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Blockchain adoption in the maritime supply chain: Examining barriers and salient stakeholders in containerized international trade

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ABSTRACT

This study aimed to investigate the relationships between blockchain adoption barriers and identified the salient stakeholders for blockchain adoption in containerized international trade. The interpretative structural modelling and Cross-Impact Matrix Multiplication Applied to Classification analyses indicated that the most impactful among the eight barriers are lack of support from influential stakeholders, lack of understanding regarding blockchain, and lack of government regulations. The stakeholder mapping analysis demonstrated that the high salient stakeholders among 11 legitimate stakeholders are container lines, ports, beneficial cargo owners, freight forwarders/third party logistics, and customs authorities. The study is original and contributes to theory and practice as it uncovers both impactful barriers and critical stakeholders by adopting a stakeholder theory perspective and offers significant implications to practice, policy, and theory by combining these two analyses.

1. Introduction

Containerisation has expedited international trade, enabled the formation of global supply chains (SCs), and triggered the 20th century economic globalisation (Bernhofen et al., 2016). However, the developments in international trade and global SCs have outpaced the progression in container shipping. With the advancements in SCs, companies worldwide have become more sensitive in on-time, faster deliveries and traceability, and transparency of their shipments (Shou et al., 2021). Unfortunately, container shipping does not meet these contemporary requirements of SCs. An international movement of a container from point A to B involves a large number of bilateral interactions between numerous ecosystem members including shippers, carriers, freight forwarders, customs authorities, ports, banks, insurance companies, and relevant governmental bodies (Loh et al., 2020). The exchange of goods and documents—often paper-based—is subject to bilateral permissions and transactions between these organisations. For instance, a conventional flower export from Kenya to the Netherlands requires over 200 different bilateral communications between over 20 organisations (IBM, 2021). Consignees must wait around 10 days for the documents to be processed and delivered (Ganne, 2018). The nature of containerised international trade (CIT) leads to delays in deliveries, lack of visibility and traceability, susceptibility to frauds, and numerous cost and time inefficiencies.

Blockchain technology (BT), a decentralised and immutable technology using distributed ledgers by the peer-to-peer network,

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offers significant avenues to overcome the existing challenges of CIT. It enables ecosystem members to access trusted data in real-time, invulnerable to alternation and corruption (Yang, 2019). In containerised shipment context, blockchain functions as a network platform in which shipment information and trade documents can be securely accessed in real-time by all relevant authorised members. BT allows the eradication of numerous bilateral information and document exchange between many organisations involved in a containerised shipment. For instance, a proof of concept of blockchain designed by Maersk and IBM allowed a Kenyan flower grower to upload export documents to a BT-based platform and different export authorities approved these documents through the platform. Each of these approvals and information updates, such as container sealing, inspection of goods, and container movements are encrypted and can be tracked by all permissioned members, such as the Dutch customs and port authorities, the container line, freight forwarders, buyers' and sellers' banks, and customs agents (IBM, 2021). These features of BT can accelerate the CIT, simplify its process, decrease inefficiencies, and increase its visibility (Pu & Lam, 2021). Thanks to blockchain, apart from the more trusted, transparent, and effective SCs, the total cost of international maritime transport and international trade can also be reduced by 15% and 14.3%, respectively (Ganne, 2018). In fact, BT is even considered as the 'containerization of shipping documentation' due to its potential revolutionary impact on the industry (Li & Zhou, 2020; p:11).

Despite the potential benefits of BT to the industry and the existence of some practical initiatives such as Tradelens and Global Shipping Business Network (GSBN), its practical application in CIT is not progressing at the desired level. The literature also indicates the slow adoption or even non-adoption of BT in the shipping industry (Papathanasiou et al., 2020). The possible reasons for slow or non-adoption are multidimensional including various factors (Pu and Lam, 2021; Papathanasiou et al., 2020). Lack of trust, for instance, is considered to be one of the barriers, which is not surprising as the industry has witnessed cyber-attacks in leading companies such as Maersk and MSC. The misconception of BT-based platforms identical to fluctuating cryptocurrencies also adds up to lack of trust. The slow adoption may also occur due to lack of regulations and legal framework for BT in the CIT context (Jović et al., 2020). CIT involves operational and legal complexities, and lack of regulations may discourage the stakeholders to adopt BT. Another factor that can impede the BT adoption is that stakeholders might be concerned about sharing their business information on a platform (Hackius et al., 2019). Moreover, the slow adoption may be caused by the perception of stakeholders who perceive the implementation of BT as costly (Zhou et al., 2020).

The multidimensional characteristic of BT adoption barriers in the CIT context entails an investigation of relationship between these barriers. That is, the relationship between barriers should be identified so that the fundamental barriers – those influential barriers that affect the emergence of other barriers – and their impact on other barriers can be understood. For instance, trust and privacy concerns may arise due to a lack of government regulations, lack of knowledge regarding BT, or low early adopters. Conversely, trust and privacy concerns may also lead to a lack of adopters or government regulations. Revealing those fundamental barriers will enable to tackle the adoption problem more effectively. Thus, the structural relationship between barriers to adoption needs to be uncovered in the CIT context. However, the literature shows that although some barriers are underlined in maritime SC domain (Pu and Lam, 2021; Zhou et al., 2020; Munim et al., 2021), no study has thus far revealed the structural relationships between barriers of BT adoption in maritime SCs.

Besides uncovering the structural relationship, it is of utmost importance to determine salient stakeholders who have a critical role in adopting BT (Rodríguez Bolívar et al., 2021). In this way, the role of different stakeholders in tackling the barriers to BT adoption can be comprehended. Although some studies on other SCs revealed the relationship between barriers by applying interpretive structural modelling (ISM) methodology (Kamble et al., 2020; Yadav et al., 2020), none of the SC studies has supported this method by identifying which stakeholders can play a key role in the relationships explored in ISM analysis. Accordingly, the main aim of this study was to identify and reveal the relationships between BT adoption barriers and determine key stakeholders in BT adoption in CIT.

We conducted ISM to find out the structural relationship between BT adoption barriers and supported this method by implementing a stakeholder mapping analysis based on the theory of stakeholder identification salience (TSIS). The study makes original contributions to the literature and practice significantly revealing the structural relationships between barriers and determining salient stakeholders can allow researchers, policymakers, and industry members to address BT adoption effectively. The combination of the two analyses has enabled providing several important implications in the study. This study contributes to methodology in several other ways as well. First, instead of using a discrete scale (yes/no), we utilised a continuous scale (0 to 4) while identifying stakeholders' possession of attributes, which helped researchers provide a more accurate classification. This improvement in the methodology allows better reflection of reality, in which stakeholders might possess attributes at different levels. Second, since we used different levels of possessions, a more specific classification necessity arose for definitive stakeholders. Hereof, we classified definitive stakeholders as high definitive and low definitive stakeholders. Third, this study enables creating contextual linkages between identified barriers of blockchain adoption in CIT utilising the ISM-MICMAC based approach. The utilisation of MICMAC analysis also assisted researchers to categorise identified barriers into different categories, including independent, dependent, autonomous and dependent, to interpret their nature. Moreover, adopting the ISM approach helps to minimise the gap between practice and theory by combining insights from experts and practitioners instead of just focusing on the academy point-of-view.

2. Literature review

2.1. Blockchain technology in maritime supply chain

Blockchain is a peer-to-peer network where the data is recorded and transferred between participants rather than central storage (Papathanasiou et al., 2020). It uses a distributed ledger of transactions that the participants can digitally verify. Blockchain is immutable as the ledgers of transactions are timestamped and distributed to each participant who keeps the exact identical copy. Thus, it enhances the credibility of transactions (Ahmad et al., 2021). The record of transactions cannot be altered without the consent of all or majority of participants (Dutta et al., 2020). Each transaction in the blockchain is, therefore, cryptographically validated.

Blockchain has two main categories: permissioned (private) and permission-less (public). Every participant can access permission-less blockchain in the network, and the consensus process is open to the public. Permissionless blockchains are truly decentralised, that is, a central authority is not required. Cryptocurrencies such as bitcoin are examples of permission-less blockchain (Kouhizadeh et al., 2021). In permissioned blockchain, the consensus process is open to only pre-identified participants such as customs authorities, container terminals, lines, and forwarders in shipping (Pu & Lam, 2020). Tradelens and GSBN platforms in the shipping industry are examples of permissioned blockchains. They are not truly decentralised as the participation needs to be validated by the operator. However, after validation, the transactions occurring through blockchain do not need the verification of a central authority. Permissioned blockchain also differs from permission-less owing to its flexibility to change rules or revise transactions. The data entered in the blockchain cannot be deleted but only altered, and the alteration of any data or transaction can be seen by all network members.

The working mechanism of BT in maritime SC can be explained through how the technology can be implemented in the permissioned-blockchain based platforms in the CIT contexts. In such platforms, all transactions, including document approvals and cargo release permissions, and shipment information, such as cargo details, tracking info, and sensor readings, are timestamped and recorded by network members on a distribution ledger basis. The transactions consist of chains of blocks which are created by cryptographic hashing of each information and documents shared in the platform. For instance, certificate of origin, packing list, bill of lading, and commercial invoice uploaded by the shipper are converted into a separate unique digital fingerprint, which is named as hashing and it is the ID of the created block (Green et al., 2020). The authenticity and correctness of this new block is only shared with and validated by permissioned and authorized members in the network, i.e., the bank, export and import custom authorities, and the importer. After transactions in the block are validated, they are submitted to the ledger and added to other blocks, thereby creating the chain of blocks. Each block in the chain is timestamped by validating members to prove the shipment information and documents in the block exist, and to show chronological order of these transactions. These blocks are shared by all relevant members in the platform. If any alteration is required in any document or data, this can only be done by the consensus of permissioned members and each alternation can be tracked.

The properties of BT enable it to be successfully applied in the maritime industry. Immutability of BT, for instance, makes it very suitable for maritime SC in which paper-based conventional transactions are time-consuming, costly, and susceptible to fraud and mistakes (Pu and Lam, 2021). The decentralized feature of BT also increases efficiency and security in maritime SC as ecosystem members do not have to rely on a central organization, such as banks, to verify authenticity of documents and correctness of transactions (Papathanasiou et al., 2020). Since each transaction and document is stored in different permissioned nodes, it also ensures security of transactions against firm-level cyber-attacks such as the incident Maersk and its customers experienced in 2017. The lack of transparency and traceability leads to a poor SC performance (Shou et al., 2021). The transparent and traceable characteristics of BT allows ecosystem members to monitor the shipment and all its transactions from point of origin to point of final destination. The need for transparency and traceability has recently become more evident for the maritime SC following several disruptions such as COVID-19, empty container issue, and Suez Canal clogging by MV Ever Green.

Thanks to its suitability to be applied in maritime SCs, BT offers various critical solutions and improvements. Previous studies have indicated various potential benefits of BT in maritime SCs. Yang (2019) suggests that BT can improve the digitalisation of operations and ease paperwork, tracking and tracing, custom clearance, and standardization. Pu & Lam (2020) propose that BT can be helpful in the electronic bill of ladings, leading to efficient and effective shipping operations, ship finance, and marine insurance. Papathanasiou et al. (2020), on the contrary, suggest that the shipping industry can benefit from blockchain in document exchanges, container utilisation, intelligent transportation, and container weighing. Zhong et al. (2021) suggest that the BT adoption by container lines and its effective usage can help diminish price war between container lines.

Hasan et al. (2019) demonstrated a smart-contract solution utilising smart containers equipped with an Internet of Things (IoT) sensor for efficient shipment management. Authors have illustrated how real-time tracking of vaccines, including temperature, humidity, and air pressure monitoring, can be achieved via BT. In their conceptual study, Lambourdiere and Corbin (2020) proposed that BT can positively impact information exchange, SC coordination, SC visibility, and performance in maritime SCs. Jović et al. (2020) conducted a literature review with a sustainability perspective and categorised the advantages of BT in maritime SC as economic, social, and environmental. Li and Zhou (2020) investigated pilot applications in the maritime SC and listed significant benefits of BT, such as acceleration and cost reduction in processes and documentation, the secure record for food safety, real-time tracking, efficient coordination between different modes of transport, and efficiency in various shipment regulations and marine insurance. Munim et al. (2021) reviewed the blockchain literature in the maritime context and revealed 17 potential uses of BT.

2.2. Blockchain adoption in containerized international trade

BT-based digital platforms, that allow sharing of shipment data and verification of trade documents, are relevant to be adopted by stakeholders in the CIT domain. One of the most well-known blockchain platforms is Tradelens, initially established by Maersk and IBM partnership and then extended with the participation of some key ecosystem members such as MSC, CMA CGM, ZIM, APM Terminals, PSA, Yilport, CEVA, and Damco (Tradelens, 2019a). Another major platform is the GSBN which was founded by the key carrier and terminal companies, including Cosco, Hapag Lloyd, OOCL, DP World, PSA, Hutchison Ports, as well as shipping software solution provider Cargosmart. As of July 2021, the website of Tradelens shows a total of 285 ecosystem members including government authorities, ocean carriers, terminals, intermodal providers, and inland depots. On the contrary, the GSBN website, does not display any members other than the eight shareholders. In addition to these two platforms, several proof-of-concept BT-based shipments have been delivered. One of them is a shipment by Samsung SDS from South Korea to the Netherlands, in which the Dutch bank ABN AMRO, Port of Rotterdam, and Korean Customs collaborated over a BT-based platform named DELIVER (Port of Rotterdam, 2019). Another example is the BT-based platform provided by Accenture. A consortium consisting of Accenture, Kuehne-Nagel, APL, AB InBev (a beer brewing company), and a European customs organisation has tested a successful application of blockchain in CIT (Accenture, 2018).

Beneficial cargo owners (BCO) are the central actors of CIT, and their adoption of BT is essential. Through a thorough research, we ascertained that only very few BCOs are associated with a blockchain platform specific to CIT. P&G, a multinational consumer goods corporation, is one of them. Michele Eggers from P&G stated that the company was investigating and testing the Tradelens platform to monitor their containerised shipments transparently and gain efficiency (Tradelens, 2019a). Toyota Tsusho and Mitsubishi Heavy Industries are other global companies associated with a blockchain platform in the CIT context. Most recently in June 2021, PUMA used Tradelens to receive real-time notifications about discharged containers at the Port of Bremerhaven.

The adoption of banks to BT-based platforms also plays a vital role as all original shipment and trade documents are controlled and exchanged between buyer and seller banks when the payment term is letter of credit or documentary collection. The role of banks is essential in payments in CIT as they guarantee payment to shippers (if all required documents are submitted) and verify the authenticity of documents so that consignees are ensured they only need to pay if the agreed shipment is delivered. However, this process takes over 10 business days until the consignee receives original documents (Ganne, 2018). Moreover, the courier costs of document transportation increase total logistics costs substantially. The banks should adopt BT-based platforms to validate authenticity of documents and approve payments. In this manner, the total cost and time of manual documentation can be decreased significantly. However, like BCOs, very few banks are associated with the BT within CIT. One of the exceptions is the Standard Chartered Bank which has announced joining the Tradelens platform. Another example is the Bank of China (Hong Kong), which is joining the GSBN platform.

Customs authorities are other key members whose adoption of BT-based platforms can significantly improve the efficiency and cost-effectiveness of CIT. The paper-based manual customs permissions often cause delays in cargo release and inefficiencies in paperwork costs, operations, and human resource requirements. BT adoption of customs authorities can help permissions to be granted in a secure and faster manner. Very few customs authorities have adopted BT-based platforms. Customs in Azerbaijan, Indonesia, Thailand, Malaysia, Ukraine, Peru, The United Arab Emirates, and China have either conducted a pilot test of blockchain or agreed to collaborate with a blockchain platform.

However, container terminals seem to be keener to adopt BT. For instance, the Tradelens involves a total of 179 container terminal members. Although a significant number of these members are APM Terminals, an AP-Moller-Maersk division, terminals from all around the world, including North America, South America, Europe, The Middle East, Southeast Asia, and the Far East, have adopted the platform. DP World, Yilport, Port of Halifax, KL-Net, SAAM, PSA, Hutchison Ports, and APM are some key terminals adopting BT-based platforms in CIT. Container terminals are expected to improve efficiency and effectiveness of their container movements and other operations as they can monitor the details of containers arriving at their terminals from the very beginning of the shipment journey.

Freight forwarders and 3PLs are expected to benefit from BT by digitalising their services and increasing visibility, thereby achieving a competitive advantage. However, the benefits forwarders and 3PLs will receive after a BT adoption are not discussed in detail. In fact, some reports indicate that BT adoption can even be harmful especially for small- and medium-scale forwarders, as the transparency the blockchain provides may halt the information asymmetry forwarders exploit (BCG, 2019; Koh et al., 2020). Considering the exploitation of information asymmetry in the market, the adoption of BT-based platforms by freight forwarders can be tricky. Yet, some global-scale forwarders, such as Agility and Kerry Logistics, have adopted such platforms. DHL adopts BT for tracking pharmaceuticals worldwide while Kuehne-Nagel has adopted the technology for verified gross mass portal usage.

The investigation of ecosystem members' adoption of BT-based platforms indicates that the adoption among stakeholders is not at the same pace. Container terminals and lines seem to be eager in adopting the technology while BCOs, banks, and forwarders seem more conservative or apathetic to adopt BT in the CIT context. Also, large and global-scale companies seem to adopt BT more than smaller organisations. If BT is to be utilised effectively and CIT is to reap its full benefits, it should be adopted by the majority of ecosystem members, if not all. Yet, the number of adopting maritime SC ecosystem members still lags far behind its desired level. A Boston Consulting Group survey conducted in the transport and logistics industry indicates that, although 88% of experts believe that BT will significantly disrupt the industry, almost 75% of them also say they are still exploring the opportunities and the BT superficially or have not thought about adopting it (BCG, 2019).

The existing studies on maritime SCs have conducted limited analysis barriers to adoption. Pu and Lam (2021) mention three main application challenges, such as legal, operational, and technical challenges, in their conceptual study. Jović et al. (2020) conducted a literature review and identified a total of 20 barriers in maritime transport, such as lack of consensus and standards, absence of regulations, stakeholder hesitation or resistance, data quality, inadequate knowledge, energy intensiveness, and immaturity. In their review study, Munim et al. (2021) revealed a total of six major challenges for BT adoption in the maritime context: lack of authority for standardisation, interoperability and lack of scale, antitrust law and commercial privacy, environmental concerns, dispute resolution, and data tampering and hacking.

Papathanasiou et al. (2020) conducted qualitative interviews with SC managers in Greece and reported three main inhibitors of BT application in shipping. The first barrier is complexity, which refers to implementation challenges, such as lack of expertise and regulations. The second one is culture, which means the resistance to change. The third barrier is insecurity, which refers to confidential information disclosure. Hackius et al. (2019) carried out workshops for the pilot trial of BT at Port of Hamburg and pointed out that privacy concerns represent the most significant barrier to the adoption of BT. Zhou et al. (2020) conducted an analytical hierarchy process method to rank the relative importance of challenges for BT implementation in the Singapore maritime ecosystem. The most critical challenges in order are 'cost of implementation, lack of experienced partners, lack of data privacy, lack of blockchain knowledge, fear of transiting to a new operating structure, and scalability' (Zhou et al., 2020; p: 6).

There exist significant gaps in the literature regarding adoption of BT in maritime SCs. First, none of the previous studies has focused on CIT. The BT has various usage applications in different segments of the maritime SC. It can be used for vessel inspection and auditing in Class Society and Port State Control inspections as well as for underwriting processes in marine insurance, tracking containers, and in charter party agreements (Czachorowski et al., 2019; Pu and Lam, 2021). Since the context, complexity, and ecosystem members of these applications are different, the adoption challenges are expected to be different as well. Considering the magnitude of CIT on global economy, a focus on BT adoption barriers in CIT is essential. Second, our review has identified only a single study examining adoption barriers quantitatively (Zhou et al., 2020), which applied AHP to rank relative importance of barriers. However, the relationship between adoption barriers is quite complex that the interdependencies between them should be identified. Managers and policy makers should know the most impactful barriers that can lead to the emergence of other barriers. ISM methodology is the most appropriate methodology to address this problem, but previous studies have not applied ISM in the maritime SC context. Third, the adoption issue should be tackled by incorporating stakeholders and investigating their impact on adoption. So far, no studies have adopted the stakeholder perspective to examine BT adoption barriers in maritime SCs. The identification of most impactful barriers and interdependencies between them should be reinforced by uncovering the most salient stakeholders in BT adoption in maritime SC. In fact, our review also indicates that none of the SC studies utilising the ISM method for BT adoption has bolstered their findings by finding out impactful stakeholders. Accordingly, as a research conducting ISM and stakeholder mapping analysis for BT adoption in CIT, our study fills an important gap in the existing literature. Adopting a stakeholder perspective, our study also investigates some barriers that are not examined by previous maritime SC studies. Lack of support from influencing stakeholders and lack of early adopters are introduced and examined quantitatively for the first time in BT adoption in maritime SCs. Inclusion of these two barriers is also another contribution of our research to the literature.

3. Methodology

This study implemented ISM and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analyses to uncover the structural relationship between BT adoption barriers in CIT. A stakeholder mapping analysis was also performed to identify salient stakeholders in BT adoption in CIT. Fig. 1 shows the research process.

After identifying the literature gap as well as the barriers and potential salient stakeholders to BT adoption, seven interviews were conducted with industry experts to examine the barriers and identify stakeholders that should be included in the analysis. These

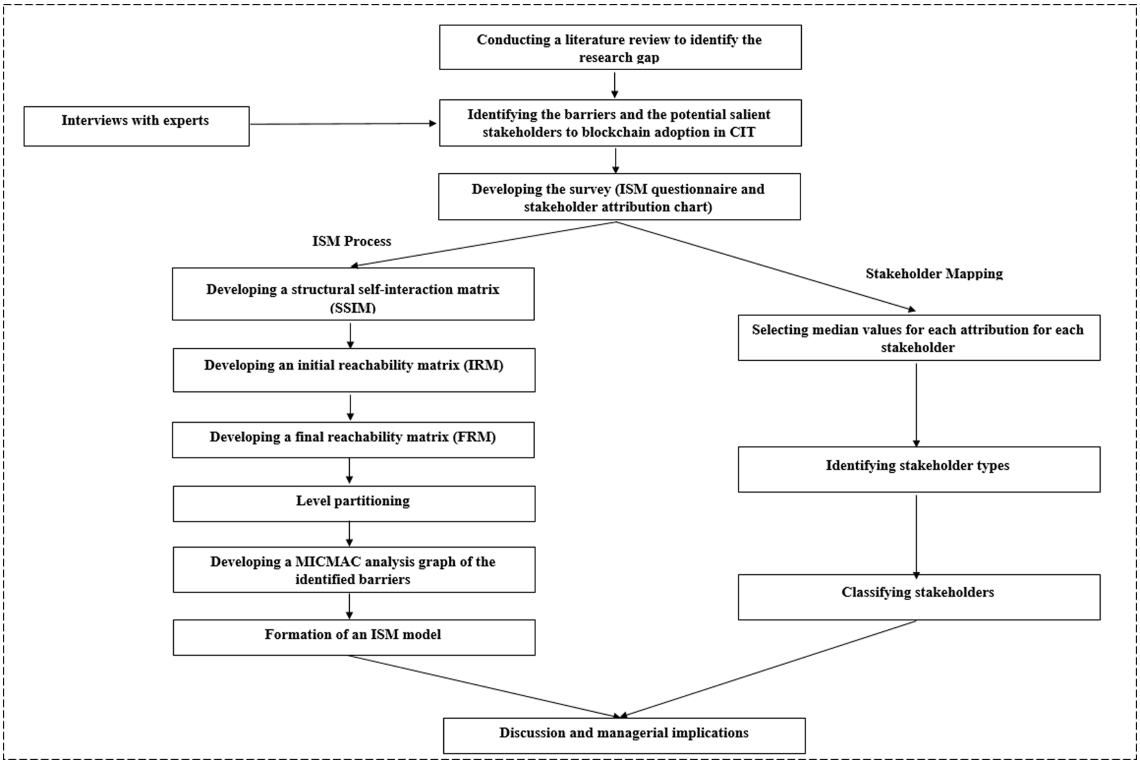

Fig. 1. Research process. Resource: Compiled by authors.

experts were from different segments of CIT and had at least six or more years of experience (see Table 1). All interviews were conducted online over Microsoft Teams application. Each interview took between 30 and 40 min. During the interviews, interviewees were asked to name the potential barriers to BT adoption, the reasons why BT adoption in CIT is not widespread, which stakeholders might participate in the blockchain platforms, and which stakeholders might have high influence on other stakeholders to adopt BT.

Once the barriers and potential stakeholder lists were finalised, a survey questionnaire was created. The first part of the survey consisted of questions enquiring the demographics of the respondents. The second part of the survey included the ISM questionnaire. Finally, the third part of the survey involved questions regarding the stakeholder mapping analysis (stakeholder attribution chart). We adopted a judgmental sampling, as the number of experts in the subject is still limited. Linkedin platform—the effectiveness of which is shown in survey research in container shipping (Kaliszewski et al., 2021)—was used to reach experts. Accordingly, experts who follow blockchain platforms in container shipping, share posts regarding the topic, and work in blockchain-related positions in the CIT domain were carefully selected. A total of 30 responses were received (see Table 2).

The experts presented a good demographic diversity and experience. Around 74% of the respondents were found to have an experience of seven years or more. Over half of the respondents' organisations were already a member to a blockchain platform. A great majority of other respondents' organisations were also considering engaging in a platform. The respondents worked in various organisations, including container lines, ports, cargo owners, and software providers. One of the respondents was from Africa; over 40% were from Europe; 30%, from Asia; and around 23%, from America. All the respondents resided in developed or developing countries.

3.1. ISM methodology and process

Developed by Warfield (1974), ISM is an organised and collaborative approach to uncover the relationships between variables of the research problem (Magalhães et al., 2021). Utilising the expert opinions, ISM transforms unclear and poorly articulated interpretive models into visible and well-defined structural models by determining hierarchy and relationships between the variables (Kwak et al., 2018; Venkatesh et al., 2015). The logic of the ISM is as follows. A set of variables related to a problem or a topic is created. While creating this variable set, methods such as literature review and expert opinion can be used. A contextually relevant subordinate is then selected. An aspect needs to be added to this contextual relationship (for example, does variable A affect variable B?). After the data set and contextual relationships are determined, the modelling group is prepared to perform all pairwise comparisons. Two variables are selected, and their pairwise comparison is done. The final decision on pairwise comparison is made according to the choice of the majority. Based on the responses of the pairwise comparisons, ISM infers specific answers due to the transitivity of the contextual relationship and asks for answers to other specific pairwise comparisons. The transitivity of contextual relationship is a fundamental assumption in the ISM, which states that if A is related to B and B is related to C, then A is necessarily related to C. When the necessary input information is available, a structural model is constructed in the form of a digraph that is assumed to reflect the collective characteristics of the group's thinking.

ISM can deal with complex real-life problems and reveal dynamic complexities. Furthermore, integrating ISM with MICMAC analysis provides relatively robust results. It is more suitable for analysing the contextual relationships between variables where their internal links are not previously scrutinised in the literature (Mangla et al., 2018). Other methods could be utilised to identify the hierarchical structure such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), or Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Developing a model with the mentioned tools requires the dominance level of interactions between the two variables, while ISM does not require dominance level. Instead, to establish a model, ISM requires interrelation between the variables, which is needed for the research problem of our study. Therefore, the developed model with ISM could present better results than the other multi criteria decision modelling (MCDM) tools (Gardas et al., 2017). In addition, ISM can reveal dynamic complexities while AHP or ANP has less ability to capture dynamic behaviours (Magalhães et al., 2021).

To fulfil the first research objective of this study, we employed an ISM analysis owing to the following reasons: (1) since all variables are considered with potential pairwise correlations either by asking experts or transitive extrapolation, the process is systemic; (2) since the transitive interpretation can diminish the relational queries by 50–80 %, the process is efficient; (3) since the significance of the variables and the contextual relationships between variables are revealed, the process acts as a learning tool; (4) in the process, the complex topics are guided and recoded effectively and methodically (Attri et al., 2013). However, the ISM approach has some limitations. First, the experts must be knowledgeable about the topic. Second, as the number of variables increases, the complexity of the methodology increases. Third, the ISM models are not empirically validated (Attri et al., 2013). We overcame these limitations by (1) only selecting experts by their knowledge about BT in the CIT; (2) identifying the optimum number of barriers by conducting a

Table 1
Demographics of the interviewees.

Organisation	Position	Experience	Country
Container line	Regional customer service manager	7 years	Italy
Port terminal	Marketing manager	16 years	Turkey
Container line	Platform product owner	14 years	The UK
Freight forwarder	Operations manager	10 years	Germany
Container line	Blockchain advisor	8 years	The Netherlands
Beneficial cargo owner	Export manager	13 years	Turkey
University	Lecturer	6 years	The UK

Table 2
Expert demographics.

Profile	Frequency	Percentage
Type of company		
Container line	7	23.3%
Freight forwarder/3PL	4	13.3%
Port/Terminal	5	16.7%
Cargo owner	3	10%
Software/Blockchain platform	5	16.7%
Academics	2	6.7%
Others	4	13.3%
Membership to a Blockchain platform		
Yes	17	56.7%
No (10 of which considering)	13	43.3%
Experience of respondent		
4–6 years	9	26.7%
7–10 years	3	10.0%
11–14 years	8	26.7%
15 and over	10	33.3%
Age of respondent		
26–34 years old	10	33.3%
35–44 years old	12	40%
45–54 years old	6	20%
55 and more	2	6.7%
Region of respondent		
Africa	1	3.3%
America	7	23.35
Asia	9	30.0%
Europe	13	43.3%

Table 3
BT adoption barriers in CIT.

B #	Barrier	Brief explanation	References
B1	Lack of government regulations	Refers to lack of regulations of transactions, their recognition by authorities, and uncertainty of legal application when a dispute arises.	(Jović et al., 2020; Lohmer & Lasch, 2020; Munim et al., 2021; Papathanasiou et al., 2020; Yadav et al., 2020)
B2	Lack of trust towards BT	Many stakeholders still do not trust BT, and the interviewees also confirmed the same. Experts stated that this arises either from an unorthodox technology or is often mistaken by highly volatile cryptocurrencies.	(Lohmer & Lasch, 2020; Yadav et al., 2020)
B3	Privacy/business information sharing concerns in blockchain platforms	Maritime SC stakeholders have concerns over disclosing essential business information, such as customers, suppliers, and freight details. Interviewees also suggest that many forwarders and intermediaries earn their profits thanks to information asymmetry, which may obstruct a full adoption.	(Hackius et al., 2019; Jović et al., 2020; Papathanasiou et al., 2020; Sahebi et al., 2020; Yadav et al., 2020; Zhou et al., 2020)
B4	Lack of knowledge/ understanding about BT	The majority of stakeholders do not know what BT is (how the system works, the difference between public and private blockchain, etc.) and how it can contribute to their businesses.	(Caldarelli et al., 2021; Lohmer & Lasch, 2020; Sahebi et al., 2020; Yadav et al., 2020; Zhou et al., 2020)
B5	Lack of support from influencing stakeholders	Interviewees consider lack of support as a significant barrier. They indicate that, except for a few container lines, influencing stakeholders do not adequately support and promote the adoption of BT in maritime SCs.	Interviews
B6	Resistance of some stakeholders to adopt	Regardless of trust or other concerns, many unwilling stakeholders, especially SMEs, will resist adopting blockchain, like they resist other new technologies.	(Jović et al., 2020; Mathivathanan et al., 2021; Papathanasiou et al., 2020; Yadav et al., 2020) Interviews
B7	Perceived resource and initial capital requirements	Organisations need to train and upskill employees and invest some time and resources. Interviewees state that it will be predominantly a concern for SMEs as they will need to invest in advanced IT systems and software to reap BT's benefits fully. The integration to current programs, such as SAP, will cause the extra cost for companies.	(Yadav et al., 2020; Zhou et al., 2020)
B8	Lack of early adopters	Interviewees suggest the number of early adopters is still very limited. It inhibits the adoption of organisations willing to join a blockchain platform but prefers to wait to see more adopters.	Interviews

Note: SC, supply chain; BT, blockchain technology; CIT, containerised international trade; SMEs, small and medium enterprises.

literature review and validating via semi-structured interviews; (3) creating the framework to identify the interrelationships within the challenges not for empirical validation.

This study employed ISM to identify the structural relationship between barriers to BT adoption in CIT. The process of the ISM is illustrated in Fig. 1. The results reveal a graphical structural map of the barriers highlighting the connections between them. The ISM approach includes several steps (Haleem et al., 2016). For the mathematical notations of ISM, we benefitted from the studies of Mangla et al. (2018), Venkatesh et al. (2015), and Kannan & Haq (2007). Steps are explained alongside the objective of this study (to identify the relationship between barriers to BT adoption in CIT), and they are as follows:

Step 1: Identify the variables related to the research objective. We conducted a literature review to identify BT adoption barriers. Since previous studies were carried out in different industries, we interviewed experts to understand whether the barriers we identified are valid in CIT. A total of seven interviews were conducted (see Table 1). After the interviews were completed, we finalised the BT adoption barriers in CIT. A total of 30 experts completed the survey (see Table 2). Table 3 shows the barriers, brief explanations, and references.

Step 2: Developing a self-interaction matrix (SSIM). A contextual relationship is ascertained among each barrier, and the pairs of barriers would be examined via questionnaires and data collection. The contextual relationship, which is in the form of a matrix, is called an SSIM. To develop the SSIM, we asked the experts to use four letters to represent the relationship between each barrier. V means that barrier *i* leads to barrier *j*; A means that barrier *j* leads to barrier *i*; X means that barrier *i* leads to barrier *j* and vice versa; O means that barriers *i* and *j* are unrelated.

Step 3: Developing an initial reachability matrix (IRM). The SSIM is transformed to a binary matrix with the changing V, A, X, and O values to 0 and 1 by implementing the following rules. If the *(i,j)* input in the SSIM is V, the *(i,j)* input in the reachability matrix becomes 1, and the *(j,i)* input becomes 0. If the *(i,j)* input in the SSIM is A, the *(i,j)* input in the reachability matrix becomes 0, and the *(j,i)* input becomes 1. If the *(i,j)* input in the SSIM is X, the *(i,j)* input in the reachability matrix becomes 1, and the *(j,i)* input becomes 1 as well. If the *(i,j)* input in the SSIM is O, the *(i,j)* input in the reachability matrix becomes 0, and the *(j,i)* input becomes 0 as well.

Step 4: Developing a final reachability matrix (FRM). To develop FRM, transitivity checking must be implemented. The transitivity relation is based on the assumption that if V1 is related to V2 and V2 is related to V3, then V1 is necessarily related to V3. The new matrix obtained after the transitivity control is called as FRM.

Step 5: Level partitioning. Next, the matrices are disintegrated based on the importance of establishing a hierarchical structure via reachability, antecedent, and intersection sets. Reachability involves the processing of each barrier and the other identified barriers that could be affected. The antecedent includes the barrier and all other barriers that may have an impact on it. The intersection of reachability and antecedent sets gives an intersection set, and it is named Level I. After identifying the intersection set, the set is eliminated, and the process is duplicated until all barriers are dealt with.

Step 6: Completing the MICMAC analysis. The purpose of the MICMAC analysis is to understand the driving and dependence power of each barrier. The driving power is calculated by summing the rows of FRM, while dependence power is calculated by summing the columns of FRM. The driving and dependence powers are utilised to determine the positions of each barrier across one of the four clusters in the MICMAC matrix. The barrier's cluster illustrates how the barrier fits the ISM model in addition to showing the barrier's power and dependence relative to other barriers. The four clusters are as follows: independent, dependent, autonomous, and linkage.

Independent cluster refers to barriers that are of weak dependence power but high driving power. Barriers positioned in independent clusters are often seen as crucial factors.

Dependent cluster refers to barriers that have strong dependence power but weak driving power. Other barriers heavily influence barriers positioned in dependent clusters.

Autonomous cluster refers to barriers with weak driving and dependence powers. Barriers located in the autonomous cluster have minimum impact and maintain few links with other barriers. In other words, barriers identified in this cluster are considered relatively disconnected from the system.

Linkage cluster refers to barriers with high driving and dependence powers. Barriers located in the linkage cluster are considered unstable, and any action that includes these barriers will probably have a reciprocal reaction, which affects themselves and other barriers.

Step 7. Developing the ISM-based model. After the MICMAC analysis, the ISM model is developed using nodes/vertical and lines of edges.

3.2. Stakeholder mapping analysis

Stakeholder mapping categorises different stakeholders by classifying them based on their potential influence and power among a phenomenon (Carroll, 1993). Analytical categorisation and reconstructive methods are the two main stakeholder classification approaches (Reed et al., 2009). While analytical categorisation uses data gathered from experts and ensures classification with theoretical underpinning, reconstructive methods use parameters identified by the stakeholders (Hare and Pahl-Wostl, 2002). In this study, we employed analytical categorisation; the theoretical underpinning is validated by the TSIS while identifying the salient stakeholders for BT adoption in CIT (Mitchell et al., 1997). TSIS offers a dynamic framework, and the salience level can be altered over time depending on changes in the environment or particular issues. According to TSIS, stakeholders can be classified considering their possession of three attributes: legitimacy, power, and urgency (Wood et al., 2021).

Power is defined as 'the probability that one actor within a social relationship would be in a position to carry out his own will despite resistance' (Weber, 1947). Power attribute refers to the degree of imposition of the stakeholder's will on others through coercive, utilitarian, and normative means (Weitzner & Deutsch, 2015). Legitimacy is defined as 'a generalised perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions' (Suchman, 1995). Legitimacy attribute refers to the degree of merit for managerial attention (Mitchell et al., 1997). Urgency refers to the degree to which a stakeholder's request is time-sensitive or critical (Parent and Deephouse, 2007).

Stakeholders can be classified into four groups according to the number of attributes they possess (Surucu-Balci et al., 2020). If a stakeholder possesses only one attribute, then they are classified as a latent stakeholder. Based on possession of attribute, the latent stakeholder can be identified as a demanding stakeholder, discretionary stakeholder, and dormant stakeholder. Demanding stakeholders only possess the urgency attribute, while discretionary stakeholders possess the legitimacy attribute. Dormant stakeholders possess the power attribute only. When a stakeholder possesses two attributes, they are classified as an expectant stakeholder. Based on the possessed attributes, expectant stakeholders can be named dangerous stakeholders, dependent stakeholders, and dominant stakeholders. Dangerous stakeholders have power and urgency attributes, while dependent stakeholders have urgency and legitimacy attributes. Dominant stakeholders possess power and legitimacy attributes. Dominant stakeholders will typically have some formal mechanism in place to help them act. Their communication and participation requirements must be met at all times. In fact, according to Mitchell et al. (1997), dominant stakeholders are those who are viewed by many as the firm's only stakeholders.

Stakeholders who possess all three attributes are called definitive (salient) stakeholders. Definitive stakeholders receive the most attention from the organisation because they are legit partners of the system, and they have the power to dictate their request and urgency to act. In this study, definitive stakeholders are classified into two, namely, high definitive and low definitive stakeholders. Although the stakeholders possess all three attributes, the level of possession can be different for each attribute. For example, one stakeholder can be classified as a definitive stakeholder by possessing each attribute at a low level (1), and another stakeholder can be classified as a definitive stakeholder by possessing each attribute at a high level (3). Although both stakeholders are classified as definitive, the level of impact will be different. Therefore, to reveal the difference in the impact level, here, we decided to use high definitive stakeholder and low definitive stakeholder.

We asked the respondents to evaluate the possession level of the legitimacy, power, and urgency attributes to identify and classify selected stakeholders. We created the stakeholder attribution chart to understand the attribution possession of each stakeholder regarding power, legitimacy, and urgency. In this study's context, power is considered the extent to which a party imposes BT adoption through its physical, material, prestige, and social resources. Legitimacy is considered the degree to which an entity is the core, legal, and contractual member of the blockchain system and can have moral or financial claims. Urgency is defined as the degree to which stakeholder claims call for immediate adoption of the blockchain.

The selection of the stakeholders was based on the initial interviews conducted with experts (see Table 1). All related stakeholders, who are projected to be active members of blockchain platforms, were identified and included in the survey. Eleven stakeholders were identified: container lines, ports/terminals, freight forwarders/3PLs, beneficial cargo owners, custom authorities, banks, trade associations, government authorities, insurance companies, software companies, and customs brokers. These stakeholders are also the most illustrated organisations in the diagrams of existing blockchain platforms. For instance, among the potential members Tradelens illustrate, only inland transportation companies were not included in our analysis (Tradelens, 2019b).

We asked the experts to evaluate the level (ranging from 0 to 4) of legitimacy, urgency, and power attributes of each stakeholder. The rating 0 meant that the stakeholder does not possess any attribute; 1, the stakeholder has a low level of possession for the attribute; 2, the stakeholder has a medium level of possession; 3, the stakeholder has a high level of possession for the attribute; and 4, the stakeholder has a very high level of possession. Since the collected data were skewed, the median of the collected data was chosen. When the data is not distributed normally, the mean cannot reveal the best central location, while the median can reveal the same. Using the data, the classification was done according to the attributes of the predetermined stakeholders. The stakeholders were classified as latent with one attribute, expectant with two attributes, and definitive with three attributes. Furthermore, definitive stakeholders were classified as low and high. Whether the stakeholder was a high or low definitive stakeholder was determined after all salient stakeholders were identified. Accordingly, the values given for the criteria were summed up and averaged, and those above the average were determined to be high salient and those below the average, low salient.

4. Data analysis

4.1. ISM model

Data about the interrelationships of barriers were gathered from 30 respondents working in CIT. We employed a convenience

Table 4
SSIM for the barriers to BT adoption in CIT.

Barriers	B8	B7	B6	B5	B4	B3	B2
B1	O	O	O	X	O	O	V
B2	V	O	V	O	A	X	
B3	V	O	V	A	A		
B4	V	O	V	O			
B5	V	O	O				
B6	X	V					
B7	V						

Note: SSIM, self-interaction matrix; BT, blockchain technology; CIT, containerised international trade sampling approach to choose experts knowledgeable about BT implementations in international CIT. The experts include different stakeholders of CIT, such as container lines, freight forwarders, ports, academics, and cargo owners. Table 2 shows experts' demographic traits.

Since there is a possibility that each expert can evaluate each relationship differently and assign a different letter for the relationship of two barriers, the contextual relationships between barriers were decided by the 'the minority gives way to the majority' rule, which was proposed by Shen et al. (2016). Thus, when a majority of a letter is achieved for the contextual relationship of two barriers, that letter was written to SSIM. The number of given letters by the experts is provided in Appendix A. Following this rule and Step 2 (explained in the ISM methodology section) SSIM is presented in Table 4.

The next step after SSIM is developing IRM based on giving the numerical equivalent of the letter values. As per the rules explained in Step 3, IRM is presented in Table 5.

Once the IRM is ready, it is essential to check for transitivity. The transitivity check is ensured according to the rule explained in Step 4. After the transitivity check, FRM is illustrated in Table 6.

The next step is to convert the FRM to the canonical matrix format by arranging the elements according to their levels. To determine levels, different sets, that is, reachability, antecedent, and intersection sets, are formed based on the rules explained in Step 5. We iterate the rule until each barrier has been labelled with at least one level. We had three iterations to ensure that all BT adoption barriers have obtained one or another level for developing an ISM-based model.

Table 7 illustrates the level partitioning the results of the eight barriers. According to Table 7, Level I comprises 'Resistance of some stakeholders to adopt' (B6), 'Perceived resource and initial capital requirement' (B7), and 'Lack of early adopters' (B8). 'Lack of trust towards BT' (B2) and 'Privacy/business information sharing concerns in blockchain platforms' (B3) form Level II. Level III includes 'Lack of government regulations' (B1), 'Lack of knowledge/ understanding about BT' (B4), and 'Lack of support from influencing stakeholders' (B5).

By following Step 6, we calculated each barrier's dependence and driving power and created Fig. 2, demonstrating the MICMAC diagram.

According to Fig. 2, most barriers are within the Independent and Dependent clusters. This indicates that the majority of the barriers have high driving and dependence powers. Four barriers, 'Lack of knowledge/understanding about BT' (B4), 'Lack of government regulations' (B1), 'Lack of support from influencing stakeholders' (B5), and 'Lack of trust towards BT' (B2) have been categorised as Independent in our study. These barriers require careful considerations because they are the root cause of all the other barriers. Furthermore, these barriers may help remove other barriers, appearing at the middle and bottom of the ISM-based hierarchical framework. Barriers with high driving power demand to be handled with priority because they are influencing some barriers. Only one barrier, 'Privacy/business information sharing concerns in blockchain platforms' (B3), has been categorised as the Linkage in this study. The main feature of this barrier is that any deficiencies among them will have a domino effect and may potentially cause a breakdown of other barriers due to its nature and high number of interconnections. Thus, this barrier must be observed closely by the practitioners.

Three barriers, which are 'Resistance of some stakeholders to adopt' (B6), 'Perceived resource and initial capital requirement' (B7), and 'Lack of early adopters' (B8), have been classified as Dependent. These barriers must be treated as essential barriers; their strong dependence indicates that they should remove all the other barriers for the adoption of BT in CIT. In this study, none of the barriers were identified as Autonomous. This demonstrates that all of the identified barriers influence the BT adoption in CIT.

The results of the MICMAC analysis are quite reasonable considering the characteristics of the shipping industry. The shipping market requires international standard regulations owing to complexity of operations, inclusion of multiple nationalities in each single shipment, and susceptibility to frauds. Hence, the fundamental role of the lack of government regulations in BT adoption makes sense. The shipping industry is also considered to be relatively conservative, which is attached to the traditional ways of implementing the business. This conservative attitude can explain why the lack of knowledge and trust has great importance with regards to other barriers. The linkage role of 'Privacy/business information sharing concerns' also adds up considering several characteristics of the shipping industry, and they are as follows. First, the industry involves business transactions with high invoice amounts and confidential data, and the recent cyber-attacks and traditional structure of the industry may create concerns regarding information sharing among ecosystem members owing to the lack of trust. Second, the willingness of information sharing in the industry can have a major impact on early adopters and elimination of the resistance attitude. Hence, it is truly a linkage variable that is affected by fundamental barriers which, in turn, affects other key barriers.

Following the MICMAC analysis, we utilised the FRM to structure the ISM model of barriers in BT adoption (Step 7), which is shown

Table 5
Initial reachability matrix.

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

Table 6
Final reachability matrix.

Barriers	B1	B2	B3	B4	B5	B6	B7	B8	DRP
B1	1	1	1*	0	1	1*	0	1*	6
B2	0	1	1	0	0	1	0	1	4
B3	0	1	1	0	0	1	1*	1	5
B4	0	1	1	1	0	1	1*	1	6
B5	1	0	1	0	1	1*	0	1	5
B6	0	0	0	0	0	1	1	1	3
B7	0	0	0	0	0	1*	1	1	3
B8	0	0	0	0	0	1	1*	1	3
DNP	2	4	5	1	2	8	5	8	35

* Adding transitivity.

Table 7
Level partitioning results.

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

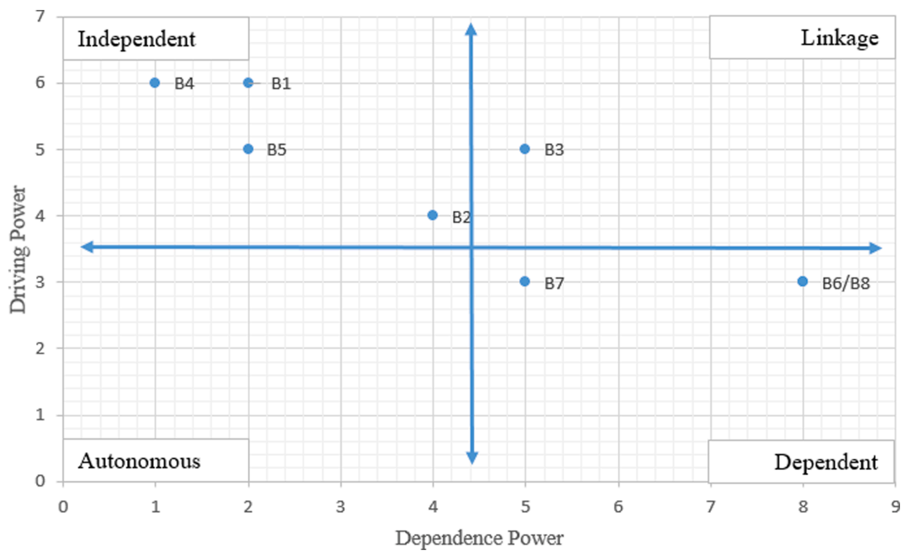

Fig. 2. MICMAC diagram.

as a digraph in Fig. 3. This model symbolises the barriers by visually illustrating the relationship between them. Each barrier is located considering their driving and dependence powers. The levels are related to four clusters in the MICMAC diagram in Fig. 2. No strict rule exists as to which level represents which quadrant, but the model considers the score of each barrier in terms of its driving and dependence powers, which are identified in the matrix.

The top level of the digraph pinpoints three variables as 'Lack of early adopters' (B8), 'Perceived resource and initial capital requirement' (B7), and 'Resistance of some stakeholders to adopt' (B6). The reason why these three barriers are on the top of the model stems from Level I partitioning, supported by MICMAC with the highest dependence and the lowest driving powers among all barriers.

The second level of the digraph consists of two barriers which are 'Privacy/business information sharing concerns in blockchain platforms' (B3) and 'Lack of trust towards BT' (B2) as these variables were filtered out from Level II partitioning with moderately high depending power. As validated through the MICMAC analysis, B3 acts as a Linkage variable—while independent barriers (B4, B1, and B5) affect B3, B3 affects the dependent variables (B7, B6, and B8). The bottom level of the digraph contains three variables 'Lack of early adopters' (B8), 'Perceived resource and initial capital requirement' (B7), and 'Resistance of some stakeholders to adopt' (B6).

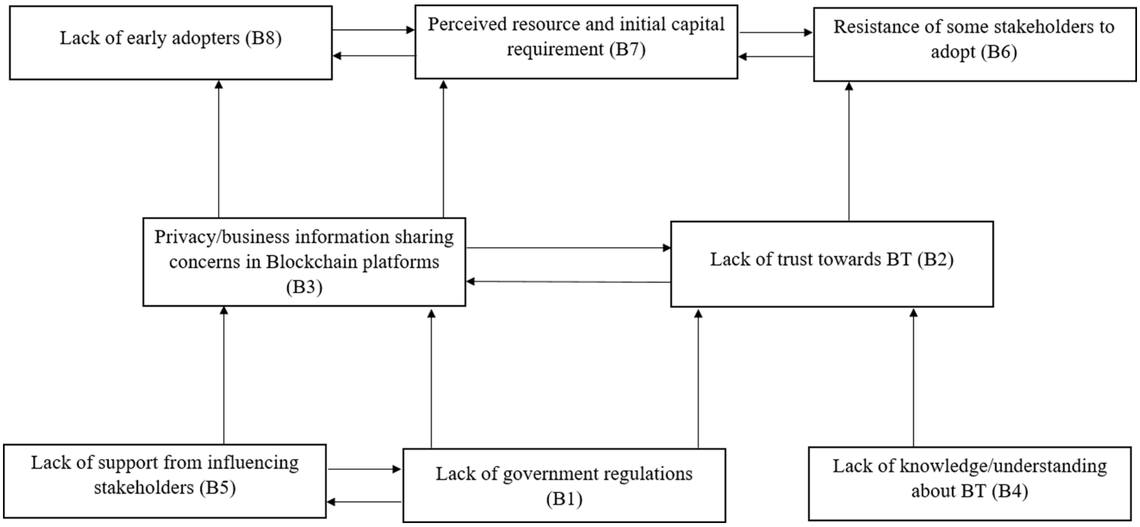

Fig. 3. ISM model for barriers to BT adoption in CIT.

These three variables are filtered out at the Level III iteration and have the highest dependence power from the MICMAC diagram.

4.2. Stakeholder mapping

Following the rules explained in the methodology, we completed stakeholder mapping, and Table 8 shows the classification of identified stakeholders. No stakeholder was classified as a latent stakeholder. This was expected because we focused only on active members of a blockchain platform.

According to Table 8, nine out of 11 stakeholders are classified as definitive stakeholders—they possess all three attributes and are considered salient. Although nine stakeholders have all three attributes, the difference in possession level of each attribute has led us to make a further classification among definitive stakeholders. Thus, container lines, ports/terminals, freight forwarders, beneficial cargo owners, and customs authorities are classified as high definitive stakeholders, while trade associations, government authorities, insurance companies, and software companies are classified as low definitive stakeholders. These stakeholders are legitimate actors of a potential BT ecosystem, and among the rest of the stakeholders, they have power to adopt the technology. Furthermore, a demand or invitation to adopt BT, which comes from these salient stakeholders, will be received urgently and acted upon. These stakeholders have the highest salience with regards to BT adoption in CIT. Therefore, the impact of these stakeholders should be considered during policy-making. Banks and custom brokers are classified as expectant stakeholders, that is, they possess power and legitimacy attributes. Banks and custom brokers are legitimate actors of a potential BT ecosystem, and they have some level of power as well, so they are essential for the success of the BT ecosystem, yet their stakes will not be considered urgent.

5. Conclusions and discussion

This study uncovers the structural relationships between BT adoption barriers in CIT and reveals the most salient stakeholders for the adoption underpinning the stakeholder theory perspective. A total of eight barriers were identified, and their relationships were uncovered through ISM methodology. This study identified the most salient stakeholders for BT adoption among 11 identified stakeholders who are projected to be directly involved in blockchain-based transactions and operations.

Table 8
Results of stakeholder mapping.

Stakeholders	Power	Legitimacy	Urgency	Type of stakeholder	Saliency of stakeholder
Container lines	4	4	3	Definitive	High definitive
Ports/terminals	3	4	3	Definitive	High definitive
Freight forwarders/3PL companies	3	4	2	Definitive	High definitive
Beneficial cargo owners/shippers	4	4	2	Definitive	High definitive
Customs authorities	4	4	1	Definitive	High definitive
Banks	1	3	0	Dominant	Expectant
Trade associations	2	2	1	Definitive	Low definitive
Government authorities (other than customs)	4	3	1	Definitive	Low definitive
Insurance companies	2	3	2	Definitive	Low definitive
Software companies	2	2	1	Definitive	Low definitive
Custom brokers	1	1	0	Dominant	Expectant

The ISM and MICMAC results indicate that the most pivotal barriers with the highest driving power and least dependencies are lack of government regulations, lack of support from influencing stakeholders, and lack of knowledge regarding BT. This finding is partly similar to some studies which found the lack of knowledge and lack of government regulations at the bottom level as the most fundamental barriers (Mathivathanan et al., 2021; Yadav et al., 2020; Zhou et al., 2020). However, lack of support from influencing stakeholders has not been revealed as one of the most fundamental barriers in previous studies. Lack of trust and privacy concerns were found at the second level of the ISM model in our study, which is unlike the results of Yadav et al. (2020) who found lack of trust at the fourth (bottom) level and privacy concerns at the second level. According to Yadav et al. (2020), lack of trust influences lack of stakeholder awareness in agriculture while our results show the opposite. Our results revealed that the lack of knowledge about BT causes lack of trust in the CIT context. This discrepancy may derive from industrial or geographical difference as their studies are applied to Indian agricultural stakeholders. Our study also utilised 'lack of early adopters' barriers for the first time in the maritime SC context and disclosed it at the first level of ISM, which shows that the elimination of this barrier highly depends on other fundamental barriers.

Level 3 barriers are fundamental barriers that influence other barriers. This finding is relevant considering the vital role of these barriers in BT adoption. Government regulations play a significant role in international shipping and trade, and stakeholders will require BT-based transactions to be recognised by related authorities to exchange original documents, delivery of cargoes, and payment of invoices. As they are sensitive issues, parties can demand legal action. Thus, as is evident from our results, it is expected that the recognition by governments and the existence of new regulations governing these transactions will eventually affect the trust issues of stakeholders and other dependent barriers.

The high driving power of lack of support from influential stakeholders also makes sense, as true success in BT adoption can only be achieved by involving all salient stakeholders. It is expected that if key stakeholders support the blockchain, trust and privacy concerns of stakeholders can be diminished, early adopters may increase, and resistance behaviour of unwilling stakeholders can be altered. For instance, COSCO is one of the largest global container lines and has a very high influence in Chinese CIT. COSCO has led the GSBN platform and supported BT adoption significantly. Their support and effort resulted in the participation of the Bank of China, a key cargo-owner in China, and a key cargo-owner in Saudi Arabia to launch a blockchain-based bill of lading for a pilot project. This confirms our results: the support of COSCO has enhanced the trust of these stakeholders and enabled them to be one of the early adopters, which is believed to enable BT adoption at a larger scale in the industry.

Lack of knowledge regarding BT also significantly affects other barriers, which makes sense, as the majority of stakeholders, especially among small and medium enterprises (SMEs), are believed to not fully understand how blockchain functions and how it can be helpful for businesses. Blockchain is often considered the equivalent of cryptocurrencies such as Bitcoin, and the volatile structure and susceptibility to value manipulation of cryptocurrencies cause trust and privacy issues. The lack of understanding regarding BT benefits this misunderstanding in CIT; therefore, it is no surprise that lack of knowledge is a key barrier that influences other important barriers.

The second level of ISM structure includes lack of trust and privacy/business information sharing concerns. These are significant barriers as they play a crucial role in connecting Level 1 and Level 3 barriers Without overcoming these barriers, it is difficult to diminish Level 1 barriers (B6, B7, and B8). The lack of trust observed in the second level is expected to be highly influenced by lack of knowledge and lack of government regulations, and it affects other barriers, similar to the findings of Yadav et al. (2020). In parallel to some previous studies by Mathivathanan et al. (2021) and Yadav et al. (2020), privacy concerns are also influenced by other barriers and affect others, although with a relatively lower driving power based on the MICMAC analysis.

In the MICMAC analysis, lack of trust has a higher dependency compared to privacy concerns. The result is pertinent in the container shipping domain because many sensitive private business data, such as customers, suppliers, product invoices, and freight invoices, exist in each container shipment. Blockchain is considered to be a platform in which the data are shared among all permitted participants. Considering the amount of sensitive business data and data share of blockchains, privacy concerns are expected to be less dependent on other barriers. Managing privacy and business data share concerns regarding blockchain adoption would be especially challenging with freight forwarders who tend to keep the information asymmetry between lines and cargo owners and exporters who want to keep their customer and invoice data as discrete as possible.

The third level barriers have the least driving power and highest dependency. Particularly, lack of early adopters and resistance of some stakeholders have the highest dependence levels. This finding is parallel to the results of Mathivathanan et al. (2021), who found business owners' unwillingness to adopt blockchain at the top level of their ISM diagram. These two barriers can be considered the final barriers before the large-scale adoption of BT. They can be eliminated by handling more pivotal barriers in the second and third levels of the ISM diagram. The elimination of barriers in the third level, such as lack of knowledge and lack of government regulations, will help handle the second level of barriers, such as lack of trust, which will eventually help eliminate the first level of barriers.

The stakeholder mapping analysis indicates that container lines, shippers, customs, and other government authorities have the highest power in terms of BT adoption. This result is relevant, as cargo owners/shippers are the primary buyers of container shipping service while container lines are the leading suppliers of the service. Considering the importance of the lack of government regulations observed after the ISM/MICMAC analysis, the very high power of government authorities is also reasonable. Many stakeholders in our analysis have a high level of legitimacy, as we selected only those expected to be involved in a blockchain platform.

In terms of urgency, the results indicate that container lines and ports have the highest urgency levels. It is probably because these stakeholders are believed to achieve a significant level of operational efficiencies and effectiveness if a blockchain is adopted in the industry. Beneficial cargo owners are expected to gain significant cost, time, and operations-related benefits from BT adoption. However, the results show that they have a medium level of urgency, and their urgency level is lower than ports and container lines. This can be explained by the fact that, although large cargo owners such as Walmart and Procter & Gamble are aware of the benefits of blockchain, the majority of small and medium-sized cargo owners still have little or no understanding of blockchain and its potential benefits, or at least not as much as ports and container lines which are currently leading the blockchain platforms, Tradelens and GSBN. This finding in stakeholder analysis also reiterates the importance of the barrier, lack of understanding, in the ISM analysis.

5.1. Implications for practice and policy

This study has identified eight key barriers to BT adoption in CIT. Three of these barriers, lack of support from influential stakeholders, lack of regulations, and lack of knowledge, have high driving power and can be considered as the root causes of the non-adoption of BT in the CIT. Tackling these barriers will help resolve other important barriers such as lack of trust, privacy concerns, and resistance to adopt BT. Thus, policy makers and managers should prioritise these three independent variables. Lack of trust and privacy concerns also have relatively higher driving power that affects the first level barriers in the ISM model. These two barriers also require a special attention from managers as elimination of these barriers will help handle first level barriers. The stakeholder mapping analysis we conducted demonstrated the most influential stakeholders in the adoption of BT. High definitive stakeholders particularly play a major role in tackling these barriers to adopt BT in the CIT context.

Our results indicate that large-scale BT adoption in CIT can be achieved through government regulations and recognition of blockchain platforms. Recently, the blockchain platform, COSCO-led GSBN, received regulatory approvals to operate in Hong Kong. Although regulatory approvals and engagement of authorities in blockchain platforms are encouraging and needed for BT adoption, this is one of the few locations wherein a blockchain platform is currently recognised. Considering government authorities' high power and legitimacy scores in the stakeholder analysis and the importance of government regulations in ISM analysis, more government authorities should approve the blockchain platforms engaged in the system and design-related regulations. The European Parliament has issued a report named 'Blockchain for supply chain and international trade' in which several policy suggestions at the government level are introduced. Such government-led research and initiatives will increase the awareness of blockchain, trigger necessary government regulations, and increase trust among stakeholders, thus ameliorating key barriers to BT adoption in CIT.

The results indicate that lack of support from influential stakeholders is one of the key barriers that trigger other barriers. The support offered by salient stakeholders is expected to help eliminate other barriers as well. Container lines are the most salient stakeholders, according to our analysis. Some container lines, such as Maersk and COSCO, already promote BT adoption. Although many global scale container lines have become members of GSBN or Tradelens systems, more support from global lines and critical regional players, such as Wan Hai, Arkas, or Unifeeder, are required. The support could be provided through promotions via communications channels, such as social media and trade meetings, and by increasing dialogue with custom authorities and related government bodies whose power and legitimacy are very high but urgency is low or nil. The support given by container lines should lay more focus on informing other stakeholders about BT, as the lack of understanding is one of the pivotal barriers. Although not determined as definitive stakeholders in BT adoption in CIT, banks and customs brokers are legitimate and important players in the market. Thus, their support for BT adoption will be highly impactful for companies in their industries. If key players in these industries adopt BT, then they will become early adopters, lack of which was found as a barrier in the ISM analysis. The memberships of Standard Chartered Bank to Tradelens and Bank of China (Hong Kong) to GSBN platforms are good examples of early BT adoption in CIT among banks.

The criticality regarding the lack of understanding about BT should be recognised and tackled by all stakeholders, particularly those with higher power scores in stakeholder analysis. Apart from the stakeholders included in our analysis, universities, who are not ecosystem members of blockchain platforms, also play a key role in increasing the knowledge and understanding about BT. Schools that teach international trade, shipping, logistics, and SC subjects at undergraduate and postgraduate levels can include BT-based SC and trade into their curriculums, which will increase understanding of BT. We suggest that definitive stakeholders should collaborate with universities for the involvement of BT in curriculums. Similarly, trade unions and associations can also design courses about BT and train their members to increase awareness.

The privacy/business information sharing concern seems to be a challenging one to overcome. There appears to be a conflict of interest among stakeholders regarding this barrier. On the one hand, container lines, ports, customs authorities, and some global cargo owners would like to benefit from open data sharing among ecosystem members to advance their operations and increase traceability. On the other hand, some forwarders/3PLs, cargo brokers, and SME cargo owners want to avoid data sharing either because they want to keep the existing information asymmetry to sustain their profitability and business or they want to keep their customers and invoice details as confidential as possible. Although the blockchain system can determine which stakeholders can access specific data and documents, the system is transparent, as data and documents are shared among permissioned platform members. This situation creates a conflict of interest, and in such an environment, gaining full support from all stakeholders could be challenging. Thus, we suggest that stakeholders keep the communications as open as possible and reach a consensus with other stakeholders regarding the privacy issue.

5.2. Theoretical implications

This study contributes to the literature in several ways. One of the most important contributions is the combination of examining barriers via the ISM technique and identifying salient stakeholders by stakeholder mapping analysis. The ISM technique has been used to analyse BT adoption barriers in previous SC studies (Mathivathanan et al., 2021; Yadav et al., 2020). Barriers have also been examined through other multi-criteria decision methods such as AHP and ANP (Orji et al., 2020; Zhou et al., 2020). Although these studies have examined the relationships between barriers, they are silent or not precise about which stakeholders can play a more important role in tackling BT adoption barriers. Our study has identified salient stakeholders and revealed the structural relationship barriers, so a more precise picture is presented as to how these barriers can be overcome.

This study also contributes to BT adoption literature in trade and SC perspective by adopting a stakeholder theory perspective. Our view is that the adoption of private blockchains can only be successful if all legitimate stakeholders are engaged in blockchain platforms. Thus, underpinning stakeholder theory, blockchain platforms can be treated as the core organisation. Engagement to these platforms should be investigated by considering each stakeholder's power, legitimacy, and urgency.

Adopting the stakeholder theory perspective has also led to another contribution—the utilization of 'support from influential stakeholders' to mend the barriers in BT adoption—for the first time in the SC context. In fact, this barrier is also found as one of the most fundamental barriers that influence other key barriers in our analysis. Moreover, this study also contributes to the BT adoption literature as this was the first study to conduct stakeholder mapping analysis within the SC and international trade contexts.

Our study also contributes to maritime SC and freight transportation literature as the first study to implement ISM to analyse BT adoption barriers. Scholars have investigated barriers by conceptual or literature reviews (Jović et al., 2020; Munim et al., 2021) or conducting qualitative interviews (Papathanasiou et al., 2020). AHP and ANP analyses were conducted among few quantitative studies to rank barriers based on their importance (Orji et al., 2020; Zhou et al., 2020). These studies are of vital importance for understanding barriers within the maritime SC context. However, they are limited in terms of understanding how BT adoption barriers affect each other. The ISM and MICMAC techniques were employed here to reveal these structural relationships and identify which barriers have higher driving powers influencing other barriers.

This study focused on CIT rather than the entire maritime SC, which allows the scrutiny of the BT adoption in a specific context. The barriers and salient stakeholders may vary depending on the context in which BT is adopted. Previous studies in maritime SC investigate BT adoption in a general context by involving other segments of the maritime industry such as bulk shipping, ship classification and insuring, and port-state controls. Our study has focused on BT adoption in CIT, a specific area yet a highly impactful one considering its vital role in international trade. Thus, this is also one of the early studies investigating BT adoption in international trade.

5.3. Limitations and future research

This study is subject to several limitations. First, it does not include certain technological barriers, such as scalability and system speed. Even though the study includes the lack of government regulations as a barrier, it does not involve some other legal and legislative barriers, such as antitrust concerns and dispute resolutions. One of the reasons for omitting barriers was to retain their number at a level in which respondents would reflect their judgements more accurately, as their judgements can deteriorate when number of variables increases (Attri et al., 2013). This was also essential especially considering the fact that the survey involved stakeholder mapping questions as well. The second reason is that the barriers are mainly created from the stakeholder perspective. Future studies can focus on technological and legal barriers to scrutinise them more effectively.

All respondents in the survey were from developed or developing countries with good internet connections. This is important because poor internet connection can hinder BT adoption, and the technological barriers could become fundamental barriers. Regarding our conclusions, the barrier 'perceived resource and initial capital requirements' would have turned up on another level if respondents from countries with poor internet connections were included. Respondents in the survey are, therefore, considered representative of developed and developing countries with good internet connection. To fully reap the benefits of BT, stakeholders should adopt it in less developed countries as well. Thus, a future study focusing on less-developed countries is essential, as the level of barriers and driving powers might be different. This is particularly important as those seven preliminary interviews to ensure content validity of barriers were conducted with experts from Europe. Different barriers, such as technological barriers, could be identified if these interviews were conducted in less developed countries.

Future studies may conduct regression-based statistical methods to find out which barriers affect the adoption decision of stakeholders. However, finding a sufficient number of respondents for such statistical analyses can be challenging considering the limited number of people with a good knowledge of BT in the industry. Moreover, the results of this study suggest that the elimination of other barriers will help decrease the resistance of some stakeholders to adopt. However, the resistance behaviour of stakeholders is a complex issue in which the characteristics of individuals can play a significant role. Future studies should pay particular attention to stakeholders' resistance behaviour, possibly by underpinning the theory of reasoned action, theory of planned behaviour, and technology acceptance model.

CRediT authorship contribution statement

Gokcay Balci: Conceptualization, Methodology, Investigation, Resources, Visualization, Writing – original draft, Writing – review & editing. **Ebru Surucu-Balci:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Responses of participants for each comparisons

Pairwise Comparison	Number of V	Number of A	Number of X	Number of O	Selected Variable
B1 → B2	25	3	2	0	V
B1 → B3	3	2	2	23	O
B1 → B4	3	4	4	19	O
B1 → B5	4	6	20	0	X
B1 → B6	5	6	2	17	O
B1 → B7	6	7	1	16	O
B1 → B8	2	5	5	18	O
B2 → B3	7	2	21	0	X
B2 → B4	1	23	5	1	A
B2 → B5	1	7	2	20	O
B2 → B6	26	3	1	0	V
B2 → B7	3	4	1	22	O
B2 → B8	19	6	3	2	V
B3 → B4	8	19	3	0	A
B3 → B5	8	17	5	0	A
B3 → B6	21	0	6	3	V
B3 → B7	4	4	2	20	O
B3 → B8	17	6	7	0	V
B4 → B5	1	6	2	21	O
B4 → B6	20	4	6	0	V
B4 → B7	0	2	9	19	O
B4 → B8	20	6	0	4	V
B5 → B6	7	4	2	17	O
B5 → B7	1	1	5	23	O
B5 → B8	19	4	4	3	V
B6 → B7	21	0	7	2	V
B6 → B8	4	1	25	0	X
B7 → B8	18	9	3	0	V

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