BLOCKCHAIN APPLICATIONS IN MARITIME INDUSTRY

(DENİZ LOJİSTİĞİNDE BLOCK ZİNCİR UYGULAMALARI)

by

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Date: ----------

LIST OF SYMBOLS

IoT	**:** Internet of Things
SWOT	**:** Strengths, Weaknesses, Opportunities, Threats
TOPSIS	**:** Technique for Order Preferences by Similarity to Ideal Solution
PKI	**:** Public Key Infrastructure
Tps	**:** Transaction per Second
AI	**:** Artificial Intelligence
NVOCC	**:** Non-Vessel Operating Common Carrier
ROI	**:** Return on Investment
GSCP	**:** Global Shared Container Platform
WEDBA	**:** Weighted Euclidean Distance Based Approach
MCDM	**:** Multi Criteria Decision Making
AHP	**:** Analytic Hierarchy Process
WED	**:** Weighted Euclidean Distance

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ABSTRACT

The aim of this paper is to help decision makers to choose the best smart solution that fits their needs appropriately in the maritime industry. Maritime industry is the most preferable transport method in the supply chain environment. Sea freight is the most efficient and preferred way of transport. With the help of sea freight, delivery time decrease in a great measure and these journeys become more economical and safe. Sea freight helps cost savings in the companies. According to the researches, more than %90 of the world trade is carried out by sea transportation and this rate is increasing day by day.

In today's maritime transport processes, there are too many involved parties. Most of the transactions are handled with written documents. Due to the involvement of multiple parties and the excess of manual workforce, companies have difficulty following transactions. Costs increase with each party involved. Safety and efficiency in the transactions made are decreasing. For this reason, companies look for various solutions that increase productivity, prioritize security, minimize costs and prioritize profits.

Every day technology is developing and creating new era of usages in different areas. Blockchain is one of the newest discoveries of the technological development. It enters our lives with the Bitcoin concept in 2009. Blockchain is a peer-2-peer network, which provides consensus mechanism. It secures the data with a cryptographic hash. It's s ledger system, that keeps the records of each transaction. Each transaction kept unchanged. Once the transaction is done it is unalterable. With every transaction, a new link is added o the chain. Since the links attached to the chain cannot be broken, the data is safely protected. Privacy, transparency, reliability and security are the main features provided by the blockchain system.

Blockchain usage is spreading all over the industries and different sectors as time passes. This usage is encountered in various areas. Banking, transportation, health, insurance and textile can be considered as examples for these sectors.

In this study, alternative blockchain solutions are examined. In the study, 12 alternative solutions were included in the evaluations. Studies on these subjects, especially the concepts of blockchain, smart solutions, supply chain, maritime transportation, and the maritime sector in the literature examined. Selection and evaluation criteria are taken from the literature. The 58 determined criteria grouped under the titles of cost, technique and efficiency and reduced to 20. Trained and experienced experts evaluate selected criteria. The evaluations were made by prioritizing the criteria according to the determined smart solutions. Criteria and alternatives were analyzed using the Multi Criteria Decision Making Methods TOPSIS and WEDBA. The evaluations are weighted by the Entropy method.

In the future researches, the effect of selecting and applying a new technology in companies on the operational and opportunity cost can be analyzed.

Key Words: smart solutions, blockchain, hyper ledger, MCDM, TOPSIS, WEDBA, maritime industry, supply chain

ÖZET

Bu çalışmanın amacı, denizcilik sektöründe çalışan karar vericilere şirketlerinin ihtiyaçlarına göre en ideal akıllı çözümü sunmaktır. Denizcilik sektörü, tedarik zinciri içerisinde en çok tercih edilen taşıma yöntemidir. Deniz taşımacılığı ise en verimli ve tercih edilen yöntemdir. Deniz taşımacılığı sayesinde uzun mesafeler arasındaki yolculuklar daha ekonomik ve güvenli hale gelmektedir. Yapılan araştırmalara göre dünya ticaretinin %90'dan fazla deniz taşımacılığı ile yapılmaktadır ve bu oran her geçen gün artmaktadır.

Günümüz deniz taşımacılığında, süreçlere dahil olan birden fazla taraf bulunmaktadır. Çoğu işlem yazılı dokümanlarla halledilmektedir. Birden fazla tarafın dahil olması ve manuel iş gücünün fazlalığı yüzünden şirketler işlemleri takip etmekte zorlanmaktadırlar. Her dahil olan tarafla birlikte masraflar da artmaktadır. Yapılan işlemlerdeki güvenlik ve verimlilik azalmaktadır. Bu yüzden şirketler, verimlilik arttırıcı, güvenliği ön plana alan ve masrafları minimum indirip kazançları ön plana alan çeşitli çözümler aramaktadırlar.

Her gün teknoloji gelişerek karşımıza yeni kullanım olanakları çıkarmaktadır. Blokzincir de bu yenliklerden biridir. Blokzincir ilk olarak hayatımız Bitcoin kavramıyla 2009 yılında girmiştir. Blokzincir peer-2-peer bir teknolojidir. Uzlaşma mekanizmasıyla çalışmaktadır. Sistem içerisine girilen veriler kriptografik şifreleme ile korunmaktadır. Defter sistemine sahiptir. Her girişin kaydı tutulur ve girilen kayıtlar değiştirilmeden korunur. Blokzincir zincir yapısına sahiptir. Her yapılan işlemle zincire yeni bir halka daha eklenmektedir. Zincire eklenen halkalar kırılamadığı için veriler güvenle korunur. Gizlilik, şeffaflık, güvenilirlik ve güvenlik Blokzincir sisteminin sağladığı temel özelliklerdir.

Blokzincir kullanımı zaman geçtikçe daha çok yayılmaktadır. Çeşitli sektörlerde değişik alanlarda bu kullanım karşımıza çıkmaktadır. Bankacılık, taşımacılık, sağlık, sigorta ve tekstil bu sektörlere örnek olarak sayılabilir.

Bu çalışmada, alternatif blokzincir çözümleri incelenmiştir. Çalışma içerisinde 12 tane alternatif çözüm baz alınarak değerlendirmelere katılmıştır. Literatürdeki blokzincir, akıllı çözümler, tedarik zinciri, deniz taşımacılığı, denizcilik sektörü kavramları başta olmak üzere bu konulardaki çalışmalar incelenmiştir. Seçim ve değerlendirme kriterleri literatürden alınmıştır. Belirlenen 58 tane kriter, maliyet, teknik ve verimlilik başlıkları altında gruplanarak 20 taneye indirilmiştir. Seçilen Kriterler eğitimli ve sektöründe deneyimli uzmanlar tarafından değerlendirilmiştir. Değerlendirmeler, belirlenen akıllı çözümlere göre kriterlerin önceliklendirmesi şeklinde yapılmıştır. Kriterler ve alternatifler, Çok Ölçütlü Karar Verme Yöntemlerinden TOPSIS ve WEDBA yöntemiyle analiz edilmiştir. Değerlendirmeler Entropi yöntemiyle ağırlıklandırılmıştır.

Gelecekteki çalışmalarda, yeni bir teknolojinin firmalar tarafından seçimine etkisi ve seçilen uygulamaların uygulama ve fırsat maliyetleri analiz edilebilir.

Anahtar Kelimeler: akıllı çözümler, blokzincir, hyperledger, MCDM, TOPSIS, WEDBA, denizcilik sektörü, tedarik zinciri

1. INTRODUCTION

Sea freight is the most widely used type of transportation in the global arena. It is the safest and lowest cost among all transport modes. Sea freight is the most preferred transport method in the world. More than 90 per cent of the world trade is carried by the sea. Approximately 4 trillion dollars' worth of goods and materials are moving around the world with containers. (Shirani et al., 2018)

We are in a world which is developing day by day. According to that development each sector has to find their own methods and tactics to catch up the modern standards to gain the maximum profit and to compete with the rival firms. This competition can be achieved by digitalization. Majority of the companies are still working with the traditional methods: Time-consuming paper works, stocking manual files… If we want to name a few of these traditional methods they can be listed as follow charter party agreements, port documents, letters of credit, bills of lading, agreements for ship sales and purchases, cargo carriage documents. Because of the involvement of the many parties to the traditional methods of exchanging documents, there is a huge risk of human errors and fraud. By the digitalization they can cut of the administrative costs and they can invest that money in new era of the businesses, decrease the human errors and theft.

Most popular technology in nowadays is the "Blockchain Technology". That technology came to our lives with the cryptocurrency named "Bitcoin" in 2009. In many platforms, blockchain is seen as the most important invention since the Internet. It has a huge potential of transforming and reshaping the industries, economies and the governments.

Blockchain is a distributed ledger system that keep records of every transaction between parties in a permanent way. With the peer-2-peer network, a consensus mechanism secures the validity of the data before recording to the ledger. Once a transaction is done, that record is unalterable and permanent. It is a shared database between multiple parties

this way it eliminates the intermediaries for verifying the data. The main components of the transactions are receiver, sender and the transaction information. Every transaction uses a cryptographic hash and has a time stamp. Each transaction has a digital signature. Figure 1.1 shows the main components of the blockchain. As seen in the Figure 1.1, every component is connected to the other. All the components work as a gear of a machine. They are all in harmony.

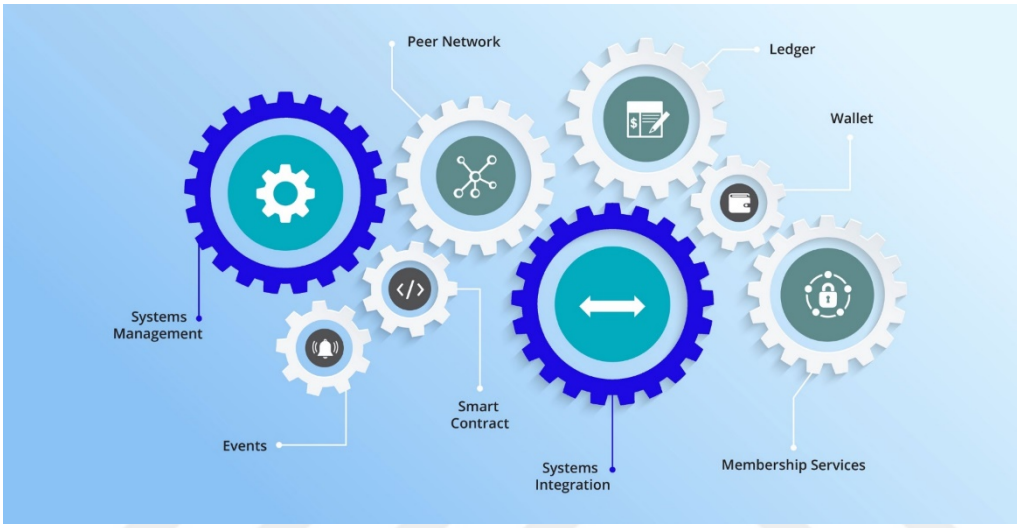

Figure 1.1: Main Components of the Blockchain (edx.org, 2019)

Key characteristics of blockchain are decentralization, data transparency, reliability, privacy, anonymity, security, auditability. In recent years, integration of these characteristic to the maritime industry gained interest. Companies want to take advantage of the blockchain technology by improving their operational efficiency. By the help of blockchain, intermediaries can be eliminated, transaction costs can be lowered, transactions can be automated and run by smart contracts, ports can become smarter, real time order tracking can be maintained, customer satisfaction can be augmented, container tracking and tracing can become faster and reliable, real time tracking of the vessels and containers can be provided with the aid of IoT and fraud and theft can be eliminated. However, there are also some barriers to overcome before adopting the blockchain technology. For instance, lack of knowledge about the blockchain technology, legal boundaries, absence of trust between partners. Therefore, selecting the most appropriate blockchain application is crucial for the companies. They have to justify their technology investments in blockchain based on their needs.

In this work, we aim to choose a best smart solution for the selected company by choosing the best alternative solution based on the evaluations of the industry experts. All the criteria are taken from the literature. MCDM methods are preferred for this study. The preferred methods are TOPSIS and WEDBA. The main reason of selecting the WEDBA method is the usability of the objective and subjective weights at the same time.

In the next section literature review, the key words, and the main aspects of the research is analyzed. In section 3 main principles of blockchain concept is demonstrated. In part 3.1 blockchain mechanism is explained briefly. In 3.2 different types of blockchain is analyzed. Part 3.3 examines the blockchain application areas and part 3.4 details the blockchain actors. In section 4, blockchain applications in maritime industry is demonstrated. Part 4.1 explains the aspects of the maritime industry. Part 4.2 explains the main criteria in choosing the blockchain solutions. Parts 4.3 enlists the alternatives of the blockchain solution and finally in part 4.4 disadvantages of blockchain concepts is discussed. In section 5, MCDM methods are explained. In section 6, mathematical applications are demonstrated and in section 7 inferences and discussions are explained. Finally, in the last section conclusion part, results and future research areas are discussed.

2. LITERATURE REVIEW

The main subject of this paper is the blockchain applications in maritime industry. Literature reviews are made to gain knowledge about the selected research area. In this paper, review is made on databases such as Web of Science, Science Direct, Google Scholar and supporting documents. Selected key words for the database searches are blockchain, shipping, supply chain, sustainability, logistics, maritime, maritime logistics, maritime industry and blockchain technology.

Takahashi (2016) discusses the legal basis of the blockchain technology with the electronic bills of laden. Weernink et al. (Spring 2017) published a paper named *"The Blockchain Potential for Port Logistics"* and they try to give a clear insight about the blockchain technology and the possible application areas in the port logistics and digital ports. They claim that blockchain technology can help the digitalization and increase the efficiency of the supply chain processes. From the perspective of K. Czachorowski et al. (January 2019) blockchain can reduce the pollution and provide a green supply chain by improving the environmental efficiency in the maritime industry.

Biggs et al. (2017) also analyze the barriers of the acceptance of the blockchain technology. From their perspective "… is that the technology is still in its infancy, especially in terms of bringing it to scale enough for widespread corporate industry use." Gausdal, Czachorowski and Solesvik (June 2018) published the *"Applying Blockchain Technology: Evidence from Norwegian Companies"* where they discuss the main drivers and barriers of the technological innovation in the maritime industry and the possible application areas of the blockchain. They suggest that the blockchain can be implemented in the communication and documentation processes for an efficient and safer communication. According to their research the primary barrier for accepting the blockchain technology is the lack of knowledge about the blockchain.

Petersan et al. (October 2018) discuss the expectations, benefits and disadvantages of the blockchain technology through the sector professionals in their paper *"Mapping the Sea of Opportunities: Blockchain in Supply Chain and Logistics".* They conclude that companies should try small scale blockchain applications to find out if this technology is useful for their business. Angelis and Silva (2018) explained a methodology for managers to choose and implement the blockchain technology with value drivers and value opportunities.

Kshetri (December 2017) looks at the various applications of the blockchain in 11 different companies with respect to supply chain management objectives such as cost, quality, speed, durability, risk reduction, sustainability and flexibility. Tijan, Aksentijevic, Ivanic and Britchenko et al. (March 2018) order the benefits of blockchain such as consistency and transparency in the network, minimization of the errors, protection against fraud, real time feedback etc. Jardas (February 2019) suggest that the blockchain can be useful traceability of the goods and the information and the transparency in the supply chain.

Dubrovnik et al. (July 2018) enlist the potential blockchain application areas in logistics by identifying the four transformation phases such as single-use, localization, substitution and transformation to help managers understand the different aspects of the blockchain. Verhoeven et al. (July 2018) identify the characteristics of the blockchain technology in the logistics supply chain management field.

Lumieux (2016) investigates the record keeping feature of the blockchain along with its boundaries and benefits. Daniel Macrinici et al (2018) conduct an analyze over the smart contracts with the systematic mapping study. According to their study the awareness level of the smart contract concept is rising. Zhao Yang et al. (2018) analyze the security of the marine data and they come up with two methods such as marine data security system and marine data security storage with help of the decentralization feature of the blockchain to maintain the security and the reliability of the collected data. Yingli Wang et al. (2019) study the impact of the new blockchain technology on the supply chain management and they state that the advantages of this technology are not so clear and the disadvantages are unpredictable.

Shirani (2018) discuss the feasibility of the usage of the blockchain in the shipping industry with a web-based proof of concept prototype. He enlists the motivation for adopting the blockchain as strategic asset, time and cost saving, need for transparency in his paper “Blockchain for Global Maritime Logistics”.

Baştuğ and Yıldız (2018) discuss the weakness and strength of the electronic blockchain based electronic bill of ladings. They recommend that the electronic bill of lading provide a safe, fast, error saving and cost saving transfer between the partners.

Biktimirov et al. (2017) demonstrate a mathematical modelling by considering the blockchain as a system level integrity by entitling the individual elements of the blockchain system by atoms.

Gareth R. T. White (2017) conduct a Delphi Study over the blockchain technology. He suggests that people should spend more effort to understand the potential of this new technology. Lumieux (2017) conduct a Swot Analysis over recordkeeping function of blockchain to demonstrate the strengths, weaknesses, opportunities and threats. H. Tang et al. (2019) used entropy and Topsis method in their paper. They rank the public blockchains and evaluate the weighs of the indicators. As a result, recognition, activity and technology are the most influential indicators by comparison to other indicators.

Rødseth et al. (2019) compare the Public Key Infrastructure (PKI) and the blockchain technology with three different application areas and examples. As a result, PKI is better at ship to shore or vice versa communications and the blockchain is better at trade related data.

Quitzau, Jörn et al. (2018) analyzes the financial aspects of the digitalization and new technologies in shipping industry. They suggest that the changes will affect the structures and the business models in the sector.

Kim et al. (2019) discuss the methods of overcome the vulnerability of the IoT devices with the blockchain technology using Color Spectrum Chain. They aim to solve the security vulnerabilities like hacking and theft of the sensor multiplatform of the IoT devices.

Sadouskaya (2017) discuss the interests and doubts about the blockchain of the participants of the supply chain in the logistics sector. She concludes that the time by time firm will build a trust for the blockchain and it will spread all over the supply chain.

In the research paper published by Inmarsat (2018), there are various sector-based comparisons of the IoT adoption, security, data, skills, connectivity, investment and ROI. They showed that biggest security challenge associated with use of IoT based solutions is the risk of external cyber-attack.

Table 2.1: Detailed Table of References

Title	Publication Date	Authors	Keywords
1. The Blockchain Potential for Port Logistics	Spring 2017	Marissa Oude Weernink, Willem van den Engh, Mattia Francisconi, Frida Thorborg	Blockchain, digitalization, port logistics
2. The Application of Blockchain Technology in the Maritime Industry	January 2019	Karen Czachorowski, Marina Solesvik, Yuriy Kondratenko	Blockchain technology, maritime industry, green supply chain
3. Blockchain Technology and Electronic Bills of Lading	2016	Koji Takahashi	Blockchain, blockchain technology, bill of lading
4. Applying Blockchain Technology: Evidence from Norwegian Companies	2018	Anne H. Gausdal, Karen Czachorowski, Marina Solesvik	Blockchain technology, innovation, maritime industry, supply chain
5. Blockchain: Revolutionizing the Global Supply Chain by Building Trust and Transparency	2017	Jonathan Biggs, Sheri R. Hinish, Michael A. Natale, Matt Patronick	Blockchain, supply chain, transparency

Table 2.1: Detailed Table of References *(Cont. d)*

6. Mapping the Sea of Opportunities: Blockchain in Supply Chain and Logistics	2018	Moritz Petersan, Niels Hackius, Birgit von See	Blockchain, logistics, supply chain
7. Blockchain Adoption: A Value Driver Perspective	2018	Jannis Angelis, Elias Ribeiro da Silva	Blockchain, value drivers, decision making, distributed ledger
8. Blockchain Technology Implementation in Logistics	2019	Edvard Tijan, Saša Aksentijevic´, Katarina Ivanic, Mladen Jardas	Blockchain, logistics, big data, internet of things
9. Blockchain's Role in Meeting Key Supply Chain Management Objectives	2018	Nir Kshetri	Blockchain, supply chain, sustainability, network effects
10. Blockchain Technology into the Logistics Supply Chain Implementation Effectiveness	March 2018	Britchenko, T. Cherniavska, B. Cherniavskyi	Blockchain, logistics, supply chain, effectiveness
11. Blockchain for and in Logistics: What to Adopt and Where to Start	September 2018	Mario Dubrovnik, David M. Herold, Elmar Fürst, Sebastian Kummer	Blockchain, supply chain management, logistics, transformation
12. Examples from Blockchain Implementations in Logistics and Supply Chain Management: Exploring the Mindful Use of a New Technology	September 2018	Peter Verhoeven, Florian Sinn, Tino T. Herden	Blockchain, logistics, supply chain management, mindfulness

Table 2.1: Detailed Table of References *(Cont. d)*

13. Trusting Records: Is Blockchain Technology the Answer?	2016	Victoria Louise Lemieux	Blockchain, reliability, technology, trusted digital repository
14. Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study	2018	Daniel Macrinici, Cristian Cartofeanau, Shang Gao	Blockchain, smart contracts, systematic mapping
15. Marine Data Security Based on Blockchain Technology	2018	Zhao Yang, Weiwei Xie, Lei Huang, Zhiqiang Wei	Blockchain, decentralized technology, marine data
16. Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda	2019	Yingli Wang, Jeong Hugh Han, Paul Beynon Davies	Blockchain, supply chain management, new technology, information transparency
17. Blockchain for Global Maritime Logistics	2018	Ashraf Shirani	Blockchain, distributed ledger, maritime logistics, containerized shipping
18. E-Bill of Lading in the Context of Blockchain Technology	2018	Ramazan Özkan Yıldız, Sedat Baştuğ	Blockchain technology, e-bill of lading, smart contracts
19. Blockchain Technology: Universal Structure and Requirements	2017	M. R: Biktimirov, A. V. Domashev, P. A. Cherkashin, A. Yu. Shcherbakov	Blockchain, mathematical model, encryption, distributed data storage

Table 2.1: Detailed Table of References *(Cont. d)*

20. Future Applications of Blockchain in Business and Management: A Delphi Study	2017	Gareth R. T. White	Blockchain, competitive advantage, innovation, Delphi study
21. Blockchain Recordkeeping: A Swot Analysis	2017	Victoria L. Lumieux	Blockchain, recordkeeping, swot analysis
22. Public Blockchain Evaluation Using Entropy and TOPSIS	2019	Huimin Tang, Yong Shi, Peiwu Dong	Blockchain, evaluation, ranking, TOPSIS, entropy method
23. PKI vs. Blockchain when Securing Maritime Operations	2019	Ørnulf Jan Rødseth, Per Håkon Meland, Christian Frøystad, Ovidiu Valentin Drugan	Blockchain, maritime operations, security, PKI
24. Shipping in an Era of Digital Transformation	2018	Jörn Quitzau	Blockchain, digitalization, transformation
25. A Study on Improvement of Blockchain Application to Overcome Vulnerability of IoT Multiplatform Security	2019	Seong-Kyu Kim, Ung-Mo Kim, Jun-Ho Huh	Blockchain, IoT, authentication
26. Adoption of Blockchain Technology in Supply Chain and Logistics	2017	Krystsina Sadouskaya	Blockchain, logistics, supply chain

Table 2.1: Detailed Table of References *(Cont. d)*

27. Industrial IoT on Land and at Sea	2018	Inmarsat	Blockchain, technology, IoT

3. BLOCKCHAIN TECHNOLOGY

Blockchain is a revolutionary new technology. Its aspects are breathtaking. Each day new era of use of this technology arises. It is a software protocol based on cryptographic transactions for public databases. This new technology gathers people all around the world together. According to researches global spending on the blockchain technology in 2019 is $2.9 billion, and it will become $12.2 billion in 2022. (IDC Spending Guide, 2019)

3.1 Blockchain Mechanism

The world is developing in every manner. Especially in the technological way. As seen in the Figure 3.1, there is a huge development in the computer world. It started with a Mainframe in 1970s, and then PC's in 1980s. After Internet showed up in 1990s and with the appearance of the Internet, in the 2000s the Social and Mobile Networking take over the world. In the last years, well-known actor names blockchain had appeared. Blockchain enter our lives with the cryptocurrency named Bitcoin in 2009 with the Satoshi Nakamoto. Each day the progress in the computing world is rising. Figure 3.2 shows a brief history of the blockchain from 1900s to 2000s.

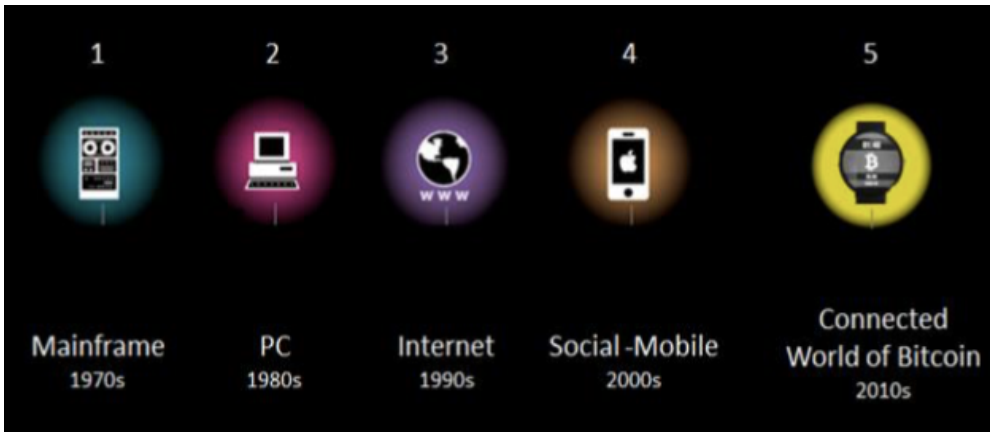

Figure 3.1: Progress in the Computing World (Swan, 2015, 12)

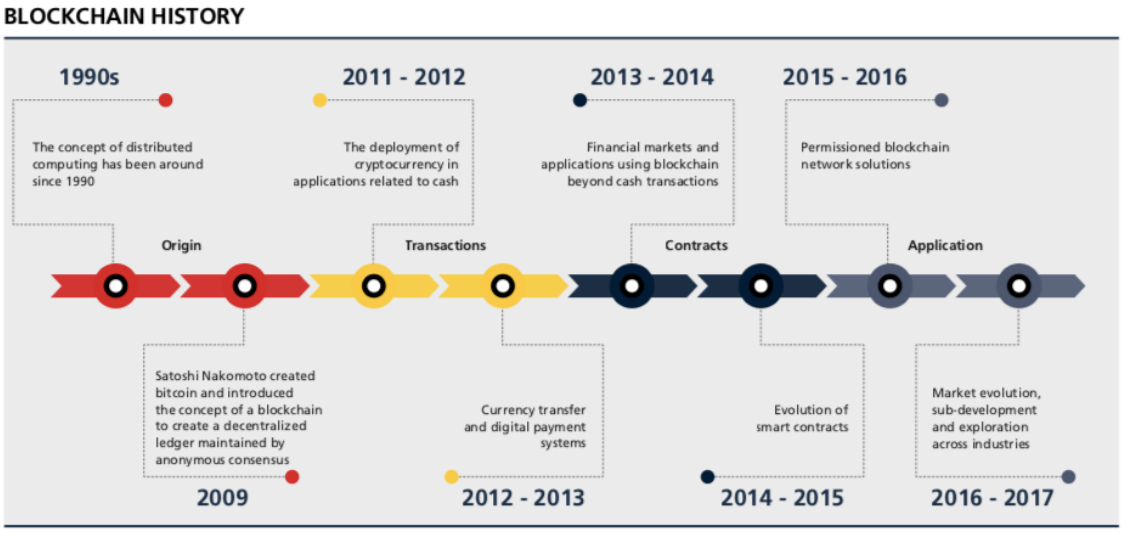

Figure 3.2: History of a Blockchain Technology (Accenture, 2018)

Blockchain is a distributed ledger technology. It allows the transactions among the parties in the network using a chain of blocks. Each chain starts with a genesis block. Each block is connected to the previous block by a cryptographic hash value which is 256-bit random numbers generated randomly. This connection ensures the security of the transactions. No single party controls the data or the information.

Transactions are secured by the public and private keys. Each public key has a matching private key. Public keys indicate the destination of a transaction and the private key is like decipher of that public key. Owner of the private key, signs digitally the transaction to gain the ownership of the transaction. Communications realize between the peers without an interference of a central node. Users can remain anonym or they can provide proof of their identity based on their wishes.

Each block holds the complete list of transactions. Each transaction has a timestamp and a digital signature which con not be copied or altered. Once the information is entered it cannot be deleted. The entries in the network are distributed among the nodes all over the world. These nodes can be servers or computers. These nodes provide a consensus mechanism. This way all the data among the network can be reachable from all the nodes. Blockchain technology use cryptography to ensure the authenticity and to ease the tracking of the changes and actions.

The transaction in a blockchain system can be modeled as follows.

- A wants to send money to B
- A transaction is created between A and B
- The transaction is published to the network and validated
- The transaction is added to the system as a new block
- The network approves the block and added to the chain
- The transaction is executed
- Money moves from A to B

Blockchain provides anonymity, decentralization, data transparency, reliability, privacy, security, auditability. The data is immutable in the system. The date and time stamp provide the proof of validation. Figure 3.3 shows the benefits of the blockchain.

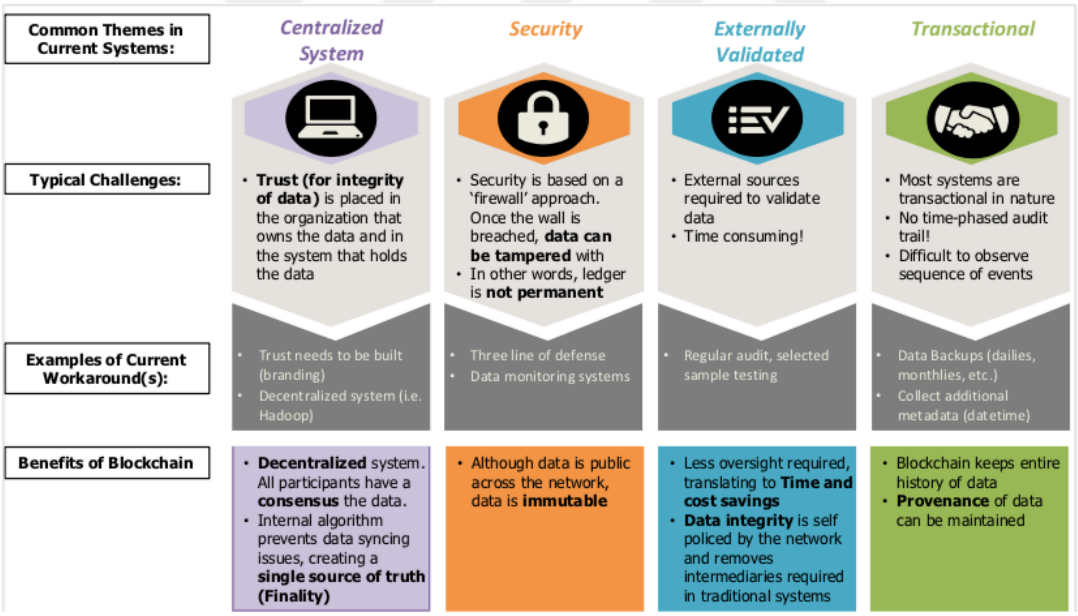

Figure 3.3: Benefits of the Blockchain (blockchainhub.net, 2019)

In centralized systems, each transaction must be validated by a trusted agency but in the decentralized systems the transaction can be made without an interfere of a central agency between peers. This way cost reduction in the operational and development can be achieved. Users can hide their identities and obtain an anonymity. Auditability and reliability are provided by the timestamp and digital signatures of the transactions.

Previous records can be easily tracked by accessing the nodes in the network. This way users achieve the traceability and transparency in the transactions.

Everyday more and more new blockchain technologies are evolving based on the performance requirements by the users. Most influential indicators to measure the popularity of the blockchain is the recognition, activity and the technology based on a research. According to the same research, the five most influential second level indicators are market capitalization, the fork in GitHub, the star in GitHub, the Transaction per Second (TPS) and the Google search heat in the previous month. (H. Tang et al., 2019)

Blockchain can combined with other technological aspects. Such as Internet of Things (IoT), Artificial Intelligence (AI), Big Data Analytics, Safety and Security. Table 3.1 shows the interaction with other technologies.

Table 3.1: Interaction of Blockchain With Other Technologies

ARTIFICAL INTELLIGENCE	INTERNET of THINGS	BIG DATA ANALYTICS	SAFETY AND SECURITY
Dynamic Pricing	Real Time Tracking	Delay Forecasting	Verification of Products
Capacity Allocation	Safety and Privacy	Cost Forecasting	Identification of the Ownership
Product Quality Determination	E-Business	Supply and Demand Balancing	Land Registration
			Privacy Protection

3.2 Types of Blockchain

There are three types of blockchains. They can be listed as public blockchain, private blockchain and consortium blockchain. Table 3.2 shows the comparison between the blockchain types. These comparisons made for the six different properties. These properties are consensus determination, read permission, immutability, efficiency, centralization and consensus process.

In public blockchains every node can join the consensus process but in the private blockchain only the selected node or nodes can join the consensus process. The transactions in the public blockchains are visible to everyone. In the private blockchain

only the parts which have a permission to read can access the transactions. In public blockchains there a many node and it can lower the efficiency but in the private blockchain there are limited number of nodes and this can increase the efficiency. Public blockchains are decentralized, consortium blockchain is semi-centralized and private blockchains are fully centralized systems. To join the consensus of a private or consortium blockchain, parties need a permission to join the network.

Table 3.2: Comparison of the Blockchain Types (Zheng et al. 2018)

PROPERTY	PUBLIC BLOCKCHAIN	CONSORTIUM BLOCKCHAIN	PRIVATE BLOCKCHAIN
CONSENSUS DETERMINATION	All Miners	Selected Set of Nodes	One Organization
READ PERMISSION	Public	Could be Public or Restricted	Could be Public or Restricted
IMMUTABILITY	Nearly Impossible to Tamper	Could be Tampered	Could be Tampered
EFFICIENCY	Low	High	High
CENTRALISED	No	Partial	Yes
CONSENSUS PROCESS	Permissionless	Permissioned	Permissioned

Public blockchains are decentralized systems. They are fully independent. They are not under control of a central authority like a single person or an institution. In contrast private blockchains are centralized systems. They are under control of an authority such as a bank, firms.

Public blockchains are permissionless systems. Anyone who wants to join the system can participate it without an authentication. They can read, write and perform transactions and join the consensus freely. Private blockchains are the permissioned systems. Each node has an identity and the people who want to participate must have an authentication to participate.

3.3 Blockchain Application Areas

Blockchain technology has a wide range area of application. It can be used in supply chains, logistics, maritime industry, finance sector, food and agriculture, pharmaceutical industries. With the ease of tracking and traceability, theft and counterfeit can be prevented.

In Business-to-Business transactions there are some challenges. These challenges can be listed as follows:

- Processes are in a repetitive cycle
- Huge dependence on a paper work
- Huge dependence on people
- Greater amounts of fees and charges
- Risk of fraud

To overcome these challenges blockchain offers successful solutions. With the help of the blockchain more efficient processes can be realized, security of the documents are increased, dependency on the paper work and people are reduced, precautions against fraud and theft by unchangeable and time stamped data, transparency of the data.

Blockchain can be combined with other technologies such as IoT. For example, in the food and agriculture industry, the origin of the foods can be traced by the IoT based devices, RFID's. RFIDs can also be used in the maritime industry to track the ships and containers. Usage areas of the blockchain can be listed as follows.

- Governmental:
    - Voting
    - Tax
    - Energy Saving
    - Privacy
- Industrial:
    - Internet of Things (IoT) Device Management
    - Manufacturing

- Finance:
    - Foreign Exchange
    - Trading
    - Payments
    - Risk Management

- Insurance:
    - Claims
    - Ownership Titles
    - Sales and Underwriting
- Retail
    - Letters of Credit
    - Identity Management
    - Capital Assets Management
- Healthcare
    - Medical Records
    - Assurance Contracts
    - Pharmaceutical Tracking
- Maritime
    - Letter of Credit
    - Bill of Lading
    - Smart Contracts
    - Real Time Tracking
    - Legal Documents
    - Energy Saving
    - Cost Reduction
    - Third Party Elimination

3.4 Blockchain Actors

Blockchain system works in harmony with other systems thanks to their actors. There are several actors in this technology such as developers, architectures and end users. First actors are the Architects. They can be an individual or a group of people who create and

design the backend code of the blockchain. Second actors are the Operators. Operators are the nodes. They join the system to create peer-2peer network. They keep a copy of every transaction and distribute them among the other nodes. Third actors are the Developers. They help creating the smart contracts. They play a huge rule in the designing and writing of the contracts. To expand the capabilities of the network; developers have to upload the contracts to the network. Fourth actors are the Regulators. They are the people who have an access to view the ledgers of the transaction within the organizations. Each organization have their own regulations based on their data storage policies. Fifth actors are the End Users. They use the solutions that blockchain technology offers. Sixth actor is the Data Storage. This technology provides an immutable and distributed storage function. Just like many other systems, blockchain has a capacity. To benefit from the maximum capacity, instead of conserving huge amounts of data, the hash of the data is stored on the blocks. This also provides a protection of the data from modifying from unwanted parties. Seventh and the last actor is the Data Processing. All the actions on the blockchain network run simultaneously. All the peers of the network execute the code at the same time.

4. BLOCKCHAIN APPLICATIONS IN MARITIME INDUSTRY

Marine transport is one of most of the preferred method of transport. With the developing technologies, companies try to adapt the innovations and try to catch the trends. Otherwise, they cannot modernize and facilitate their business process to compete with other firms.

4.1 Maritime Industry

Maritime industry constitutes the huge part of the global trade. It places itself as the main component and the main stakeholder of the global supply chain by establishing international trade. It supports many industries. Manufactured goods, heavy materials, huge machineries, raw materials, food and various goods are transported from one point to another around the world. The most common way to carry the goods over the vessels is the usage of the containers. There are various types of containers. These container selections depend on the types of the carried goods.

In the current shipping supply chain, almost all the operational procedures and information system actions contain various parts with many participants. Due to these interactions of the various parts, the companies face some barriers against their trades. Many of the business processes are paper based. These paper-based actions cause delays to the importers, exporters, companies and augment the total cost of the work. Customs clearances and border administrations cause bureaucratic delays because of the mass of paperwork and involvement of the third parties.

The port environments play a huge role in the maritime industry. It has three main components, which are port, port authority and terminal. Ports are the connectors of the lands and the seas. Vessels load and discharge their cargos at the ports. Port authorities

are the persons or institutions that are responsible to provide maritime services for the vessels and the companies. Terminal is the location, which belongs to the port. In the terminals, specific actions are done based on the types the goods to be transported. Cargo handlings and storage options are available in the terminals.

Cargo carriage is the main responsibility of the maritime logistics. Maritime logistics consist of planning, implementing and managing steps of the movements of the goods and information in ocean carriage (Song & Panayides, 2012). The main components of the maritime logistics are shipping companies, terminal operators and forwarders. Forwarders connect the customers and companies by organizing and coordinating the transportation of the goods. Their main function is preparing the custom clearance papers, preparing bill of laden and other shipping documents.

Authorities in the customs are obligate to enforce the import and export regulations in the countries. They check the authenticity of the information on the necessary documents such as bill of laden. This paper serves as a receipt and obliges the carriers to carry the goods of the customers. They contain the general information about the goods, the vessel and the destination. The figure 4.1 represents the current processes in the shipping industry.

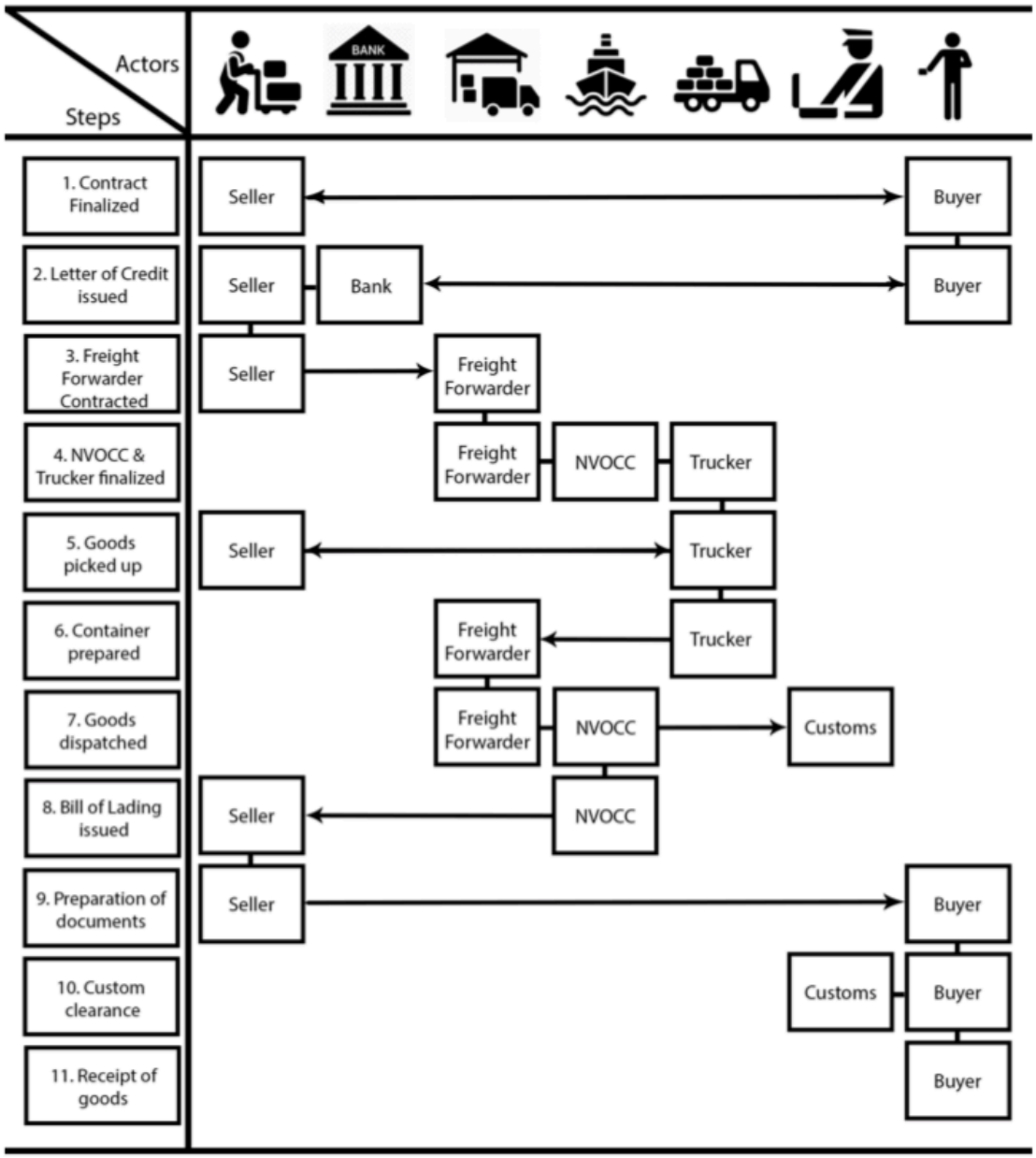

Figure 4.1: Current Processes in Shipping Industry (Jain, 2018)

1) The seller and the buyer come together. They enter to an agreement for the sale of the goods. This agreement is a paper-based agreement. They are signed and exchange within the involved parties. In most cases, the transaction values are high, and the parties do not know each other. In these cases, seller want a letter of credit from the buyer. The letter of credit is taken from the banks. They guarantee the payment.

2) Buyer requests a letter of credit from their bank. With this request, buyer also sets the terms of the payment. Buyers bank send a copy of a letter of credit to seller's bank.

3) Agreement is signed, and the seller prepares the goods to be shipped. Seller searches for a forwarder to assist the shipping processes of the goods. Forwarder prepares a freight quote which consist of routing information, transport mode and equipment and shipment details. Seller studies various quotes. Once the quote is chosen and accepted, he provides the commercial invoice, Certificate of Origin, Material Data Safety Sheet and Shipper's Letter of Instruction to the forwarders. Certificate of Origin is used for the cargo reporting in customs clearance. Material Data Safety Sheet is for hazardous goods. Shipper's Letter of Instruction contains the routing information, consignee details and incoterms.

4) Forwarder receives the documents and organizes a trucking company and non-vessel operating common carrier (NVOCC). They organize the bookings with the liners. They provide a confirmation of the booking to the forwarders. This booking confirmation includes booking number, equipment size, transport plan, cut off dates, load itinerary. It is sent via email to the forwarder and the forwarder transfers this information to the seller via email.

5) Seller prepares the goods for the truckers.

6) Forwarder receives the goods and starts to prepare the containers to be loaded to the ships. When the containers are ready, trucks take them to the port with the packing list.

7) Trucks arrive to the port and enter the port with the relevant papers. Forwarders communicate with the customs for the clearance of the goods to load them to the ships. Otherwise, the demurrage cost will incur for the remaining goods on the port. Forwarders also communicate with the NVOCC for the bill of laden. It is proof that all goods are cleared by the customs.

8) Forwarders approve the bill of laden and the containers are loaded to the ships. Three copies of the bill of laden are sent to forwarder by NVOCC via courier services.

9) When the forwarder receives the copies of the bill of laden, he keeps the one copy to himself. He sends the second copy to the bank to receive his payment. The third copy is sent to buyer by a courier to receive their goods from the ports.

10) Buyer prepares the necessary documents to obtain their cargo in the ports. He prepares the Bill of Entry for the customs clearance, commercial invoice, bill of laden, import license, insurance papers, letter of credit and tax documents.

11) Goods are taken by the buyer if all the papers are correct and consistent otherwise, the demurrage cost incurs.

As seen in Figure 4.2, there are multiple parties and steps in the standard process. Each step requires an enormous documentation. Important and legal documents are printed and executed on paper. This may cause fraud and theft. The papers can disappear or can be changed by others. It is difficult to track that much printed documentation. That also causes a wastage in terms of time, resources and labor. This wastage affects negatively the efficiency and performance of the supply chain in the shipping industry. Intermediate parties should be eliminated for cost saving.

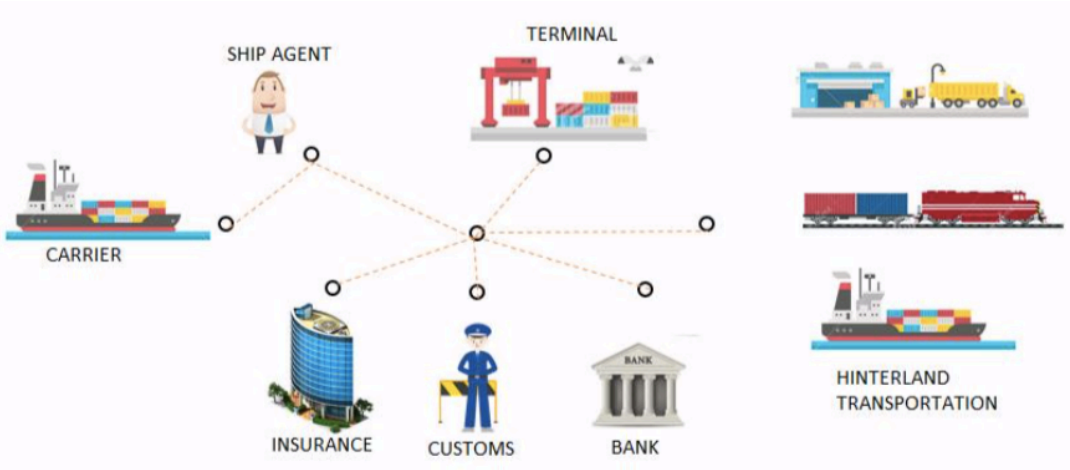

Figure 4.2: Involved Parties in Port Logistics (Weernink, 2017)

4.2 Main Criteria in Choosing the Blockchain

All the criteria are obtained from the literature and the comparison criteria in the current process are displayed in the Table 4.1. Source column represents the main article of those criteria.

Table 4.1: Criteria

	BLOCKCHAIN APPLIED SYSTEM	CURRENT SYSTEM	SOURCE
1	Operating without a trusted third party	Standard operations with multiple parties	"Blockchain for Global Maritime Logistics"
2	Fast and inexpensive transactions	Slow and expensive transactions	"Blockchain for Global Maritime Logistics"
3	Validating data integrity without constant connectivity	Validating data integrity without constant connectivity	"Trusting Records: Is Blockchain Technology the Answer?"
4	Proof of identity	Proof of identity	"Blockchain for Global Maritime Logistics"
5	Integrity Protection	Integrity Protection	"Trusting Records: Is Blockchain Technology the Answer?"

Table 4.1: Criteria *(Cont. d)*

6	Storing transactions openly across many nodes	Storing data manually in files	"Trusting Records: Is Blockchain Technology the Answer?"
7	Smart contracts for online agreements	Paper contracts with the third party involvements	"Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study"
8	Greater automation of business processes	Standard Manuel business processes with the human involvement	"Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study"
9	Security	Security of manual processes	"The Blockchain Potential for Port Logistics"
10	Adoption	Habits	"Trusting Records: Is Blockchain Technology the Answer?"
11	Investment and ROI	Willing to make investments	""Trusting Records: Is Blockchain Technology the Answer?""
12	Efficiency on custom administration	Efficiency on custom administration with standard processes	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
13	Efficiency on Import-Export procedures	Efficiency on Import-Export procedures with standard processes	"Blockchain Technology and Electronic Bills of Lading"
14	Transparency on Border Administration	Transparency on Border Administration with standard processes	"Blockchain: Revolutionizing the Global Supply Chain by Building Trust and Transparency"
15	Carrier to terminal coordination and planning	Carrier to terminal coordination and planning on standard processes	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"

Table 4.1: Criteria *(Cont. d)*

16	Supply chain visibility and information sharing	Supply chain visibility and information sharing on standard processes	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
17	Coordination across shipper and shipper alliance	Coordination across shipper and shipper alliance on standard processes	"Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study"
18	Cargo flow visibility on terminal operations	Cargo flow visibility on terminal operations on standard processes	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
19	Approval frequency on transactions	Approval frequency on transactions on existed methods	"A Study on Improvement of Blockchain Application to Overcome Vulnerability of IoT Multiplatform Security"
20	Privacy	Privacy	"Trusting Records: Is Blockchain Technology the Answer?"
21	Transaction fee	Transaction fee	"A Study on Improvement of Blockchain Application to Overcome Vulnerability of IoT Multiplatform Security"
22	Immutability	Theft and fraud on paperwork	"Blockchain for and in Logistics: What to Adopt and Where to Start"
23	Speed and cost	Speed and cost of the existed paperwork processes	"Trusting Records: Is Blockchain Technology the Answer?"
24	Human factor	Human factor	"Applying Blockchain Technology: Evidence from Norwegian Companies"

Table 4.1: Criteria *(Cont. d)*

25	Legal Complexity	Legal Framework	"The Application of Blockchain Technology in the Maritime Industry"
26	Recognition	Recognition	"Examples from Blockchain Implementations in Logistics and Supply Chain Management: Exploring the Mindful Use of a New Technology"
27	Activity	Activity	"Public Blockchain Evaluation Using Entropy and TOPSIS"
28	Technology	Technology	"Public Blockchain Evaluation Using Entropy and TOPSIS"
29	Applicability	Applicability	"Public Blockchain Evaluation Using Entropy and TOPSIS"
30	Trust in records=Reliability	Trust in paper records	"The Blockchain Potential for Port Logistics"
31	Authenticity	Authenticity	"Blockchain for and in Logistics: What to Adopt and Where to Start"
32	Long-term digital preservation	Long-term non-digital preservation	"Blockchain for and in Logistics: What to Adopt and Where to Start"
33	Data localization	Data localization	"Trusting Records: Is Blockchain Technology the Answer?"
34	Transparency	Transparency	"Blockchain: Revolutionizing the Global Supply Chain by Building Trust and Transparency"

Table 4.1: Criteria *(Cont. d)*

35	Waste Reduction	Usage of huge amounts of paper	"The Application of Blockchain Technology in the Maritime Industry"
36	Cost of Innovation	Cost of non-technological processes	"Applying Blockchain Technology: Evidence from Norwegian Companies"
37	Size of the Organization	Size of the Organization	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
38	IT Readiness	IT Readiness	"Applying Blockchain Technology: Evidence from Norwegian Companies"
39	Competitive Pressure	Competitive Pressure	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
40	Environmental Uncertainty	Environmental Uncertainty	"Blockchain Technology into the Logistics Supply Chain Implementation Effectiveness"
41	Industry Support	Industry Support	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
42	Inter-organizational Relationships	Inter-organizational Relationships	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"
43	Degree of Managerial Support	Degree of Managerial Support	"Understanding Blockchain Technology for Future Supply Chains: A Systematic Literature Review and Research Agenda"

Table 4.1: Criteria *(Cont. d)*

44	Political changes	Political changes	"Blockchain for Global Maritime Logistics"
45	Social factors	Social factors	"Blockchain for Global Maritime Logistics"
46	Cybersecurity	Security of the assets	"Trusting Records: Is Blockchain Technology the Answer?"
47	Ecological Factors	Ecological factors of the standard processes with the mass amount of paper work	"The Application of Blockchain Technology in the Maritime Industry"
48	Dependence on Blockchain operators	Dependence on Custom and port operators	"Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study"
49	Lack of technological Maturity	Awareness of new technologies	"Blockchain for Global Maritime Logistics"
50	Uncertainty of Benefits	Expectations	"Blockchain for Global Maritime Logistics"
51	Risk of external cyber-attacks	Theft	"Trusting Records: Is Blockchain Technology the Answer?"
52	Degree of network security	Degree of physical security of business-related assets	"Trusting Records: Is Blockchain Technology the Answer?"
53	Security of storage of the collected data	Degree of physical security of business-related assets	"Trusting Records: Is Blockchain Technology the Answer?"
54	Supplier/partner data regulation requirements	Data regulations	"Smart Contract Applications within Blockchain Technology: A Systematic Mapping Study"
55	Training the users	Standard user behaviors	"Industrial IoT on Land and at Sea"
56	Identifying efficiency and cost saving operations	Being open minded for the innovations	"Mapping the Sea of Opportunities: Blockchain in Supply Chain and Logistics"
57	Productivity monitoring	Efficiency of the productivity	"Industrial IoT on Land and at Sea"

Table 4.1: Criteria *(Cont. d)*

58	Automation of business processes	Non automated business processes	"Marine Data Security Based on Blockchain Technology "

All the 58 criteria are examined and are shortened to 20 criteria as seen in Table 4.2. They are grouped under three titles. These titles are technical, efficiency and cost. They are shortened to 20 criteria, after detailed analysis with experts. They are chosen by the suitability to the selected topic.

Table 4.2: Usage of Blockchain in Different Industries

	BLOCKCHAIN APPLIED SYSTEMS	GROUP
1	Operating wtihout a trusted third party	Efficiency
2	Fast and inexpensive transactions	Cost
3	Security and privacy	Efficiency
4	Storing transactions openly across many nodes	Technical
5	Greater automation of business processes and less human impact	Efficiency
6	Investment and ROI	Cost
7	Efficiency and transparency on custom administration	Efficiency
8	Efficiency on Import-Export procedures	Efficiency
9	Carrier to terminal coordination and planning	Efficiency
10	Supply chain visibility and information sharing	Technical
11	Transparency and speed	Technical
12	Recognition of the technology	Technical
13	Legal Complexity	Efficiency
14	Authenticity	Technical
15	Long-term digital preservation	Techical
16	Waste reduction	Efficiency
17	Size of the organization	Cost
18	IT readiness	Technical
19	Competitive pressure	Cost
20	Sector support	Efficiency

To better understand the usages and the process of the blockchain concept in maritime industry, the detailed description of each criteria can be found as follows.

1) Operating without a trusted third party

Users can process, approve and track their data without a help of a third parties among the servers. All data is stored among the servers.

2) Fast and inexpensive transactions

Paperwork is eliminated. Long waiting hours for administrative approvals, tons of paperwork, human impact and many things are eliminated. In processes without blockchain, one standard paper-based approval for a shipment takes more than 20 days but with the blockchain this time is reduced to seconds.

3) Security and privacy

Blockchain helps automation and eliminates the third parties and human factor in every action. All the transactions are stored with a time stamp and a digital signature. Each block is connected to the previous block with a hash value. Users can remain anonymous. In transactions, private and public keys are used.

4) Storing transactions openly across many nodes

In blockchain, data are stored across many nodes over the world. That means that nodes are unalterable. If all the nodes are stored in a same location, they will be vulnerable to the cyberattacks.

5) Greater automation of business processes and less human impact

Automation of the processes can eliminate intervention of the humans to the business processes. Authorized people can only make the final check after all the processes are completed. This will help saving time and money and it provides a security. Smart contracts can be used to execute the deals between the parties.

6) Investment and ROI

Making investment in new technologies is a difficult choice. All the risk and returns should be calculated carefully. Higher investments lead higher returns. Beginning investment and operational costs should be calculated and spread to long-term activities.

7) Efficiency and transparency on custom administration

With the elimination of the third parties and unnecessary human involvement, the theft and fraud risk are reduced. All the transaction is accessible with public and private keys. Transactions are immutable.

8) Efficiency on Import-Export procedures

Paperwork is dismissed. Human intervention is minimized, fraud and theft are dissuadable.

9) Carrier to terminal coordination and planning

All steps from carrier to the terminal are planned and organized via blockchain systems. All the steps are transparent. The information is accessible from all the parties.

10) Supply chain visibility and information sharing

All the processes are traceable and transparent to the all parties. All the information is stored on the nodes.

11) Transparency and speed

All the transaction run in seconds. Processes, which take days are reduced to seconds. It is a distributed ledger system. All the data stored openly across many nodes with a time stamp.

12) Recognition of the technology

Blockchain enter our lives with the bitcoin concepts and now in today's world it begun to be used almost in every sector by different parties.

13) Legal Complexity

It is a new technology and it is keep developing day by day. Legislative rules for blockchain should be created and accepted by everyone.

14) Authenticity

All the transactions are stored with a time stamp and digital signature. Blockchain uses cryptography to track all the digital changes. This way, data are unalterable.

15) Long-term digital preservation

Transactions are stored across many nodes and they can be accessible from everywhere. For a long-term digital preservation, digital storages are necessary.

16) Waste reduction

With the use of blockchain, all the paperwork will be eliminated. Unnecessary usage of paper, power and electricity will be reduced.

17) Size of the organization

Size of the organization determines the willingness to invest huge amount and money and time in renovations. Small companies mostly prefer the follow and collaborate with the pioneer companies with consortium agreements.

18) IT Readiness

Blockchain is a huge technological concept. Without a prepared and educated IT people, companies can't benefit from this technology fully.

19) Competitive Pressure

Each company wants to be the leader of their sector. This willingness to be a leader causes a huge pressure on the managers and the company owners. They want to make right decisions and right investments.

20) Sector Support

Middle and small-scaled companies need a support and incentive from the leaders of the sector. They seek for collaboration based on their goals and needs.

4.4 Alternatives of the Blockchain Solutions

There are several blockchain applications are on the market. Each application has a different functionality and each one address different sizes of the companies. These blockchain applications are as follows.

1. Tallysicks - Smart contracts
2. Wave - Electronic bill of laden
3. Skuchain - Handling cargo paper documentation
4. Hyperledger - Configuration of a consensus mechanism, open distributed ledgers
5. Provenance – Transparency
6. Fluent - Low cost and secure payment
7. Chain of Things - Monitoring and recording data
8. Solas VGM - Collaboration between different parties
9. Tu Delft Blockchain Lab - Transaction speed and cryptography
10. Global Shared Container Platform (GSCP - Real time tracking
11. Blockfreight - Fast transaction with the elimination of third parties

12. BitNautic - Transparency and tracking

Tallysticks mainly focus on the execution of the smart contracts. It aims to eliminate paper-based proforma and invoices to prevent the fraud with transparency.

Wave aims to eliminate the usage of the electronic bill of laden by connecting the involved parties.

Skuchain also aims to eliminate the paper-based documents such as Letter of Credit. Its main goal is to create a consensus mechanism between the parties. These parties can be buyers, sellers, banks, trusted third parties and service providers.

Hyperledger is developed by the collaboration of the IBM. It aims to create a consensus mechanism. It supports an open distributed ledger system.

Provenance targets the final customer. It ensures the transparency, digital security and trust. It tries to prohibit the fraud on the physical products.

Fluent aims low cost and secure payment processes. It targets the banks and financial institutions.

Chain of Things uses IoT for monitoring and tracking the goods for insurance issues.

Solas VGM aims to create a consensus mechanism between the shippers, terminals and shipping lines.

Tu Delft Blockchain Lab works on the transaction speed. It is based on cryptography.

Global Shared Container Platform aims to provide a real time tracking of the containers and managing container-based transactions.

Blockfreight aims to eliminate the third parties to run the transactions fast and more accurately.

BitNautic provides transparency on the information sharing and real time tacking.

4.4 Disadvantages of the Blockchain Technology

Blockchain is an extremely innovative technology. Like all the discoveries, blockchain has advantages and disadvantages. Before choosing the best solution, all the advantages and disadvantages should investigate carefully.

Blockchain is a digital solution. The main disadvantage of blockchain is a consumption of a huge amount of energy. This energy and power is necessary to keep the blockchain system as a real time ledger.

Another disadvantage is the high cost of the implementation of this solution. These costs show up by hiring developers, licensing costs, maintenance costs, storage costs of the servers. If the companies willing to keep the servers in their own locations, they need huge warehouses and huge operations to keep them safe. If they want to collaborate with other firms, they have to pay fees.

The other huge disadvantage is the legal complexities. Blockchain solution is not fully accepted by the governments. The legal boundaries have not been defined clearly yet. This uncertainty causes confusion in authorities.

The blockchain technology is more secure than other systems but that does not mean that it is % 100 secure. In the future quantum computers will become capable of hacking the blockchain systems.

5. MCDM METHODS

This paper evaluates the decision-making process with multiple criteria and multiple alternatives with MCDM Methods. MCDM Methods signifies Multi-Criteria Decision-Making Methods. MCDM Methods help decision makers to find the ideal solution among infinite number of alternatives. Selected methods for this study are TOPSIS and WEDBA. Entropy method is used to calculate the weights, which are used in computations.

5.1. TOPSIS

Yoon and Hwang develop this method in 1981. It is multi criteria decision-making model. The meaning of the word TOPSIS is, Technique for Order Preference by Similarity Method. This method is based on choosing the criteria and alternatives, ranking them and then sorting them to find the best ideal alternative, which is closest to the ideal solution and farthest from the negative ideal solution. First step in this method, is the forming the decision matrix. Next step is finding the normalized matrix and then, the obtained values are multiplied by the criteria weights. The other step is the calculation of the positive and negative ideal solutions. The last step is the ranking step. In this step, alternatives are listed based on closeness to the ideal solution. In this paper, the Entropy Method calculates the weights.

5.1.1 Application of Entropy Method

Entropy helps to evaluate the weights of the criteria. Claude Shannon proposes this method in 1948. Suppose that there are m alternatives, n criteria, and a Decision Matrix D.

1. Step: Let's assume P_{ij} is the projected weight where x_{ij} represents the ith alternative value of the jth criteria

$$P_{ij} = \frac{xij}{\sum_{i=1}^{m} xij} \forall i, j \quad (1)$$

2. Step: E_{ij} is the Entropy value where k signifies the positive constant value and P_{ij} represents the projected weight

$$E_{ij} = -k \sum_{i=1}^{m} Pij \, lnPij \; \forall j \tag{2}$$

3. Step: Positive constant value k is calculated with the following equation where m signifies the alternatives

$$k = \frac{1}{lnm} \tag{3}$$

4. Step: Calculation of the diversification degree is computed as follows

$$d_j \; = 1 - Ej, \forall j \tag{4}$$

5. Step: Weight is computed with the following equation where dj represents the diversification degree

$$W_j \; = \frac{dj}{\sum_{j=1}^{n} dj} \; , \forall j \tag{5}$$

5.1.2 Application of the TOPSIS Method

The main goal in using this method is to find the ideal solution between the other alternatives. The weights are obtained from the entropy method. Let's assume that X represents the decision matrix.

1. Step: Normalization of the decision matrix is determined with the following equation where r_{ij} represents the value of the jth alternative in the ith criteria and x_{ij} represents the ith alternative value of the j th criteria

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}} \textit{ (i=1,...,m;j=1,...,n)} \quad (6)$$

2. Step: Weighted decision matrix is obtained by multiplying the weights obtained from the entropy and the normalized matrix where w represents the weight of the i th alternative

$$V_{ij} = w_i r_{ij} \textit{ (i=1,...,m;j=1,...,n)} \quad (7)$$

3. Step: Determination of the positive and negative ideal solutions are computed by the following equations.

$$V^{+} = \{v_1^{+} \dots v_n^{+}\} \quad (8)$$

$$V^{-} = \{v_1^{-} \dots v_n^{-}\} \quad (9)$$

4. Step: Distance between positive and negative ideal solution are calculated as follows.

$$s_i^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ji} - v_j^{+}\right)^2} \textit{ (i=1,...,m;j=1,...,n)} \quad (10)$$

$$s_i^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ji} - v_j^{-}\right)^2} \textit{ (i=1,...,m;j=1,...,n)} \quad (11)$$

5. Step: Performance Indicator Value P_i is calculated with the help of the positive and negative ideal solution as follows where s_i^{+} represents the positive ideal solution and s_i^{-} represents negative ideal solution.

$$P_i = \frac{s_i^{-}}{s_i^{+} + s_i^{-}} \quad (12)$$

6. Step: Ranking is made according to the preferences from smallest to the largest value.

5.2.WEDBA

Wedba method is also known as the Weighted Euclidean Distance Based Approach. This method mainly focuses on the weighted distance of the alternatives to the most and the least ideal points. The points can be defined as best and the worst values of the attributes respectively. Ideal point represents the attribute which has the all best value and the anti-ideal solution is the alternative which has all the worst values. The steps in this method can be listed as follows (Rao et al. 2012)

1. Step: Construction of the decision matrix. Consider there are N alternatives and M attributes, where m_{ij} represents the performance value of jth attribute of alternative i. The decision matrix is denoted by D and can be seen Figure 5.1.

$$D = \begin{bmatrix} m_{11} & \dots & m_{1j} & \dots & m_{1M} \\ \dots & \dots & \dots & \dots & \dots \\ m_{i1} & \dots & m_{ij} & \dots & m_{iM} \\ \dots & \dots & \dots & \dots & \dots \\ m_{N1} & \dots & m_{Nj} & \dots & y_{NM} \end{bmatrix}$$

Figure 5.1: Decision Matrix

2. Step: Standardization of the Decision Matrix D is denoted as D* and can be seen in Figure 5.2. The computation of the standardized value of Z_{ij} can be found in equations (13) to (17). Where Z_{ij} represents the standardized value of X_{ij}, μ_{ij} represents the mean value of the jth attribute and σ_{ij} represents the standard deviation of the attribute j.

$$D^* = \begin{bmatrix} Z_{11} & \dots & Z_{1j} & \dots & Z_{1M} \\ \dots & \dots & \dots & \dots & \dots \\ Z_{i1} & \dots & Z_{ij} & \dots & Z_{iM} \\ \dots & \dots & \dots & \dots & \dots \\ Z_{N1} & \dots & Z_{Nj} & \dots & Z_{NM} \end{bmatrix}$$

Figure 5.2: Standardized Decision Matrix

$$Z_{ij} = \frac{X_{ij} - \mu_{ij}}{\sigma_j} \quad (13)$$

$$X_{ij} = \frac{m_{ij}}{\max_j(m_{ij})} \text{ ; if attribute j is beneficial} \quad (14)$$

$$X_{ij} = \frac{\min_j(m_{ij})}{m_{ij}} \text{ ; if attribute j non-beneficial} \quad (15)$$

$$\mu_j = \frac{1}{N}\sum_{i=1}^{N} X_{ij} \quad (16)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{N}(X_{ij} - \mu_j)^2}{N}} \quad (17)$$

3. Step: Determination of the ideal and anti-ideal points. These points are the highest and lowest values of the attributes obtained in the matrix D*. A* represents the ideal solutions and B* represents the anti-ideal solutions.

4. Step: Determination of the attribute weights. Attributes weights can be objective, subjective or integrated.

    a. Objective weights can be obtained by Entropy method, Ideal Point method, statistical variance procedure.
    b. Subjective weights can be calculated by AHP, Nominal Group Technique, Ranking Method, Ratio Method, Swing Method, Points Method.
    c. Integrated weight is a combination of an objective and subjective weights. It is used, when decision maker wants to use the both objective and subjective weights. There are two types weights to consider.

        i. First type: Decision maker decides the degree of importance that he wants to assign to the objective and subjective weights. Let us assume that W_j^O represents the objective, W_j^S represents the

subjective weights of the attribute j and W_j^I represents the integrated weight. W^O and W^S are the given weightages.

$$W_j^I = W^O w_j^O + W^S w_j^S \tag{18}$$

$$W^O + W^S = 1 \tag{19}$$

ii. Second type: This type is used when the weightages of the objective and subjective weights are not clear. W_j^{I*} represents the integrated weight of the attribute j.

$$W_j^{I*} = \frac{w_j^O w_j^S}{\sum_{k=1}^{M} w_j^O w_j^S} \tag{20}$$

5. Step: Weighted Euclidean Distance Calculation. Selected alternative should have shortest distance to the ideal solution and farthest distance to the anti-ideal solution. The shortest distance between two points is equal to the Euclidean distance. WED_i^+ represents the weighted Euclidean distance between the alternative i and the ideal solution A* and WED_i^- represents the weighted Euclidean distance between the alternative i and the anti-ideal solution B*.

$$WED_i^+ = \left[\sum_{j=1}^{M}\left\{w_j\left(Z_{ij} - a_j^*\right)\right\}^2\right]^{1/2} \text{ where } i=1, 2, \ldots, N \tag{21}$$

$$WED_i^- = \left[\sum_{j=1}^{M}\left\{w_j\left(Z_{ij} - b_j^*\right)\right\}^2\right]^{1/2} \text{ where } i=1, 2, \ldots, N \tag{22}$$

6. Step: Index score calculation and ranking. Index score signifies the closeness to the ideal solution of the selected alternative. The higher index score means that the particular alternative is getting closer to the ideal solution. The best alternative has the highest score.

$$Index\ Score_i = \frac{WED_i^-}{WED_i^+ + WED_i^-} \tag{22}$$

6. APPLICATIONS

There were 20 criteria, 12 alternatives and 10 decision makers. All the decision makers are the experts of their area. They are in the maritime sector more than 10 years. They are the managers and directors. They work in the Operations, IT, Planning and Import-Export Departments in the selected company. The evaluations take more than one month because each criterion is evaluated for each alternative. The decision makers have their own business that's why they divide the evaluation process into several sections to complete it.

The evaluation scale of the decision makers can be seen in Table 6.1 signifies "Very Low" and 5 signifies "Very High". Each decision maker evaluates criteria and alternatives. After all the evaluations, the average score is calculated and Table 6.2 is constructed.

Table 6.1.: Evaluation Scale

Evaluation Scale	Numerical Values
Very Low	1
Low	2
Moderate	3
High	4
Very High	5

In Table 6.2, first row represents the criteria and first column represents the alternatives. The last row shows the summation of each column.

Table 6.2.: Average Values of the Obtained Evaluations

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
A1	5	5	5	4	1	4	5	5	5	4	4	4	5	4	5	4	5	5	5	4
A2	5	5	5	5	3	4	5	5	5	5	5	3	5	4	4	2	4	4	4	4
A3	4	5	5	3	2	5	4	5	4	4	4	3	4	3	4	3	3	5	5	5
A4	5	5	5	3	1	5	5	5	4	4	5	3	5	2	5	2	4	3	5	3
A5	4	5	5	4	1	3	4	5	5	4	5	4	4	4	5	3	1	5	5	3
A6	3	4	4	3	3	5	5	4	4	5	4	5	4	4	4	3	4	5	3	5
A7	4	5	3	3	2	5	5	4	4	5	4	5	5	5	5	3	4	5	3	4
A8	4	5	5	5	2	3	3	5	5	5	5	4	3	3	3	2	5	4	5	4
A9	5	4	5	4	1	4	4	3	4	3	5	3	5	3	5	2	3	5	4	5
A10	3	4	4	5	4	4	5	4	4	4	5	5	5	4	4	1	5	4	4	4
A11	5	4	3	4	3	5	4	5	5	4	5	3	4	3	4	2	4	5	4	4
A12	4	4	5	4	4	4	5	5	4	4	5	3	5	5	4	3	5	5	4	4
SUM	51	55	54	47	27	51	54	55	53	51	56	45	54	44	52	30	47	55	51	49

6.1.Entropy

Table 6.3 demonstrates the projected weights P_{ij}.

Table 6.3.: P_{ij} Values

Pij	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
C1	0,098039	0,098039	0,078431	0,098039	0,078431	0,058824	0,078431	0,078431	0,098039	0,058824	0,098039	0,078431
C2	0,090909	0,090909	0,090909	0,090909	0,090909	0,072727	0,090909	0,090909	0,072727	0,072727	0,072727	0,072727
C3	0,092593	0,092593	0,092593	0,092593	0,092593	0,074074	0,055556	0,092593	0,092593	0,074074	0,055556	0,092593
C4	0,085106	0,106383	0,06383	0,06383	0,085106	0,06383	0,06383	0,106383	0,085106	0,106383	0,085106	0,085106
C5	0,037037	0,111111	0,074074	0,037037	0,037037	0,111111	0,074074	0,074074	0,037037	0,148148	0,111111	0,148148
C6	0,078431	0,078431	0,098039	0,098039	0,058824	0,098039	0,098039	0,058824	0,078431	0,078431	0,098039	0,078431
C7	0,092593	0,092593	0,074074	0,092593	0,074074	0,092593	0,092593	0,055556	0,074074	0,092593	0,074074	0,092593
C8	0,090909	0,090909	0,090909	0,090909	0,090909	0,072727	0,072727	0,090909	0,054545	0,072727	0,090909	0,090909
C9	0,09434	0,09434	0,075472	0,075472	0,09434	0,075472	0,075472	0,09434	0,075472	0,075472	0,09434	0,075472
C10	0,078431	0,098039	0,078431	0,078431	0,078431	0,098039	0,098039	0,098039	0,058824	0,078431	0,078431	0,078431
C11	0,071429	0,089286	0,071429	0,089286	0,089286	0,071429	0,071429	0,089286	0,089286	0,089286	0,089286	0,089286
C12	0,088889	0,066667	0,066667	0,066667	0,088889	0,111111	0,111111	0,088889	0,066667	0,111111	0,066667	0,066667
C13	0,092593	0,092593	0,074074	0,092593	0,074074	0,074074	0,092593	0,055556	0,092593	0,092593	0,074074	0,092593
C14	0,090909	0,090909	0,068182	0,045455	0,090909	0,090909	0,113636	0,068182	0,068182	0,090909	0,068182	0,113636
C15	0,096154	0,076923	0,076923	0,096154	0,096154	0,076923	0,096154	0,057692	0,096154	0,076923	0,076923	0,076923

Table 6.3: P_{ij} Values *(Cont. d)*

C16	0,133333	0,066667	0,1	0,066667	0,1	0,1	0,1	0,066667	0,066667	0,033333	0,066667	0,1
C17	0,106383	0,085106	0,06383	0,085106	0,021277	0,085106	0,085106	0,106383	0,06383	0,106383	0,085106	0,106383
C18	0,090909	0,072727	0,090909	0,054545	0,090909	0,090909	0,090909	0,072727	0,090909	0,072727	0,090909	0,090909
C19	0,098039	0,078431	0,098039	0,098039	0,098039	0,058824	0,058824	0,098039	0,078431	0,078431	0,078431	0,078431
C20	0,081633	0,081633	0,102041	0,061224	0,061224	0,102041	0,081633	0,081633	0,102041	0,081633	0,081633	0,081633

After calculating the projected weights, the Entropy value can be calculated. To obtain the entropy value, first the positive constant value is calculated with the help of the equation 3 as seen in the Table 6.4.

Table 6.4.: Positive Constant Value

m(alternatives)	12
k	0,40243

The entropy value, diversification degree and the calculated weights are demonstrated in Table 6.5.

Table 6.5.: Entropy Calculations

	E_j	d_j	W_j
C1	0,99400	0,00600	0,54476
C2	0,99764	0,00236	0,21434
C3	0,99374	0,00626	0,56775
C4	0,99243	0,00757	0,68736
C5	0,95168	0,04832	4,38527
C6	0,99400	0,00600	0,54476
C7	0,99563	0,00437	0,39684
C8	0,99579	0,00421	0,38214
C9	0,99752	0,00248	0,22520
C10	0,99599	0,00401	0,36380
C11	0,99789	0,00211	0,19131
C12	0,99040	0,00960	0,87102
C13	0,99563	0,00437	0,39684
C14	0,98883	0,01117	1,01396
C15	0,99572	0,00428	0,38866
C16	0,98032	0,01968	1,78623
C17	0,97996	0,02004	1,81850

Table 6.5: Entropy Calculations *(Cont. d)*

C18	0,99579	0,00421	0,38214
C19	0,99400	0,00600	0,54476
C20	0,99498	0,00502	0,45524

The weights, which are obtained from the calculations above, are used in the TOPSIS.

6.2.TOPSIS

The normalized decision matrix obtained from the equation (6) can be seen in Table 6.6.

Table 6.6.: Normalized Decision Matrix

Rij	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
C1	0,780869	0,780869	0,624695	0,780869	0,624695	0,468521	0,624695	0,624695	0,780869	0,468521	0,780869	0,624695
C2	0,780869	0,780869	0,780869	0,780869	0,780869	0,624695	0,780869	0,780869	0,624695	0,624695	0,624695	0,624695
C3	0,707107	0,707107	0,707107	0,707107	0,707107	0,565685	0,424264	0,707107	0,707107	0,565685	0,424264	0,707107
C4	0,707107	0,883883	0,53033	0,53033	0,707107	0,53033	0,53033	0,883883	0,707107	0,883883	0,707107	0,707107
C5	0,242536	0,727607	0,485071	0,242536	0,242536	0,727607	0,485071	0,485071	0,242536	0,970143	0,727607	0,970143
C6	0,707107	0,707107	0,883883	0,883883	0,53033	0,883883	0,883883	0,53033	0,707107	0,707107	0,883883	0,707107
C7	0,707107	0,707107	0,565685	0,707107	0,565685	0,707107	0,707107	0,424264	0,565685	0,707107	0,565685	0,707107
C8	0,707107	0,707107	0,707107	0,707107	0,707107	0,565685	0,565685	0,707107	0,424264	0,565685	0,707107	0,707107
C9	0,780869	0,780869	0,624695	0,624695	0,780869	0,624695	0,624695	0,780869	0,624695	0,624695	0,780869	0,624695
C10	0,707107	0,883883	0,707107	0,707107	0,707107	0,883883	0,883883	0,883883	0,53033	0,707107	0,707107	0,707107
C11	0,624695	0,780869	0,624695	0,780869	0,780869	0,624695	0,624695	0,780869	0,780869	0,780869	0,780869	0,780869
C12	0,8	0,6	0,6	0,6	0,8	1	1	0,8	0,6	1	0,6	0,6
C13	0,707107	0,707107	0,565685	0,707107	0,565685	0,565685	0,707107	0,424264	0,707107	0,707107	0,565685	0,707107
C14	0,624695	0,624695	0,468521	0,312348	0,624695	0,624695	0,780869	0,468521	0,468521	0,624695	0,468521	0,780869
C15	0,780869	0,624695	0,624695	0,780869	0,780869	0,624695	0,780869	0,468521	0,780869	0,624695	0,624695	0,624695
C16	0,8	0,4	0,6	0,4	0,6	0,6	0,6	0,4	0,4	0,2	0,4	0,6
C17	0,707107	0,565685	0,424264	0,565685	0,141421	0,565685	0,565685	0,707107	0,424264	0,707107	0,565685	0,707107
C18	0,707107	0,565685	0,707107	0,424264	0,707107	0,707107	0,707107	0,565685	0,707107	0,565685	0,707107	0,707107

Table 6.6: Normalized Decision Matrix *(Cont. d)*

C19	0,780869	0,624695	0,780869	0,780869	0,780869	0,468521	0,468521	0,780869	0,624695	0,624695	0,624695	0,624695
C20	0,707107	0,707107	0,883883	0,53033	0,53033	0,883883	0,707107	0,707107	0,883883	0,707107	0,707107	0,707107

Weights are multiplied with the values in the normalized decision matrix. After that, the optimal value and the worst value of every alternative is determined. Table 6.7 shows these values.

Table 6.7.: Optimal and Worst Values

	A*=Amax	A'=Amin
C1	0,425387	0,255232
C2	0,167373	0,133898
C3	0,401457	0,240874
C4	0,607549	0,364529
C5	4,254339	1,063585
C6	0,481505	0,288903
C7	0,280608	0,168365
C8	0,270214	0,162129
C9	0,17585	0,14068
C10	0,321558	0,192935
C11	0,149384	0,119507
C12	0,87102	0,522612
C13	0,280608	0,168365
C14	0,791772	0,316709
C15	0,303493	0,182096
C16	1,428988	0,357247
C17	1,285874	0,257175
C18	0,270214	0,162129
C19	0,425387	0,255232
C20	0,402378	0,241427
	Vj*	Vj'

Distances between positive and negative ideal solutions are calculated and calculated distances factor in the calculation of the Performance Indicator Value P_i. Table 6.8 show the P_i and the ranking of the alternatives.

Table 6.8.: Rankings

	Pi	RANK
A1	0,331307	9
A2	0,631825	4
A3	0,38779	8
A4	0,22095	10
A5	0,205408	11
A6	0,66716	3
A7	0,427592	6
A8	0,409736	7
A9	0,184078	12
A10	0,752914	2
A11	0,621873	5
A12	0,863162	1

As we can see in the in the Table 6.8, the biggest positive ideal solution takes the first place in the ranking and the smallest ideal solution takes the last place. First place belongs to Alternative 12 and last place belongs to Alternative 9. Alternative 12 represents BitNautic and Alternative 9 symbolizes Tu Delft Blockchain. These are both blockchain based smart solutions. From the computations, we can understand that the smart solution that fits best to the company's needing is BitNautic. This solution provides transparency and eases tracking.

6.3. WEDBA

In our problem there are 12 alternatives and 20 criteria where N=12 and M=20. Table 6.9 represents the standardized decision matrix.

Table 6.9.: Optimal and Worst Values

Zij	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12
C1	1,03923	1,03923	-0,34641	1,03923	-0,34641	-1,73205	-0,34641	-0,34641	1,03923	-1,73205	1,03923	-0,34641
C2	),845154	),845154	0,845154	0,845154	0,845154	-1,18322	0,845154	0,845154	-1,18322	-1,18322	-1,18322	-1,18322
C3	),654654	),654654	0,654654	0,654654	0,654654	-0,65465	-1,96396	0,654654	0,654654	-0,65465	-1,96396	0,654654
C4	0,10976	,426935	-1,20741	-1,20741	0,109764	-1,20741	-1,20741	1,426935	0,109764	1,426935	0,109764	0,109764

Table 6.9: Optimal and Worst Values *(Cont. d)*

C5	-1,14708	0,688247	-0,22942	-1,14708	-1,14708	0,688247	-0,22942	-0,22942	-1,14708	1,60591	0,688247	1,60591
C6	-0,34641	-0,34641	1,03923	1,03923	-1,73205	1,03923	1,03923	-1,73205	-0,34641	-0,34641	1,03923	-0,34641
C7	0,774597	0,774597	-0,7746	0,774597	-0,7746	0,774597	0,774597	-2,32379	-0,7746	0,774597	-0,7746	0,774597
C8	0,650945	0,650945	0,650945	0,650945	0,650945	-0,91132	-0,91132	0,650945	-2,47359	-0,91132	0,650945	0,650945
C9	1,183216	1,183216	-0,84515	-0,84515	1,183216	-0,84515	-0,84515	1,183216	-0,84515	-0,84515	1,183216	-0,84515
C10	-0,42008	1,260252	-0,42008	-0,42008	-0,42008	1,260252	1,260252	1,260252	-2,10042	-0,42008	-0,42008	-0,42008
C11	-1,41421	0,707107	-1,41421	0,707107	0,707107	-1,41421	-1,41421	0,707107	0,707107	0,707107	0,707107	0,707107
C12	0,301511	-0,90453	-0,90453	-0,90453	0,301511	1,507557	1,507557	0,301511	-0,90453	1,507557	-0,90453	-0,90453
C13	0,774597	0,774597	-0,7746	0,774597	-0,7746	-0,7746	0,774597	-2,32379	0,774597	0,774597	-0,7746	0,774597
C14	0,392232	0,392232	-0,78446	-1,96116	0,392232	0,392232	1,568929	-0,78446	-0,78446	0,392232	-0,78446	1,568929
C15	1,069045	-0,53452	-0,53452	1,069045	1,069045	-0,53452	1,069045	-2,13809	1,069045	-0,53452	-0,53452	-0,53452
C16	1,963961	-0,65465	0,654654	-0,65465	0,654654	0,654654	0,654654	-0,65465	-0,65465	-1,96396	-0,65465	0,654654
C17	0,971666	0,074744	-0,82218	0,074744	-2,61602	0,074744	0,074744	0,971666	-0,82218	0,971666	0,074744	0,971666
C18	0,650945	-0,91132	0,650945	-2,47359	0,650945	0,650945	0,650945	-0,91132	0,650945	-0,91132	0,650945	0,650945
C19	1,03923	-0,34641	1,03923	1,03923	1,03923	-1,73205	-1,73205	1,03923	-0,34641	-0,34641	-0,34641	-0,34641
C20	-0,13019	-0,13019	1,432078	-1,69246	-1,69246	1,432078	-0,13019	-0,13019	1,432078	-0,13019	-0,13019	-0,13019

After computing the standardized decision matrix, the ideal and anti-ideal solutions are obtained and listed in Table 6.10. A* signifies the ideal solution and B* signifies the anti-ideal solution.

Table 6.10.: Ideal and Anti-Ideal Solutions

	A*	B*
C1	1,039	-1,732
C2	0,845	-1,183
C3	0,655	-1,964
C4	1,427	-1,207
C5	1,606	-1,147
C6	1,039	-1,732
C7	0,775	-2,324
C8	0,651	-2,474

Table 6.10: Ideal and Anti-Ideal Solutions *(Cont. d)*

C9	1,183	-0,845
C10	1,260	-2,100
C11	0,707	-1,414
C12	1,508	-0,905
C13	0,775	-2,324
C14	1,569	-1,961
C15	1,069	-2,138
C16	1,964	-1,964
C17	0,972	-2,616
C18	0,651	-2,474
C19	1,039	-1,732
C20	1,432	-1,692

We use the objective weights that we obtained with the Entropy in the previous section. Weighted Euclidean Distances are calculated. Table 6.11 summarizes WED_i^- and WED_i^+ values.

Table 6.11.: Weighted Euclidean Distances

	WED_i^+	WED_i^-
A1	12,2763	10,7450
A2	6,9972	10,7958
A3	9,8355	8,0036
A4	13,9579	6,7224
A5	14,2524	6,3759
A6	5,9852	11,4506
A7	9,0819	9,5205
A8	10,0867	8,9129
A9	13,9295	5,5714
A10	7,5498	14,4417
A11	7,5269	10,3349
A12	3,7521	15,3314

After the calculation of WED_i^- and WED_i^+ values, the index score is computed. After the calculation, the ranking based on the index scores is done and can be seen in Table 6.12.

Table 6.12.: Index Scores and Ranks

	Index Scores	RANK
A1	0,46674	8
A2	0,60674	4
A3	0,44866	9
A4	0,32506	10
A5	0,30909	11
A6	0,65673	2
A7	0,51179	6
A8	0,46911	7
A9	0,28570	12
A10	0,65669	3
A11	0,57860	5
A12	0,80338	1

As we can see from the Table 6.12, Alternative 12 has the lowest index score. It means that alternative 12 is near the ideal solution. Alternative 12 represents BitNautic. Alternative 9 has the lowest index score and it takes the last place in the ranking. Alternative 9 represents Tu Delft Blockchain Lab. The applied WEDBA method suggests that the alternative 12 is the best solution for the company.

7. INFERENCES&DISCUSSIONS

In this study, blockchain concept and its various usage area in maritime industry is investigated. The main goal of this research is to find the best blockchain solution for the selected maritime company based on their needs. We aim to find the best solution based on the opinions and evaluations of the experts from the maritime sector.

All the experts are chosen from the selected company. They are experienced in this industry more than 10 fully years. They are selected based on their experiences and their knowledge about the blockchain and the maritime industry. They work in the Operations, IT, Planning and Import-Exports departments as managers and directors. They have too much workload that's why the evaluations of the criteria take more than a one month. They divide the evaluation process into several sections to assess each criterion and alternative. There were 20 criteria, 12 alternatives and 10 decision makers.

In this work, we aim to choose a best smart solution for the selected company by choosing the best alternative solution based on the evaluations of the industry experts. MCDM methods are used for this study. TOPSIS and WEDBA methods are selected for this research because WEDBA method provides the usability of the objective and subjective weights at the same time. At the end of the computations, we determine the best solution that fit the needs of the selected company. Weights utilized in these methods are computed by Entropy method.

First applied method is the TOPSIS. Entropy helps us to generate the weights to be utilized in TOPSIS. At the end of the computations, the ranking is made and the Alternative 12 takes the first place. Alternative 12 represents BitNautic, which eases tracking and provides transparency. Second applied method is WEDBA. This method also gives us the best smart solution that fits the needs of the selected company which is Alternative 12.

The main question about the selected alternative is the economic and the technical viability of these smart blockchain solutions. Do the companies really need these

solutions? Are they capable of providing every necessity to create their own blockchain system or do they want to participate other already existing blockchain networks? Are they financially adequate to afford the expenses of construction of the blockchain system? Which kind of blockchain solution do the need in their current system? These are the most important question to answer before adopting and investing in a new technological solution. This study aims to find the answers to those questions.

After detailed researches and analysis, it comes out that the best blockchain solution that fit the needs of the company should focus on the tracking and transparency. Tracking is vital for the company and it is an essential factor in their processes. Maritime industry plays huge role in a global trade. The goods and vessels travel all around the world to deliver the goods to the buyers. Suppliers and buyers and wants to track their goods or vessel at anytime and anywhere without an error or interruption. Every company included the selected company in this research needs transparency. Transparency is a foundation of every commercial and non-commercial transactions. That's why, the evaluations and applications show that the best solution is BitNautic which provides transparency and eases tracking. That solution satisfies the both requirements of the company. In this research financial conditions of the company is neglected. Financial capability of meeting the requirements of building a new blockchain system should be analyzed in details to decide whether they are capable of building a new blockchain system of their own or to participate an already existing blockchain network. That financial analysis can also provide an answer to the question if they are financially adequate afford the expenses of construction and participation to a blockchain system.

CONCLUSION

Blockchain can be implemented in the maritime industry in several ways. In current situation, before loading to the vessels, companies should create a bill of lading with the help of intermediaries. Bill of laden is a complete list of goods, which are loaded to the containers including the sender/receiver information, origin and the quantity of the goods, which are carried. This document is an obligation for all the shipments. Construction and approval of the bill of laden consist of multiple governmental constitutions and a lot of paperwork. With the help of the blockchain implementation, paperwork elimination can realize and done in seconds instead of days. With the elimination of the third parties, fraud can be eliminated too. The application of blockchain has the potential of cutting the administrative and operational risks. Blockchain technology can also ease the tracking of the containers. It can combine with the IoT technology. This union offers a chance of real time tracking. Another benefit of this technology is the smart contracts. With the smart contracts, parties can execute an agreement when certain predefined conditions are met. For example, payments can be realized with smart contracts when a shipment is done. By the help of blockchain technology, maritime industry can become more efficient, secure and smart.

The main participants of the blockchain technology may be the exporters, importers, port authorities and shipping companies. Exporters may have a permission to read, write and create assets in the system. They can be the wholesalers or agents. Importers may have a permission to read, accept and reject the transactions. They can be he individuals or the organizations. Port authorities may have a permission to read, accept and reject transaction. Shipping companies may have some privileges to read the records.

With the help of the blockchain, fraud and errors can be reduced and eliminated. Delays from paperwork can be reduced. Inventory management can be improved. Courier costs

can be minimized. Waste can be reduced. Issues can be identified faster. Secure the transparency across the supply chain.

Blockchain can make the ports smarter. With the shared consensus principle among different parties, the information stored on the network is reliable. This creates a trust between parties. It can increase the visibility. That way, tracking and tracing the containers and ships become easy. Real time access to the information builds trust among different participants. Processes can take minutes instead of days.

In this study, two selected MCDM methods are applied. First one is the TOPSIS and second on is the WEDBA. Weights are obtained from the Entropy method in both of the approaches. There were 12 alternatives and 20 criteria. The experts evaluate each of the criteria and alternatives. Both of the approaches suggest that the ideal solution for the selected company is BitNautic and the least ideal solution is the Tu Delft Blockchain Lab. BitNautic focuses on the transparency and tracking. Tu Delft Blockchain Lab focuses on the transaction speed and cryptography. With the help of the selected smart solution, tracking can become very easy and efficient. From anywhere and anytime, people can monitor their supply chain easily and safely. In the future researches, the effect of selecting and applying a new technology in companies on the operational and opportunity cost can be analyzed. In addition, new selection criteria can be added to the current list.

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BIOGRAPHICAL SKETCH

Melis Kaşka was born in Istanbul 1993. After completing her schoolwork at Istanbul Private Saint Joseph High School in 2012. After the high school, she entered Kadir Has University in 2012, studied Industrial Engineering, and graduated in 2016. In 2017, she started Galatasaray University Logistics and Financial Management Master Program. She is now working at a software company as a consultant.

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