of critical reasoning skills were collected and later analyzed by ISM and MICMAC methods. This was one-time study in which data are gathered once, during the experts' meeting and later analyzed.

The experts used the following scheme to assess the constructs (C1-C8) that represent the constraints for wider adoption of blockchain in maritime industry and business: F - constraint i leads to barrier j; R - constraint j lead to barrier i; FR - constraint i leads to barrier j, and vice versa; and, X - constraint i and j are unrelated. Each expert gave his/her opinion and afterwards, regarding the frequencies of denominators' F, R, FR and X appearances in the individual assessment matrices, we came up with the cumulative

structural self-interaction and initial reachability matrices (Table 1 and Table 2).

TABLE I. THE INTERACTION STRUCTURAL MATRIX (SOURCE: OWN).

	C1	C2	C3	C4	C5	C6	C7	C8
C1	FR	F	F	X	F	F	X	X
C2	R	FR	FR	R	F	F	X	R
C3	R	FR	FR	R	F	F	X	F
C4	X	F	F	FR	F	F	X	F
C5	R	R	R	R	FR	R	R	R
C6	R	R	R	R	F	FR	FR	R
C7	X	X	X	X	F	FR	FR	X
C8	X	F	R	R	F	F	X	FR

TABLE II. THE INITIAL REACHABILITY MATRIX (SOURCE: OWN).

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	1	1	0	1	1	0	0
C2	0	1	1	0	1	1	0	0
C3	0	1	1	0	1	1	0	1
C4	0	1	1	1	1	1	0	1
C5	0	0	0	0	1	0	0	0
C6	0	0	0	0	1	1	1	0
C7	0	0	0	0	1	1	1	0
C8	0	1	0	0	1	1	0	1

After multiplying initial reachability matrix with itself twice, by the process of Boolean matrices multiplication expressed by formula (1):

$$(AB)_{ij} = \bigcup_{k=1}^n (A_{ik} \cap B_{kj}), \quad (1)$$

it became stabilized. In fact, we got so-called final reachability matrix (Table 3).

Thanks to the final reachability matrix, we can identify the reachability set of nodes for each construct, as well as the set of the ascendant nodes and the intersection set (Table 4). Through the iterative process, equality of ascendant and intersection sets is examined, by eliminated elements from these two sets that are equal and continuing the process until all barriers are covered and associated with the appropriate level of

hierarchical structure of the constructs [25]. The iterative process starts with the constructs(s) for which ascendant and intersection element(s) is(are) identical.

TABLE III. THE FINAL REACHABILITY MATRIX (SOURCE: OWN).

	C1	C2	C3	C4	C5	C6	C7	C8	DRP
C1	1	1	1	0	1	1	1	1	7
C2	0	1	1	0	1	1	1	1	6
C3	0	1	1	0	1	1	1	1	6
C4	0	1	1	1	1	1	1	1	7
C5	0	0	0	0	1	0	0	0	1
C6	0	0	0	0	1	1	1	0	3
C7	0	0	0	0	1	1	1	0	3
C8	0	1	1	0	1	1	1	1	6
DNP	1	5	5	1	8	7	7	4	

TABLE IV. FINAL REACHABILITY MATRIX ANALYSIS (SOURCE: OWN).

	Reachability	Antecedents	Intersection	Iteration	Level
C1	1,2,3,5,6	1	1	1	I
C2	2,3,5,6	1,2,3,4,8	2,3	3	III
C3	2,3,5,6,7	1,2,3,4	2,3	2	II
C4	2,3,4,5,6,8	4	4	1	I
C5	5	1,2,3,4,5,6,7,8	5	5	V
C6	5,6,7	1,2,3,4,6,7,8	6,7	4	IV
C7	5,6,7	6,7	6,7	4	IV
C8	2,5,6,8	3,4,8	8	3	III

Due to the results given in Table 4, we created an interpretive structural model, which is presented in Figure 1. According to this ISM scheme, at the first hierarchical level (I), there are constructs C1 and C4. This means that the insufficient level of government regulations, along with the lack of knowledge and understanding of blockchain technology are the basic impediments. Then, at the next level (II), we have construct C3, i.e. business information sharing concern. Further, the constructs C2 and C8 are at the upper level (III). These constructs correspond to the low level of trust towards blockchain technology and the rarity of early new technology adopters in maritime, while the later affects former. Then, we have criteria C6 and C7 at the level up (IV). The criteria C6 and C7 are mutually connected and refer to resistance of some stakeholders to adopt blockchain technology, partly due to relatively high investment costs.

Finally, at the top level (V), we have stakeholders' lack of support towards implementing this new technology.

Further analysis is based on MICMAC technique to find out more about the nature of these influences. The initial action in conducting this technique is to calculate the dependence and driving powers of each variable. The dependence power (DNP) is calculated by adding all the values in column *j* of the final reachability matrix (Table 3). Meanwhile, the driving power (DRP) of a variable is calculated by adding all the values in row *i* of the final reachability matrix (Table 3). The results of this examination are given in Figure 2. The driver – dependency 2D graph is composed of four quadrants. The *dependency power* is presented along X-axis, while the driving power is presented along Y-axis.

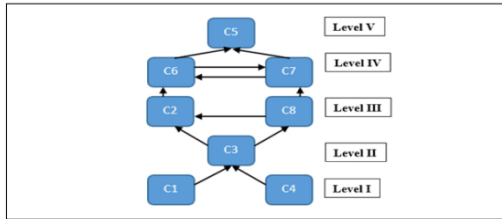


Figure 1. The ISM: BCT adoption barriers in maritime. (Source: Own)

All the constraints are drawn in the graph as points based on the particular driving and dependency levels, while the following can be observed:

- Quadrant I contains no constructs in the model.
- Quadrant II contains C5, C6 and C7 constructs. This means that these constraints have high dependent and low driving level. This is obvious from ISM hierarchical scheme, as well. These constructs are so-called dependent variables in the model.
- Quadrant III contains C2 and C3 constructs. These have moderate dependent and high driving power, and represent linkage barriers. They deserve careful analysis, since they can cause domino effect and breakdown of other constraints due to the high level of connectivity.
- Quadrant IV contains C1, C4 and C8 constructs. These independent constructs need thorough analysis since they are the basic for all other impediments in maritime blockchain implementation. They may help remove other constraints in the model.

In the analyzed case, the decision makers have to pay attention in particular to the variables C1: insufficient level of government regulations, C4: insufficient level of knowledge and understanding of blockchain technology), and C8: scarce early novel technology adopters in maritime as crucial for blockchain successful implementation across maritime cluster.

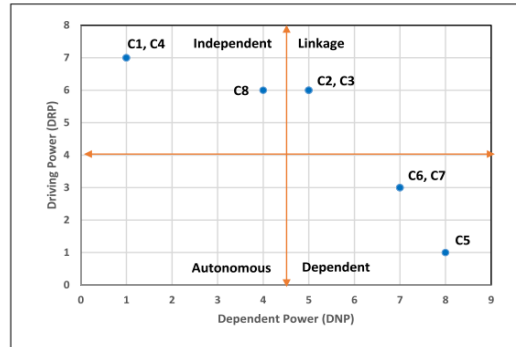


Figure 2. The MICMAC: BCT adoption barriers in maritime. (Source: Own)

V. CONCLUSION

The article established and analyzed the relationships among the impediments towards wider adoption of blockchain in maritime business. The applied methodology based on ISM and MICMAC techniques helps us to develop strategies to mitigate the barriers in complex maritime environment. The group decision-making process has to place high priority on those constraints that are at the base level of the ISM model because they would drive other impediments in implementing and adopting blockchain in shipping industry and port management. Therefore, lack of government regulations and knowledge and understanding of blockchain are the foundation of ISM hierarchy. These two barriers have low level of dependence and high level of driving power, and as such influence in a great extend the other barriers. Alleviating these two impediments, can assist decision makers to overcome the other barriers. In addition to the commitment from the government, it is recommendable to upraise the level of knowledge and understanding of this disruptive technology. Then, the resistance of the stakeholders to adopt this innovation can drop down, and lack of trust among the actors can go down, too. Nevertheless, we have to be aware of the subjectivity of the assessments of the experts' individual pairwise comparisons of the constructs in the model. This requires a carefully search for the experts with long lasting experience in maritime and high level of critical thinking to ensure reliability of the group decision-making process based on applied ISM and MICMAC techniques.

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APPENDIX 7: PRESENTED AT THE INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGY

28th International Conference on Information Technology (IT)
Žabljak, 21 – 24 February 2024

Blockchain applications and cybersecurity threats: A review

Lindani H. Ntshangase, and Sanja Bauk

Abstract - This paper provides a brief overview of the development of blockchain technology, with reference to Bitcoin as the main platform and the cryptocurrency of the same name that runs on top of it. A major part of the paper deals with some of numerous applications of blockchain technology in different areas of human life and work. Special attention is given to actual and prospective deployments of blockchain technology in maritime business and industry. The paper also provides an overview of the most common types of cyber-attacks on blockchain networks.

I. INTRODUCTION

The first idea about blockchain technology appeared in David Lee Chaum's PhD dissertation "Computer Systems Established, Maintained, and Trusted by Mutually Suspicious Groups", defended at the University of California, Berkeley in 1982. Then, in 1991, Haber & Stonett published the paper "How to Time-Stamp a Digital Domain", in which they developed the concept of cryptographic time stamping of digital data. Later, in 1998, Nick Szabo developed the Bit Gold concept as an attempt to create a decentralized cryptocurrency system. The Szabo's idea is considered as the basis of Satoshi Nakamoto's 2008 Bitcoin protocol, which principles are published in the paper "Bitcoin: A Peer-to-Peer Electronic Cash System" [1]. This group of programmers, under the pseudonym Satoshi Nakamoto developed Bitcoin platform and bitcoin cryptocurrency (BTC), which is still the most powerful one [2], despite of high energy consumption issues [3]. Within Bitcoin network, miners' rewards for successfully completing 1 block halve every 210 000 blocks, or an average every four years. Therefore, the number of bitcoins will be capped at 21 million, but with the mining rate being reduced over the time. Likely, the final bitcoin would be circulated until the year 2140. Bitcoin miners will earn then only from transaction fees [4]. A histogram of the historical development of Bitcoin platform and its cryptocurrency is shown in Figure 1.

Over the years, different blockchain platforms and cryptocurrencies developed in the following chronological

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order: 2012-Ripple (XRP) and Dogecoin (DOGE), 2013-Ethereum (ETH), 2014-Stellar (XLM), Neo (NEO) and Monero (XMR), 2017-Solana (SOL), 2018-Tron (TRX), 2021-Chia (XCH), 2022-Eos (EOS), etc. According to some sources, there are more than 1,000 different blockchain platforms [5] and some 9,000 different cryptocurrencies in existence today [6].

It is obvious that the primary purpose of blockchain technology is to work with cryptocurrencies. Over time, it has become clear that blockchain technology can have a much wider range of applications, which are unrelated to the monetization or tokenization of tangible and intangible assets. In the following text, we will attempt to provide an overview of some of the key blockchain applications, with a review of the most common types of cyberattacks they may be exposed to, in today's hyper-connected world.

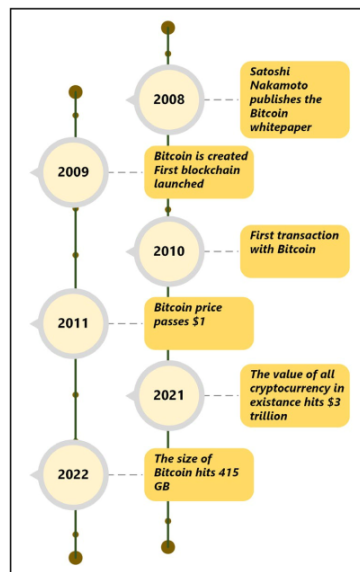


Figure 1. Bitcoin development histogram (Source: own research).

II. BLOCKCHAIN PRINCIPLE AND USAGE

The blockchain is a distributed database of transactions'

records, the objects of which are tangible and intangible assets. This base of transactions' records is usually protected by some algorithm of asymmetric cryptography, and with a particular mechanism of consensus between all the participants in the chain of transactions. In the case of Blockchain, SHA-256 (Secure Hash Algorithm-256) is used as a key asymmetric cryptography tool, while PoW (Proof of Work) is used as a consensus mechanism through which all nodes approve the transaction and synchronize their ledgers with the actual status of the blockchain [7,8]. The same principle applies to different types of blockchain. However, the asymmetric cryptographic functions and consensus mechanisms vary. In fact, the main function of blockchain technology is two-fold: (1) to enable financial transactions without intermediaries such as banks, and (2) to protect the property and rights of users, who make transactions, again without intermediaries such as lawyers, for instance. Different combinations of these two functions are used in different areas of human activity [1,9].

III. BLOCKCHAIN KEY APPLICATIONS

Blockchain has a wide range of applications. Some of these are briefly outlined below.

Finances. The first applications of blockchain technology are related to the financial sector. Blockchain enables cheaper and faster transactions than traditional money transfer. It enables new investment schemes through smart contracts that run on top of blockchain. Additionally, this new technology enables inclusion of those who were previously ineligible for loans, for instance. This is particularly important for people who live in the less developed parts of the world. But, it is important not to lose sight of the need for further regulation of the cryptocurrency market worldwide.

Health system. The healthcare sector is another important area of application for blockchain technology. This technology can be used to protect confidential data contained in the health services users' files. This technology can also be used to control the accuracy, distribution, and price of medicines. Moreover, blockchain is opening new possibilities for health insurance, and the like.

Legal sector. In the legal domain, blockchain technology is being used for smart contracts and the protection of documents, including those relating to the deeds of title. Blockchain can replace effectively and efficiently some services that used to be lawyers' exclusivity.

Education. This emerging technology could have mainstream application in education administration, including students' enrolment and assessments, issuing certificates and diplomas, and in enhancing the intellectual rights of both teachers and students. The information systems currently used in this sector are largely unprotected in respect of all above mentioned segments.

Copyright and royalties. Blockchain technology can secure copyrights and royalties for artistic creations such as paintings, photographs, musical works, and films. Until now, these rights have been largely unprotected. A detailed ledger

of artists, their deeds and intellectual rights should enable them to be settled through appropriate rewards in cryptocurrencies.

Voting. Unfortunately, today there are many doubts about the legitimacy of voting systems worldwide. Blockchain could be a promising solution to prevent incrimination in elections, thanks to additional security mechanisms that are inherent to it. In addition, this sophisticated technology can automatically provide voting results.

Energy sector. Blockchain technology can be used successfully in the energy sector, in the electricity market through local micro-smart and two-way networks. Micro-smart grids can be self-sufficient in the production and sale of electrical energy. In another words, using blockchain technology, consumers can not only sell, but also buy energy in real time when they are short of it. Metering and settlement services can be also automated through smart contracts.

Satellite systems. Emerging blockchain technology can be implemented in satellite-as-a-service business models, that is, for advertising and subscription purposes regarding different broadcast channels. This can relate to controlling marketing and advertising via satellite-based media streams. Furthermore, satellite navigation, communications, and surveillance are inseparable parts of contemporary way of life and work. Consequently, the communication of satellite constellations needs to be secured, which can be achieved through multi-secured blockchain networks.

Supply chains. Blockchain technology has wide variety of applications in supply chains, particularly where there are perishable goods and goods with high specific value. In food supply chains, for instance, where there is a need to know the origin and quality of food, blockchain technology can be of utmost importance. In addition, this new technology can help to increase the visibility of small-scale farmers on the food market, etc.

Toll settlements. Toll collection systems based on blockchain technology should prevent the possibility of toll evasion, especially when vehicles are moving in platoons [10]. In addition to preventing theft, these systems can store all the information relating to the vehicles like driving history and credential information of every registered vehicle. This information can be recorded and verified by blockchain. As examples, we can mention the system deployed at Monterrey-Salttillo highway in Mexico [11].

Maritime sector. Blockchain technology can be used in many ways in the maritime: for tracking and tracing cargo, automating port operations, protecting trade documents, certifying ships and equipment, managing vessel traffic, making payments, concluding smart contracts, etc. Some of the (prospective) maritime blockchain applications are shown in Figure 2.

In shipping industry, blockchain technology has been used for smart contracts, especially for electronic Bill of Lading (eBL). The eBL has three-fold function: (1) receipt for the shipment of goods, (2) evidence of the terms of the contract between the carrier and the cargo owner, and (3) document of title [12].

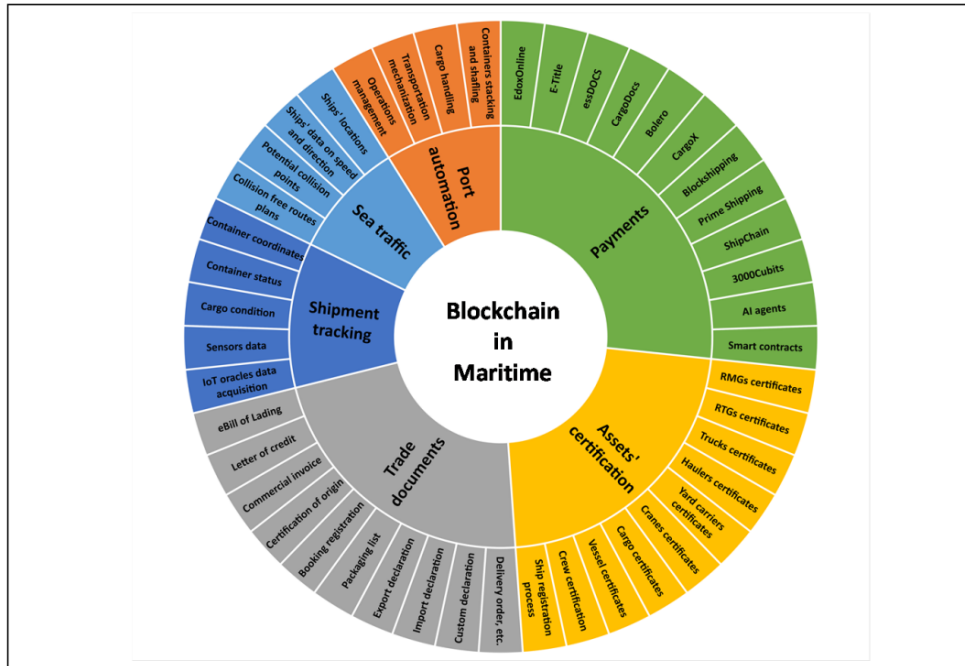


Figure 2. Blockchain maritime applications (Source: own research).

Besides transactions with eBLs, blockchain technology is used for empty containers optimal shipments around the world. A well-known framework and for this purpose is Blockshipping system [13].

Despite the many opportunities blockchain technology offers in the maritime sector, there are several obstacles to widely adopting this technology. Some of them are lack of regulations, trust, knowledge and understanding of blockchain technology, high investment costs, vague revenue, conservatism in maritime sector [14], etc., and additional work needs to be done to overcome these impediments.

Here are presented some of the likeliness applications of blockchain technology in a broad outline, or in a high level of abstraction. The real solutions, implemented in specific cases, are very complex and would require deeper analysis.

IV. CYBERSECURITY THREATS

Cyberthreats and frauds have increased by more than 40% over the past five years [11]. Here we outline some of the most common cyber-attacks in the context of blockchain technology. Of course, we are aware that the range of possible attacks on blockchain is much wider, and that its boundaries are expanding as the technology develops.

The 51% attack. This type of attack is primarily related to Bitcoin and the PoW consensus mechanism. It occurs when

majority of nodes hijacking the network, taking over the verification of transactions and preventing other participants from competing equally in solving the difficulty puzzle and guessing new block's hash nonce. Crypto currencies like Bitcoin, Hanacoin, Vertcoin, Verge, Expanse, and Lincon Cash are prone to 51% attacks [15]. This type of attack can be avoided, for instance, by using PoS (Proof of Stake) consensus algorithm, which is inherent to the Ethereum.

Sybil attack. In a Sybil attack, hackers create fake nodes that flood the network with fake traffic, causing it to collapse. Using these fraud nodes, hackers can take control of the network and disrupt the normal flow of transactions.

Malicious nodes. This type of attack occurs when a dishonest participant gains access to the network and attempts to reroute transactions or flood regular network traffic. This is a threat of only one malicious node at the network.

Phishing attack. In this type of attack, malicious hackers send deceptive emails to blockchain users to trick them into revealing their credentials and wallet details. If they succeed, intruders can enter the system and take control of it.

Routing attack. In this type of attack, intruders intercept network traffic before it reaches the router connected to the ISP (Internet Service Provider), gaining confidential information that they can use to break into and interrupt the blockchain regular operation.

Endpoint vulnerabilities. This is also a common type of cyber-attack on blockchain networks. It is based on intruders

sniffing around users' end-devices, such as mobile phones, laptops, and desktop computers, and stealing passwords to access these endpoints. Once they get into these devices, they are halfway into the blockchain network, and consequently they can cause serious problems.

Private key disclosure. Blockchain technology uses two keys - public and private ones. Hackers can guess the private key if it is simple, or if user does not keep it well. Therefore, it is recommended that the private key is as complicated as possible, so that it is harder to be guessed, and that it is kept well, as something extremely private.

These and other intrusions can block the operation of the blockchain network, cause irreversible damage to participants and to the system as a whole, reduce the value of cryptocurrencies on the financial market and ultimately threaten the reputation of the entire business and technical system behind it, in the eyes of current and potential participants.

V. CONCLUSION

This paper provides a brief overview of the chronology of the development of blockchain networks and related cryptocurrencies. As the number of blockchain mechanisms and cryptocurrencies is measured in thousands, it is obviously impossible to cover them all in a work of this dimension and scope. The article also provides a brief overview of various blockchain applications, with reference to the actual and potential ones in shipping and port operations and management as an important segment of world transport and trade.

Although blockchain technology was developed with the intention of making digital transactions faster, easier, and cheaper, there are many barriers to its widespread adoption. The biggest are a lack of trust among users and stakeholders' reluctance to share business information. Lack of regulation, large investments and related risks are also among the barriers to blockchain widespread adoption. However, the greatest threat is from cyber threats and attacks, which can cause system failure or complete collapse, significant material damage and, as a result, diminish the reputation of the whole system. Understanding this technology can greatly help to raise awareness of cyberattacks and help developers and users to protect against them. We need smarter, more secure and privacy-preserving, holistic and adaptable framework for further development and mainstream deployment of blockchain technologies.

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<https://www.jmr.unican.es/index.php/jmr/article/view/736/766>

2# Jovanovic, Marin and Kostić, Nikola and Sebastian, Ina and Sedej, Tomaz, Managing a Blockchain-Based Platform Ecosystem for Industry-wide Adoption: The Case of TradeLens (September 9, 2022). Technological Forecasting and Social Change, Volume 184, November 2022, 121981, Available at SSRN:
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Yours sincerely

Prof Sanja Bauk

Honorary Professor at the Durban University of Technology
Durban, South Africa

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