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The key challenges and critical success factors of blockchain implementation: Policy implications for Singapore’s maritime industry

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ABSTRACT
Blockchain has the potential to improve the efficiency and transparency of maritime businesses and operations. Nevertheless, few studies have been conducted to identify the key challenges and critical success factors (CSFs) of blockchain implementation in the maritime industry. A case study approach based on Singapore’s maritime industry is adopted. Four interviews are conducted to establish the face validity of the survey questionnaire before data are collected from 30 maritime professionals from Singapore’s maritime industry. In addition to analytic hierarchical process (AHP), a fishbone diagram and PESTEL analysis are also adopted to organize and discuss the results. The results show that there are six key challenges and six CSFs for blockchain implementation. Using a fishbone diagram, the six identified challenges along with 13 personal concerns are categorized into five dimensions related to people, methods, organization, external environment, and technology. The CSFs are sufficient capital, staff training, ease of local legislation, support from the shipping community, support from the senior management, and professional consultation and assistance. This study implicates marine policy formulation in relation to subsidies and investments, blockchain talent and knowledge acquisition, and workforce training and education to accelerate blockchain implementation in the maritime industry.

1. Introduction

With the increasing pace of globalization during the last two decades, seaborne trade has made up a crucial part of global trade. Although there is an existing trend of de-globalization and regionalization, maritime transportation still holds its strategic significance given its efficiency and low-cost feature. However, the maritime business operations can be complicated and tedious as multiple parties, a tremendous volume of transport documents, and the compliance of maritime law and insurance clauses are involved. Meanwhile, the world economy had been recovering slowly since the 2008 financial crisis [1]. However, the COVID-19 pandemic further slows down the recovery. Hence, the maritime industry needs to speed up the rate of digitalization to improve its efficiency and reduce the costs for survivability and long-term sustainability.

The blockchain technology refers to “a distributed database of records, or public ledger of all transactions or digital events that have been executed and shared among participating parties” [2]. It can also be regarded as a platform which provides decentralized shared services [3]. Normally, it would be a paradox that safety and convenience could exist simultaneously in a type of technology. However, blockchain seems to be a counterexample. Blockchain’s encrypted security guarantees the authenticity and finality of the databases, forbidding them from alteration and corruption [4]. Meanwhile, the information throughout the blockchain is stored and traceable all the time, establishing the corner stone of the commercial intercourse among multiple parties [5]. Moreover, blockchain allows simultaneous auditing between commercial partners, satisfying the dynamic nature of maritime business and paving the way for real-time and transparent decision making [6,7]. Given the powerful strength of blockchain, this new technology has been tested and adopted in many industries including banking and transportation [8,9], and the maritime industry shall not be an exemption.

The application of blockchain technology in the maritime industry has a wide spectrum. First, blockchain can be applied to improve the degree of digitalization, thus reducing the paperwork [10]. The degree of digitalization in the maritime industry is relatively low compared with other industries. Due to the international and cross-border nature of maritime business, the procedure of trade and transactions can be complicated and laborious. A huge amount of paperwork is involved...
during the process of maritime business and operations, including but not limited to booking notes, shipping orders, loading lists, bills of lading, commercial invoices and insurance documents. The storage, transaction, and management of the paperwork require a lot of resources and may even delay shipping dates, causing extra demurrage at the ports. With the help of blockchain, such paperwork can be reduced significantly and most of the documents can be shared, transacted and stored efficiently and safely [6]. Second, blockchain can be adopted for cargo and vessel tracking. With the involvement of the relevant parties throughout the value chain of maritime operations (e.g. terminal operators, shipping companies, freight forwarders and shippers), information can be accessed much more easily and timely via blockchain instead of taking extra time exploring the respective home page of multiple institutions [11]. Third, blockchain can accelerate the process of green innovation in the maritime industry [12]. With the help of blockchain and other sensors, the regulators (e.g. port authorities) can timely track and examine the emission of the ships [13]. The emission behavior of each vessel (e.g. using heavy diesel oil in ECA) can be recorded and updated via blockchain, helping the maritime industry to be more environmental-friendly.

Since blockchain technology has huge potential of being adopted in the maritime industry [14], the key players of this industry need to be mentioned. Singapore beholds its strategic location in Malacca Strait and has formed a maritime cluster comprising different maritime sectors [15]. Besides, Singapore was ranked fifth place in Lloyd’s 2019 list of top 10 flag states. It is also notable that Singapore has launched the memorandum of understanding “to build an advanced digital blockchain ship registration preparation system for international adoption” [16]. Given that the tremendous efforts which have been put into the Singapore maritime R&D development [17,18], the wide spectrum of maritime services provided by Singapore, as well as the diversity of the resident organizations within the country, Singapore’s maritime industry can be regarded as a suitable research scope of this study.

Given the benefits that blockchain can confer to maritime businesses, it is vital to analyze the roadblocks and facilitators of its implementation. The objective of this paper is (1) to analyze the key challenges of blockchain implementation in the maritime industry and (2) to empirically explore the critical success factors of blockchain implementation.

The rest of this paper is structured as follows. In Section 2, the barriers and success factors of implementing blockchain technology are reviewed. Thereafter, Section 3 describes the in-depth interviews and a survey which were conducted with maritime professionals in Singapore’s maritime industry to collect data for this research. The data is analyzed using a fishbone diagram and PESTEL analysis in Section 4. Finally, conclusions are drawn, together with discussion on theoretical and managerial implication, limitations and future research recommendation.

2. Literature review

Although the barriers and success factors of blockchain implementation in various industries have been studied in the previous literature, to the best of the authors’ knowledge, this topic in the maritime industry still remains unexplored, nor in Singapore’s maritime industry. This study distinguishes itself from existing studies by identifying the key challenges and critical success factors of blockchain implementation in the maritime industry using data collected from Singapore’s maritime industry. In the following sub-sections, the relevant literature is reviewed.

2.1. The blockchain application in the maritime industry

The blockchain application in the maritime industry can be currently categorized into four themes, namely (1) ship operations, (2) shipping transactions, (3) marine insurance, and (4) ship registry.

For ship operations, firstly, blockchain can be adopted to track the movements of cargo. For B2B transactions, tracking the physical movements and implementing effective quality control of cargo are vital challenges [19]. Nevertheless, real-time dynamic shipment monitoring and tracking cannot be effectively achieved by the existing logistics and information system, causing relevant potential economic losses [20,21]. To tackle this issue, blockchain can provide real-time immutable and traceable cargo movements throughout the maritime supply chain. Secondly, the traditional paper-based bills of lading process can cause delays due to its physical complexity [22]. The current electronic bills of lading systems rely on the authentication of a central party, limiting users’ accessibility and control of the process [23]. In this regard, blockchain can enable the shippers to use their digital signature to secure the information which can only be decrypted by the designated recipient without a central party [24]. Thirdly, information sharing in the maritime industry is another weak point, constraining supply chain integration and operation performance [25]. For example, the container capacity information sharing has been impeded due to the lack of mutual trust between liner shipping companies and shippers [26]. Blockchain can provide real-time update of transparent and unmodifiable information, achieving data integrity and responsibility [27], further building trust among the involved parties [28]. In the maritime industry, Maersk and IBM have jointly developed a blockchain solution named “TradeLens”, improving visibility and efficiency across the supply chain [29]. CargoX developed a blockchain documentation transaction system to provide a faster, safer and more reliable process of shipping documents, especially bills-of-lading [30].

For shipping transactions, due to the global nature of shipping businesses, cross-border transactions are common. The process of cross-border transactions takes a few days and relies heavily on Society for Worldwide Interbank Financial Telecommunication system [31]. Moreover, about 5–20% of the transaction amount is deducted during the process [32]. Blockchain provides a more efficient, more economical and safer solution compared to the current SWIFT system [33]. Another issue is the escrow of container booking. The default problem in container booking can raise commercial disputes. The cryptocurrency function of blockchain can be regarded as a form of deposits to settle the payment to the counterparty if the other party forfeits the contract, mitigating the credit risk of business [34].

For marine insurance, the underwriters need to evaluate the physical status of asset vessels as well as their accident and operation records, which is a tedious process. The blockchain would enable accurate, verified data sharing of the targeted asset, facilitating a more efficient underwriting process. Meanwhile, the premium rate of the insured can also be adjusted accordingly based on the blockchain-stored data [35,36].

For ship registry, the validating process requires purchase certificate, IMO ship registration number, tonnage certificate, load line certificate and etc., along with other technical information of the vessel [37]. The same information needs to be validated again when the vessel is going to be sold to another ship owner or a bank. With blockchain, the detailed information of the vessel can be recorded and updated timely without distortion, allowing real-time access by the authorized party. Moreover, port state control can also record the inspection results in the system, assisting the shipping management of the flag state.

2.2. The barriers of blockchain implementation in the maritime industry

There are some barriers of blockchain implementation in the maritime industry identified by the extant literature. First, the main barrier of blockchain implementation in the maritime industry is the cost, which relates to the initial development and further maintenance. Moreover, there would be more costs if the companies need to switch the systems and train their employees to acquire the knowledge of blockchain [38]. Besides, the main disadvantage of blockchain is the high energy consumption. The real-time ledger needs live power. When a new node is established in the blockchain, it communicates with other nodes,
Another barrier is that the reliability of blockchain is doubted by some professionals in the maritime industry. The blockchain technology is currently immature and needs further development [41]. A problem with blockchain is that the nodes which are operating on old software will not accept the transactions in the new chain [39]. Besides, given the specialty of the maritime industry, the internet speed can be low when the working stage is offshore, limiting the timeliness of data uploading and upgrading function of blockchain [38]. In addition, blockchain can be attacked by different threats which are connecting with the Proof-of-Work and Power-over-Ethernet protocols. The concern of data safety and privacy is also raised by some professionals in the maritime industry. The blockchain technology is designed for information sharing. However, some partners among the supply chain consider such information as a competitive advantage [45]. Principally, the blockchain technology is designed for information sharing. However, some partners among the supply chain consider such information as a competitive advantage [45].

The involvement of the managers and owners is recognized as a success factor of the implementation of new technology [53]. As blockchain is a relatively new technology, its implementation needs support from the senior management through various means, such as demonstrating commitment, helping the team to overcome obstacles, and providing encouragement to the team. During the implementation of blockchain, senior management involvement means that the top executives are obliged to provide effective support to the projects from its initiation to the end [54]. This would facilitate the implementation of blockchain at the organizational level.

3. Methodology

3.1. Data collection

Semi-structured interviews and a questionnaire survey are employed as the data collection methods for this research. In total, four interviews were conducted, and 30 responses of the online questionnaire survey were received. The targeted interviewees and survey respondents are professionals working in Singapore’s maritime industry.

Semi-structured, in-depth interviews were first conducted with the purpose of obtaining feedback on the structure and content of the survey questionnaire. Thereafter, the improved version of questionnaire is distributed via Google Forms, an online survey platform. The responses were consolidated and exported to an excel file for further analysis.

For the interviews, responses from four interviewees working at maritime organizations were compiled. The interviews were conducted through email and skype, with each interview lasting for an average of 30 min.

For the survey questionnaire, as mentioned above, Google Forms was adopted as the platform to administer the survey. Overall, 15 questions were embedded in the questionnaire, with 13 fixed-alternative questions, two open-ended questions. Among the 13 fixed-alternative questions, six are related to the respondents’ demographic and their firm’s information whereas the others pertain to their opinions about maritime blockchain implementation. Moreover, there are a total of four fixed-alternative questions allowing multiple choices. Apart from that, one ranking question is about the key challenges of blockchain’s organizational implementation. As for the two open-ended questions, one solicits input on the personal concerns when implementing blockchain, while the other is related to the acknowledged benefits of implementing blockchain.

3.2. Sampling

The targeted population of this research is the professionals of the

the pace of adopting the new technology. Besides, the guaranteed reliability of blockchain is another success factor for its implementation [49]. Security and trust are frequent problems in a system which adopts new technology [39]. The blockchain security technology is designed to carry out transaction processes blocked by encryption techniques, bringing safety and trust to the involved parties. Overall, the new technology should have no crucial weakness in terms of technological features or capabilities [50]. Only when the new technology is proved to be mature and financial, the corresponding adoption can be expected to grow rapidly.

Accessibility is also identified as a success factor of blockchain implementation [51]. This means that there should be sufficient blockchain solutions providers to tackle the occurring problems in the customer companies. Moreover, the cultivation of a blockchain ecosystem in the industry is also a success factor [50]. The industrial community can facilitate the process of garnering participation throughout the supply chain involved in the blockchain. In addition, the opportunity of blockchain-relevant skill training is recognized as another success factor [52]. In this regard, training activities can be organized by the companies or the local governments.

Although there is few research about the success factors of blockchain implementation in the maritime industry, some studies have investigated the topic in a general context. Institutional and governmental support is crucial for the implementation of blockchain [48]. Without such external support, the companies are bearing the risks alone and more inclined to slow down

Consuming substantial amounts of computing power [39]. Moreover, another reason is the high initial investment costs. Paying huge amount of money to technology companies to work on a “private blockchain” is a risk hurting its adoption in the maritime industry [40]. Further, the major liner shipping companies are the most likely parties to benefit from blockchain given the complexity of their supply chains, diverse stakeholders’ needs and huge requirement on financial resources.

The limitation of knowledge and expertise of blockchain also keeps the maritime industry from adopting this new technology [42]. The supply chain operated via blockchain requires multiple parties to comply with various regulations and laws [43,44], increasing the complexity of the new technology. This limitation may result in business failure and further hamper decision to adopt blockchain.

Moreover, the low level of digitalization within the maritime supply chain is also a barrier. The maritime industry can be regarded as a service-based industry which mainly provides transportation services. If the suppliers and customers are not embedded in the blockchain network, the investment in blockchain can be risky to the supply chains [38]. Besides, an international body is required to direct blockchain initiatives into a cooperative standardization, without which the scalability of interoperability will not be optimized. A group of digital leaders from Maersk, CMA CGM, Hapag-Lloyd, MSC and ONE have started discussing the creation of common information technology standards in the maritime industry [45]. Principally, the blockchain technology is designed for information sharing. However, some partners among the supply chain consider such information as a competitive resource, and are unwilling to share this valuable information [46]. This can further limit blockchain’s improvements.

In addition, the maritime industry’s willingness to bear the risk of adopting undeveloped new technology is low and the old-fashioned culture makes the decision makers inclined to be conservative [38]. The maritime industry is regarded as a late adopter of new technology, lacking digital innovation in the process of operation [12]. Besides, from the policy perspective, the threat of overregulation prevents many companies from investing in the blockchain technology. For example, Europe’s tendency to overregulate might prevent European blockchain companies from becoming global leaders in the blockchain field. Germany has been set to strictly regulate the technology as of January 1, 2020. The new legislation will have far-reaching economic consequences for start-ups and companies [47]. From the intra-organizational aspect, some top managers of the maritime industry fail to provide long-term commitment and sufficient support to adopt the new technology. Further, there is an absence of the necessary organizational policy to explain and clarify the usage of blockchain [41].
various maritime organizations located in Singapore’s maritime industry.

For the four in-depth interviews, all the interviewees have either blockchain-related knowledge or maritime industrial experience. As shown in Table 1, interviewee A is an experienced former member of an international quality assurance and risk management organization in the shipping sector, having participated in the organization’s planning and research phase of blockchain implementation. Interviewee B is a safety officer from a ship management organization dedicated to ensuring vessels under their care remain qualified to sail. Interviewee C is a consultant under the maritime advisory department of an international quality assurance and risk management organization. Interviewee D is a lecturer at a prestigious local university specialized in the financial aspect of blockchain application.

For the survey questionnaire, since this research concerns the challenges and CSFs of blockchain implementation in Singapore’s maritime industry, the targeted population covers a wide spectrum of maritime organizations located in Singapore. To construct a sample frame which can represent the population of interest [55], 30 maritime organizations were thereafter identified from the Sea-web Directory by IHS Fairplay. In terms of the type of the organizations represented by the respondents, there are shipping agent, general cargo operator, ship manager, offshore marine supplier, ship owner, freight forwarder, research company and academic institution (Table 1). Hence, the respondents’ backgrounds are widely distributed within the scope of maritime industry, providing this report a broader perspective in determining the key challenges and CSFs of blockchain implementation in Singapore’s maritime industry. As shown in Table 2, 29 out of 30 respondents hold titles such as executive, manager or director.

### 3.3. Data analysis methods

The interview data are used for the establishment of face validity of the survey questionnaire. Thereafter, the data obtained from the questionnaire survey is analyzed and presented using analytic hierarchy process (AHP). Consequently, basing on the survey results, a fishbone diagram and PESTEL analysis are conducted to assist the discussion about the key challenges and CSFs respectively.

A survey questionnaire with a nine-point ranking scale is designed to indicate the relative importance of the identified challenges and CSFs of implementing blockchain in Singapore’s maritime industry. As shown in Table 3, 1 denotes equal importance and 9 denotes the highest degree of priority [56]. The responses on the paired comparison of the criteria formed the pairwise comparison matrices. As a top-down multi-criteria decision-making approach, the principle of AHP is to determine the relative weights of the criteria and alternatives. The major advantage of AHP is that it does not require a large sample size to statistically ensure the robustness of the results [57]. Some studies used sample sizes ranging from four to nine, and only a few studies used sample sizes greater than 30 [58]. The classical AHP has five main steps [59]:

Step 1: Determine the relative importance of the criteria, and construct an n × n pairwise comparison matrix A for the criteria.

### Table 1
Demographics of the interviewees.

| Interviewee   | Title                  | Maritime Sector                        |
|---------------|------------------------|----------------------------------------|
| Interviewee A | Experienced former member | International quality assurance and risk management |
| Interviewee B | Safety officer          | Shipping management                     |
| Interviewee C | Consultant              | International quality assurance and risk management |
| Interviewee D | Lecturer                | Academic                                |

### Table 2
Demographics of the survey respondents.

| Demographics               | Responses |
|----------------------------|-----------|
| Details                    | No. of responses |
| Designation                |            |
| Executive                  | 16         |
| Manager                    | 12         |
| Lecturer                   | 1          |
| Director                   | 1          |
| Years of experience in the shipping sector | |
| 1–5 years                  | 12         |
| More than 5 years          | 12         |
| Less than a year           | 6          |
| Type of organization       |            |
| Shipping agency            | 9          |
| General cargo              | 6          |
| Ship manager               | 5          |
| Offshore marine supplier   | 4          |
| Ship owner                 | 3          |
| Freight forwarder          | 1          |
| Research                   | 1          |
| Academic institution       | 1          |
| Total number. of responses | 30         |

### Table 3
Nine-point relative importance ranking scale [56].

| Relative importance          | Numerical index |
|-----------------------------|-----------------|
| Equal importance            | 1               |
| Weak importance             | 3               |
| Essential or strong importance | 5            |
| Demonstrated importance     | 7               |
| Absolute importance         | 9               |
| Intermediate values between two adjacent importance | 2, 4, 6, 8 |

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Step 1: Determine the relative importance of the criteria, and construct an n × n pairwise comparison matrix A for the criteria.

\[
A = \begin{bmatrix}
    a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\
    \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
    a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\
    \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\
    a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn}
\end{bmatrix}
\]

(1)

where \(a_{ij} = 1/a_{ji}\), A is reciprocal. For every survey respondent, there is a matrix A.

\[
a_{ij} = w_i/w_j (i, j = 1, 2, ..., n)
\]

(2)

where \(a_{ij}\) is the relative importance of criteria i over criteria j. \(w_i\) is the importance weight of criteria i, and \(w_j\) is the importance weight of criteria j.

Step 2: Normalize the column average and row average of every pairwise matrix in a sequential matter. Aggregate all the decision makers’ pairwise matrices. Normalize the row average of the aggregated matrix to reveal the priority vector using the following formula:

\[
p_i = \frac{\sum_{j=1}^{n} a_{ij}}{n}
\]

(3)

where \(p_i\) is the priority weight of criteria i.

Step 3: Determine the relative weight of each alternative with respect to each criterion. Determine the overall priority weight of each alternative.

Step 4: Calculate the consistency index (CI) and consistency ratio (CR) of the pairwise matrices to examine whether the decision makers have made a rational choice.

\[
CI = \frac{\lambda_{max} - n}{n - 1}
\]

(4)
Stage of blockchain implementation in the organizations.

| Current Implementation Stage | Frequency | Percentage (%) |
|------------------------------|-----------|----------------|
| Planning stage               | 8         | 26.7           |
| Initial implementation stage | 6         | 20             |
| Full implementation stage    | 3         | 10             |
| Not considering blockchain technology | 3   | 10             |
| Not applicable               | 10        | 33.3           |
| Total                        | 30        | 100            |

| Current Adopting/Planning Period for Blockchain | Frequency | Percentage (%) |
|------------------------------------------------|-----------|----------------|
| Less than one year                          | 11        | 64.7           |
| Less than five years                         | 4         | 23.5           |
| More than five years                         | 2         | 11.8           |
| Total                                        | 17        | 100            |

where \( n \) is the size of the pairwise comparison matrix, which is six in this research. \( \lambda_{max} \) is the eigenvalue, \( CI \) is the consistency index, and \( RI \) is the random index which is set to 1.24 here [60].

Step 5: Determine the ranking to get the best alternative. In terms of AHP ranking, the challenges and CSFs in this research are not decomposed into sub-criteria because they are directly obtained from the survey and literature. The objective of this research is to identify and rank the challenges and critical success factors of blockchain implementation in Singapore’s maritime industry according to their relative weights.

4. Results and discussion

4.1. Interview results

The results of the four interviews show that the key challenges and critical success factors of blockchain implementation in the maritime industry extracted from the literature are acknowledged by the interviewees. Besides, one more key challenge and one additional CSF were proposed by the interviewees apart from the literature and were adopted into the survey questionnaire. Moreover, the concept of blockchain has already been recognized to be a game changer by some maritime organizations, which are actively preparing to embrace the change brought about by the blockchain technology. All the interviewees’ concerns about the blockchain implementation in the maritime industry are reflected in and aligned with the corresponding parts of the survey questionnaire. They pointed out that the lack of industry knowledge in terms of blockchain implementation and execution can lead to further complications.

Besides, the interviewees were also asked about the parties that they have involved in each of their organization’s blockchain implementation projects. The results show that the parties to be involved are reflected in the questionnaire survey’s targeted population, namely shipping agents, ship managers, offshore marine suppliers, ship owners, freight forwarders, research organizations and academic institutions.

Following the results of the interviews, the designed survey questionnaire is affirmed to be suitable for the following study.

4.2. Survey results and discussion

4.2.1. Survey information

First, 76.7% of the respondents are familiar with the blockchain technology, indicating the responses regarding the blockchain are valid, and blockchain technology has been brought to the forefront of Singapore’s maritime industry.

Next, as shown in Table 4, 17 out of 30 respondents’ organizations are working either in the planning, initial, or full implementation stage of blockchain technology, with eight in the planning stage, six in the initial implementation stage, and three in the full implementation stage. With more than half of the respondents being able to provide their professional insights, this research will be more relevant and appropriate. It is notable that the three organizations which are in the full implementation stage are ship owners, while five out of six which have reported to be in the initial planning stage are ship managers. Hence, the survey data posits that ship owners and ship managers are the two most proactive types of organizations in terms of adopting blockchain technology. These 17 individuals are also required to answer two questions regarding the timeframe and form of external support. As shown in Table 4, 11 organizations have been planning or adopting blockchain technology for less than one year, and all of them are either in the planning or initial stages of blockchain implementation. Four organizations are said to have used or implemented blockchain for less than five years, with one ship owner in the full implementation stage, one offshore marine supplier in the planning stage, one shipping agent in the planning stage, and another shipping agent in the initial stage respectively. Finally, two organizations have more than five years’ experience in blockchain and both of them are ship owners in the full implementation stage.

As for the aforementioned 17 respondents’ channels of external blockchain support, 64.7% engaged the help of professional shipping consultants, 17.6% received support from blockchain development organizations, 11.8% reached out to the Singapore Shipping Association, and 17.6% sought assistance from Maritime and Port Authority of Singapore. The responses are strong indications that external sources of support are certainly helpful for organizations in their blockchain implementation process.

As for the personal concerns in blockchain implementation, 76.7% viewed the complexity of the technology as a concern, 53% were afraid that their current job skills would be incompatible or inadequate, 50% identified that the new management process is inevitable, and 43.3% foresee job losses. In addition, the respondents were also allowed to add more explanations on the concerns in the open-ended question. The open-ended responses include “fear of making mistakes since the data uploading to the platform is changeless”, “no work-in-progress standard operating procedures”, “execution plan not determined”, “requires many meetings with internal external users of the new technology”, “organization’s ability to train and upskill their employees”, “allocate sufficient time and resources to facilitate the project”, “heavy reliance on blockchain solutions providers”, “change in regulations/ lack of legislation support”, “lack of business case studies”, “reliability of technology”, and “platform interface”.

In addition, there were a total of six perceived possible benefits identified from implementing blockchain technology in the maritime industry. 80% of the respondents acknowledge constructing trade documents or contracts as a possible benefit of blockchain, 73.3% perceive information transparency and sharing, 60% recognize verifying the authenticity of information or shipping documents, 53.3% identify fraud detection, 43.3% notice streaming the shipment transaction process, and 10% considers saving printing costs. These findings also indicate that one of the most challenging problems faced by many organizations currently in the maritime industry is the process of drafting trade documents or contracts which is considered to be time-consuming and tedious.

4.2.2. Key challenges of blockchain implementation in the maritime industry

4.2.2.1. AHP results of the key challenges

The 30 respondents were required to give relative importance scores according to their judgment of the importance of one challenge over another. The AHP results demonstrate that the CR values of all the decision maker’s response regarding the key challenges are less than the acceptable threshold value.
how fast the blockchain system can process as more information is will be a lack of successful business case studies, limiting the pace of the another concern. At the early stage of blockchain implementation, there kind of financial stability is hard to achieve. Besides, the organizationsGiven the poor current financial condition of the maritime industry, this implementation (0.25), lack of experienced partners (0.22), lack of data change of legislation and regulation, which can cause extra cost, is cost the organizations a tremendous load as they have been operating down the pace of blockchain implementation [64]. Besides, the maritime organizations may heavily rely on blockchain solution providers due to their limited knowledge and resource about the technical issue of blockchain. In this case, the heavy reliance on several blockchain solution providers can gradually develop an oligopoly market. Moreover, the change of legislation and regulation, which can cause extra cost, is another concern. At the early stage of blockchain implementation, there will be a lack of successful business case studies, limiting the pace of the new technology’s further adoption.

Lastly, from the aspect of technology, the suspected scalability (i.e. how fast the blockchain system can process as more information is loaded) is widely recognized as a concern by the respondents. In addition, questionable data privacy and security can also raise the resistance of blockchain technology [65]. The reliability of blockchain technology is still questioned by the maritime organizations in the Singapore’s maritime industry. In addition, the new platform interface may cost the organizations a tremendous load as they have been operating business in the old ways for too long.

4.2.3. Critical success factors of blockchain implementation in the maritime industry

4.2.3.1. AHP results of the CSFs. The 30 respondents were required to give relative importance score according to their judgment of the importance of one CSF over another. The AHP results demonstrate that the CR values of all the decision maker’s response regarding the CSFs are the standard acceptable value (0.1), indicating that the consistency requirements are satisfied.

As shown in Table 6, the CSFs of blockchain implementation in Singapore’s maritime industry in descending order are as follows: sufficient capital (0.27), staff training (0.24), ease of local legislation (0.16), support from the shipping community (0.15), professional consultation and assistance (0.12), and support from senior management (0.06).

4.2.3.2. PESTEL discussion. Next, the survey results are synthesized and categorized into different PESTEL dimensions to investigate the CSFs of blockchain implementation in the maritime industry (Fig. 2). There are six PESTEL dimensions, namely political, economic, social, technological, environmental, and legal.

First, for the political aspect, as shown in Fig. 2, the corresponding CSF is “ease of local legislation”, which is ranked in the third place (Table 5). The government institutions and frameworks can help support the maritime organizations to facilitate the process of blockchain implementation. Some of the supportive policies can include but are not limited to (1) providing direct financial support and subsidy to organizations who wish to enroll their employees for classes that will help them in using blockchain; (2) implementing tax reliefs and rebates for organizations to lower their financial burden when implementing blockchain; (3) introducing collaborations and schemes within the sector, relevant authorities and blockchain providers; (4) investing more on the blockchain, making the technology more practical and economical to be implemented and switched to.

Second, regarding the economical aspect, the corresponding CSF is “sufficient capital”, which is ranked as the most important factor (Table 6). The economic outlook of the maritime industry has an impact on the maritime organizations’ business decision. In other words, the rate of growth of the maritime industry will determine how fast blockchain is to expand in the upcoming years among the maritime organizations. Meanwhile, maritime industry’s rate of growth is supported by sufficient capital, which can be obtained from investors and financial institutions. Hence, it is pivotal to convince the investors that the blockchain implementation in the maritime industry can generate...
Fig. 1. Challenges that lead to low feasibility of blockchain implementation in the maritime industry.

Table 6
The aggregated AHP pairwise matrix of critical success factors of blockchain implementation in Singapore’s maritime.

|                    | Sufficient capital | Staff training | Ease of local legislation | Support from the shipping community | Support from senior management | Professional consultation and assistance | Priority | Rank |
|--------------------|--------------------|----------------|---------------------------|-------------------------------------|------------------------------|-----------------------------------------|----------|------|
| Sufficient capital | 0.23               | 0.27           | 0.30                      | 0.28                                | 0.26                         | 0.30                                     | 0.27     | 1    |
| Staff training     | 0.25               | 0.22           | 0.25                      | 0.25                                | 0.24                         | 0.23                                     | 0.24     | 2    |
| Ease of local legislation | 0.16         | 0.16           | 0.12                      | 0.16                                | 0.16                         | 0.19                                     | 0.16     | 3    |
| Support from the shipping community | 0.16     | 0.16           | 0.14                      | 0.11                                | 0.15                         | 0.16                                     | 0.15     | 4    |
| Support from senior management | 0.06     | 0.06           | 0.06                      | 0.06                                | 0.05                         | 0.05                                     | 0.06     | 6    |
| Professional consultation and assistance | 0.14     | 0.13           | 0.12                      | 0.14                                | 0.13                         | 0.07                                     | 0.12     | 5    |

Fig. 2. PESTEL analysis of the critical success factors of blockchain implementation in Singapore’s maritime industry.
profitable returns in the future. The perceived possible benefits of blockchain implementation discussed in Section 4.2 can be adopted as the supportive convincing material.

Third, as for the social aspect, the CSFs are “staff training” and “support from senior management”, which are ranked as the second and sixth important factor respectively (Table 6). The social factors about the prospective users of the blockchain technology in an organization can directly impact on the success of their blockchain implementation. For instance, the demographics and social-economic traits of the working population in the maritime industry can affect the rate of blockchain implementation. With a growing proportion of millennials in the workplace, staff training can become more efficient and responsive [66]. Hence, the level of receptiveness for organizational changes within this group of young employees is also higher as compared to the older generations. In addition, senior management carries the responsibility to make decisions and they play a key role in maximizing the organization’s overall efficiency and productivity. Therefore, they need to see the value in implementing blockchain to keep the project teams remain motivated and focused. Moreover, the senior management should also be aware of the learning curves of their employees and periodically send them for development and training programs, which would help achieve a win-win situation between the employees and senior management. Special attention should also be paid assuring employees that blockchain implementation serves as a venue to add value to organizations and labor productivity, and not as a means to replace jobs.

Fourth, with regards to the technological dimension, “support from the shipping community” and “professional consultation and assistance” are the corresponding CSFs and are ranked at the fourth and fifth place respectively (Table 6). As a technology-driven product, blockchain requires partnerships from various entities with respective blockchain providers. International maritime councils such as BIMCO and IMO can encourage the cooperation between maritime organizations and blockchain solution providers. Besides, the maritime companies can also approach to the professional consulting institutions for assistance. In this way, the maritime organizations can have easier access to the technological features and process and save the costs of developing blockchain solutions originally by themselves. For maritime organizations that have the necessary competencies and resources, they can look for ways to acquire technology capabilities. After the group of maritime organizations which have implemented blockchain gets larger and more versatile, the blockchain shipping community can be more functional as there will be more channels of communications.

Moreover, for the environmental aspect, the corresponding CSF is also “support from the shipping community”, just the same as that of the technological aspect. As discussed in Section 4.2, blockchain is perceived as being able to reduce the need for the printing of documents. Other than saving operational costs for the organization, it will promote its brand image by being environmentally friendly. The maritime industry has been seen as a crucial culprit to climate change with tremendous volume of carbon dioxide emissions [67]. Hence, the maritime industry has the potential to play a critical role in reducing global warming. The implementation of blockchain can help improve its public image, which may bring about more investments, thus accelerating blockchain implementation in turn.

Lastly, for the legal aspect, the corresponding CSF is “ease of local legislation” (Fig. 2). The maritime industry is a capital-intensive industry which is also compliance driven [68]. The relevant laws and regulations regarding maritime operations and international businesses can be embedded into the blockchain implementation. Besides, the legal factors that include examples like intellectual property and other data protection laws are important for organizations and can affect their motivation to implement blockchain. In cases where a conflict between parties arises, the enforced laws in the country, such as contract law, play a crucial role in dictating the party at fault. The corresponding laws shall be passed on to make blockchain compatible or implementable.

To summarize, the findings recognize six key challenges and six CSFs of blockchain implementation in the maritime industry. The challenges along with the personal concerns have been discussed via a fishbone diagram from five perspectives, and the CSFs have been analyzed using PESTEL analysis.

5. Conclusion

5.1. Theoretical and managerial implications

This study contributes to both theory and management practices in several ways. Firstly, from the theoretical perspective, this study has identified and ranked six key challenges of blockchain implementation in the maritime industry. From the most to the least concerned challenges, there stand the cost of implementation, lack of experienced partners, lack of data privacy, fear of transitioning to a new operating structure, lack of blockchain knowledge, and scalability. The other identified personal concerns are fear of making mistakes, lack of work-in-progress standard operating procedures, undetermined execution plan, many meetings with internal external users of the new technology are required, organization’s limited ability to train and upskill their employees, difficulty of allocating sufficient time and resources to facilitate the project, heavy reliance on blockchain solutions providers, change in regulations/ lack of legislation support, lack of business case studies, suspected reliability of the technology, and unfamiliar platform interface. Secondly, this research also recognized and ranked six CSFs of blockchain implementation in the maritime industry. From the most to the least acknowledged CSF, there are sufficient capital, sufficient staff training, ease of local legislation, support from the shipping community, professional consultation and assistance, and the support from senior management. Moreover, the research also investigated the maritime professionals’ perception of the potential benefits which could be brought about by the blockchain technology. The results show that the benefits of blockchain mentioned by the existing blockchain research literature are mostly well perceived by the maritime professionals. Overall, theoretically, this research sheds light of identifying the key challenges and critical success factors of blockchain implementation in the maritime industry.

To the managers of maritime firms, it is vital to recognize the importance of blockchain and the corresponding potential benefits. They can actively cooperate with blockchain companies or outsource the relevant tasks to them. To make a seamless switch to blockchain, the managers can persuade stakeholders to provide scheduled training programs to upskill the employees and ease their anxiety of losing jobs. In addition, the collaboration with the professional consultant companies can speed up the process of acquiring the blockchain knowledge to seize the opportunity of getting maritime organizations on the blockchain track.

5.2. Marine policy implications

From the policy perspective, it is paramount that the policy makers launch plans and initiatives to encourage the maritime organizations to implement the blockchain technology, thus cultivating the environment of switching to blockchain. Besides, regulation and legislation regarding blockchain adoption in the maritime industry shall be eased and made clear to the maritime organizations. Given the global nature of the maritime industry, ensuring the ease of blockchain adoption through legislation shall be at both national and international levels. Moreover, relevant blockchain training and education programs can be promoted by the policy makers as a form of public welfare to give the employees new opportunities and help the organizations save the training costs simultaneously. Further, the governments can provide more research funds and subsidies to the relevant research projects, making blockchain more suitable and customized for the maritime business. This could mitigate the risk of frequent modifications and switch after the implementation of blockchain, lowering the additional cost. Apart from the
professional researchers and blockchain solutions providers, third-party consultant companies can also be invited by the policy makers to set up branches in the maritime cluster and to provide the cluster-resident organizations with necessary consulting service and an opened vision, paving the way of blockchain implementation. The governments can also persuade the banks to offer more relevant and meaningful terms to the maritime organizations which are planning to implement blockchain. In addition, blockchain’s potential contribution to reducing ships’ emission is not thought highly of by the maritime professionals, as compared to the other perceived benefits of blockchain technology. The IMO can make use of blockchain to examine the implementation of IMO 2020. Further, more conferences about the blockchain technology can be organized in the maritime industry to promote the blockchain concept among the senior management of the maritime organizations. Given the situation of the ongoing Covid-19 pandemic, these conferences can be held virtually.

5.3. Limitations and recommendations

Although this study sheds light on the key challenges and critical success factors of blockchain implementation in the maritime industry, there are a few limitations. First, in this study, the interviews and survey were conducted within the scope of Singapore’s maritime industry. The results may be different in other maritime countries or clusters due to the social and cultural differences. Besides, the valid sample size of four interviewees and 30 survey respondents is considered to be relatively small.

For future research, the relationships between the organizations at different blockchain implementation stages and their respective perceived challenges can be analyzed, providing reference and guidance for the organizations which are planning to implement blockchain in the future.

Lastly, there may be an increase in the maritime industry’s willingness to implement blockchain in the post-Covid-19 period. This area will likely see more interesting initiatives to help the industry overcome the inconvenience brought about by the pandemic.

CRediT authorship contribution statement

Yusheng Zhou: Methodology, Formal analysis, Writing - original draft, writing - review & editing, Visualization. Yung Shan Shoh: Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. Hui Shan Loh: Conceptualization, Supervision, Writing - original draft, Writing - review & editing. Kum Fai Yuen: Conceptualization, Supervision, Writing - original draft, Writing – review & editing.

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