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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..

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, PSCs 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].

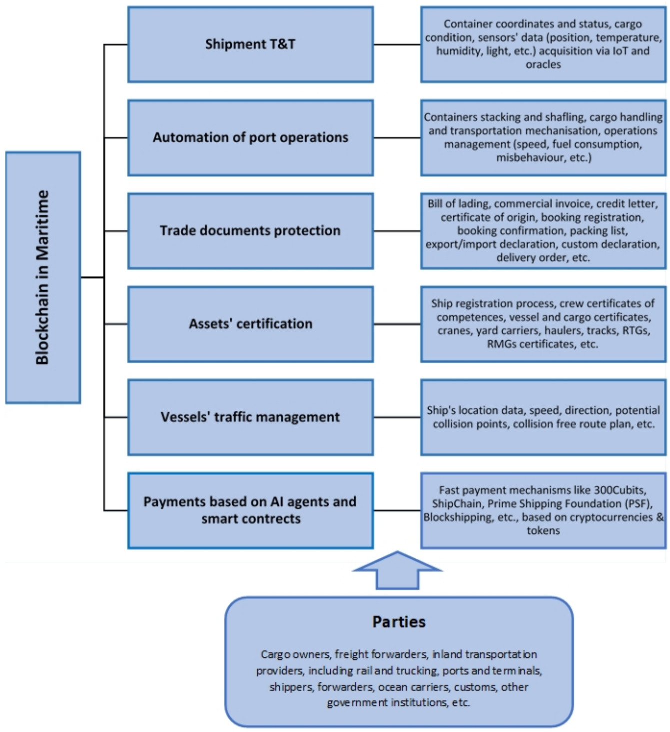
Shipping and port management involve several organizations, which have to ensure efficient flow of shipments from exporter to consignee. As complex and dynamic systems, maritime supply chains generate large amount of data on shipments, port operations, finance, and law regulations. Blockchain technology 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 NetPetya 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 Etheraum blockchain platforms are not recommendable as suitable. Bitcoin can provide seven transactions per second [24], while Etheraum 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 MICMAC 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 → j);
- R: barrier j lead to barrier i (j → i);
- FR: barrier i leads to barrier j, and vice versa (i ↔ j); and
- X: barrier i and j are unrelated (i ≠ 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):

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

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

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

Step 2

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

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

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

$$Driving\_power(DRP) : \sum_{j=1}^{8} b1j \tag{2}$$

$$Dependence\_power(DNP) : \sum_{i=1}^{8} bi1 \tag{3}$$

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.

	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: Authors.

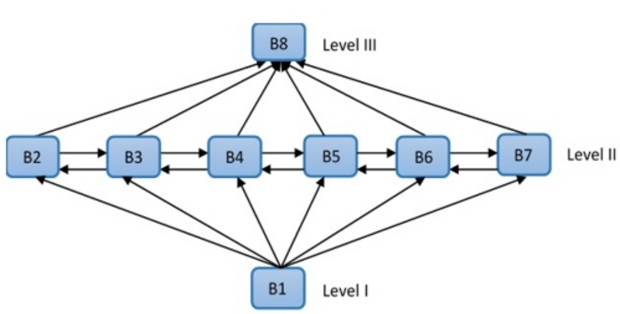
Table 6: The barriers hierarchical level identification.

	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.

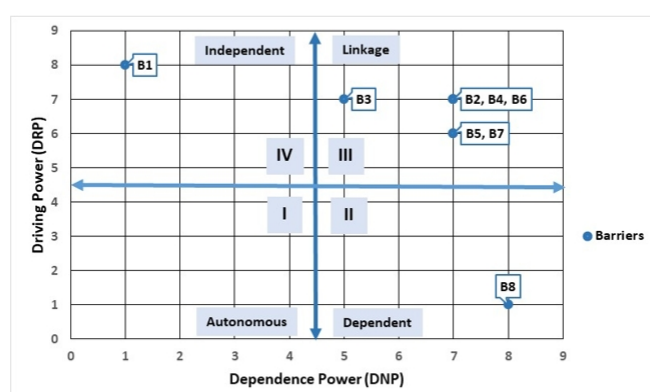


Source: Authors.

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 assists 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 hierarchal 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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