

Decentralized procurement mechanisms for efficient logistics services mapping - a design science research approach

Abstract

Companies tend to outsource logistics services for flexibility or platform operating costs reduction. To do so, they typically use centralized platforms to delegate the services procurement process. However, those platforms can be prone to information asymmetries between carriers and shippers which can lead to sub-optimal procurement outcomes. A more transparent and efficient way to manage the procurement of logistics services between carriers and shippers could be a decentralized platform based on blockchain and smart contracts. In this paper, we design, implement, and evaluate the potential for a decentralized logistics services procurement system, following a design science research approach. In so doing, we contribute by (1) developing such a decentralized logistics services procurement system that addresses the allocation problem, and (2) developing a set of nascent design principles guiding the elaboration of decentralized procurement mechanisms on blockchain.

1. Introduction

Transport logistics is a complex process with many stakeholders involved that need to be coordinated to send a shipment from A to B. A central activity in that process is the freight transportation service procurement (FTSP) mapping, where shippers negotiate their transport needs with potential carriers. The FTSP activity challenge is to map the shipper delivery request with the best available carrier offer at a certain time and place. Shippers can use dedicated platforms to find on-demand carriers to deliver merchandise [1]. For logistics services, the right mapping at the needed quality level is crucial, as the delivery quality impacts directly customer satisfaction and retention.

Existing procurement marketplaces frequently lack information transparency: for example, access to delivery histories, or allocation protocol can be restricted. As a consequence, data integrity of the

carrier profiles may not be assured, or important services records may not be kept [2]. A collusion between the procurement platform provider and a service provider is possible due to this lack of information transparency, meanwhile the shipper may not have access to correct information before hiring a carrier.

Moreover, the freight procurement platform controls all information flows which gives it a lot of centralized power and an incentive to keep the mapping of logistics services nontransparent for others [3]. A procurement platform provider may feel incentivized to abuse their power to keep things nontransparent. One example is the so-called opaque (pricing) business model, whereby companies or platforms hide the (low) price of products to generate higher revenue (e.g., Priceline).

This situation creates yet another problem, as the quality of services (QoS) provided by carriers is not accessible freely by shippers. Such restriction can qualitatively impact the allocation. The QoS of a carrier depends on its equipment, but also its history of services: poor customer satisfaction, late deliveries, or damaged goods can lead to failed deliveries and thus participate to lower the carrier QoS, leading to negative customer satisfaction and commercial losses. The lack of transparency of service allocation, influenced by information asymmetries, may lead to inadequate allocations, and thus unoptimal, or even failed, deliveries. A study conducted among 300 retailers across the UK, US, and Germany in 2018 demonstrates that the average yearly cost of failed deliveries per retailer is almost £200,000 [4].

FTSP mapping thus requires information transparency, power balance, and process effectiveness. Delivery data should be recorded, stored, and accessed in a tamper-proof fashion. It should moreover be leveraged to realize QoS allocations adequately. The process should be managed in a balanced fashion to reduce the risk of malicious behaviors on behalf of the FTSP platform. Additionally, the mapping process should be autonomized to fasten the process and optimize delivery windows. Thus, FTSP mapping

requires a technology that (1) leverages trusted delivery information to compute the QoS of carriers, (2) fosters power balance between partners, and (3) optimize the FTSP process.

The blockchain has emerged in the past years as a new tool for trustworthy decentralized data storage and decision making [5, 6] with a potential for lower operational and transaction costs [7]. The blockchain ledgers stores transactions in a tamper-proof fashion and smart contracts execute predefined protocols autonomously. Moreover, oracles can feed the blockchain with trustworthy external data: the blockchain connects to a number of oracles to triangulate the status of transaction outside the blockchain system. Thus, process effectiveness can be answered by smart contracts implementing the FTSP mapping. Meanwhile, the blockchain ledger linked to oracles can help improve information transparency as all delivery information stored in the blockchain can be accessed by the involved members and cannot be tampered. Finally, the will for a more balanced power between FTSP participants can be answered with the blockchain removing the need for a trusted third party: all members thus have an equal access to information and protocol details. A blockchain-based decentralized logistics services procurement marketplaces thus appears as an adequate technology to meet FTSP needs. More precisely, blockchain has the potential to provide an efficient FTSP protocol with smart contracts securing the mapping and settlement of a logistics service in an efficient, finite, and autonomous way [8, 9, 7]. For accounting and compliance, such a system can even record all settled transactions in a tamper-resistant fashion, and keep track of delivery information provided by different oracles and tracking sensors. Such a decentralized procurement solution executed by smart contracts would improve the carrier-shipper mapping decision-making as well as the QoS. More precisely, the decision-making regarding the choice of the carrier would be improved as the protocol would be transparent and based on tamper-proof QoS data whose computation is agreed upon by all partners. The decision-making would be based on objective data and improve customer satisfaction on the long run. Moreover, the decision making would be beneficial for the carrier as she would be ensured that her profile is selected based on past experience, and put on equal footing with respect to other carriers.

Despite several publications of blockchain-based allocation protocols to map logistics services and their procurement, there is a research gap when it comes to incorporating information flows from oracles and tracking sensors. Thus, in our research, we focus

on the efficient mapping of logistics services on a decentralized platform where information about QoS is available and incorporated into the procurement of logistics services and their mapping between shippers and carriers. Particularly, in this research we answer the following research questions: *(RQ1) How can blockchain-based FTSP mapping assist shippers in the procurement of a logistics service with regards to process effectiveness, information transparency, and power balance between platform providers and platform actors?* *(RQ2) Which design principles need to be followed that guide the development of decentralized procurement mechanisms?*

We investigate these questions by following a design science research approach anchored in the logistics field. We propose a blockchain-based FTSP mapping adapted to logistics to enhance the sector's needs for service flexibility and information transparency. The main contributions of this work are as follows: (1) we list the main requirements related to FTSP and derive a priori principles and features to match the procurement needs; (2) we design an artifact holding the features and validate our approach through two evaluation cycles; (3) we propose a set of nascent design principles for the development of blockchain-based FTSP mappings.

The remainder of this paper is organized as follows. Section 2 introduces key concepts around blockchain-based FTSP mappings. Section 3 reviews related work. Then, section 4 presents the design science research methodology approach. In section 5, we describe the blockchain-based FTSP mapping design requirements and define the design features needed for blockchain-based FTSP mapping. We present our practical and academic contributions derived from the iterative design cycles in section 6. The paper concludes with section 7.

2. Preliminaries

This section introduces some key concepts about FTSP and the blockchain technology, before investigating related work on decentralized allocation protocols using blockchain.

FTSP: The freight transportation procurement process is one of the primary activities in the logistics field. The FTSP holds three stakeholders: the shipper (i.e., the service buyer) who initiates the allocation request, the carrier (i.e., the service seller) who sells its delivery services, and an intermediary, often a digital platform, responsible for the carrier-shipper allocation [10, 11]. The allocation request concerns two market types: long-term markets, which are delivery

contracts signed for years, for example, and spot markets concerning one-shot agreements for a single specific request. It comprises two stages: first, the matching stage, where the set [service request/resource provider] is defined, and then the allocation, which generates a mediation contract, the CMR (i.e., CMR Convention: Convention on the Contract for the International Carriage of Goods by Road). In a competition context [12, 13], both carriers and shippers are looking to cooperate for cost optimization and efficiency gains [10, 14]. Especially, carriers can also use the platforms to exchange on-hand merchandise. Indeed, platforms optimize transportation costs and enact allocations autonomously. Multi-modal freight transportation among carriers is a practical example. It is worth noting that the platforms' service procurement process will be the same for either shipper-to-carrier or carrier-to-carrier allocations.

The blockchain technology: A blockchain is a distributed database based on a peer-to-peer network, i.e., a database spread across multiple nodes, or servers [15]. Blockchains keep track of the transfer of assets between several parties. They lower the cost of trusted transactions by making databases tamper-proof by design [16]. Blockchain systems store data transactions hierarchically, using linked blocks of aggregated transactions [5]. Cryptography hashes and asymmetric encryption enforce the non-tampering of the transactions. The trusted behavior of blockchain systems builds upon the consensus protocol used to update the chain of blocks. The consensus protocol states the strategy used by participants to settle on a shared state of truth. This protocol ensures the tamper-proof growth of the database [5]. Smart contracts are deterministic scripts enforcing a set of agreements between parties in the blockchain [17]. Smart contracts can use oracles to connect to off-chain data, coming from sensors or databases [18].

Design Science Research Design science research refers to a scientific method to develop artifacts answering real-world problems [19, 20]. Its interest lies into the methodology making sure that the identification and specification of the underlying problem are realized, leading to its resolution at some level of completeness and abstraction. Consequently, stakeholders and their problem are considered before designing a solution. The finality of a design science research approach is to abstract design knowledge to generate theoretical insights framing the building of future solutions.

Figure 1 presents the three main steps of a design science research approach. The first step refers to the

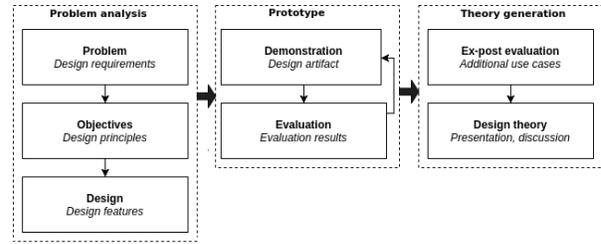


Figure 1. Design science research methodology.

analysis of the problem leading to generating a set of objectives. A set of features are then derived from these objectives. The second step is to develop and evaluate the artifact iteratively. The third step is to abstract design knowledge under a set of design principles.

3. Related-work

Compared to traditional allocation systems, blockchain-based allocation protocols unlock trustworthy process automation [9, 21, 22]. Indeed, integrity of the protocol can be ensured as all carriers are considered before attributing a request, while historic data stored in the blockchain is tamper-proof. When a conflict occurs, the history of transactions can be retrieved and used as the single source of truth. Blockchain-based FTSP mappings can moreover go one step further by managing autonomously and reliably the end-to-end service enactment.

Table 1 presents the main known related work investigating blockchain support for allocation procedures. *On the one hand*, several papers investigate the use of blockchain and smart contracts for the autonomous allocation of services such as energy or computation power [23, 24, 25, 2, 26]. These papers leverage smart contracts for autonomous contractualization [24, 2], incentives to encourage service completion [25, 2], or delivery settlement [27]. However, these papers do not focus specifically on the FTSP use case, and do not use oracles to compute QoS ratings or integrate sensor feedbacks. Moreover, these artifacts were not realized using a design science research approach and thus do not provide design principles for developing decentralized procurement mechanisms on blockchain. *On the other hand*, several papers propose a design science research approach to investigate the use of blockchain applications. Two papers, [28, 29], focus respectively on the development of blockchain-based IoT applications and smart-parking. However, the retrieved design principles do not concern FTSP mappings specifically, and oracles are not integrated in the research works. Two design science research papers, [30, 31], focus on the use of

Table 1. Blockchain artifacts in design science research (DSR)

Ref	Logistics	Allocation	Oracle	DSR approach
[23, 24, 25, 2, 26, 27]	no	yes	no	no
[28, 29]	no	no	no	yes
[30, 31]	yes	no	no	yes
Our approach	yes	yes	yes	yes

blockchain for logistics but do not focus specifically on the FTSP protocol. The first paper focuses on the management of bills of lading via blockchain. Retrieved design principles are process digitization, tamper-proof storage, accessibility, and user authentication. The second paper focuses on food supply chains; the retrieved design principles are mainly related to data privacy and keeping sensitive data off-chain. It is also to note that none of the retrieved work leverages oracles to realize a QoS-based allocation.

Thus, in this research, we address this research gap regarding the potential of decentralized FTSP mapping using blockchain, smart contracts, and oracles. We do so using a design science research approach.

4. Design science research methodology

We follow a design science research approach to elaborate a blockchain-based FTSP mapping (cf. section 2). Our rationale for choosing the design science research approach is the scarcity of (1) decentralized procurement mechanisms on blockchain, and (2) FTSP field evaluations in the blockchain literature.

First, we analyze the literature regarding FTSP to analyze the problem, propose a list of design requirements to answer FTSP-related issues, merge it into a set of three design objectives, and decline each objective into a set of features. Next, we start the prototype development. We proceed with conducting two iterative development/evaluation cycles. During the first iteration, we evaluate the artifact through user testing. We proceed to a moderated usability test with 14 master students of the Service-oriented architecture field having no former blockchain experience to assess the artifact's validity and analyze the potential of adoption of blockchain-based FTSP mappings with non-technical users. Users followed installation instructions provided as a script and accessed the dApp autonomously. Users followed a script asking them to find a delivery person fitting a scenario request. We collected their feedback

using a questionnaire. The second iteration of the artifact involved two focus groups. The groups were composed respectively of two academics in freight transportation and three industry experts specialized in the procurement process of logistics services. Each session followed the same methodology. We launched a demonstration of the artifact before letting the experts debate. The focus groups lasted around one hour each. We did not launch a naturalistic evaluation in a freight procurement setting as the artifact is presented as a minimum viable product, designed to understand how the blockchain can improve current FTSP mechanisms (cf. [32]). Finally, we focus on knowledge abstraction and theory generation. We propose three nascent design principles based on our iterative empirical development and evaluation cycles. Besides, we confront the proposed nascent design principles under the light of nascent design principles extracted from other design science research papers.

5. Designing a blockchain-based FTSP mapping: from requirements to design principles and features

5.1. Designing requirements

To get the list of design requirements linked to enhanced FTSP platforms, we carry out a set of interviews with academics in freight transportation. We also query the literature to gather articles related to (1) FTSP mapping current issues, and (2) blockchain-based FTSP mapping proofs-of-concept. More precisely, we generate two subjective search strings [33]. The first one refers to current FTSP mapping limitations. The output search string is ("*freight transportation*" OR "*service procurement*" OR "*freight allocation*" OR *logistics*) AND (*challenges* OR *issues*). The second search string refers to resource allocation and blockchain. The output search string is (*resource allocation* OR *market place* OR *matching* OR *freight procurement*) AND (*blockchain* OR *DLT* OR *smart contracts*).

We identify five design requirements that a resource allocation artifact should meet to circumvent current FTSP mapping issues (R1-R5 hereinafter).

First, a solution must provide allocation flexibility (R1) to shippers and carriers [10, 2, 34]. On the shipper side, the shipment flows are variable and costly, primarily via spot markets. On the carrier side, there is a need to exchange and re-bundle items effortlessly with competitors to perform economies of scale (e.g., increasing fill rate) and economies of scope (e.g., lane exchanges). Second, a solution must provide an autonomous allocation process (R2) [35, 36, 37]. The

flexibility is low, and frequently trucks are half-full for spot deliveries [38]. One of the causes is the heavy load of administrative tasks, with still paper-based contracts, e.g., the *CMR* papers [37]. The third requirement is that a solution must provide enact real-time payment (R3) to help carriers optimize their commercial processes and operating costs [10, 39, 37, 40]. There is a need for a cost-efficient, secure, and fast payment process right after delivery on the carrier side [38]. Fourth, a solution must comply with *CMR* regulations (R4) [41, 42, 39]. Indeed, the administrative overwork linked to *CMRs* can discourage flexible hiring and item re-bundling. Finally, a solution must provide delivery history integrity and traceability (R5) [43, 44, 37, 45, 34, 40]. The allocation should be objective and delivery history should be traceable. Additionally, carriers and shippers should not be able to modify or contest a settled delivery.

5.2. Artifact principles

We gather the aforementioned (R1)-(R5) requirements into three principles (i.e., P1, P2, P3 hereinafter) that a resource allocation artifact should meet to circumvent current FTSP issues.

First, *platform operating costs reduction* (P1) of the FTSP system should be considered to enhance the transportation process. On the one hand, platform operating costs reduction relies on an eased allocation process (cf R2). Fostering autonomous freight procurement systems would render the procurement infrastructure less costly for each stakeholder as they would need to provide less time to administrative activities (e.g., settling a delivery). On the other hand, platform operating costs reduction also relies on allocation flexibility (cf R1). Indeed, customized allocation requests will be more prone to answer the shipper's standards. Consequently, less time will be spent to finding the perfect carrier for a task, and the risk for failed deliveries due to poor customer satisfaction will decrease. Blockchain smart contracts can answer this need for cost reduction, as they can be used as autonomous services in untrusted environments [30].

Second, the platform should offer *contractual flexibility* (P2). The inner flexibility of the allocation mechanism ensures contractual flexibility (cf R1). For example, if the allocation mechanism makes it possible for freight re-bundling, it will enhance contractual flexibility. Contractual flexibility is also related to real-time payment (cf R3). The fast, simple and secure payment processing enabled by the smart contracts will make carriers be paid right after delivery to accelerate the cash flow and flexibility. Real-time payment and contractual flexibility can be managed by a dedicated

smart contract. The latter could manage offers, and re-bundle them if needed.

Finally, *allocation integrity* (P3) should be considered, be it for the allocation process, the record of service rates, and the management of *CMR*. The integrity of the digitalized *CMR* (cf R4) is paramount to be in phase with regulatory authorities. Integrity in terms of delivery history and protocol should be considered (cf R5). Providing adequate performance feedbacks to future shippers requires delivery history integrity. Meanwhile, an objective allocation requires protocol integrity: the protocol should consider all carriers for a given service request without bias. The integrity of *CMRs* and delivery history can be ensured by the tamper-proof affordance of the blockchain ledger [30]: all approved transactions cannot be contested nor changed. The integrity of the allocation is moreover ensured by smart contracts as they are deterministic: the inner logic of the smart contract will be respected at each stage of the allocation process.

5.3. Emerging features

We elaborate a set of blockchain-based FTSP mapping features to answer the needs for platform operating costs reduction (P1), contractual flexibility (P2), and allocation integrity (P3) in FTSP patterns (see section 6.1 for implementation details).

Regarding platform operating costs reduction (P1), we propose an autonomous allocation mechanism to reduce cognitive weights on the user side, coupled to the generation of a digital *CMR* agreement. Moreover, we offer to integrate real-time payment facilities once the delivery completes. On the shipper side, there are minimum search actions to find a carrier and enact an agreement. On the carrier side, the allocation is faster and requires less paperwork: the overall allocation cost decreases. Regarding contractual flexibility (P2), we propose a customizable QoS allocation to the shipper. The latter can tune each rating's weights referred to as P_O to compute the carriers' QoS. The QoS is calculated as a weighted normalized mean, using both P_O and the set of weighting parameters α : $\forall i \in \text{Candidates}, QoS_i = \sum_{j=0}^n \alpha_j \|P_{O_j}\|$. If a weighting factor equals zero, then P_O is not considered for the QoS computation. If it equals one, then P_O will be fully considered for the QoS computation. For example, if the carrier experience is a primary criterion of selection, the shipper can set a weight of 1 to this parameter. Finally, concerning allocation integrity (P3), the blockchain can map carrier offers (e.g., pricing or availability) to their tamper-proof records of services, accessible via a dedicated profile smart contract recording the QoS of

each service. Moreover, a smart contract operates the allocation to ensure protocol integrity and objectivity: the carrier with the highest QoS (or the lowest costs or CO2 emissions, etc.) will obtain the assignment.

Tamper-proof performance feedbacks can have multiple shapes, such as delivery time or temperature threshold coming from sensors and injected by oracles, customer satisfaction ratings sent through a smart contract transaction to a dedicated rating function of the smart contract. The combination of both subjective (customer satisfaction rating), and objective metrics (temperate threshold or delivery time) constitute the QoS and thus moderate poor performance reviews by a shipper. Moreover, the update of the QoS can be computed with a weighted exponential average that puts more weights on the last deliveries. Additionally, at initial stages, new comers are assigned with a maximum QoS rating to avoid the case where they would never be selected.

The following section presents the findings generated from the building of an artifact holding these features.

6. Implementing a decentralized trust-free FTSP mechanism

In this section, we present the practical contribution of this research work: the decentralized FTSP prototype. We then focus on the academic contribution by discussing the nascent design principles emerging from the development and evaluation cycles.

6.1. The blockchain-based FTSP mapping prototype

We propose a blockchain-based FTSP mapping protocol to fulfil the needs for platform operating costs reduction, allocation flexibility, and allocation integrity. The prototype architecture is multi-tiers, with (i) an application layer (the web client), (ii) the backend (smart contract, oracle) running on a blockchain, (iii) a Rest API for bridging the application layer with the blockchain. The front end is in React, using web3.js and Metamask for API calls to the blockchain. The smart contract backend is written in Solidity and deployed to the Ethereum blockchain Ropsten testnet. We use one of the Ethereum-compatible oracles named Provable¹ to generate API calls from our smart contract.

The blockchain-based FTSP mapping process follows the subsequent steps (cf. Fig. 2). Initially, representatives from both shippers and carriers instantiate the FTSP mapping. The representatives state

the metrics that the smart contract will use to compute the on-chain QoS. Afterward, the carrier-shipper mapping can occur. Two stakeholders, carriers and shippers, interact with the FTSP smart contract. Carriers share with the smart contract eligibility information (e.g., location, licenses, truck capacity, and equipment) (step 1.a.). The smart contract associates this information with initially empty QoS metrics used to record the history of their past services (e.g., number of deliveries, and average delay) (step 1.b.). Shippers trigger the smart contract to find a carrier matching their needs by specifying filtering criteria (e.g., price, location, shipping date, equipment, merchandise volume) and sorting criteria (e.g., preferred experience, or maximum delay) (step 2.). The smart contract will filter the candidates (step 3.a.) and delegate the QoS computations according to the required sorting criteria to the oracle (step 3.b.-3.c.). The oracle provides to the smart contract the best-matching carrier (step 3.d.). Finally, the smart contract generates a digital delivery agreement as a decentralized version of the CMR (step 4.). The user (shipper or carrier) can retrieve all contracts bounded to its public address (cf Fig. 3).

We refined the prototype following two iterative cycles. User tests underlined the need to display computation information to enhance trust in the system. Indeed the black-box effect appeared, linked to users using a technology they are not expert with occurs. Users can only trust the machine, as they do not know the underlying protocols. This dependency may trigger mistrust. We thus displayed all resource profiles to the users and the ratings obtained for each resource. The second evaluation round consisted of focus group discussions. Testimonies underlined the need for an almost entirely autonomous system. We revisited the artifact by merging the matching and allocation stages into one single step.

The smart contract enables platform operating costs reduction by managing allocations autonomously. The smart contract also allows contractual flexibility as it speeds cash flow; payment is enacted right after the shipping is settled. Finally, the combination of (1) the blockchain ledger, (2) the smart contract protocol, and (3) the oracle-based QoS computations ensures tamper-proof and objective management of the allocation requests. Thus, carrier-shipper mappings can be done in a secure, trusted, reliable way by a blockchain system.

As a side note, regarding carrier competition, a carrier wishing to delegate the delivery service to another carrier can take the role of the shipper. The generated CMR contracts holds a link to the initial CMR contract. When the new carrier-carrier CMR is settled (i.e., the

¹<https://docs.provable.xyz/>

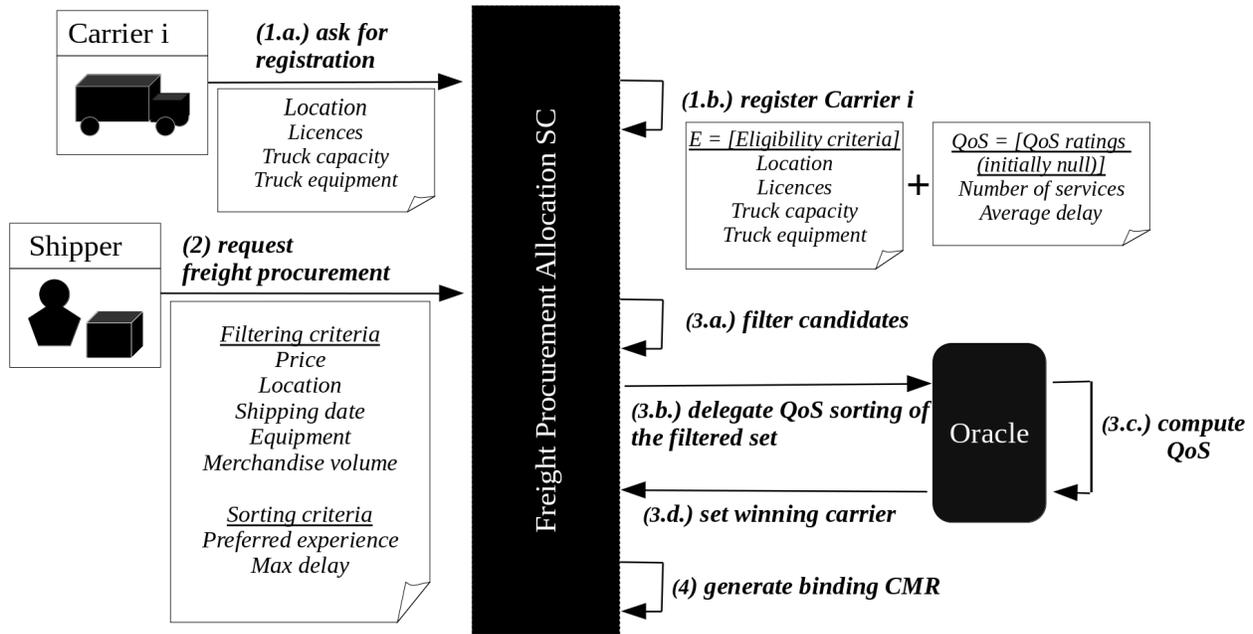


Figure 2. Blockchain-based FTSP mapping protocol

Table 2. Blockchain-based FTSP mapping nascent design principles

Understandability	The smart contract shipper-carrier allocation protocol must be displayed to the shipper
Automation	The FTSP process must be carried on in an end-to-end fashion by the smart contract
QoS-metrics privacy	The allocation mechanism must keep sensitive data off-chain in competitive markets

delegated delivery has been fulfilled), the status of both CMR contracts is set as settled, and the smart contract transfers the corresponding escrowed payments. The QoS rating obtained for the delivery is stored in both carrier profiles.

6.2. Theory generation

In this subsection, we propose three nascent principles stemming from the prototype development cycles in order to dig onto the reasons making the artifact successful [46]. We then discuss these findings under the light of other design science research papers.

Table 2 presents the three emerging design principles detailed hereinafter.

First, **understandability** of the smart contract shipper-carrier allocation is needed to encourage

non-technical users adoption (DP1). Delegating the allocation process to the blockchain triggered some concerns during the user testing stage. More precisely, the use of an oracle raised concerns related to integrity gains. Having no access to the decision protocol, several users were puzzled regarding the end result, as they did not have access to the smart contract reasoning for such allocation. Thus the FTSP platform should display the decision protocol alongside the data output to avoid the technological black-box effect. We propose to display to the shipper the outputs of the computation for each profile to counter the black-box issue.

Moreover, **automation** of the FTSP process is necessary (DP2): the FTSP process must be carried on in an end-to-end fashion by the smart contract. Indeed, one of the significant benefits underlined by both testers and experts is process optimization. Experts have made suggestions for enriched process automation. More precisely, they foresee blockchain-based FTSP mapping as autonomous agents managing request bundling, re-pricing, or matching. To integrate automation into our artifact, we merge the service request and contractualization stages into one step. The service status is tracked and managed within the blockchain for integrity and efficiency. Nonetheless, oracle latency is at stake regarding allocation queries, as it can take up to several minutes to process an request. According to one expert, *'latency variability seems acceptable for long-term markets where contracts can be set for a year or so [...]'* In spot markets, the service provider could

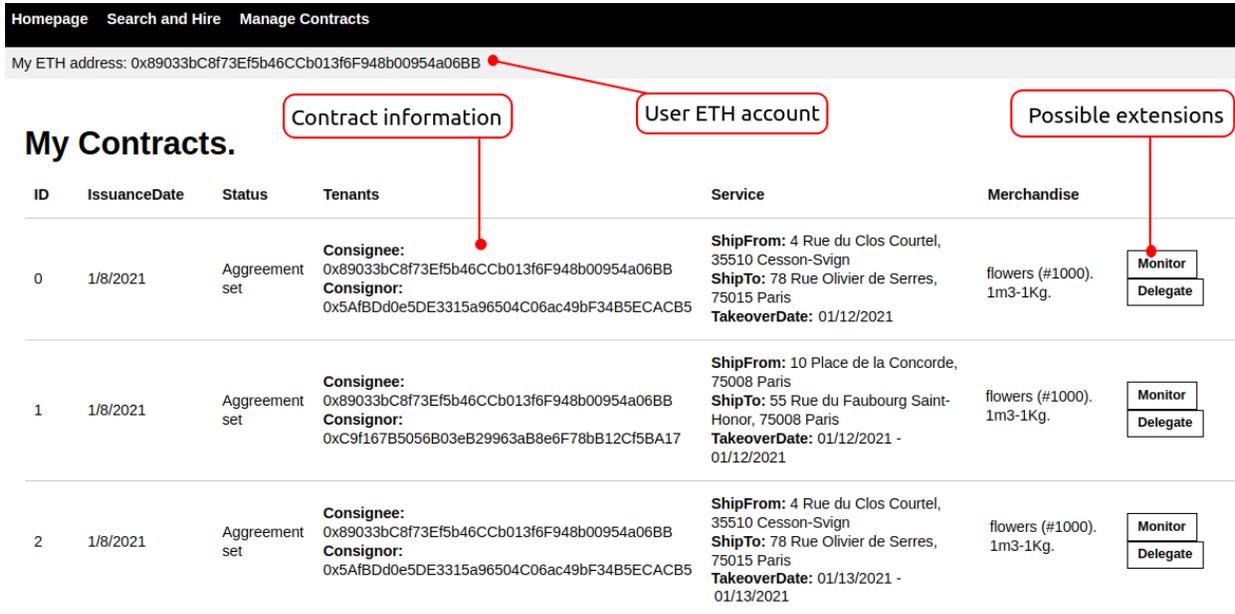


Figure 3. Screenshot of the digital CMR agreements stored in the blockchain.

become unavailable before the end of the query.’ Thus, the automation of the FTSP mapping should take into account allocation latency.

Finally, **metrics privacy** should be considered (DP3). The allocation mechanism must keep sensitive data off-chain in competitive markets. On the evaluation side, the disjunction between private and public data appears in several testimonies. Such sensitivity needs to adjust to the market at stake. Price and capacity data are sensitive and should remain private to other carriers’ eyes. Though our prototype saves QoS metrics to the blockchain, a better option is to encrypt the price and volume metrics. We leave it for future work.

These nascent design principles resonate with several design principles proposed in the design science research literature.

Accessibility of blockchain-based applications to non-technical users is one of the design principles of [30]. The design principle (DP1) stands on the necessity to explain adequately the smart contract decision-making process to users. Though blockchain smart contracts prone automation and transparency, protocol and data trust comes at the condition that users understand well the mechanisms motivating a decision (a delivery request allocation here). (DP1) is thus reinforced as a design principle.

Moreover, allocation automation (DP2) resonates with the need for digitizing paper-based processes in [30]. The issuance of CMR contracts implies the production of several paperwork copies that need to

be approved by both shipper and carrier at the start of the delivery. Consequently, the paperwork slows down the delivery process, reduces overall efficiency, and implies tampering risks. (DP2) also resonates with the potential for smart contracts to manage processes presented in [29]. (DP2) is thus also reinforced as a design principle.

Lastly, the privacy of allocation metrics (DP3) resonates with the need to manage in an off-chain fashion private and sensitive data. These needs were underlined in [47] that performed a design science research study in the trucking industry: private carrier and shipper information should remain off-chain. The need for sensitive data privacy is also underlined as a design principle in [31] and [28]. QoS metrics act as private and sensitive data in our setting. In the future, the QoS metrics of our proposed mechanism should consequently whether be ciphered so that they cannot be understandable by other competitors, or kept off-chain.

Thus, (DP1-3) can be considered as design principles regarding the development of a blockchain-based FTSP solution.

The contribution of this paper to theory lies into investigating the use of the blockchain in the logistics industry with respects to coepetition [12]. The current FTSP related literature mostly focuses on the traditional carrier-to-shipper market. Little attention has been paid to carrier-to-carrier market; and the application of blockchain and smart contract in such market is still a brand new research topic. The FTSP process is applied

in a cooperative and cooperative environment as (1) competing carriers agree to use the same platform to gain a service auction, and (2) competing shippers agree to use the same platform to find an adequate carrier. Both shipper and carrier participants have a shared interest in using the blockchain-based FTSP platform as the system has the potential to reduce operational costs, increase visibility of the carriers, and transparency and integrity of the deliveries.

7. Discussion, conclusion, and future work

This paper focuses on answering the need of logistics services procurement for more effectiveness of the carrier-shipper mapping process, alongside information transparency, and power balance. To do so, we investigate on the potential of the blockchain technology that offers decentralized and trustworthy scripting capabilities. To this aim, we carry out a design science research project focusing on the use of blockchain for decentralized logistics services procurement.

The paper addresses two research gaps in the blockchain literature: the scarcity of blockchain-based freight procurement applications, and the scarcity of theory-driven considerations. To address these concerns, we present a prototype that illustrates how blockchain can help to make carrier-shipper allocation processes more autonomous, objective, and trustworthy. We also provide nascent design principles for FTSP applications that aim to mitigate the transactional risk and uncertainty that is inherent to logistics systems. More precisely, we derive three design principles for the design of blockchain-based FTSP mappings based on the study: understandability, automation, and metrics privacy.

Hence, the issue of information asymmetry is addressed as blockchain smart contracts remove the need for a trusted third party. The tamper-proof capability of the blockchain ledger answers the need for information transparency. Finally, the use of smart contracts also fosters process effectiveness as qualitative mappings can be reached through leveraging blockchain-based carrier QoS.

To be close to the field's reality, we designed the artifact by extracting the main allocation metrics used in FTSP. For the user tests, we gathered a population with no experience of blockchain. Thus we can assume that their answers are close to carriers discovering the technology for the first time. Furthermore, we constituted the focus groups with logistics field experts. Thus, we can assume that we qualitatively assessed the potential of blockchain-based FTSP mapping in the

logistics context. Regarding internal validity and results correctness, we tried to influence the least possible user testing experiments by letting the users free to use the application. The focus group panel was also broad enough to underline the most salient benefits and challenges of using blockchain-based FTSP mappings. However, we acknowledge that the logistics researchers and the industry experts are an estimator of what happens in logistics services' procurement process. At last, the design science research approach is anchored in a FTSP context, and thus findings are not generalizable.

An avenue for future work is to leverage our platform to answer the *metrics privacy* design principle. To do so, we plan to investigate on the use of cryptography methods to cipher the data to be computed for the QoS in order to preserve the procurement privacy required in competitive markets.

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