Second International Symposium on Foundations and Applications of Blockchain

Proceedings

Sumita Barahmand
Shahram Ghandeharizadeh
Bhaskar Krishnamachari
Diego Lugones
Raghunath Nambiar
Tijs Slaats

University of Southern California
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Message from the Chairs

The second International Symposium on Foundations and Applications of Blockchain (FAB) brings together researchers and practitioners of blockchain to share and exchange research results. This one-day event is held at the beautiful campus of the University of Southern California, Los Angeles, CA, on April 5, 2019.

The program consists of four exciting refereed technical papers from around the world, a timely panel on the future of blockchain, and seven invited keynotes from academia and industry. The peer reviewed papers were provided with 3 to 4 reviews. This year, the evaluation process included a one week rebuttal period for the authors to respond to reviewer comments.

One of the peer-reviewed papers titled "BDML: Blockchain-based Distributed Machine Learning for Model Training and Evolution" stood out and was recognized with the best paper award. We congratulate the authors for their timely technical contribution.

We thank our international program committee, Gowri Sankar Ramachandran as the webmaster, and Brienne Jessica Moore for her logistical support of the event. Finally, we wish to thank the authors and keynote speakers for their contributions and the panelists for an exciting discussion of the future of blockchain.

Sumita Barahmand, Proceedings Chair
Shahram Ghandeharizadeh, Program Co-Chair
Bhaskar Krishnamachari, General Chair
Diego Lugones, Industrial Co-Chair
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Smart Contracts and Demurrage in Ocean Transportation

Haiying Jia
SNF Center for Applied Research, 5045 Bergen, Norway
and
Center for Transportation and Logistics, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA
+1 617 401 5231; Haiying.jia@snf.no

Roar Adland
Department of Business and Management Science, Norwegian School of Economics, 5045 Bergen, Norway
and
Center for Transportation and Logistics, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA
+1 617 2587 311 roar.adland@nhh.no

ABSTRACT
We explore how blockchain-based smart contracts may automate the monitoring and execution of demurrage clauses in logistics. Building on the legal framework for the ocean transportation of bulk commodities, we outline the benefits and challenges in streamlining the demurrage process. Our findings suggest that while many of the contractual clauses relating to demurrage can be resolved algorithmically by remote sensing data, the need for subjective human opinion remains. The main challenge in adopting smart contracts is the reliance on 'trustworthy' off-chain resources and the difficulties in aligning the interests of participants in the system. Our analysis is important as an input to ongoing industry initiatives in the design of blockchain applications for supply chain management.

Categories and Subject Descriptors
Application use cases

Keywords
Smart contracts, blockchain, logistics, demurrage, charterparty

1. INTRODUCTION
Transportation contracts typically include a "laytime and demurrage" clause in order to allocate the cost of delays caused by prevalent risks such as terminal congestion or strikes, in addition to the typical case of cargo being delayed. The term demurrage, which originated in ocean transportation and now extends to other transportation modes, refers to the "penalty payment" for the extended time period that the transportation capacity (be it a vessel, container or railroad car) remains in possession of the charterer (shipper) after the agreed period allowed for loading and unloading (laytime). Accordingly, demurrage is a potential payment from the user of the transportation asset to its disponent owner. It is a source of revenue used to off-set per diem on transportation capacity held solely for the benefit of customers and thus can be viewed as extended freight (Jia and Adland, 2018).

The occurrence and realization of demurrage is subject to conditions and provisions that are outlined in the contract. Complicating factors include operational procedures, such as when to give Notice of Readiness (NOR) to commence laytime (i.e. the contracted time for loading and discharge), and the large number of stakeholders involved (shipowner, port authority, charterer, agents and/or cargo owner). Most importantly, contracts tend to use ambiguous language, creating disagreements over what is said in the laytime and demurrage clauses. Sometimes a comma can make a difference. For instance, a typical phrase may look like:

"Cargo to be furnished and received by ship at port of loading as fast as vessel can receive in ordinary working hours, and to be received from alongside ship at port of discharge as customary as fast as steamer can deliver in ordinary working hours."

As a consequence, demurrage is arguably one of the most disputed contractual terms in the transportation industry (Summerskill, 1989). In cases when disputes arise, the interpretation of these conditions is left to arbitrators, lawyers and the courts. This is not only a concern to the contractual parties directly involved in the transportation service, but also to importers and freight forwarders as it relates to documentation and clearance of goods at ports. For instance, there has been reports of increasing congestion in US seaports due to idle containers (Mongelluzzo, 2000a, b). Mongelluzzo and Bonney (2014) reported an increasing number of complaints by truckers and shippers about demurrage penalties in US ports. Indeed, there is currently a US shipper-driven petition seeking policy guidelines that would make it easier to challenge demurrage and detention (Bonney, 2018). Veenstra (2015) argues that demurrage (and detention) can cause a general delay in the global supply chain. As a consequence, it is recognized by industry organizations and individuals that improved clarity and precision is vital (Laffaye, 2013).

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Smart contracts can potentially resolve some of these challenges by virtue of reducing or eliminating ambiguities in the execution and encouraging better information sharing among stakeholders. A smart contract, the term of which was first coined by cryptographer Nick Szabo (Szabo, 1994), is a set of promises, specified in digital form, including protocols within which the parties perform on these promises (Szabo, 1996). It is a computer protocol based on if-then statements intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract. When a pre-programmed condition is triggered, the smart contract automatically executes the corresponding contractual clause. Blockchain technology, with key features such as distributed consensus mechanisms and near-tamper-proof data records, provides an interesting platform for smart contracts, and may ultimately facilitate a move from automated contracts to truly autonomous smart contracts capable of self-execution and self-enforcement.

The objective and contribution of this paper is to explore the application of smart contracts to execute the laytime and demurrage clause in ocean transportation. We identify and discuss the various legal, technical, and business issues in relation to the use of blockchain-based smart contracts for managing laytime calculations and demurrage payments. In a wider context, our research also highlights the inefficiency caused by the concept of demurrage, both in terms of productivity, legal costs and environmental issues. We find that the main advantage of smart contracts is that they force the use of precise contractual terms in place of the current ambiguous common-law terms that are the source of most disputes. Their use may also lead to greater standardization of ocean freight contracts, reducing the time and cost for their negotiation and drafting. Our research is important for the design and evaluation of blockchain-based applications for the ocean transportation industry.

The remainder of the paper is organized as follows. Section 2 reviews legal framework for demurrage. Section 3 outlines the architecture for a smart contract on demurrage. Section 4 discusses the challenges and managerial implications. Section 5 concludes and presents challenges for future research.

2. THE LEGAL FRAMEWORK OF DEMURRAGE

A contract is an agreement between parties about rights and obligations (including prohibitions, such as exclusions for where a vessel may operate). These may be obligations for actions that named parties are supposed to take at various times, generally as a function of a set of conditions. Commercial contracts are meant to be mutually beneficial, so that one of the reasons for contracting is reallocating or sharing benefits and risks (Shavell, 2003). In ocean transportation, the contract for the hiring of a ship for either a certain period of time (a timecharter) or a voyage between pre-defined port pairs (a voyage charter) is termed a charterparty. The charterparty sets out the terms and conditions for the use of the vessel by the charterer (the buyer of the transportation service), For voyage charters, a key clause in the charterparty relates to laytime and demurrage. The 'laytime' defines the time period available for loading and discharge to the shipper (charterer) and is subject to terms used in the contract, while demurrage is the daily penalty payable by the charterer should laytime be exceeded. The crucial – and often contentious point – is therefore the conditions that need to be satisfied before laytime commences, pauses, and stops. Broadly speaking, commencement of laytime occurs when the ship has *reached the destination*, is *reachable* and ready for cargo operations (*readiness*), has tendered its Notice of Readiness (NOR) and the charterer has accepted such NOR.

In this section, we break down the legal terms and conditions associated with demurrage clauses and examine the aspects that are prone to disputes. We note that the topic of laytime and demurrage is so large that it merits a separate book on its own (see, for instance, Cooke *et.*, 2014), and so we here only touch upon the essential terms and conditions.

2.1 Destination

For the purpose of the demurrage calculation, the destination is the focal point where the allocation of responsibilities and risks occur. Therefore, the geographical boundary is of utmost importance and needs to be clearly defined. In water transportation, destination may refer to a port or a berth. In land transportation, it may refer to a station or a terminal. In reality, even when the individual contract specifies a destination, disputes still arise. For instance, in cases when a port is named as the destination in the charterparty, but there is congestion within the port area and the ship has to wait at other places in the port, does this count as reaching the destination so that laytime starts counting? In courts, such disputes can refer to the "Reid test", a crucial passage in the judgment of Lord Reid in *Oldendorff (E.L.) & Co. G.m.b.H. v Tradax Export S. A.* (1973)[1].

As an effort to reduce disputes in this regard, particularly in tramp shipping, BIMCO (2013) has published an updated set of terms on basis of the widely adopted Voylayrules 1993

[1] Lord Reid reads: "…. Before a ship can be said to have arrived at a port she must, if she cannot proceed immediately to a berth, have reached a position within the port where she is at the immediate and effective disposition of the charterer. If she is at a place where waiting ships usually lie, she will be in such as position unless in some extraordinary circumstances proof of which would lie in the charterer…… if the ship is waiting at some other place in the port then it will be for the owner to prove that she is as fully at the disposition of the charterer as she would have been if in the vicinity of the berth for loading or discharge."

(BIMCO et al. 1993) in conjunction with calculating the running of laytime and demurrage. BIMCO (2013) defines the area of port as a rather wide concept: "any area where vessels load or discharge cargo and shall include, but not be limited to, berths, wharves, anchorages, buoys and offshore facilities as well as places outside the legal, fiscal or administrative area where vessels are ordered to wait for their turn no matter the distance from that area."

The transportation facility, such as a ship or a container, needs not only to physically present itself at the destination, but also notification and acknowledgement needs to be sent and received by different parties. In ascertaining whether a ship has arrived at the port, the courts consider not only the views of users of the loading and discharging facilities but also the extent of the activities of the various port authorities (Summerskill, 1989). This also involves an acknowledgement that the extents of the legal, administrative, fiscal and geographical boundaries may be taken into account.

2.2 Reachable on arrival

To have arrived at the destination for the purpose of the laytime commencement, the transportation facility must not only be within the port, but also be *"reachable on arrival, "always accessible"* or *"at the immediate and effective disposition of the charterer"*, according to the terms typically used in transportation contracts (e.g. BIMCO *et al.* 1993, BIMCO 2013). These terms and conditions may cause different understanding among the contractual parties. For example, in *K/S Arnt J. Moerland v. Kuwait Petroleum Corporation of Kuwait* (1988), the ship arrived at the pilot station and gave her NOR. Owing to her high draught, the ship did not move to the commercial port area until four days later and a series of unexpected events followed resulting in demurrage. The degree to which a ship is "reachable" involves a great deal of interpretation and arbitration.

If a ship is not able to be *always accessible* or at *the immediate and effective disposition* of the charter, due to events such as bad weather, waiting for next tide, waiting for tug or pilot, congestion, restriction on night navigation, etc., the question becomes which party is liable for breach. The level of liabilities with regards to the degree of reachability is also dependent on the negotiation power and market conditions. Many standard charterparty terms place the risk of port congestion or delay in berthing on the charterer (Cooke *et al.* 2014).

2.3 Readiness

A ship, a container or a railroad car is ready to load or discharge, in the sense that carriers can give a proper NOR, when it is available for shippers to use. The vessel must be "ready in a business and mercantile sense" (*Armement Adolf Deppe v. John Robinson & Co.,* 1917). The requirement that the facility (a ship, a container or a railcar) is ready involves a distinction between mere routine formalities –those which do not prevent her being regarded as ready – and matters which will cause delay. The usual checklist for physical readiness for a ship include, but is not limited to, her having loading/discharging gear ready, and adequate supply of fuel and boiler water. It is common to provide "whether Customs cleared or not" and "whether in free pratique or not" (*AET v. Eagle Petroleum*, 2010).

Once the captain or shipowner tenders the NOR, the charterer or his agent needs to *officially* accept it in clear and unequivocal terms to the effect that the charterer treats the NOR as valid, irrespective of its actual status. Where a charterer or his agent "accepts" a NOR, which is in fact invalid, but his acceptance is unqualified, the charterer may thereafter lose the right to assert that invalidity (see, *Sofial v. Ove Skou Rederi,* 1976; *Surrey Shipping v. Compagnie Continentale,* 1978). It suggests that the acceptance of NOR is not simply an act of replying to an email; the charter is also recommended to actually check the *readiness* of the vessel.

2.4 The commencement of laytime

Once the seaworthy vessel has arrived at the designated destination and tendered her valid NOR which is officially accepted by the charterer, laytime starts counting. Typically, the charterparty specifies the time that laytime commences in words, for example: "laytime shall commence at 1 p.m. if NOR is given before noon, and at 6 a.m. next working day if notice given during office hours after noon." Shipowners sometimes may contend that laytime has begun even though there has not been compliance with the contract provision. For instance, if loading and discharging happens on Saturday (non-working day), is this Saturday included in the laytime? Court practice is somewhat ambiguous in this regard.

The agreed duration of laytime can be stated in many ways. Examples of usual terms include: agreed a fixed time, "running hours", weather working days, or working days of 24 consecutive hours. In some cases, laytime is defined by loading/discharging rates, such as "tons per hatch per day" or so many tons "per available or workable hatch per day". In the case of "weather working days" or "weather permitting", the law of nature plays an important role. It is generally understood that weather conditions include heat, cold, wind, fog and precipitation, and their immediate consequences such as waves or swell (Cooke et al. 2014). In the current framework, the contractual language is very descriptive, and some distinctions seem somewhat artificial. For instance, rain may not prevent or endanger the cargo operations as such, but presents a risk of damage to the cargo if the operation is continued.

2.5 Demurrage accounting

If the vessel is detained in loading or discharging beyond the agreed laytime (the *free time*) the charterer is in breach of charterparty and therefore the shipowner is eligible for demurrage payment, payable at a fixed rate per day (hour) and pro rata. Surprisingly, the great majority of charterparties impose no express limit on the period of demurrage. This suggests that demurrage payment can be claimed, in theory, forever.

This no-cut-off period is also a source of disputes. For instance, in *MSC Mediterranean Shipping Company SA v. Cottonex Anstalt* (2016), 35 containers with cotton cargo remained uncollected for an extended period of time. The Carrier (MSC) brought a claim for over US$1 million in respect of container demurrage. The Court imposed a cut-off point in its decision, by saying “it would have been wholly unreasonable for the carrier to insist on further performance (demurrage payable).”

It may seem obvious that charterer is liable to pay demurrage. However, the ownership of the cargo can change at the loading port from the FOB (Free on Board) buyer, or at the discharging port from the CIF (Cost, Insurance and Freight) seller. It then seems to be the case that the bill of lading holders are liable for demurrage incurred at both loading and discharging ports. In Gencon 1976, the ambiguous “merchants” are liable for demurrage.

3. SMART CONTRACTS

Unlike conventional contracts that are established through written words, and enforced by actions, arbitration or courts, smart contracts are algorithms built as self-executing and self-enforcing computer programs (Szabo, 1994). While not a recent invention, advances in information technology – particularly the decentralized consensus architecture built around blockchains - has caused renewed interest in the concept. The term blockchain refers to a fully distributed ledger system for cryptographically capturing and storing a consistent, immutable, linear event log of transactions between networked actors (Risius and Spohrer, 2017). Built upon primary distributed ledger functionality, recent platforms such as Ethereum or Hyperledger comprise elements for managing a fully distributed network of peers, different cryptography-enabled consensus mechanisms for capturing and storing transactions, and programming languages to create smart contracts (Glaser, 2017). We note here that smart contracts need not be deployed on a blockchain but the shared features of the two suggest a good fit: Smart contract execution is triggered by a sequential occurrence of events involving nodes in an ecosystem, while a blockchain relies on a similar distributed system to generate a distributed, secure, sequential, immutable and consensus-based data structure. We note here that this structure is also aligned with the physical movement of a single ship or cargo in both time and space – it is by definition linear and sequential.

For the remainder of this paper we will discuss the application of smart contracts with the implied assumption that it runs on top of a distributed system of nodes where information can be sequentially and cryptographically stored and consensus on the business process can be reached in an automated fashion. We do not delve deeper into the technology discussion. However, we acknowledge that a key decision in the actual implementation would be whether to employ a private (permissioned) platform or open (public) blockchain solution. In a permissioned system only invited parties can participate, potentially limiting the scope to the stakeholders in any given contract, albeit with access to different functionality and authorization levels. This gives the participants greater control in terms of who can access data and reduces the well-known concerns relating to the scalability and energy consumption of large public blockchains. Open blockchains, on the other hand, encourage industry-wide standardization and adoption, reduce the duplication of development efforts, and decrease concerns relating to the dominance of a single player. Both already have real-world supply chain implementations (c.f. IBM/Maersk’s TradeLens platform vs. CargoX for trade documentation), and both have their pros and cons. However, we do not take a stand in this important discussion here.

As seen in the previous section, the way in which traditional ocean transportation contracts are worded can often result in ambiguity. In many instances, ambiguous language (open terms) can make it easier for parties to enter in to a contractual arrangement, creating flexibility in terms of contractual performance (Gergen, 1992; Hadfield, 1984). The presence of some commercial flexibility can in fact be valuable in a physical system operating under great uncertainty, such as the global supply chain. However, ambiguity can also be used by parties to scuffle free from contractual conditions. Smart contracts can potentially provide a solution to this problem by incorporating provisions into computer code. In particular, we see two major potential advantages[2]: Firstly, while smart contracts may not reduce the need for interpretation of a complex physical situation in relation to the terms of a contract, the parties implicitly pre-agree on that interpretation by committing to execution of the contract by an associated set of smart contracts and associated external resources. This should reduce the time and cost in monitoring and enforcing the legal provisions of the laytime and demurrage clauses. Secondly, if the implementation of smart contracts lead to a de facto industry standard (of the contract and its interpretation) this will reduce the time and economic costs in negotiating and drafting legal provisions. These are the main economic arguments for adopting smart contracts in our context.

[2] We thank an anonymous referee for this interpretation.

3.1 Validity and enforcement

Despite differences in the civil law and common law system in the approach to contract formation, it is generally recognized the key elements in the formation of a contract include: (1) it is a mutual arrangement and (2) the agreement is enforceable by law (see, for instance, Shavel, 2003; Bag, 2018). Assuming that both the shipowner and charterer has entered willingly into the transportation agreement as a result of a standard search-offer-acceptance process, another requirement for the contract to be legally valid is that both parties mutually assent the contract, in the form of digital signatures[3]. In the case of smart contracts, such assent would be in the form of private and public encryption keys. We note here that a court may not regard a smart contract as either itself being a legal contract, nor having priority in specifying the contract over other paper-based representations of the agreement, or indeed over "reasonable" or precedent-based interpretations of agreements. However, there is precedent for courts to recognize enterprise software systems to perform and monitor contracts, which would be the main purpose of the smart contract in our use case. Digital signatures are still important for supporting those mechanisms.

Most countries now have laws governing digital signatures, for instance, the European Union's Electronic Identification, Authentication and trust Services (eIDAS) (EU, 2014), the Federal Electronic Signatures in Global and National Commerce Act ("ESIGN Act") and the Uniform Electronic Transactions Act ("UETA") in the US, the Electronic Signatures Regulation in the UK, and the Electronic Signature Law of the People's Republic of China. The United Nations has published the guideline under UNCITRAL Model Law on Electronic Signatures for countries to follow. Basically, the laws ensure that: if a law requires a signature, an electronic signature suffices; and if a law requires a record to be in writing, an electronic record suffices. Cryptographic signatures fit the definition of "electronic signature" contained in this category. Once a contract is concluded, i.e. offered and accepted electronically, it is legally binding and enforceable in a court of law (UETA, 1999). In a prescient acknowledgement of smart contracts, UETA even recognizes the validity of "electronic agents" - computer programs that are "capable within the parameters of its programming, of initiating, responding or interacting with other parties or their electronic agents once it has been activated by a party, without further attention of that party". Overall, it is not at all clear that a new legal framework is required to ensure the validity or enforceability of signatures, records, or contracts that use smart contracts. Instead, commentators worry that the types of legislation currently under consideration are not only unnecessary, but may serve to create confusion rather than clarity (Hansen et al 2018).

3.2 System architecture

While the early blockchain-based smart contract applications have been purely digital[4], their implementation in a logistics setting requires a very different interaction with the physical world. For instance, consensus on the existence and ownership of a Bitcoin is based on the "Proof of Work" protocol developed by Dwork et al (1993) and is done solely "on chain", i.e. without any external input other than the energy consumed for computing power. Clearly, verification and consensus on the geographical position and state of readiness of a ship can only be achieved with knowledge of the physical world. Consequently, smart contracts dealing with demurrage must be able to access the external ("off chain") data streams that are required to control their business logic.

This requirement introduces an important component into the smart contract ecosystem - the oracle. In computer science terms, an oracle is an interface that delivers data from an external source via a secure channel to the smart contract (Bashir, 2018). In the context of demurrage and laytime calculations, such external data will include satellite vessel location data, onboard vessel sensor data, the vessel's electronic logs, weather data and inspection reports. An oracle can also be another blockchain storing authenticated data. Importantly, the requirement to use oracles and "off chain" resources reintroduces the issue of trust and potential for providing inaccurate or manipulated data. We will revert to this discussion later.

In addition to oracles, the smart contract ecosystem incorporates the nodes of the blockchain itself, that is, a distributed network of computer servers that record the data (e.g. the timestamps of milestones during the port call) and run the consensus mechanism that decide on the true state of the system. The owners of these nodes naturally include the two parties to the charterparty (i.e. the disponent shipowner and charterer/shipper) but also other stakeholders that have an interest in maintaining a copy of the data underlying the smart contract execution. The latter group might include the captain/vessel, cargo terminals, port state control (PSC) authorities and customs agencies. However, depending on the consensus mechanism and network structure (public or private), the nodes may simply also represent third-party cloud-based computing power or block miners. Each node is connected to the platform by authenticating with its own

[3] We acknowledge that a broader implementation of smart contracts in the chartering process may make the supply chain entirely autonomous such that the traditional search-offer-acceptance negotiation process no longer exists but is replaced by an algorithm, which could be a central platform or decentralized application. We here consider only the narrow implementation of smart contracts in relation to demurrage.

[4] The most well-known examples are perhaps the trading of cryptocurrencies such as Bitcoin and digital assets such as "Cryptokitties"

private key, which also determines the node's authorization level. Figure 1 shows the architecture of the smart contract ecosystem conceptually. We have here differentiated between the storage and verification of primary data on the blockchain, and the execution of the smart contract in a layer built on top. This may be necessitated by the ability of certain blockchain solutions to scale.

We note that while the objective for smart contract implementation would be automated monitoring and execution, we cannot rule out that one outcome would be a dispute (i.e. the nodes cannot reach consensus on the true state of the situation). In this case, the smart contract terminates and the resolution of the dispute is handed back to a pre-selected arbitrator, tribunal, or court in the physical world, as illustrated in Figure 1.

Although automatic settlement of any agreed demurrage payment could be an integral part of the smart contract itself, this is not a key element in our mind. Firstly, payments are not recognized as a pain point in an industry which is relies on large international bank transfers on a daily basis. Secondly, the number and frequency of transactions would be too small to justify a separate digital currency. Thirdly, in order to ensure automated payment, funds would need to be tied up when the parties enter into the contract. Such liquidity requirements – to cater for an event which may not occur – would unnecessarily increase the cost of doing business. The output of our smart contract is therefore simply an agreed calculation of the amount payable.

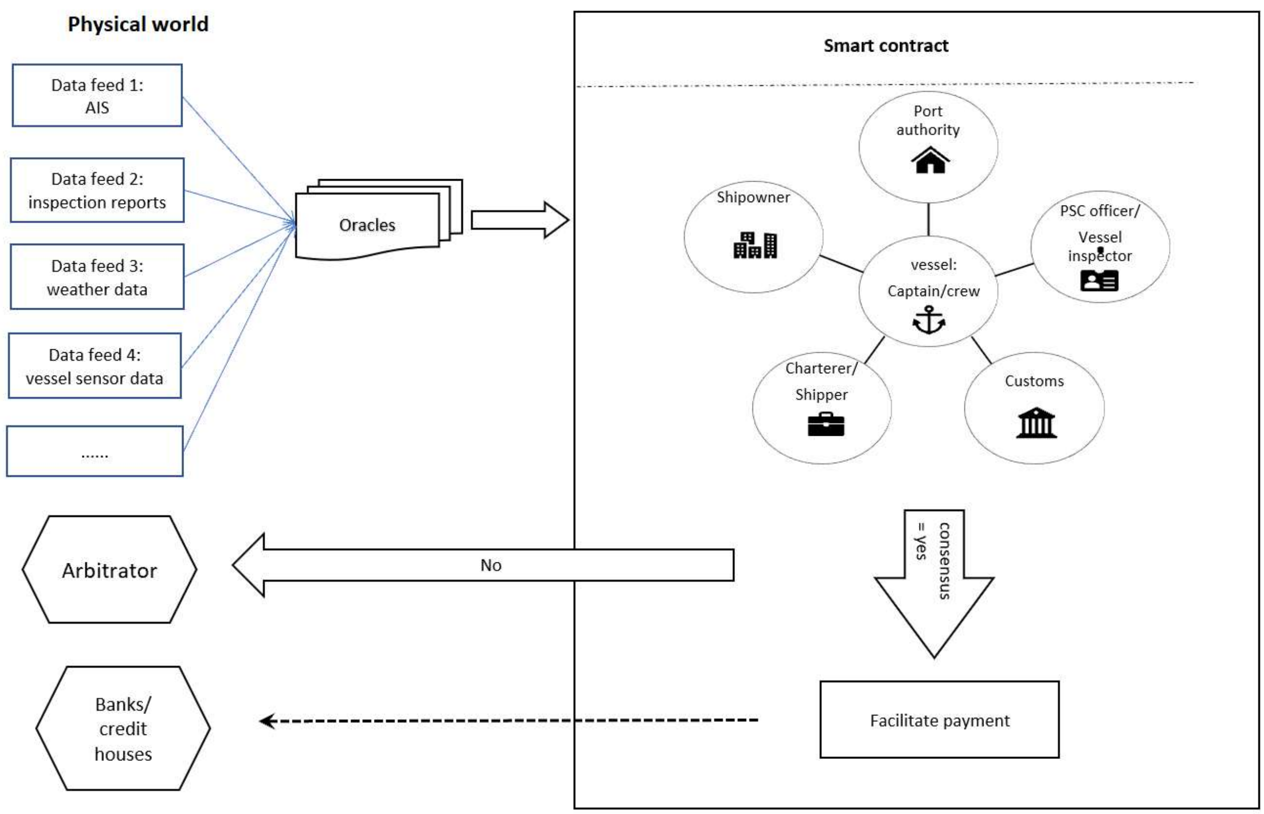


Figure 1. Architecture of the smart contract ecosystem

3.3 Verification and consensus mechanisms

With this ecosystem in mind, let us consider how the conditions for demurrage to occur, as outlined in Chapter 2, could be monitored and verified by our smart contract. The objective would ultimately be to break down and standardize the legal language into conditions that can objectively be categorized by a computer algorithm. Let us consider the relevant charterparty clauses in turn.

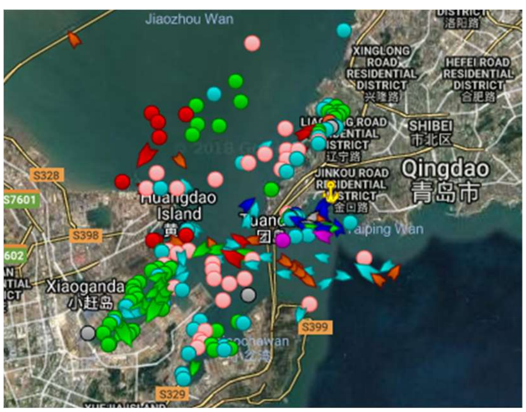
3.3.1 Whether a ship has reached the destination

In principle, the existence of ship position data from the global Automated Identification System (AIS) enables remote continuous tracking of all ocean-going vessels over time. In this manner, port waiting areas and terminals can be mapped electronically – usually by way of algorithms clustering observations of stationary vessels inside polygons. The timestamp of a ship entering the polygon therefore defines the time of arrival at the destination. Which geographical areas that constitute the destination can be pre-selected in the contract, and can easily account for the wide definition in BIMCO (2013), “any area where vessels load or discharge cargo and shall include, but not be limited to, berths, wharves, anchorages, buoys and offshore facilities as well as places outside the legal, fiscal or administrative area where vessels are ordered to wait for their turn no matter the distance from that area.” Indeed, from observing the past operational behavior of similar ships in the port, such vague language can be made objective and executable by computer code.

3.3.2 Whether a ship is ‘reachable’

The commonly used ‘Reid test’ for whether a ship is reachable and at the immediate and effective disposition of the charterer can be summarized as: if “she is at a place where waiting ships usually lie, she will be in such a position” (c.f. footnote 1). Accordingly, the empirical observation, based on historical AIS data, of where similar ships are waiting will generally be sufficient evidence to determine whether this clause is satisfied.

Figure 2 shows a snapshot of ship traffic in the Chinese port of Qingdao, courtesy of Marinetraffic.com. The port waiting areas and cargo handling terminals for different types of ships are clearly visible.



Notes: Snapshot of vessel traffic in the port from Marinetraffic.com. Circles indicate stationary vessels and arrows indicate moving vessels.

Figure 2. AIS reported ship traffic in the port of Qingdao

3.3.3 Whether a ship is ‘ready’

Clearly, the assessment of whether a ship is ready to load or discharge is, for now, beyond the possibilities of algorithms based on onboard sensor data, electronic logs or AIS data. Assessing readiness thus becomes a matter of trust in the opinion or information given by an “off chain” resource such as the captain, crew, supercargo or port agents. This is in some sense the antithesis of blockchain as a champion of ‘trustless’ interaction. However, the blockchain data structure can still facilitate secure sharing of the relevant information. For instance, the AIS data provider can confirm that the vessel has reached the destination port and is waiting at an assigned anchorage, the chief engineer can confirm that the vessel has adequate fuel supplies, and the chief officer and port agent can confirm that the cargo holds and gear are ready for loading. Consensus can then be reached that the ship is ready and the NOR can be tendered electronically on the blockchain, triggering the commencement of laytime.

Another point of contention would be interruption of loading or discharge due to events beyond the control of the charterer, usually due to inclement weather leading to closure of the port or endangering the quality of the cargo. While the occurrence of rain showers, for instance, can be monitored by onboard sensor data, whether the severity of the weather allows for laytime to stop counting remains somewhat subjective.

4. CHALLENGES AND IMPLICATIONS

As noted by Levi and Lipton (2018), it is quite likely that a court today would recognize the validity of computer algorithms that execute provisions of a traditional contract, such as the demurrage clause within a charterparty, given the existing legal framework for recognizing electronic contracts. The challenge to large scale adoption may, therefore, have less to do with the limits of the law than with the differences between how smart contract code operates and how parties transact business. Levi and Lipton (2018) also point out that blockchain-based smart contracts are not truly “trustless” as a great deal of trust is placed in the programmer translating legal principles and clauses into computer code, not least because recent research (e.g. Nikolic et al., 2018) suggests that technologists still do not have a full picture of what a security hole in a smart contract looks like.

As an important general point, the mere entry of data on a blockchain and generation of consensus based on such data does not guarantee that the data is accurate and trustworthy. The source of most demurrage disputes is, after all, a lack of agreement on the timeline and sequence of events. This could be because of a lack of recorded information altogether, a belief that the recorded information has been tampered with, or a lack of trust in the data quality or the provider of the information. A blockchain-based smart contract can only help with the first two of these trust-related issues: the recording of key data and timestamps, with immutability of the records as a key feature. However, as long as there is an electronic/human/physical interface, data can be entered incorrectly, either due to sensor malfunctioning, typos, miscommunication or human mischief. For instance, it is well known that ship positions and even ship identities reported by the AIS system can be spoofed and manipulated (Katsilieris et al, 2013). A similar problem may arise because of the latency inherent in the satellite communication required for ship-to-shore communication, creating inconsistencies in the timestamps of events. By itself, blockchain, or more generally distributed ledger technology, therefore cannot completely establish trust in the input data underlying the monitoring of contractual performance and laytime calculations.

This brings us to another key issue – the economic interests of the contractual parties in the chain. The interests of the nodes in the blockchain (c.f. Figure 1) are typically not aligned, creating incentives to misreport, delay data reporting, stall the consensus mechanism or even collude to approve an outcome which is factually wrong. In this manner, merely creating a blockchain for storing and exchanging data does not solve all of the current problems leading to disputes. However, we believe it will facilitate quicker dispute resolution, as a substantial part of the timestamps and data would be hard to argue with. It remains an open question whether a blockchain-based system can be built to better align the interests of the contracting parties, for instance, through the adoption of a token platform that rewards correct reporting and penalizes misbehavior and we leave this for future research.

On a higher level, the entire concept of demurrage is increasingly being questioned, with suggestions being made to abandon the principle altogether. Importantly, from the point of view of "greening" the supply chain, demurrage acts as a contractual barrier to increasing environmental efficiency. For instance, Jia and Adland (2018) show that demurrage has the perverse effect of increasing the optimal sailing speed (and corresponding ship-to-air emissions) in poor freight markets, when the daily profit from claiming demurrage exceeds that of sailing the vessel. In practice, together with the First-in-First-out berth allocation policy in most ports, the demurrage clause encourages the oft-observed "hurry-up-and-wait" behavior in ocean transportation (Psarros, 2017). Trying to increase the efficiency of the demurrage process is therefore akin to treating the symptom rather than the cause.

For managers, the implication is that care should be taken before heavy investment is made in autonomous smart contract applications related to the demurrage process. The challenges related to data quality and incentive systems need to be solved first. However, our analysis also points to the value of digitalizing and storing a common event log, accessible to all stakeholders and based on input from sensor and tracking technology that is already available, as a basis for resolving potential demurrage disputes. However, such a shared electronic log need not be based on blockchain technology. Indeed, given the potential for errors, the immutability of data records could be more of a drawback than a selling point.

5. CONCLUDING REMARKS

The major obstacle facing blockchain-based smart contracts in physical industries such as ocean transportation is the fact that their execution relies heavily on "off chain" resources for the input and verification of data, be it physical sensor data or human input. There simply is no algorithm that can verify the physical status or location of a vessel by mathematical computations alone. The challenging interaction with the real physical world is not unique to our application to smart contracts for demurrage in ocean shipping.

Such reliance on off-chain resources creates a new set of practical challenges in the implementation of smart contracts. Firstly, high error rates in the input data may create incorrect consensus and contract execution, or necessitate multiple data revisions on the blockchain to correct to the 'true state'. Secondly, misaligned interests between the nodes in the distributed system (i.e. contracting parties, their agents, and other off-chain resources), creates incentives to collaborate to trick the system for financial gain (i.e. wrongfully reducing or increasing demurrage payments in this case). Merely relying on the voting of the majority in a blockchain-based consensus mechanism therefore does not guarantee the correct outcome. Thirdly, even it was in everybody's interest to act fairly, the high cost and intrinsic latency of global satellite communication connecting ships, distributed sensors and shorebased agents would create computational difficulties in agreeing on even a simple timestamp.

Many of these challenges can be resolved over time, either through new and improved systems and data protocols for tracking vessel positions, cheaper satellite communication, or the creation of incentive systems (possibly digital tokens) that can align the interests of nodes in the chain or expand the pool of 'oracles' verifying the true status of a vessel.

In the meantime, the main benefit of implementing blockchain technology for demurrage calculation is simply the digitalization and structuring of the data input required, without the autonomous execution that is promised by smart contracts. This may in itself be a benefit that will reduce disputes and increase the efficiency of the supply chain.

With regards to future research, a key part in a successful future implementation of smart contracts for demurrage claims in ocean transportation is clearly the incentive system that needs to be in place to increase accuracy and reduce the potential problems caused by misaligned incentives. Such an incentive system would have to be based on the idea that those who benefit from increased efficiency and reduced demurrage claims (i.e. mainly shippers) would share some of these financial benefits with agents who provide accurate information on the location and status of a vessel and cargo handling operations, likely through digital tokens built on the smart demurrage contracts The economics of such digital tokens is a research area in its infancy, but clearly the logistics industry – with its many pain points related to demurrage costs and delays – is ripe for such innovation.

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