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# Boosting the Decision-Making in Smart Ports by Using Blockchain

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**ABSTRACT** Blockchain technology (BC) offers an innovation platform for decentralized and transparent transactions in the maritime port industry. This technology allows guaranteeing trust, transparency and traceability of cargo and data to be tracked. Today, in the port systems of emerging market countries, BC technology is increasingly being incorporated into information and communication processes. In parallel, the social domain has begun to be explored due to the lack of link between the port and the city it occupies, and the need to incorporate public actors in decision-making at the governance level. In this sense, the present work aims to promote BC technology in order to transform data and information into useful knowledge for effective decision making, through the use of Crowdsourcing. A Crowdsourcing Blockchain CrowdBC conceptual framework and its architecture are generated for a port system in which the cyber-technological, social and cognitive domains (CSTC) of smart ports, the knowledge generation process and Crowdsourcing technology are interrelated. Finally, opportunities are discussed for ports that are in permanent development to reduce the gaps with the smart industry. As a discussion, two possible scenarios and recommendations for future implementations that consider the social and cognitive aspects of Industry 4.0 are presented.

**INDEX TERMS** Blockchain, Crowdsourcing, cybernetic-social-technological-cognitive model, smart port.

## I. INTRODUCTION

### A. BLOCKCHAIN IN MARITIME PORTS

Blockchain (BC) enables improving processes involved in Information and Communication Technologies [1], by increasing the number of transactions carried out in foreign trade businesses, and reducing costs and time involved in transactions [2]. In the maritime industry, technology has been used to improve efficiency and facilitate negotiations between buyers and sellers with online records that do not involve third parties [3]. More secure data transactions can be carried out without risk of loss, as they are stored in blocks that form a chain; decentralized transactions are maintained, thus, increasing the speed of transmission with distributed, auditable and sustainable features [4]. The anonymity of all network participants is maintained and the information can

be managed and validated by all network participants [1]. To generate a new block in the chain, all nodes in the network must participate in the validation process using a consensus protocol [5]. When the information is validated by the entire network, it is added to the existing chain and cannot be modified [6].

With public records and smart contracts, the BC automatically defines the terms between the parties through a program [7]. That is, a potential buyer can clearly determine the origin of the product, ownership details, and traceability of the cargo [8]. By using this technology, the communication between the agents that conform the export and import logistics chains can be made in a more secure way, increasing the trust relationship between the different actors, providing transparency in the processes and activities involved in each link of foreign trade [3]. Other benefits for the logistics operation relate to the fact that it is not possible to delete or modify the data entered, data can be tracked at all times; it is

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possible to efficiently send a lot of information in real time, and smart contracts are used [9]. This improves the control level for products and services in each of their links in the port industry and records all the characteristics of the products or goods being transferred [10].

BC has been investigated in container shipping to avoid wasting time in handling each container and reduce the cost of logistics activities, improving the competitiveness of a country's foreign trade [8]. BC technology has been used to protect customs documents and receipts with trust protocols with the aim of avoiding the risk of falsification, thus improving transparency, immutability and security of data and contracts [11]. In the field of public policy, it has been discussed how emerging technology can solve urban planning problems that affect the quality of life of the inhabitants of a smart city [12]. There has also been a critical evaluation of the innovation and transformation of government processes, by discussing the gaps that exist to achieve governance models with BC developments in public organizations [13].

### **B. BLOCKCHAIN BASED CROWDSOURCING SYSTEM**

Crowdsourcing is widely used in companies as it is considered part of the digital strategies that are focused on the generation of new innovation models that deliver competitive advantages to the business [14]. It is possible to define this technology as a sourcing system in which organizations and/or individuals collect from a huge group of participants large amounts of data related to citizen ideas by means of voting, with multiple microtask modules and/or with big data; with interviews and surveys that seek to reconstruct or promote the identity of a brand, among others [15]–[17]. It works with collaborative applications [18] that can be non-interactive and interactive among users [19], includes Machine Learning techniques [20], and it is relatively open and often evolves rapidly [15].

The Crowdsourcing system has been studied in the maritime field to improve the security of ship traffic surveillance in real time, increasing cooperative and multi-channel capabilities [21]. It must be mentioned that research has been mainly focused on areas such as defense, social innovation, databases, web/software development and others; but the investigation regarding seaport management is still underdeveloped [22].

On the other hand, Crowdsourcing contributes in public organizations to the creation of public policies since it facilitates the collection of information related to citizens' needs, which is useful to generate new innovative ideas that allow solving social problems and promoting organizational learning [23]. It makes public services more effective and creates value by sharing the life experiences of communities that are increasingly empowering themselves [24]. In this way, local governance is strengthened [25], the government can achieve an active role that generates value to public administration [26], or a passive role in which information that has been freely generated by the public is collected [27].

It must be mentioned that the public sector is just beginning to use this technology, and that private companies are more mature in its application [27]. More and more public administrators are recognizing the potential of using Crowdsourcing because it improves the service provided to citizens, reduces costs, generates policy innovations, and therefore, increases the participation of workers and their customers [28].

Despite the advantages of Crowdsourcing for private companies and public organizations, in which the risks of operational activities are minimized and decision making is more efficient [14], the technology presents vulnerabilities in the handling of information and private documentation, since it could be lost, disclosed or made public [23], [29]. Another weakness of the technology is that online platforms use a centralized server that can be insecure in front of attacks, damaging the security of the system [30]; reflecting a situation that generates risks in the use of information [31] and affects the organizational resources of the business [14].

As a solution for the above mentioned problem, it has been proposed to combine Crowdsourcing with BC. This new technology allows to collect ideas that can be used to innovate in Information and Communication Technologies, promoting a greater and secure participation that facilitates the interaction between people, public organizations and private companies, by means of encryption techniques that protect the system from false data [32], [33].

In addition, BC can organize knowledge-intensive activities efficiently and generate new explicit and implicit intangible social assets, created by the expression of opinions, behaviors, skills, abilities, capabilities and experience [34].

The combination of these technologies can change a company's business model by replacing human intervention with automated and flexible functions [35]. Crowdsourcing based on BC increases trust, transparency and confidentiality in the management of public data, as it is an anonymous system that protects transactional information by ensuring fair payments in the event that rewards are cancelled for data [36].

There are few studies related to the implementation of both technologies in private companies and public organizations; most of the information published refers to systems and applications of bitcoin in the field of management [37], [38]. In the literature, decentralized protocols are presented that take advantage of the multitude of sources [39] with incentive systems that improve the security and privacy of the code [40], where anonymous protocols are used based on the signature of groups, authorities, rings, and trees of hash to protect privacy with smart contracts [41]–[43]. If systems built on a hybrid structure of blocks with double registers and dual consensus algorithms have been investigated [38], a management platform zkCrowd is proposed that integrates transactions between public and private actors, that uses consensus protocols for verification from a public chain and multiple sub-chains [41]. The ZebraLancer system is deployed with fair incentive mechanisms that allow the participation of anonymous workers and users without renouncing their assigned work responsibilities [35].

### C. NOVELTY AND CONTRIBUTION

The motivation of this research is to investigate the main technological aspects that have been studied in the maritime ports, with emphasis on the identification of the inhabitants's needs, in order to reduce the negative externalities generated by the installation of a port industry in a city. In other words, the aim is to know if the social aspects are aligned with the decision making of the public-private ports in Chile, and if they are linked to public policies that would be more effective and closer to the community. By determining these aspects, both the port administrator and the State agencies that regulate, administrate and coordinate the ports could, for example: incorporate aspects of sustainability that generate shared value [29], [44]; have more transparency in the processing of information; increase the instances of dialogue that are more representative to improve port-city relations; and make predictions of events related to port stoppages, to avoid the loss of profitability generated by social problems/disturbances.

In order to investigate the aforementioned objective, it is studied how the data or information that people have could be collected by means of Crowdsourcing, to transform it into useful knowledge that can be employed by decision makers to improve their strategies. On the other hand, as the port is made up of export and import logistics chains that transmit data between its actors, it is proposed to use BC due to its technical characteristics. Then, in the present work, the following research question is posed: Can Crowdsourcing be used together with the BC in a Chilean port to solve social problems between port companies and the inhabitants of the city they occupy?. These technologies are selected since they allow to safely obtain large amounts of data that can be processed using machine learning techniques [29], [32], and due to the fact that the incorporation of technological innovation is one of the strategic challenges posed for Chilean ports by the year 2030 [45].

This article proposes a conceptual model of a Blockchain-based Crowdsourcing for a publicly owned Chilean medium-sized port concessioned to private companies, which is classified as Industry 3.0, with some attributes of Industry 4.0. For this reason, in Section II a bibliographic compilation is made to characterize BC technology according to the cybernetic, social, technological and cognitive domains [46], and thus know its attributes and find out if it can be linked to Crowdsourcing. In addition, the maritime port context in Latin America is described to find out what is the degree of development for said region. Section III proposes a conceptual port model that uses technologies and is useful for making strategic and business decisions based on the needs of the inhabitants. In Section IV, a discussion about the proposed model and design is presented; and, finally, Section V presents the conclusions of the work.

## II. BLOCKCHAIN DECISION MAKING IN PORT SYSTEMS USING A CYBERNETIC, SOCIAL, TECHNOLOGICAL AND COGNITIVE MODEL

In order to investigate whether BC can be related to a technology that can collect a large amount of social data, the systemic

Cybernetic, Social, Technological and Cognitive (CSTC) model is used for smart ports of fifth generation [46]. This model is selected as it relates the ideas, perceptions, data flows, information and knowledge that are linked to the decision making of a smart port. With Cybernetic, Social, Technological & Cognitive (CSTC) it is possible to classify the assets of a company according to four domains, which would be: cybernetic (Internet, IoT, digital networks, clouds and software platforms), social (community platforms and networks, organizational and environmental aspects), technological (IoT, Artificial Intelligence, Information Technology and Cybersecurity) and cognitive (knowledge).

### A. BLOCKCHAIN CLASSIFICATION ACCORDING TO CSTC MODEL

In Figure 1 and Table 1, through a bibliographic review and the CSTC model, the possible connections and attributes that the BC may have for the management of port logistics chains are identified.

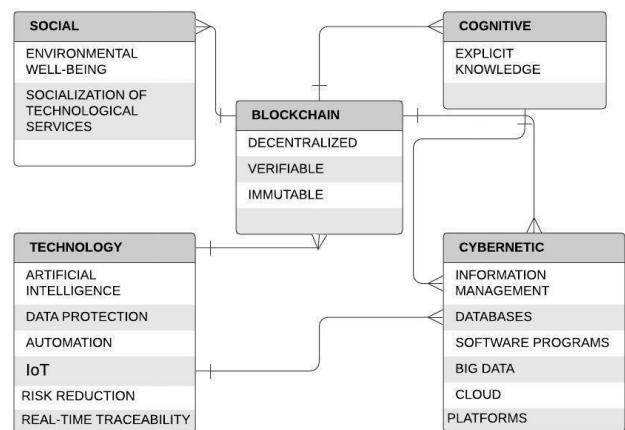


FIGURE 1. CSTC model applied to BC.

In Figure 1 it is observed that the technological and cybernetic domains have more attributes of industry 4.0, which is mainly due to the fact that new port services have been generated based on information and telecommunications networks, which require technological assets capable of processing and synthesize a large amount of data in real time. It should be said that in this sector, technological transformation is considered an added value for the systems that process strategic, business and operational information. This innovation improves decision-making, increasing the effectiveness and efficiency of the activities of the export and import logistics chains [44].

On the other hand, both in Figure 1 and in Table 1 it is noted that the social and cognitive fields have fewer attributes related to social aspects and the generation of knowledge. Further study of these aspects is required to socialize services, develop community platforms that help improve relations between the port and the city, respond to the needs of workers and improve maritime port public policies.

### B. LATIN AMERICAN CONTEXTS

Despite the fact that many Latin American ports are classified as part of Industry 3.0 with some intelligence characteristics,

**TABLE 1.** Main characteristics of BC according to CSTC model.

Blockchain characteristics	Domain	Implications
Benefits in logistics chains due to platform integration [47].	Cybernetic	The integration of technologies with BC offers many opportunities for scalability and security in the processes [48], [49].
Verification and protection of data and information by means of Smart Contracts [50].	Technological	The challenges of smart contracts, besides dealing with the technical or technological aspects, must consider the economic and regulatory / legal aspects [51], [52].
Association with relational databases built with Ethereum and MySQL in combinations with Internet of Things (IoT) [53].	Cybernetic, Technological	Generally, relational databases are susceptible to deterioration after the data set exceeds a size threshold. [54].
Improvement in Data and information protection thanks to a distributed database [55].	Technological	Chen <i>et al.</i> [56] propose applying BC technology to protect users' privacy with a database file storage method using client-side processing power in big data environments.
Environmental efficiency of maritime industry [3].	Social	Some seaports are adopting good ecological practices in logistics operations to improve economic and social performance, while respecting environmental sustainability [57]. For example, the records of heavy diesel oil movement operations using BC help creating a more environmentally friendly maritime industry [58].
Process efficiency generating reduction of commercial costs that benefit buyers, and explicit knowledge (paperless trade) [59].	Technological, Social, Cognitive	The Internet to do business can be used in a more efficient way, to serve its customers more effectively and to build long-lasting business relationships with customers [60].
Physical processes automation by means of Information Technology solutions [8].	Technological	The essence of a cyber-physical system, Industry 4.0 with last generation integrated systems in more robust communication systems using advanced artificial intelligence to have more sustainable critical production activities [61]. Rathore [63] proposes a decentralized security architecture supported by Software Defined Networking (SDN) and BC, which is supported by three core technologies of SDN, Fog, BC and mobile edge computing for the detection of attacks.
Information security by means of a decentralized computing model [62].	Technological	Fan <i>et al.</i> [64] propose a much more secure and verifiable data intercommunication scheme to solve the problem of traditional encryption schemes centered on ciphertext policy attributes (CP-ABE), which lack credibility due to centralization.
Secure and verifiable information [11].	Technological	The BC helps to develop trust between unknown actors in a supply chain by maintaining good levels of privacy and transparency at the same time [65].
Transaction transparency and data protection in the logistics chain [6].	Technological	Traceability is a must for the supply chain that satisfies BC technology [67], integrating an RFID (Radio Frequency Identification) system for the physical positioning of the goods within the supply chain process [68].
Traceability by integrating positioning technologies [66].	Technological	Real-time control of information exchange and traceability of activities in the supply chain process [68], [70].
Real-time control of the activities of a process [69].	Technological	For the development of sel IoT in a Cloud Computing and security environment with BC, it is necessary to have analytical tools for Machine Learning, Artificial Intelligence, Big Data and data science that can respond accurately in real time and be scalable [72].
Challenges are addressed by taking advantage of IoT, Artificial Intelligence, BC, Machine Learning, Big Data and Cloud Computing [71].	Cybernetic, Technological	The use of BC technology and software applications that promote cooperation between actors, by sharing information and data, allows to mitigate the lack of coordination and inefficiencies of the processes to obtain a reduction in operational costs and a better performance [74].
Efficiency improvements in administration and information management by using software, resulting in reduction of costs and risks [73].	Cybernetic, Technological	

due to the need of handling large volumes of data in secure logistics chains, they have progressively incorporated more technology from Industry 4.0 such as Artificial Intelligence, Internet of Things, BC and Big Data [75]. The use of these technologies has promoted more technological innovation and the use of standards, improved container transport operations, created more operational efficiency in container shipping, increased the speed of cargo transfers and decreased time of permanence of merchandise in seaports; and increased both transparency and real-time access to container data and shipping documents between exporters, shipping companies, port and terminal operators, inland transport and the customs authorities [76].

The incorporation of technologies related to Industry 4.0 could contribute to solve the lack of efficiency and the excessive logistics costs that are generated in ports. In particular, an improvement in the traceability of goods

and the transparency of real-time information flows in the export/import logistics chains could also optimize inventory control [77].

Based on the information obtained from the Economic Commission for Latin America and the Caribbean ECLAC, and the data extracted in real time from the Tradelens platform [75], [77], [78], it can be deduced that during 2020 in Latin America less than 1% of port operators use BC in a systemic and collaborative way. Some of the operators that use this technology are: Terminal Pacífico Sur (Chile), San Vicente Terminal Internacional (Chile), Terminal Itajai (Brazil), Port of Santos (Brazil), Port of Fortaleza (Brazil), Terminal Buenos Aires (Argentina) and Terminal Callao (Peru).

In relation to the CSTC model [46], Latin American ports can be characterized according to the above-mentioned domains:



- *Cybernetic*: Databases and computer programs interconnected with maritime traffic are used to manage the physical and information flows of the export and import logistics chain [46].
- *Technological*: There are some smart technologies that are considered as the most important and challenging for innovation in logistics processes, the port-city relationship, and sustainability [79].
- *Social*: Collaborative work platforms are created for port community management networks such as logistics forums. This domain can be described as increasingly affecting the strategic aspects of governance. Taking said domain into consideration would improve competitiveness between ports, the environment and social capital innovation [44].
- *Cognitive*: Includes the learning and knowledge acquired in the creation of synergies between the city and the State, and the changes incorporated for the modernization of the port business model.

### III. BLOCKCHAIN-BASED CROWDSOURCING SYSTEM IN CHILEAN PORTS

This work presents a proposal for a conceptual model of a technological development of Crowdsourcing based on Blockchain CrowdBC for a Chilean port, in which the task of an applicant can be solved by a network of worker nodes with privacy and security [80]. As shown in Figure 2 in a CrowdBC system, users are the workers assigned by a port Community that fulfills the function of managing and operating the port with its terminals, workers' unions, and the citizens living in the port city. It also includes the private companies that make up the export and import logistics chains, and the State agencies that fulfill the function of articulating and coordinating port management.

Users enter data in a collaborative platform, which is transformed into information and explicit knowledge useful for making strategic, business and operational decisions in the Port Community. With regard to domains, ports can evolve from the cyber-technological sphere to the social one, integrating, relating and interpreting the needs of social, private and public actors; creating intelligent synergies between the port, logistics companies, the city, and public organizations. It should be mentioned that, currently, the cognitive domain is not well developed and it is considered that this is the area that will be a great challenge for the port industry in the future [79].

#### A. PROPOSAL OF A CrowdBC CONCEPTUAL MODEL

The report on Port Strategy and Logistics in Chile for the year 2030 [81] indicates technological aspects related to the need of modernizing the labor relations of workers, increase scientific and technological research; and promote collaboration between universities, private companies and the public sector. The inclusion of the CrowdBC is a challenge for the country, which can be seen in the results obtained in the interviews with three senior executives from two Chilean ports, where

73% of the workers declare that they have some degree of knowledge on what BC is.

In Figure 3 a case study is presented regarding a shipping contract logistics process, in which there are the following stages: commercial agreement, space reservation, export procedures, container storage, inspection of forest and agricultural products, coordination of land cargo, reception in the cargo area, ship exit procedures, bills of lading, among others. Part of the document management system is shown, which is made up of the administrative entity, the terminals, the private companies that provide logistics services to foreign trade, and the public bodies that perform an oversight function.

On the other hand, Chilean ports have focused their investments on the technological and cyber domains, increasing physical assets as they generate more profitability for the business. They have also begun to explore the social domain, where there is a lack of linkage between the port and the city it occupies, and a need to incorporate public actors in decision-making at the governance level. In relation to the cognitive domain, despite the fact that intellectual, structural and social capital are intangible assets for the creation of knowledge, these aspects have been less studied. Incorporating the social and cognitive domains in the strategies and businesses of the port can generate competitive advantages [79].

Figure 3 presents a CrowdBC conceptual model for the document process shown in Figure 2. The proposed system operates as a transactional platform for electronic messages that can improve management times, giving greater visibility to the data and the information that is operated, in order to achieve effective decision making. CrowdBC can be related to the social domain, in which the platform can collect data on complaints and/or suggestions from users and transform them into knowledge or cognitive level. For example, it is possible to identify the needs for specialized digital knowledge related to the skills and profiles of the workers, as well as to determine innovative initiatives that promote the exchange of experiences among users; and a collaborative information repository could be maintained among the port system actors and city dwellers.

#### B. CrowdBC SYSTEM FRAMEWORK

In the CrowdBC proposal that is observed in Figure 4, the application could receive, process, store, simulate and model the questions, suggestions and/or complaints that are entered on the platform; either directly or anonymously, so that decision makers can analyze data and information to take preventive and predictive actions. In this sense, it is possible to contributing to more efficient and effective solutions. There are two functions in the technological system: Applicant and Worker. These roles interact with a client web application called "Crowdsourcing App", which is a CrowdBC client application that serves as a means for the Applicant, the Worker and the system.

Applicants post a task request indicating the description of the task to the programs, and workers respond to a task request indicating their interest and responding to the request.

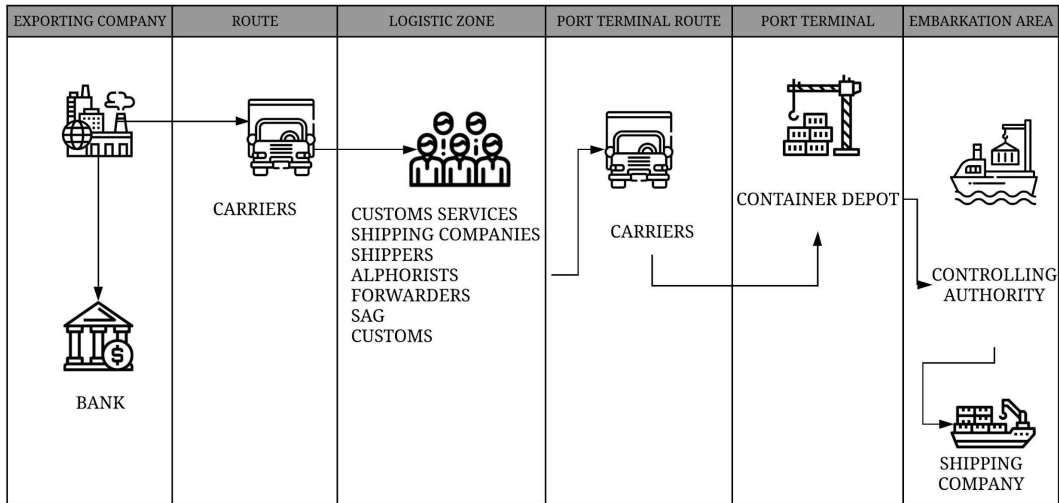


FIGURE 2. Export logistics chain of the Chilean seaport.

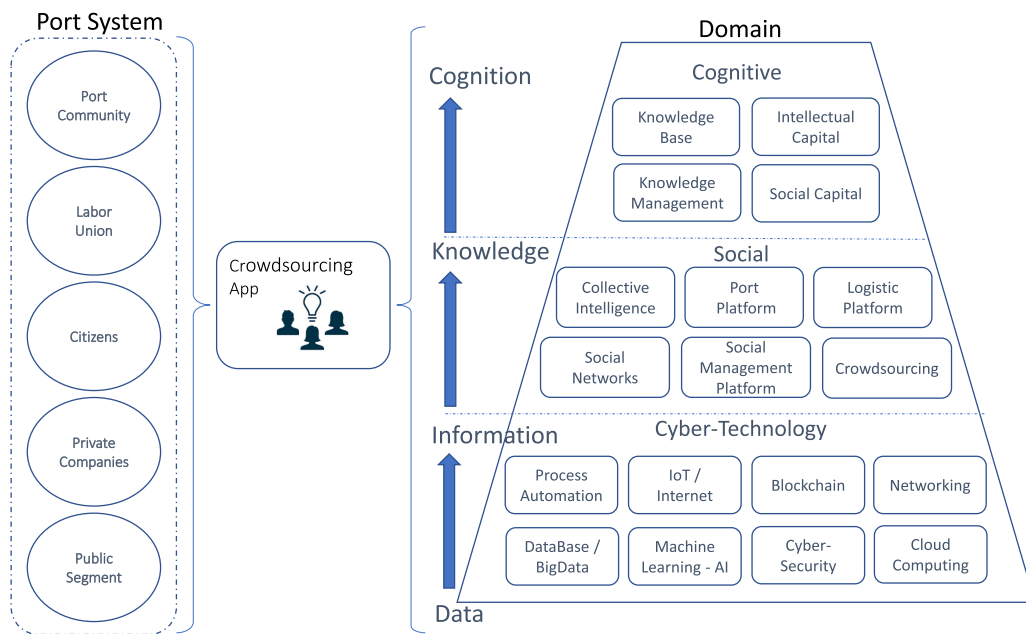


FIGURE 3. CrowdBC conceptual model.

As for the workers, they are part of the Port Community and require specific skills and knowledge to ensure the fulfillment of the assigned tasks.

The relationship between the Applicant and the Worker is important because it depends on the operation of the model. For this reason, the participation of both parties is promoted by offering them specific rewards and penalties (or ends).

It is important to mention that the Crowdsourcing application is not controlled by a third-party system, and can be executed locally on the personal computer of any user; so

that the Applicant and the Worker reach a consensus through transactions in said application. When it comes to managing user access and data in the crowdsourcing app, Applicants and Workers get unique credentials to interact with the app. Applicants and authenticated Workers can exchange data and fair rewards.

On the other hand, the CrowdBC proposal is divided into layers: first, the Crowdsourcing application; second, the smart contracts; third, the BC. As shown in Figure 4, the first two layers (located at the top) are in the logic plane,

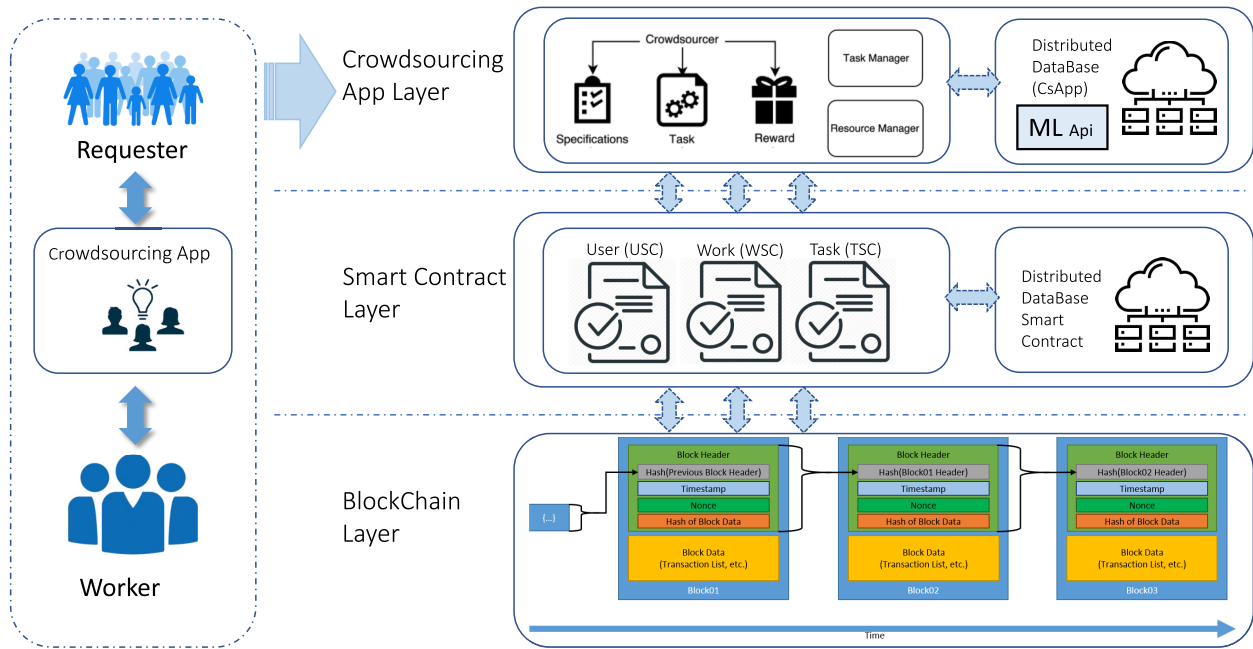


FIGURE 4. CrowdBC proposal for seaport.

and both layers extend to the stored data plane. The BC layer uses the status changes of the tasks as input, to reach a consensus between the workers and the requesters.

Each of the layers of the proposed CrowdBC system is described below.

### 1) CROWDSOURCING APP LAYER

This layer is a CrowdBC client application that serves as a medium for Requester and Worker, and the system. It is a web client that can be run locally on the user’s personal computer. In the scope of the Crowdsourcing, tasks are specified, the status of requested tasks is seen, and rewards are assigned. There are modules for task and resource management of the application. This layer has a plane to store data that have been generated by users and their interactions. Such information can be accessed by a Machine Learning model that connects through a service to a distributed database that stores the data for this layer.

### 2) SMART CONTRACT LAYER

The smart contract layer is adopted to specify tasks. In general terms, in each task, the list of requirements is detailed by the Requester. These are transferred to programs, which are known as smart contracts. Workers select the specific task, given their knowledge and skills, including their proposal, and if it is accepted, the smart contract is agreed upon. We propose three types of smart contracts: User Smart Contract (USC), Task Smart Contract (TSC), and Work Smart Contract (WSC). USC describes a valid registered user, organization, skills, payment information, among others. TSC

describes all the requirements of a specific task. WSC is a Requester-Worker relationship Smart Contract. This layer has a plane of stored data, those that have been generated for the smart contract. This information can be accessed through service to a distributed database that stores the data for this layer.

In BC the necessary and minimum data of each smart contract is stored, this is because the processing of information in BC is expensive, both in encryption and decryption and assurance of the consensus protocol. Figure 5 shows the basic data of the smart contract, which is included in each transaction in the chain.

The data stored in the smart contract of the export logistics chain shown in Figure 5 is detailed below:

- SC\_ID: corresponds to the identification code of the smart contract.
- SC\_DateTime\_Creation: is the date and time of creation of the smart contract.
- SC\_Requester: corresponds to the ID of the person requesting the information and / or task.
- SC\_Worker: corresponds to the ID of the person who responds to the request for the required information and / or task.
- SC\_State: indicates the status of the contract process.
- SC\_Request\_Type: indicates what type of requirement corresponds (Information, task, more information, questions and answers, etc.)
- SC\_Request\_Description: describes in depth what is requested by the requester and creator of the smart contract.

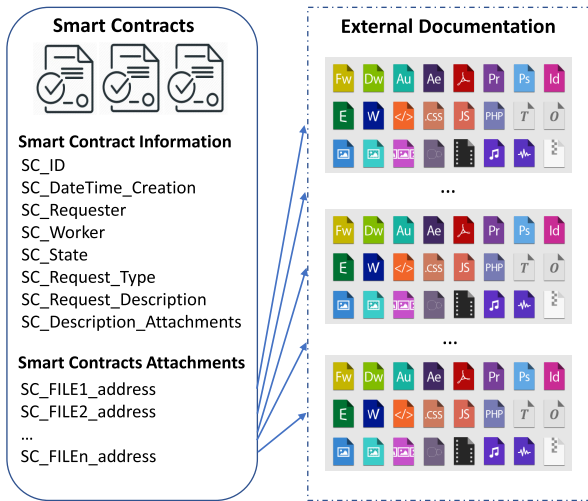


FIGURE 5. Smart contract.

- SC\_Description\_Attachments: indicates the detail and description of the files and attached information.

It is important that the information required in the request or the response to any request can include any type of file (image, text, video), which implies an excessive file size to be processed by the BC. Therefore, the attachments of smart contracts are indicated with the physical address of the files, which can be on external servers and databases anywhere in the world.

- SC\_FILE1\_address: Physical information file 1
- SC\_FILE2\_address: Physical information file 2
- ...
- SC\_FILEn\_address:: Physical information file N

### 3) BLOCKCHAIN LAYER

It represents the secure and distributed network. It provides consensus on the order in which smart contracts are generated and carried out. Furthermore, it maintains the state of the network under execution. The proposed framework determines that the logic for smart contracts corresponds to cryptographically-guaranteed transactions. Generally speaking, the blocks in the BC layer should not store too much data. To reduce the size of the data stored in this layer, the metadata is separated from the actual data storage. In detail, the task attachments and the solution data are stored outside the BC in the distributed database of the Smart Contract layer.

Although there is a large amount of data that is generated from the relationship between Applicants and Workers, the data storage capacity in the BC is limited. Therefore, we separate CrowdBC data storage into the first two layers, specifically the Crowdsourcing app and Smart Contract layer. This separation can significantly improve CrowdBC's data storage capacity. We incorporate the task metadata (such as data size, owner, hash value, pointer) in the BC layer, and the data in the smart contract layer. Thus, users do not need to trust the data stored in the smart contract layer, but can verify

the integrity and authenticity of the data in the crowdsourcing application layer.

### C. CrowdBC ARCHITECTURE

The proposed CrowdBC uses the BC system and smart contracts to use a decentralized platform, which is different from traditional centralized crowdsourcing. Figure 6 presents the CrowdBC architecture, which is composed of a modular building block with the following elements:

- Users of the Application. The upper left side of Figure 6 represents the users of the application (Requesters and Workers). Each of them must be authorized to enter the application and work on it.
- Crowdsourcing App Web. The upper right side of Figure 6 represents the CrowdBC client web application. The application is built by modular blocks, such as: an authorization and security module, a user profile module, a task management module, and a data visualisation module. In addition to a smart contract management module and a smart contract data management module, the latter includes a Machine Learning sub-module.
- The BC Network. The lower left side of Figure 6 shows a representation of how the documentation could be recorded on a block in a BC network, so that information is traceable and unchangeable. The documentation of the different activities of the process is collected in a block of the network. Each block has a precise and fixed place within the chain because they contain information about the hash of the preceding block.
- Distributed Database for Smart Contract. The lower right side of Figure 6 represents a distributed database for smart contracts. As we have previously mentioned, there is a large amount of data collected from Applicants and Workers that is passed on in smart contracts, for which we put the information of the task metadata (such as the size of the data, the owner, the hash value, the pointer) of the BC and the raw data in the smart contract module. It's encrypted and easily accessible from the BC.

In foreign trade, when generating smart contracts, the use of paper is eliminated and the process becomes faster and more sustainable; intermediate actors are not needed and costs are lowered. Also, the risk of international business transactions related to customs inspection, transportation and financing is reduced [59]. Likewise, the quality of the data is improved and clauses are written in the computer programs that are automatically executed when the conditions defined by both parties are met [69]. With smart contracts, it is possible to maintain relationships based on trust, optimising the costs and time involved due to access to information, automation, reduction of bureaucratic processes, transparency, trust, risk minimisation, traceability, and immutability in the logistics chain [6].

Regarding smart contracts in the system, we adopt a design of CrowdBC that supports smart contracts in BC. A smart



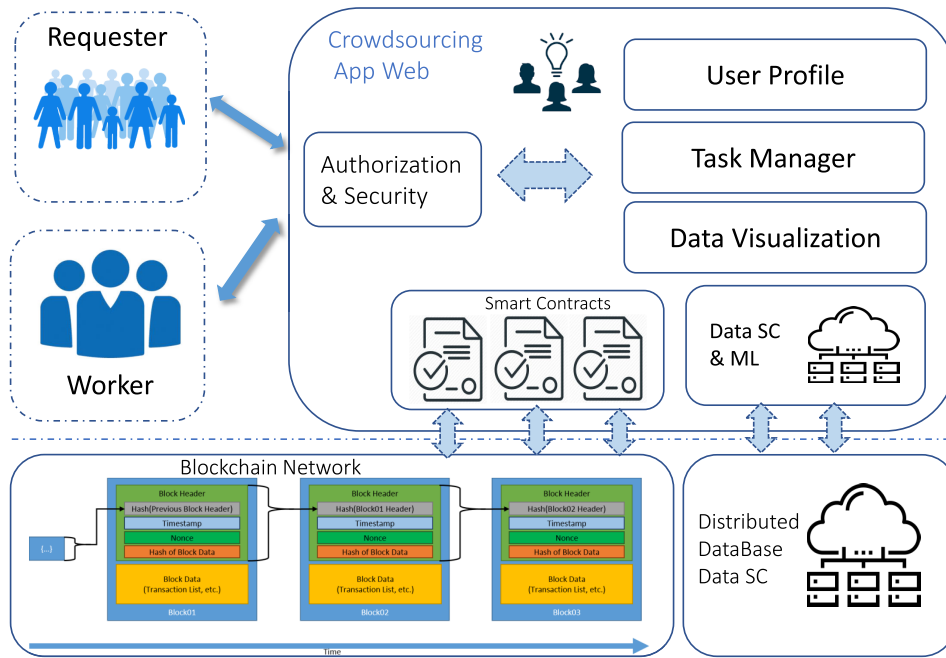


FIGURE 6. Proposal of CrowdBC system architecture.

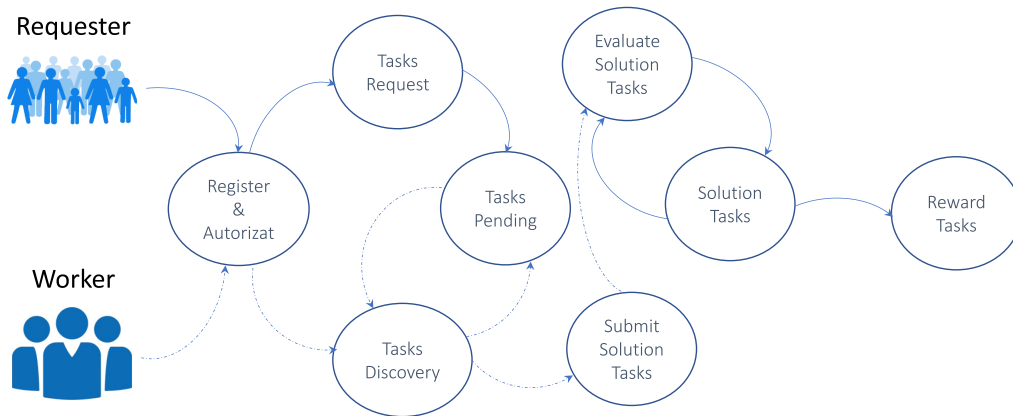


FIGURE 7. Flow of interaction between requester and worker for tasks in CrowdBC.

contract can be considered as a program, which is created when a user registers. Other contracts represent a summary and description of a user contract, and finally, one with the contractual relationship between users.

In a decentralized Crowdsourcing architecture, like the CrowdBC proposed, most operations must be re-designed, such as task posting and job matching in the proposed system. With the smart contract and decentralized BC platform, the new process of a complete crowdsourcing activity in our proposed CrowdBC system can be shown as Figure 7. Basically, the process flow can be described as follows. Duly authorized Requesters register a task request and wait for some Workers to respond to the request. Duly authorized

Workers wait for a task request, and upon finding one, they respond to the request. Workers constantly review pending tasks, and when they find a task they can solve, they make a solution proposal. The Requesters review the answers to their tasks and evaluate the proposed solutions. Requester and Worker reach a consensus on the solved task. Finally, the Worker receives a reward.

#### IV. DISCUSSION

##### A. PORT TECHNOLOGY STRATEGIES

For the modernization of Chilean ports, strategic objectives have been defined for the year 2030 that establish the need for a secure platform [81] able to connect and coordinate all

**TABLE 2.** Comparison of two possible implementation scenarios.

Dimension	Current Situation	Blockchain, Crowdsourcing or CrowdBC Situation
Cost for the service	The operation commissioned to be carried out internally by the port operators is more expensive [21].	Crowdsourcing is a more economical approach [85], which allows an economy of scale.
Quality of service Time to value	Port activities operate with quality standards [46]. The data transmission process is slow [87], which causes a loss of value over time [88].	The crowdsourcing contract must be formally endorsed [86]. High speed of reception of the needed data [21], [87], logistic chain works faster.
Scope of the solutions	It is not currently developed to provide solutions.	When using crowdsourcing, the scope of solutions is broadened, representing a key challenge. Crowdsourcing will attract a large number of participants and solutions when applied to improve the relationship of the maritime ports with the community [21].
Open innovation	Open innovation is limited to port operators, excluding outside ideas.	The concepts of open innovation and crowdsourcing help port operators can take external ideas to improve internal processes, facilitate innovation and improve productivity and competitiveness of the port [89].
Collective intelligence	Opportunities to rely on collective intelligence (provided by the community) to deal with potential conflicts are wasted.	Crowdsourcing is presented as a viable option for port operators to take advantage of collective intelligence [90].
Sustainability	Opportunities to raise sustainability projects that are born from the community are missed [44].	According to [91], crowdsourcing represents the majority of those projects that address sustainability issues.
Regulation	Regulations are reactive to the needs of port development in conjunction with the development of the city [92].	Compilation of useful data from the logistics process and the community to create internal policies; and modifications and updates of regulations for sustainable development in port cities [93].
Governance	Port systems inserted in expanding cities face complications in terms of port governance and competition [94].	An intelligent governance focused on the adoption of new technologies and data from social actors to make decisions [95]. This allows to mitigate the negative effects of work stoppages, anticipating the needs of workers; and achieving a balance of economic, social and environmental interests.
Competitiveness	A vision of port competitiveness based on resources and evaluated based on the physical attributes of the port such as its facilities and location [96].	According to Hackius and Petersen [8], BC can be applied in container transport to avoid wasting time in container handling, reducing the cost of logistics activities, and improving the competitiveness of a country.
Knowledge management	Large amounts of transactional port management data are processed and transformed into useful information for decision-making by each actor separately, which is not made explicit or related to social aspects [46].	Collaboration with society, security and reliability of logistics processes, improve resource efficiency and improve knowledge management [97].
Decision making	Decision-making is focused on information from logistics and port operations [98].	Decision-making will be focused on reliable information in logistics and port operations; including information from the community that will help to anticipate possible conflicts [99].
Port-city relationship	There is a weakening in the relationship between cities and the ports that are inserted therein [100].	Crowdsourcing helps to improve the port-city relationship, since it allows identifying the weak points that have been present during the last decades, and new conflicts [100], in this sense mitigating the negative effects.
Security	Ports have some security aspects in the interconnection of cyber space and physical environments, since budgets are insufficient to invest in the ecosystem [101].	Crowdsourcing allows to improve port security and its relationship with the community [14] and BC allows to protect information and customs documentation with trust protocols, thus improving the transparency, immutability and security of data and contracts [21].
Business model	Cost structure is mainly orientated in terms of labor; and profitability, in terms of productivity improvement [102].	The social and technology spheres are incorporated into the business model and the port-city relationship [10].

the actors in the export logistics network. It is proposed to integrate social, economic, technological and environmental aspects into business models to reduce tensions between ports and cities, increase smart assets, improve competitiveness, incorporate areas related to sustainability, have transparent information and communication processes, optimize decision-making, among others.

As mentioned in Section I in the motivation part, the port studied has only some attributes of smart industry and it still needs to develop more advanced technology such as BC, Crowdsourcing and CrowdBC [44], [82]. This is difficult to implement in the short term since it requires a high investment

in innovation, and depends on the approval of a State public committee in addition to being decreed by law.

Currently, it is difficult to ensure that long-term plans are met since the pandemic generated by Covid-19 has currently changed the foreign trade scenarios for publicly owned ports concessioned to private companies. Due to the current situation, the State of Chile has promoted different digital transformation projects such as Port Community System that seeks to minimize face-to-face procedures and reduce document management times. On the other hand, the port logistics companies changed their priorities due to the decrease in the movement of containers during the year 2020 to minimize

the interruption of maritime trade, and thus ensure the supply of local markets, in addition to implementing emergency sanitary protocols to reduce the contagion risks.

On the other hand, only the ports of San Antonio and San Vicente have already implemented BC technology in their terminals [83], [84]. In order to comply with the strategic declarations of the Terminal Pacífico Sur and San Vicente Terminal Internacional, in which the commitment to meet the needs of customers, workers, the community and their environment has been stated, it is necessary to provide a CrowdBC conceptual proposal that generates the necessary conditions to collect large amounts of social data that can be useful for the decision-making of port actors.

As can be seen in Figure 2, the implementation of this technological system requires physical infrastructure and assets from the cyber-technological and social domains; as well as public policies that provide the legal frameworks for port modernization.

## B. CONCEPTUAL VALIDATION OF THE SYSTEM

As a validation of the conceptual proposal for a long-term implementation of the CrowdBC system in Chilean ports, Table 2 is created based on a bibliographic review of the technologies studied in this work. To show the relevance of these developments, two scenarios are proposed: one without the investigated systems and another in which BC, Crowdsourcing and/or CrowdBC are used. The two mentioned situations are classified by different dimensions related to management at a strategic level, business and operational of a port industry.

As mentioned in the introduction to this paper, there is little research on Crowdsourcing based on Blockchain. For this reason, the situations in which BC or Crowdsourcing are implemented are included in the long-term scenario.

## V. CONCLUSION

BC technology is impacting the maritime industry by building efficient commercial ecosystems between port actors; providing benefits to the Port Administrator, the terminals, the logistics service providers, and the inspection bodies of the goods that are exported. It improves information and communication processes by eliminating the use of paper, and incorporates smart contracts that have benefits due to their multiple attributes: autonomy, trust, security, speed, economy and precision.

In this work, the use of BC and Crowdsourcing systems is promoted to transform data and information into useful knowledge for effective and efficient decision making. A conceptual model that relates the cyber-technological, social and cognitive domains for smart ports and the knowledge generation process is proposed, wherein it is possible to classify the characteristics and implications of BC technology. The context and opportunities generated by the development of this technology in Latin America are described. A CrowdBC framework formulated for a Chilean port system is provided in which each domain is linked to a stage of knowledge generation.

Given that currently in the literature there is not enough research related to the integration of BC and Crowdsourcing technologies in seaports, this work presents an interesting starting point for future research in the area. Finally, a more in-depth study is needed related to the skills that port workers must have to operate smart port technologies, knowledge management, socialization of services, and community platforms to help improve port and urban relations. Thus, CrowdBC could better adapt to cultural needs and respond more effectively to the specific requirements of workers and inhabitants of cities occupied by a port. By incorporating social demands into public policies, it would be possible to have a closer relationship with people, avoid port strikes, and improve the relationship between the port and the city.

## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest in the publication of this article.

## ABBREVIATIONS

The following abbreviations are used in this manuscript:

BC	Blockchain.
CrowdBC	Crowdsourcing Blockchain.
CSTC	Cybernetic, Social, Technological & Cognitive.
IoT	Internet of Things.
TSC	Task Smart Contract.
USC	User Smart Contract.
WSC	Work Smart Contract.

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