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Cost-effectiveness and gain-sharing scenarios for purchasing a blockchain-based application in the maritime supply chain

Valentin Carlan* , Christa Sys and Thierry Vanelslander

Abstract

Maritime supply chain (MarSC) stakeholders interact with third parties (e.g. freight forwarders, 3PLs, financial institutes, custom authorities) to facilitate the cargo flow and exchange of information, documents, or financials. Hence, MarSC stakeholders are increasingly interested in innovative technological solutions that vouch for the authenticity and/or the ownership of digital assets without the control of a central third party. Extended research is carried out to prove how applications based on the distributed ledger technology or blockchain address these requirements, yet limited research investigates their purchasing process and economic implications. This paper uses the phytosanitary certificate in an international supply chain flow as a case study where interaction between multiple stakeholders is fundamental and analyses the purchase scenarios of a blockchain-based tool. To do so, it uses a theoretical model that identifies and quantifies the costs and benefits incurred by MarSC stakeholders, formulates gain-sharing scenarios and presents the results of a sensitivity analysis to show the dependence between the data-use and the potential economic gains it generates. The results show that freight forwarders could share economic benefits with shippers or consignees to anticipate purchasing a blockchain-based tool.

Keywords: Cost-effectiveness, ICT innovation, Distributed ledger, Information flow, Maritime supply chain

1 Introduction

The practice of document handling in the maritime supply chain (MarSC) generates extra costs (e.g., paper documents handling, storage or error correction) and hampers MarSC stakeholders from pursuing further optimisation opportunities [1]. Hence, the potential of digital solutions is growing and thus, the use of paper-based solutions for transferring information, ownership rights or financials becomes obsolete. MarSC stakeholders are particularly interested in digital technologies and new tools that enable them to carry and verify transactions without the involvement of a central controlling authority (e.g. an authorised officer from a government department authorised by a national plant protection

organisation). In the MarSC, blockchain-based solutions have thus a high potential to change these types of information sharing practices [2–4] and even to incorporate with new technologies like IoT [5].

How a blockchain is constructed removes the need for a central authority to control or regulate the network. Data authenticity can be controlled, and thus, it can be shared securely across partners that do not trust each other, backed by cryptographic security. Using pre-agreed algorithms, blockchain-based solutions ensure data/information immutability and offer a fail- and risk-free environment for transactions that imply asset ownership transfer. In this context, the neutral intermediary handling transactions between parties is thus subject to replacement and fundamental trust is attributed to technology. This key characteristic could be exploited as well in applications in the MarSC. Moreover, knowing the economic implications of implementing this type of

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application might speed up the purchase and implementation process.

The main goal of this paper is to investigate the potential of blockchain applications launched in the MarSC, to develop a model that quantifies the cost and potential benefits brought by this type of solution, and to explore whether the use of this technology is a cost-effective solution to be used by MarSC stakeholders. It answers the following research question:

RQ: What is the cost-effectiveness of vertical data integration application regarding the transfer of the phytosanitary certificate that uses of a blockchain-enabled application?

To answer this central question, firstly, the research focuses on developing a method that quantifies the costs and benefits incurred by the supply chain stakeholders who purchase a distributed ledger technology (DLT)-based solution. Secondly, it applies this method to identify the number of PHC required to be handled in the vertical supply chain in order for MarSC stakeholders to achieve a more cost-effective working practice by purchasing a DLT-based tool. Finally, it shows which

gain-sharing strategies offer what benefits to stakeholders when they purchase a DLT-based tool.

The structure of the paper is as follows. Section 2 summarises the research method used. Section 3 provides the theoretical foundation on which this new research is built. Section 4 presents the economic analysis framework, while Sect. 5 details of the PHC case study used in this research. Section 6 presents the main findings of this research. Within this section, a discussion on the results provided by the three strategies and how this research contributes to the current state-of-the-art is elaborated. The conclusions and recommendations for future research are in Sect. 7.

2 Research approach

The research approach consists of several steps, comprising both desk research and in-depth interviews with stakeholders. Figure 1 presents fundamental steps that have been taken in this research.

The research starts with a desk research to gain insights into the theoretical background on which this research is built. The already formulated approaches in
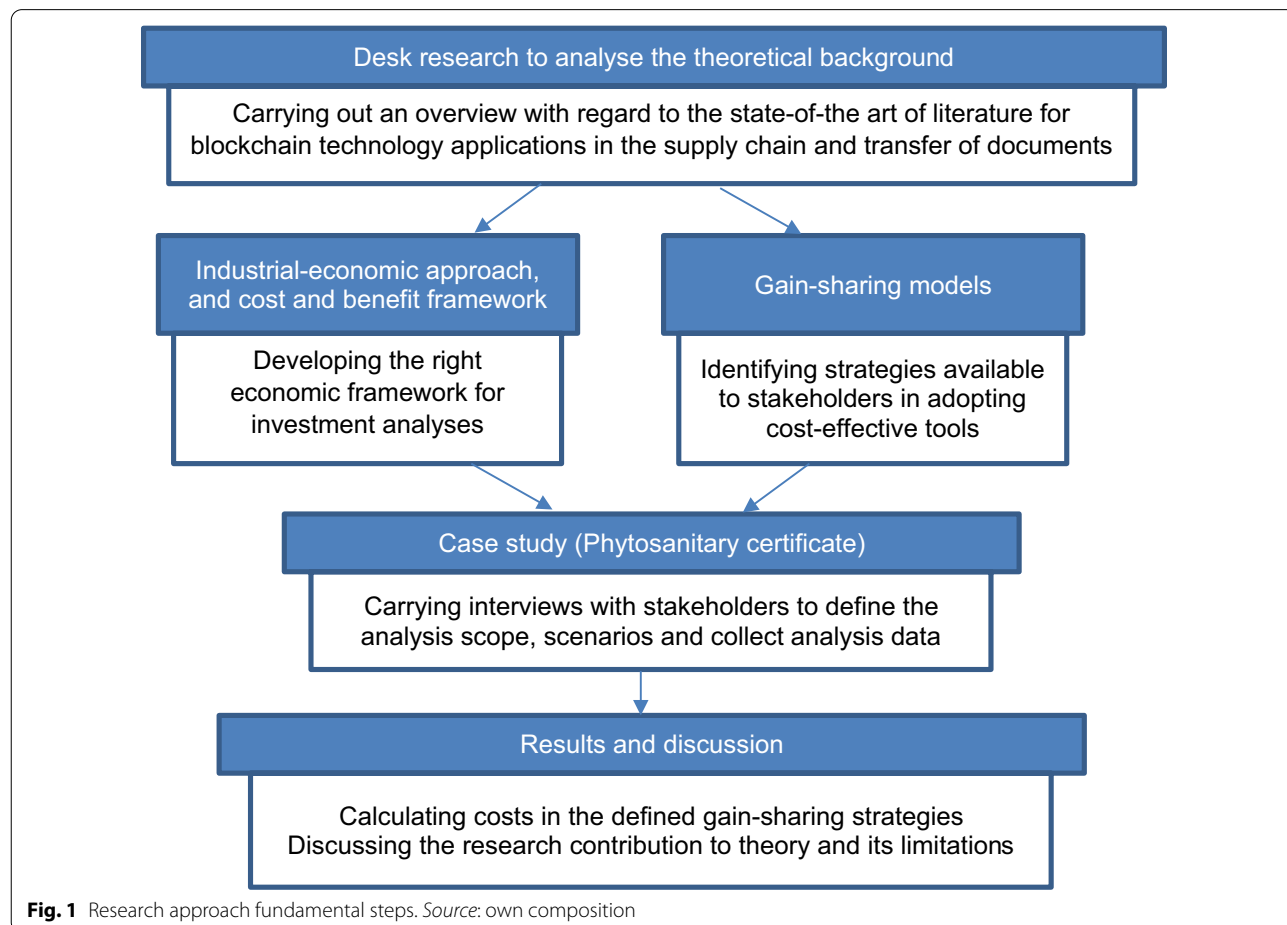

Fig. 1 Research approach fundamental steps. *Source*: own composition

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quantitative assessments of costs and benefits of innovation in the supply chain are also reviewed. From the desk research, key elements addressed in scientific publications, a.o. Lipczynski et al. [6] or Aronietis [7] and Giuliano et al. [8] are depicted. These elements are used in the analysis of the decision to innovate or purchase innovation. At the same time, gain sharing models are also analysed to see how they can be used in new blockchain implementations.

To achieve the goals of this research, five semi-structured interviews with stakeholders involved in the PHC-chain were carried out to set the scope of the case study. The interview sample consists of representatives of a shipping agent, a freight forwarder, a representative of the customs authority, a company implementing digital projects in the MarSC and an IT developer in building dedicated DLT-based solutions. The interviews had a duration of one hour. The interview structure is presented in "Appendix" and consists of three parts: a first part addressing questions with regard to the PHC handling procedure, a second one tackling implementation details of DLT-based solutions and the last one addressing questions with regard to strategies to purchase and implement DLT-based solutions in the MarSC. The results of the desk research and interviews identify and validate the costs incurred by the maritime supply chain stakeholders with regard to the handling of the PHC, the technical requirements to implement a DLT-based solution, but also define which benefits this type of solution bring.

The MarSC stakeholders and the IT developer put forward that all stakeholders involved have to reach cost-effectiveness to purchase the vertical data integration solution. Hence, the stakeholder with the lowest gain (cost-effectiveness) is the one that keeps the solution from being deployed. Gain-sharing models are relevant for this case and offer options to stakeholders for DLT-based solution implementation. In line with this outcome, several strategies are analysed that simulate a real-life business context and purchase a DLT-based solution. The interviewees put forward three strategies to be analysed from this perspective. For these strategies, the cost and benefit quantification framework is used to point out the cost-effectiveness that each stakeholder would reach. The calculated results open the scene for a discussion.

The following sections first provide an overview of the state-of-the-art research related to the blockchain topic. Later, a brief methodological overview is given to highlight the industrial economic approach and previous applications of gain-sharing methods used by academia in assessing the decision to purchase and implement innovation in the supply chain. These theoretical insights are later used in the case analysis in Sect. 5.

3 Theoretical background of blockchain

The most known application of blockchain technology is the digital currency Bitcoin (Nakamoto 2008) [9]. Most authors, like Swan [10], Vukolić [11], Franklin and Hofman [12], Michael et al. [13] or Carlan et al. [14], refer to the seminal 'Bitcoin paper' of Nakamoto (2008) when defining blockchain, although the term 'blockchain' as such does not appear in the paper of Nakamoto.

From a broader point of view, blockchain technology is seen as a digitised, decentralised ledger technology (DLT) that records in chronological order cryptographic transactions in the form of blocks of information [10, 15]. Each block contains a valid transaction, where a transaction records the change of ownership or state for an asset. The presence of several computers ensures the resilience of the system. Carlan et al. [2] define blockchain as the '*technology used for keeping a chronologically ordered list of transactions (a ledger) on multiple, independent computers (called nodes), where updates of the list should be identical on each of the nodes, and each node checks the validity of the transactions before updating its list*.' The present paper starts from the latter definition.

Previous research has addressed the topic of blockchain technology implementation and carried out extensive literature reviews. Research up to 2018 shows that blockchain experts predict a fast upscaling of applications that use this technology. The research of Kshetri [5] or Queiroz et al. [16] looks up best practices regarding studies investigating the implementation of blockchain technology. Hence, this research adds up to the literature with a review of studies published between 2018 and 2021 and examines whether recent published academic literature report otherwise. Publications are thus reviewed from journals like, but not limited to, the International Journal of Information Management, Transportation Research Part E: Logistics and Transportation Review, Journal of Cleaner Production, International Journal of Production Research, Marine Policy, Supply Chain Management: An International Journal or Journal of Air Transport Management. The main research outcomes of this literature review are presented in Table 1.

Blockchain is seen as the technology that can be implemented in the supply chain for the benefit of stakeholders involved in data exchange networks. Publications still claim that the blockchain technology's main contribution is in solving the fundamental problem of lack of trust of logistics stakeholders by introducing a digital solution that automates the certification of data and thus replaces the transfer of hard copies of documents. The research of Hawlitschek, Notheisen and Teubner [17] presents

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Table 1 Key research outcome regarding the state-of-the-art of blockchain research in supply chains. *Source*: own compilation

Observation	Sources
The adoption of blockchain adoption by logistics and supply chain management professionals is still at its nascent stage	[16]
Blockchain technology acts to the benefit of stakeholders involved in data exchange networks and helps to replace the transfer of hard copies documents in trust-free systems	[2, 16, 17]
Research shows that quantifying the computation cost in blockchain networks is done by quantifying the direct impact of the transaction cost, capturing custom development cost is complex and increasing the trust amongst data-network users through applying new methods (for example, gain-sharing strategies) can anticipate the blockchain technology adoption	[18–20]
Empirical studies have been further developed and point out new areas where trust issues are solved by the adoption of blockchain technology (for example both maritime and air supply chain, but also in the supply chain where goods traceability is needed, for example food distribution, jewellery or pharmaceutical products)	[19, 21–24]

detailed research on the limits of trust-free systems and how academia address this topic in the context of sharing economy. One of their main conclusions is that, in order to leverage the advantages of a trust-free blockchain-based platform, means of overcoming the trust-frontier between the closed technical system and the actual physical world need to be further developed by both researchers and practitioners. This conclusion fundaments the later statement of Carlan et al. [2] that a blockchain does not solve the challenges regarding trust, but it delegates' trust' from 'trust in a single third party, to 'trust in algorithms' that process data/information. Yet, the practical experience and literature reports still show that the large scale adoption of blockchain is lagging behind expectations and focus on revealing the potential of blockchain in different application domains and industries. Queiroz and Fosso Wamba [25] indicate that blockchain adoption by logistics and supply chain management professionals is still nascent. These conclusions are not different from those of studies published a few years ago, showing that research is done to prove the potential of blockchain implementation rather than analysing successful implementations.

However, theoretical research on blockchain claims that the complexity of developing and implementing such a solution depends on the knowledge about the functional possibilities offered by this technology, the systems in use, the amount of data available, and the difficulty in implementation in current operational processes etc. In essence, this complexity is captured by developing flexible enough cost calculation models to determine the cost of using blockchain applications for multiple stakeholders. Equally, previous research initiatives, a.o. Schmidt and Wagner [26], Ahluwalia et al. [27], Shahab and Allam [28] or Jabbar and Dani [18], have also been investigating the blockchain transactions and their implication on the computational cost. Jabbar and Dani [18] develop an experimental model that facilitates the design of smart contract transactions in a supply chain. Research has also investigated the critical success factors and necessary

follow up actions to implement blockchain applications successfully. These pieces of advice usually imply relatively heavy financial investments, subsequent to talent and knowledge acquisition, training and education, according to Zhou et al. [20] or Saurabh and Dey [19]. It is expected that the trust amongst data network users is increased when applying advanced methods to guarantee gain-sharing strategies [29, 30].

With reference to empirical cases, the research of Bumblauskas et al. [21] explores a use case for the deployment of blockchain in food distribution, specifically related to eggs, similarly to it, Howson [22] focuses practically on a similar issue, namely the build of trust in the supply chain management with regard to the provenance of seafood and Saurabh and Dey [19] investigate the potential drivers of blockchain technology adoption, considering the grape wine supply chain. Studies covering cases from both the maritime and air supply chain have also been carried out [23, 24, 31]. The conclusions of these studies point to the benefits of the blockchain technology, such as paperless transactions, tracking and tracing, digitalised management, and traffic management.

Up to the present moment, no model that provides insights on quantifying blockchain application development costs, cost-effectiveness, cost-benefits analysis or sharing gains strategies have been developed. Therefore, it is a need to develop a cost-effectiveness model to help stakeholders assess the implementation of any new blockchain application. Such model is also helpful in determining the individual cost structures that each stakeholder in the supply chain has when adopting blockchain-based solutions and sharing eventual benefits.

Hence, the present paper focuses on the blockchain technology that enables vertical data integration in the MarSC, more specifically on applications dedicated to handling document flows and the development of a cost calculation model and gain sharing scenarios in this context. Figure 2 visualises the flow of documents in the supply chain from both perspectives of paper use and from the theoretical use of a blockchain-based solution.
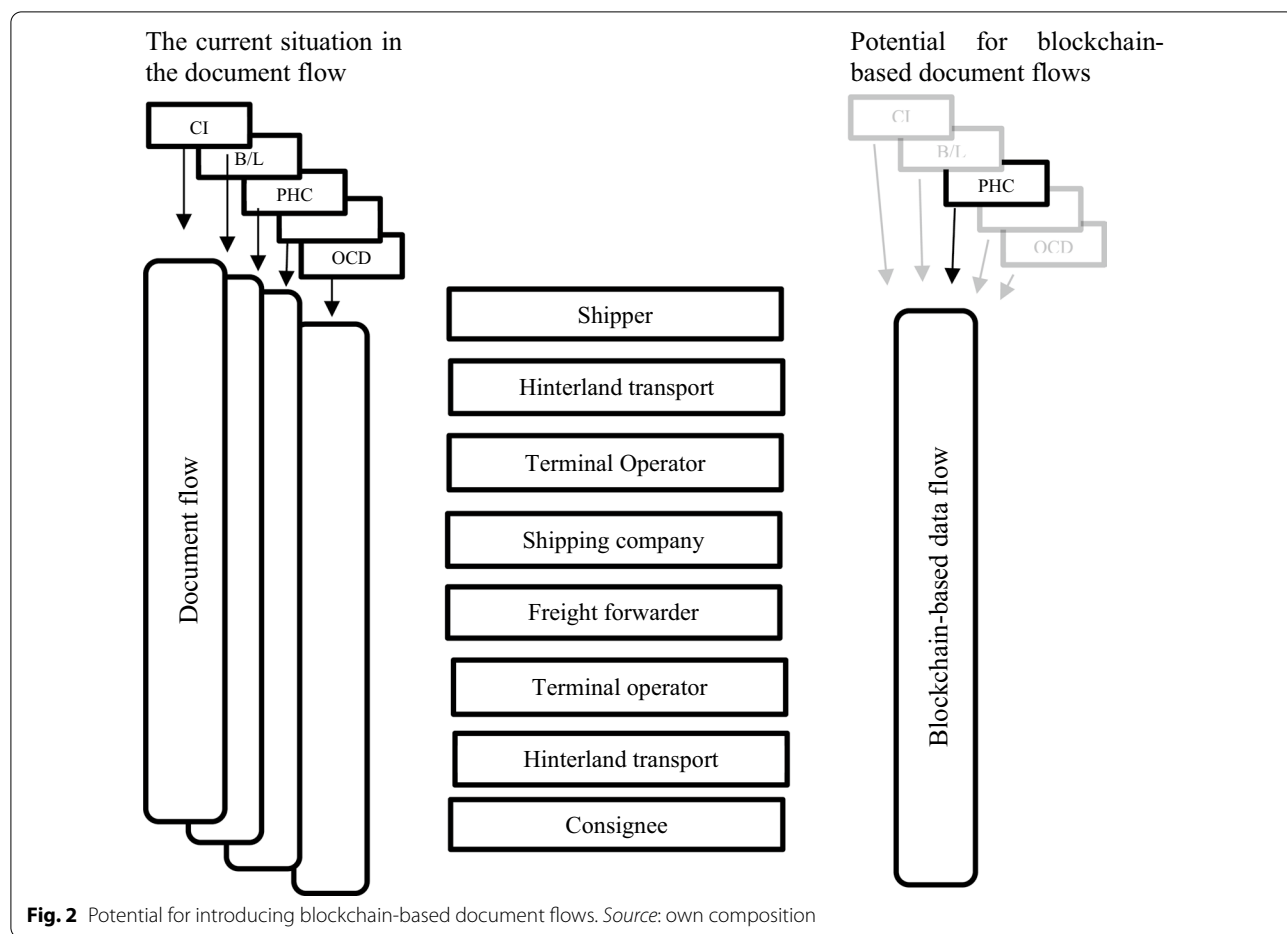
Fig. 2 Potential for introducing blockchain-based document flows. *Source*: own composition

As shown in Fig. 2, the documents in the supply chain are handled as individual flows, whereas a blockchain-based system uses a centralising element for these flows. Hinkelman [32] provides a comprehensive overview of documents used in international trade. According to his research, there are five main documents currently have to be presented in hard copy as proof of authenticity of commercial transactions and authenticity of cargo. These five documents are the commercial invoice (CI), the bill of lading (B/L), the certificate of origin, the export (at origin) customs document (ECD) and/or the import (at destination) customs document (ICD). The flows of these documents are currently independent of each other and are as well pointed out through the example in Fig. 1. In principle, the introduction of a blockchain solution that facilitates the information flow in the MarSC can be used for any type of data certification to be consulted by any supply chain and that allows for access by the necessary MarSC stakeholder, as shown in grey in Fig. 1 as potential flows addressed by a blockchain-based solution.

4 Economic analysis framework
Insights are needed on methods that can be applied to quantify blockchain application development costs, cost-effectiveness, cost–benefit analysis or sharing gains strategies have been developed. This section presents an industrial-economic approach to assessing innovation success and shows an overview of gain-sharing methods developed by academia to support the faster adoption of innovation.

4.1 Industrial-economic approach
The following sub-sections detail the costs and benefits analysis framework and present the theoretical framework to assess the decision to purchase and implement innovation in a vertical supply chain.

4.1.1 The costs and benefits analysis framework
Firstly, this research uses the costs generated by an ICT innovation as the main elements to evaluate the decision to innovate. Confronted with whether to invest or not in an ICT innovation, users lack data with regard to future

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revenues, profits and/or benefits. Moreover, even when data regarding these elements exist, it is difficult to assume or isolate the effect of a single (ICT) innovation investment on the total revenues, profits and/or benefits. These elements are highly sensitive to investments into another parallel (ICT) innovation. Therefore, the used methodology proposes to analyse the decision process when the following data is known:

- the operating costs when an ICT innovation is not in use C_i (referred to as reference operating costs or initial operating costs),
- the cost of purchasing and implementing the ICT innovation C_{ICT} and
- the costs of operating when the ICT innovation is implemented C_f (referred to as future costs or final operating costs).

In this context, the decision to purchase and implement an ICT innovation is taken based on the following equation:

$$C_i > C_f + C_{ICT} + z \tag{1}$$

where:

- C_i—initial user operating costs, generated through the current practice before the ICT innovation is implemented
- C_f—costs of future user operation practice when the ICT innovation is implemented
- C_{ICT}—costs of ICT innovation implementation
- z—is a certain threshold set by the user to claim the innovation's success. Given the further theoretical use of this model, from this point on, z is considered equal to 0

According to Eq. (1), a potential ICT user would purchase and implement an innovation in its daily operation only if the cumulated costs of operating with the ICT innovation and the costs of ICT implementation are lower than the costs of operating without the ICT innovation.

Secondly, this research calculates the benefits enabled by ICT innovation. Traditionally, the term 'benefit' refers to a desirable attribute of a good or service that a customer perceives after a purchase [33]. For the purpose of this research, the benefits are derived from implementing an ICT innovation, and it is assumed that this ICT innovation allows for a lower operating cost. In this context, benefits are given by the following equation:

$$B_U = C_i - (C_f + C_{ICT}) \tag{2}$$

According to Eq. (2), the benefits of using an ICT innovation are the difference between the initial operating costs and the costs of purchasing an ICT innovation cumulated with the costs of operating under the ICT innovation. Benefits derived from potential extra revenues are considered a separate element by this research and out of the scope of this analysis.

4.1.2 Theoretical framework to assess the decision to purchase and implement innovation in a vertical supply chain

This sub-section starts from the assumption that a company's costs to handle a number of assets are proportional to the number of assets owned [7]. Within this regard, the above equations are compiled from the point of view of a MarSC stakeholder that handles PHCs. Its goals are to determine the number of PHC at which a stakeholder would have a lower average operational cost (per handled PHC) when a data integration tool (DLT-based solution) is used in place of carrying on with the manual operational working practice, as put forward in Fig. 3. The average handling cost makes a ratio between the total cost of handling the PHCs and the number of the PHCs handled. This average cost is a preliminary indicator for a firm on their expenses for handling a particular asset.

Figure 3 uses the following notations:

- $\overline{C_i}$—average cost to handle a PHC in the initial working practice, before the ICT innovation is implemented
- $\overline{C_f}$—average cost to handle a PHC in the final working practice, after the ICT innovation is implemented
- $\overline{C_{ICT}}$—average cost of implementing the ICT innovation
- $\overline{B_U}$—average benefit

Figure 3 visualises the average costs of handling PHCs for both working practices. These costs include both the labour and the costs of the service. The average costs of implementing and using a DLT-based tool are also determined for the newly-proposed working practice. This research shows that the average cost of handling the PHCs in the initial scenario is constant, as the same operations and services are used for each certificate. The average cost of using the DLT-based tool is high if there is a small amount of exchanged PHCs and low if used for handling many. Defining these elements allows comparing the two working practices.

Formula (3) validates the decision to purchase and implement the DLT tool for one stakeholder. A stakeholder will implement a DLT-based tool when, for a certain number of PHC nr_{PHC}, the costs of handling the
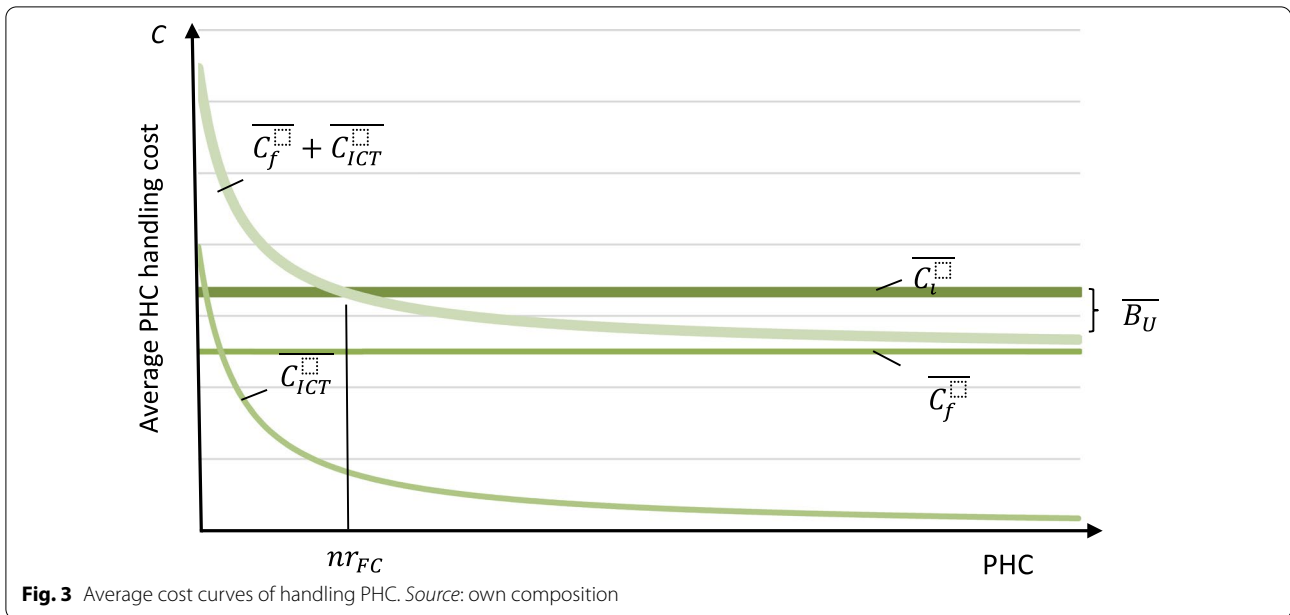
Fig. 3 Average cost curves of handling PHC. *Source*: own composition

PHCs in the initial scenario is higher than the cost of handling the PHCs using the DLT-based tool. The later cost is the sum of using the tool and the cost of implementing it.

$$C_i(nr_{PHC}) > C_f(nr_{PHC}) + C_{ICT}(nr_{PHC}) \qquad (3)$$

where:

- nr_{PHC}—number of PHC that the company handles

Further, the average costs for each PHC are determined for each of the situations initially presented.

$$\overline{C_i} = \frac{C_U^i(nr_{PHC})}{nr_{PHC}}; \overline{C_f} = \frac{C_f(nr_{PHC})}{nr_{PHC}} \text{and} \overline{C_{ICT}} = \frac{C_{ICT}(nr_{PHC})}{nr_{PHC}}$$

The initial equation is also valid for the average costs as written below:

$$\overline{C_i} > \overline{C_f} + \overline{C_{ICT}} \qquad (4)$$

Having to deal with a vertical chain means that the number of PHC (nr_{PHC}) that passes through the chain is the same for each user. However, the costs incurred by each stakeholder when handling the PHC are linked to own labour and services, thus different (due to different cost structures). This means that, while for one stakeholder that has a high costs of handling the paper PHC and might enjoy benefits if a DLT tool is used, other stakeholders might be reluctant to such solutions (as their costs of handling the paper PHC are not high). For a DLT-based tool to be used by three stakeholders A, B and C, the equations below must be simultaneously validated.

$$C_i^A(nr_{PHC}) > C_f^A(nr_{PHC}) + C_{ICT}^A(nr_{PHC}) \qquad (5)$$

$$C_i^B(nr_{PHC}) > C_f^B(nr_{PHC}) + C_{ICT}^B(nr_{PHC}) \qquad (6)$$

$$C_i^C(nr_{PHC}) > C_f^C(nr_{PHC}) + C_{ICT}^C(nr_{PHC}) \qquad (7)$$

Following Eq. (2), the benefits for each user at a specific number of PHC that flow through the chain is determined:

$$B_U(nr_{PHC}) = C_i(nr_{PHC}) - (C_f(nr_{PHC}) + C_{ICT}(nr_{PHC})) \qquad (8)$$

Knowing the above elements, the cost-effectiveness ratio is calculated for each stakeholder using the equation below. This equation shows the percentage in cost reduction for handling the PHC by each user:

$$CE(nr_{PHC}) = \frac{B_U(nr_{PHC})}{C_i(nr_{PHC})} * 100 \qquad (9)$$

The next sub-section puts forward an overview of gain-sharing models that have been applied by academia in innovation assessments in the supply chain.

4.2 Gain-sharing models applied in the maritime supply chain

The research of Yuen and Thai [34] has indicated five main barriers that hinder logistics stakeholders from integrating or developing collaboration. The identification and quantification of costs and benefits are remarked as one of these barriers. The present research starts from

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the premise that ICT developments in the supply chain require the collaboration of different stakeholders. The way forward for establishing/using collaboration platforms is to point out a fair cost and benefit allocation (among factors like governance structure, trust and privacy arguments). In some cases, the non-agreement with regard to this allocation slows down or even interrupts the innovation process, as remarked by Carlan et al. [35]. In logistics, the particularities of operational collaboration practices have already been addressed by academia [36–39].

Bergantino and Coppejans [40] develop a pricing mechanism for allocating common maritime infrastructure costs. The advantage of their method is that it considers both sides of the market. From the demand side, the model considers the stakeholders' willingness to pay, and from the supply side, they consider the costs of infrastructure sharing. Gain-sharing approaches were initially used internally by companies to encourage employees toward better performance. Research in this regard Arthur and Huntley [41], Pouliakas and Theodossiou [42], Kruse, Freeman and Blasi [43] have put forward the principles of gain sharing from a human resource point of view. Besides its individual motivational functions, gain sharing is also used in logistics coalitions. Giannoccaro and Pontrandolfo [44] seek supply chain coordination issues from a decision-making approach and develop a revenue-sharing mechanism. Similarly, Cachon and Lariviere [45] conclude that revenue sharing is equivalent to buybacks or price discounts in price-setting cases. In logistics, the gain sharing applies mostly to retailers competing in quantities, e.g., Cournot competitors. Moreover, acknowledging the fact that costs and gains are generated as a result of cooperation, Defryn [46] investigates the details of which fraction of horizontal collaboration gains goes to what partner and who should pay what part of the collaboration cost under a gain-sharing approach.

The method used by Defryn [46] to define the strategic interactions between logistics players is derived from the principles of cooperative game theory and the gain share approach. Therefore, he focuses his research on five methods of cost-sharing: the Shapley value, the Nucleolus, the Equal Profit Method (EPM), the Alternative Cost Avoided Method (ACAM) and the Volume-based method (VBM). These methods are applied in horizontal collaboration practices in the supply chain, for which it is not critical that all supply chain stakeholders are involved at once. Yet, no research applied these tools to study the gains brought by collaborative ICT innovation in the MarSC. This is what the present paper applies,it uses knowledge with regard to gain sharing models and applies it within a case study, as presented in the next section.

5 Case study: implementing a dlt-based solution to facilitate the transfer of the phytosanitary certificate case

This section presents de details of the case study used in this research. First, the context of the case study is described. Next, the strategies to implement a DLT-based solution to facilitate the transfer of the certificate of origin (or PHC) are explained. Ultimately, the theoretical analysis framework is applied.

5.1 Case study description

A special form of the certificate of origin, also known as the phytosanitary certificate (PHC), is taken as a case study for the present research. This official certificate, issued by a controlling officer authorised by the National Plant Protection Organization (NPPO), accompanies transactions that involve the import or export of plants, plant products or other materials from third countries [47]. It serves as proof concerning cargo's authenticity and low risk for infection spread. Regarding this type of document, maritime supply chain stakeholders (e.g., forwarders, customs agents or customs authorities) at the port of Antwerp seek to use new technological advancements and implement a unanimously agreed solution that allows it to be used in a digital form. In 2017 alone, approximately 6800 PHCs have passed through the Port of Antwerp (FAVV, 2018), requiring manual handling. As Peeters [48] shows, after comparing different technologies (e.g., paper, EDI, cloud storage or blockchain) used in document handling, there is a high potential for the blockchain technology to be used in this case. A technical solution developed to transfer the PHC using DLT-based technology is in the pilot stage. Figure 4 visualises the standard document exchange sequence for the PHC case. The bold-framed stakeholders are the most relevant here.

Figure 4 presents the flow of the PHC starting at the national plant protection organisation NPPO that issues it and which stakeholders in the MarSC interact with this type of document. From the NPPO, the PHC is handed over to the shipper. This stakeholder transfers the document to the consignee that has an obligation to present it to the NPPO of the destination country to have its authenticity checked and complete the import procedures. Yet, if a freight forwarder orchestrates the supply chain, the consignee hands the PHC to the freight forwarder to further handle the import procedure. This latter case is considered for further investigation by this research. In this context, a DLT-based application is proposed to be used to transfer the PHC. A DLT-based application addresses problems like cybercrime, potential errors and late deliveries of paper documents. Blockchain technology guarantees that the authenticity
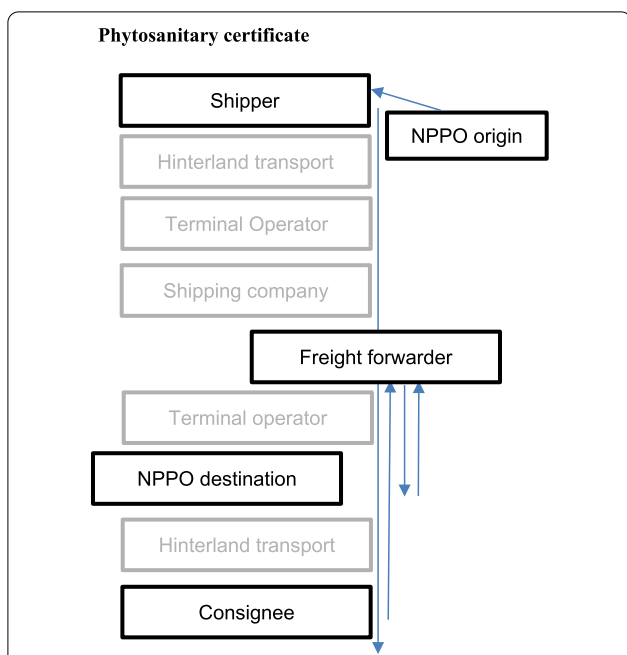
Fig. 4 The PHC handling flow through the maritime supply chain. *Source*: own composition based on Meersman et al. [49]

of the certificates has not been tampered and the actors involved can retrieve the origin of the documents in real-time. This way, the involved stakeholders immediately have all the latest information and the necessary preparations or checks can be made faster. The implementation strategies suitable to apply gain-sharing strategies are presented in the next sub-section.

5.2 Strategies for implementing a DLT-based for handling the PHCs

The interviewees suggested three strategies: cost-effectiveness achieved, cost-effectiveness achieved by all stakeholders under a gain share setting, and

cost-effectiveness achieved when an authority acts as a facilitator. Here, under strategies is understood possible development tracks to cover the costs of implementing the DLT-based tool for handling the PHC. The strategies that the involved stakeholders and the authorities can follow are shown in Table 2.

The first strategy leaves the full implementation to the stakeholders. Through this strategy, it is assumed that the stakeholders would consider the implementation of the DLT tool and cover the implementation costs individually. With this assumption, the stakeholders are motivated to finance the DLT-based tool when the costs generated by the ICT solution are equal to the cost of using the paper PHC. Sub-strategy 1a considers that this condition is met at one stakeholder determining a minimum amount of PHC needed in the chain. Sub-strategy 1b considers that all the stakeholders need to meet this condition and agree to implement the DLT-based tool for the PHC chain flow. The second strategy builds on the latest. It considers that all the stakeholders meet the assumed condition, and the number of PHC is determined (sub-strategy 1b). From this point on, the stakeholders apply two further gain-sharing strategies. In strategy 2a, the stakeholder with the highest cost-effectiveness shares its benefits with the other two. One should be aware that this type of approach creates the premises for overcapitalisation. In strategy 2b, the total benefits gained by all stakeholders are cumulated and are equally shared amongst everyone (according to the Shapley value principles). Lastly, strategy 3 discusses the collaboration between the port authority and private stakeholders to cover partially or fully the tool's development costs. These strategies are proposed to highlight on the one side the possible challenges and the interests of different stakeholders, but also to point out possible collaboration formulas towards the achievement of a digital PHC flow in the studied chain.

Table 2 Implementation strategies analysed. *Source*: own composition based on interviews

Strategy 1	Cost-effectiveness achieved
	1a. By one stakeholder
	1b. By all stakeholders
Strategy 2	Cost-effectiveness achieved by all stakeholders under a gain share setting
	2a. The party that benefits the most, shares its benefit
	2b. Equal benefits to all involved parties (Shapley value particular case)
Strategy 3	Cost-effectiveness achieved when an authority acts as a facilitator
	3a. It covers the connection costs
	3b. It covers the software development costs
	3c. It covers all development costs (except the pay per use)

The in-depth analysis framework and results are shown in the following sub-section.

5.3 Applied theoretical analysis framework and data

This sub-section firstly presents the empirical analysis framework used in this paper. Secondly, the data used is explained.

5.3.1 Applied theoretical framework

This case study analyses the decision to invest in a DLT tool that saves labour and services acquisition. In line with the methodology presented above, the average operational costs of using labour are compared with the average cost of using a DLT-based tool to process the PHCs in a vertical chain.

The current total cost of handling the PHC incurred by each stakeholder has two components. The first component consists of the cost of sending a document through a mailing service, and the second component is the labour work put into it. The cost of sending, receiving, correcting, matching or searching data is also calculated as a labour cost. This type of labour cost is calculated according to the time an employee spends on average on each of these actions and/or considering that only a percentage of the PHC requires this type of action, as shown in Eqs. (10)–(12).

The operational costs for handling PHC are calculated for each supply chain stakeholder (shipper, forwarder and consignee) for both working practices. These costs are calculated in both situations as shown by the equations below and later following the data in Table 2.

t^x_{send}—average time spent to send information, including the completion of the paper PHC

$t^x_{err_{corr}}$—average time spent to correct per PHC

μ^x_{err}—percentage of PHC that require error correction

$t^x_{info_{ser}}$—average time spent searching for information with regard to PHC

$\mu^x_{info_{ser}}$—percentage of PHC that require information search

t^x_{bi}—average time spent on broad network information, information retrieved from the network

μ^x_{bi}—percentage of PHC for which real-time status information is required

n—number of stakeholders in the chain

t^x_{use}—average time spent to handle a PHC in the tool

c^x_{serv}–cost of mailing service

$c^n_{ICT\_use}$–unitary cost of using the ICT tool for one PHC

$C^x_{infr_{dev}}$—cost of ICT tool infrastructure development (nodes) consisting of the estimated unitary development cost per day $c_{u\_inf\_dev}$ and the required amount of development days d_{inf_dev}

$C^x_{soft\_dev}$–cost of ICT tool software deployment (consensus algorithm implementation) consisting of the estimated unitary software development cost per day $c_{u\_soft\_dev}$ and the required amount of development days d_{sof_dev}

Verifying Eq. (10), the number of PHC that would meet this condition for the stakeholder x is determined by the following formula:

$$n_{PHC} > \frac{c_{u\_inf\_dev} * d_{inf\_dev} + c_{u\_soft\_dev} * d_{sof\_dev}}{y\left[c^x_u\left(t^x_{receive} + t^x_{send} + t^x_{err_{corr}} * \mu^x_{err} + t^x_{info_{ser}} * \mu^x_{info_{ser}} + t^x_{bi}*\mu^x_{bi}(n-1)\right) + c^x_{serv} - c^n_u * t^x_{use} - c^n_{ICT\_use}\right]} \quad (13)$$

$$C^x_i(nr_{PHC}) = n_{PHC}\left[c^x_u\left(t^x_{receive} + t^x_{send} + t^x_{err_{corr}} * \mu^x_{err}\right.\right.$$
$$\left.\left. + t^x_{info_{ser}} * \mu^x_{info_{ser}} + t^x_{bi}*\mu^x_{bi}(n-1)\right) + c^x_{serv}\right] \quad (10)$$

$$C^x_f(nr_{PHC}) = n_{PHC} * c^n_u * t^x_{use} + n_{PHC} * c^n_{ICT\_use} \quad (11)$$

$$C^x_{ICT}(nr_{PHC}) = C^x_{infr_{dev}}(nr_{PHC}) + C^x_{soft\_dev}(nr_{PHC}) \quad (12)$$

where:

n_{PHC}—number of PHC handled per day

c^x_u—unitary labour cost of an employee of stakeholder x

$t^x_{receive}$– average time consumed to retrieve information

5.3.2 Data used

Table 3 puts forward the elements used to calculate the costs in the case study presented. These cost elements are collected during the interviews and cross-validated. The numerical values selected as input for the theoretical model are validated and agreed upon with the interviewees. This data is validated with representatives of supply chain stakeholders and blockchain experts, as well as the results of the analysis.

6 Results and discussion

This study's numerical analysis shows the number of PHC needed to justify the implementation of an ICT in a vertical supply chain. Subsequently, the results from the perspective of each strategy are given below. For strategy 1, Fig. 5 visualises the average costs for handling PHCs

Table 3 Cost elements are used in the cost calculation. *Source*: personal interviews with representatives of supply chain stakeholders and blockchain experts

Cost element	Variable range	Values used in the theoretical model		
		Shipper	**Forwarder**	**Consignee**
n_{PHC}	Used as variable (1–2000)			
c_u^x	Varies between 20 and 50 EUR/h	31.02	35.2	20
$t_{receive}^x$	Varies between 2 and 10 min	5	10	10
t_{send}^x	Varies between 10 and 30 min	20	10	15
$t_{err_{corr}}^x$	Varies between 30 and 50 min	N/A**	30	50
μ_{err}^x	Depending on the tool used, it varies between 1 and 2%	N/A**	2%	2%
$t_{info_{ser}}^x$	Varies between 20 and 30 min	N/A**	20	30
$\mu_{info_{ser}}^x$	Depending on the necessities, it varies between 1 and 2%	N/A**	2%	2%
t_{bi}^x	Varies between 3 and 5 min	3	3	5
μ_{bi}^x	Depending on the tool used, it varies between 10 and 30%	20%	20%	20%
t_{use}^x	3 min per certificate	3	3	3
$c_{ICT\_use}^n$	Varies between 20 and 35 EUR	20	20	20
$c_{u\_inf\_dev}$	Varies between 400 and 750* EUR	500	500	500
d_{inf_dev}	Varies between 1 and 4* days	4	4	4
$c_{u\_soft\_dev}$	Varies between 400 and 750* EUR	700	700	700
d_{sof_dev}	Varies between 30 and 60* days	45	45	45

*These cost elements are indicating a DLT-based application for the handling of the PHC. This IT solution offers a data exchange rate of 1 GB per second, enabling thus 2–300 transactions per second (at a volume of max 3 kb data/transaction)

**Not applicable

incurred by each stakeholder in two cases. Each strategy visualises the operational cost calculated in the scenario when a DLT-tool is not used. This operational cost is used as a reference as it remains constant regardless of the number of PHC a stakeholder handles. The new operational cost, when an ICT tool is used, is then calculated individually at the involved stakeholders for each strategy. This cost is high when stakeholders handle low amounts of PHCs per day, but low when high amounts of PHCs are handled. Further, the results of each substrategy are given. Strategy 1a. shows the number of PHC at which a first stakeholder might consider implementing the ICT tool. According to Table 3 (strategy 1a), the freight forwarder is the actor that meets this condition and (s)he requires a volume of 189 PHC. However, this solution is not acceptable as the costs for the other stakeholders (the shipper and the consignee) of using the ICT tool are higher than the potential benefits they receive. In Strategy 1b, the number of PHC at which all the stakeholders have at least a positive balance with regard to the two situations is shown. As seen in Table 3 (strategy 1b), the stakeholders require a volume of 483 PHC. At this volume, the shipper would benefit from lower handling cost by $B_s^{1b} = 20.55$ EUR and the forwarding company by $B_f^{1b} = 40.40$ EUR.

Strategy 2 starts from the previous calculations and applies a gain-sharing methodology to stimulate the

adoption of the DLT tool. The same reference and operational costs are plotted as in Fig. 5. Figure 6 visualises, as an extra, the average operational cost incurred by each stakeholder when two gain-sharing approaches are applied. This cost is drawn for each stakeholder with dotted lines. Therefore, strategy 2a proposes that the stakeholder with the highest gain share its benefits to the other. As seen in Table 3 in this situation, the shipper would benefit from a reduction by $B_s^{2a} = 34$ EUR on its cost of handling the PHC, while the forwarder and the consignee would have a cost reduction of $B_{f,c}^{2a} = 13.5$ EUR. If one considers that this type of sharing is not completely fair, strategy 2b proposes a further approach that splits the gained benefits equally. In this strategy, each involved stakeholder benefits from the same financial advantages. Hence, in this strategy, all the involved stakeholders have an average of $B_{s,f,c}^{2c} = 20.3$ EUR reduction in costs of handling the PHC. This average handling cost reduction is shown in Fig. 6 (strategy 2b) as the difference between the operational reference cost (dark continuous line) and the operational cost achieved when a gain-sharing approach is applied (dotted line) when 483 PHC are handled through the chain.

Regarding strategy 3, it is suggested that the port authority takes the enabler role and covers the development costs. Figure 7 visualises the results. It starts from the outcome presented in the initial strategy, where the
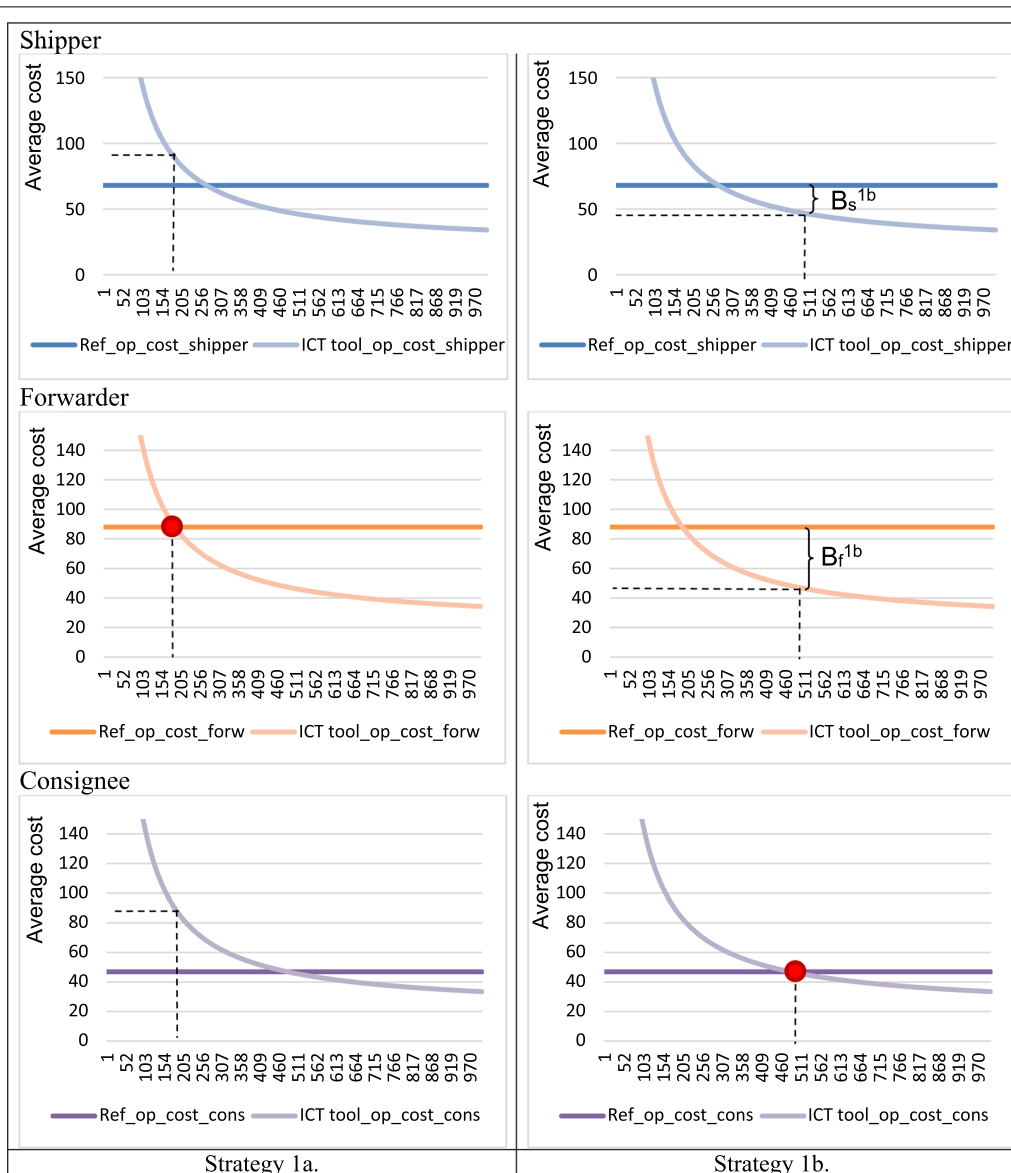
Fig. 5 User average costs if strategy 1 is applied. *Source*: own composition

reference and ICT operational costs are shown. The dotted lines show the ICT operational cost for each stakeholder in three further strategies as follows. Strategies 3a and 3b propose that the port authority covers the infrastructure connection costs and the software development cost, respectively, while the other involved stakeholders (shipper, forwarder and consignee) cover the pay-per-use fee. By doing so, the amount of PHC that is required to be processed through the chain is 405 documents for the first one and 78 documents for the second one. Strategy 3c proposes that the port authority would cover both

these costs. In this case, the cost remaining to be covered by the supply chain stakeholder is the pay-per-use one (which is constant, as shown in Fig. 7, regardless of the amount of PHC handled through the ICT tool). Given the fact that this cost is lower than the current cost of handling the PHC paper documents, all the stakeholders in the chain are encouraged to adhere to this solution regardless of the number of documents that pass through the chain. This approach has the advantage that by expanding already-in-place solutions, an immediate market for early adopters will be reached.
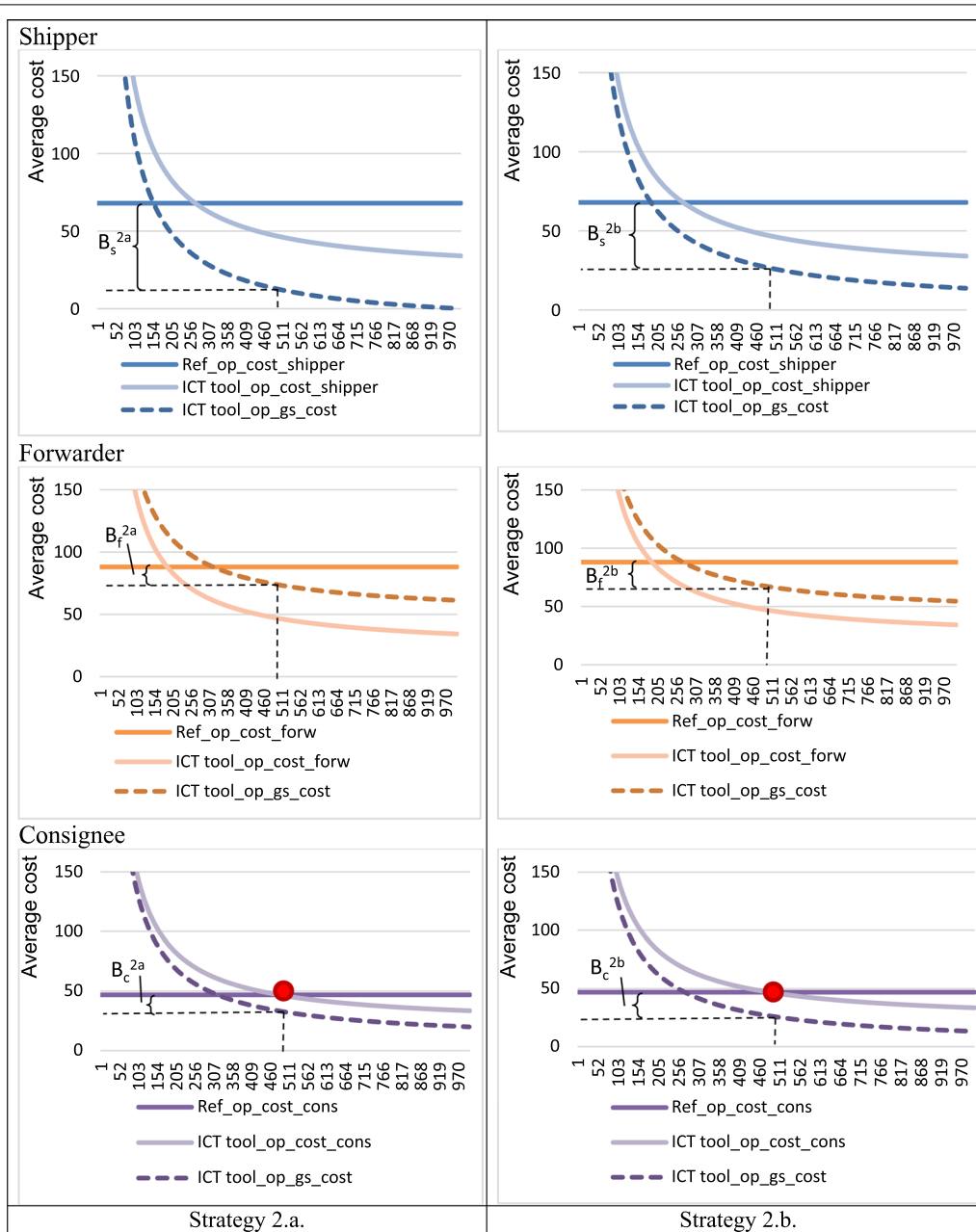
Fig. 6 User average costs if strategy 2 is applied. *Source*: own composition

In sum, Table 4 presents the results with regard to each strategy, namely the number of PHC needed to reach each strategy and the stakeholders' benefits in each case.

The results presented by this research show an equivocal answer to the cost-effectiveness of implementing a DLT-based solution in the MarSC. In a vertical supply chain integration, the blockchain implementation needs to be cost-effective for all the data exchange network users. There are several strategies to investigate that.

First, the analysis shows that strategy 1 is applied only if all involved stakeholders achieve a positive cost-effectiveness ratio (as shown in strategy 1b.). This basic strategy shows in principle that the stakeholder in the network would have the highest implementation cost or require the highest transaction volumes to economically justify the implementation of a new solution and, in practice, keep the blockchain solution implementation on hold. Second, implementing a DLT-based solution requires
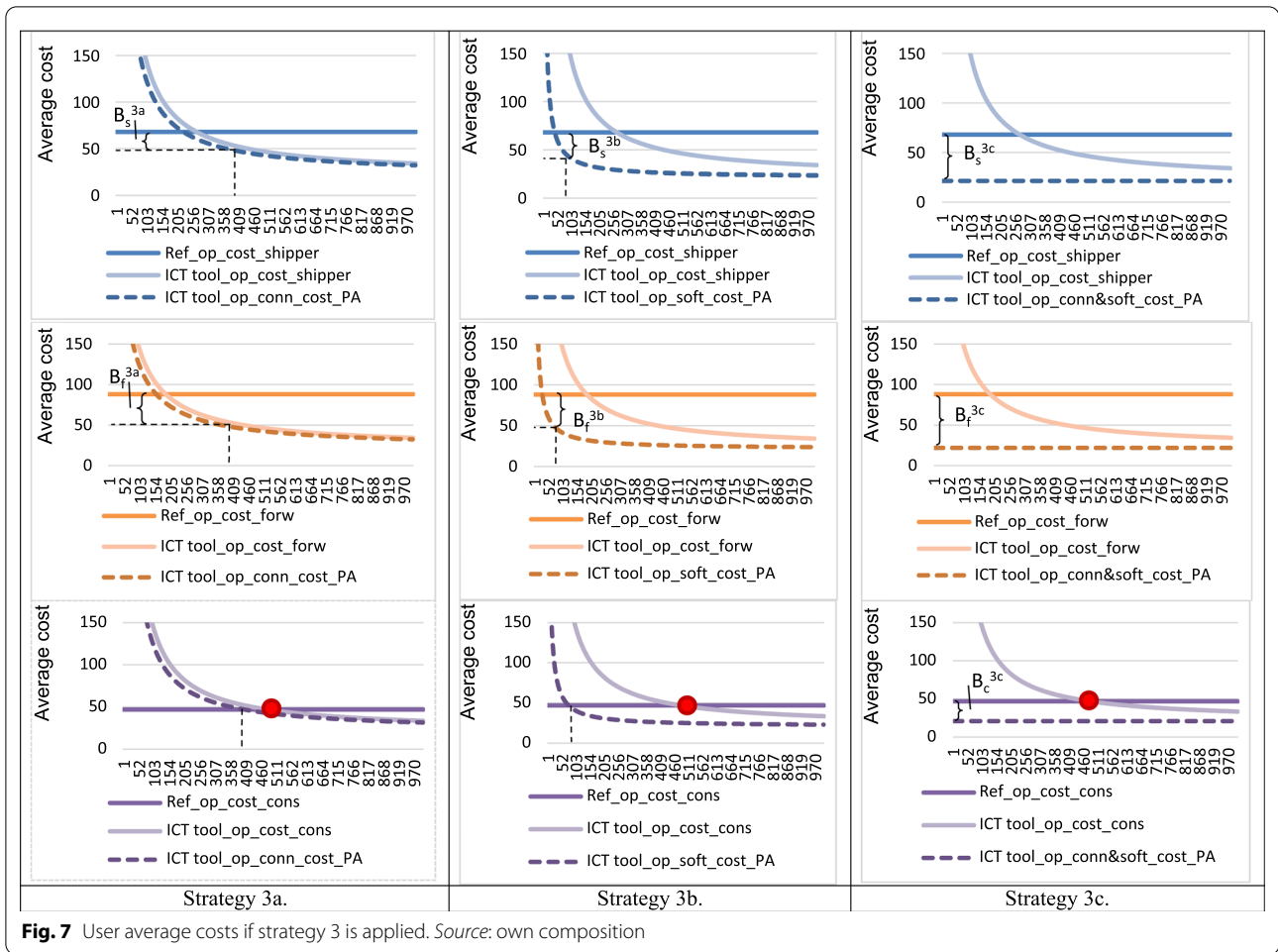
Fig. 7 User average costs if strategy 3 is applied. *Source*: own composition

Table 4 Centralisation of analysis results. *Source*: own composition based on calculations

Strategy	Minimum number of PHC	Shipper		Forwarder		Consignee	
		Euro saved	CE (%)	Euro saved	CE (%)	Euro saved	CE (%)
Strategy 1							
1a	189	− 19.7	− 29	0.1	0	− 40.3	− 59
1b	483	20.5	30	40.4	59	0.0	0
Strategy 2							
2a	483	34.0	50	13.5	15	13.5	29
2b	483	20.3	30	20.3	23	20.3	44
Strategy 3							
3a	405	20.4	30	40.3	46	0.0	0
3b	78	20.8	31	40.6	46	0.3	1
3c	1	46.4	68	66.2	75	25.9	55

that all the stakeholders are open concerning their PHC handling cost and that the stakeholder who has the most benefit can share it with the rest. In the analysed case, the freight forwarder has the most considerable advantage

and, depending on the different gain sharing strategies, either the shipper or the consignee might benefit. This strategy points, in principle, towards the stakeholder that has the most gains from implementing the network

solution. It also provides alternatives to implement a potential solution if the gain is shared amongst the network participants. In the last strategy, when a third party covers costs, the cost-effectiveness of a DLT-based solution is achieved by all stakeholders when handling lower amounts of PHC. Hence, this strategy could anticipate the implementation of the DLT-based solution. In this context, the freight forwarder benefits from a high cost-effectiveness ratio. This last strategy also tests the developed model by showing that if the costs are reduced with external intervention, the adoption of the network solution will be economically justified by lower flow volumes.

Applications that use DLT (or blockchain) technology definitely have applicability and vertical integration goals in the supply chain. In general, innovation generates both costs and benefits, and these two elements are analysed at the level at each entity before investment decisions are taken in a cost-effectiveness analysis. Yet, the present empirical analysis shows that the introduction of innovation with a vertical data integration goal is conditioned by the agreement of all involved stakeholders (innovation users). Innovation with a vertical integration goal is thus successfully adopted only if it brings (equitable) economic benefits to its users. To this extent, the vertical integration of supply chain operators could be favoured if authorities financially support the adoption of blockchain-based applications.

On a more general note, this research shows how the DLT technology can be successfully implemented in the supply chain to the benefit of stakeholders involved in data exchange networks. It adds up to the literature review by drawing conclusions from studies published between 2018 and 2021, and observes that, while previous research had claimed that blockchain technology implementation will accelerate, there are no global scale successful applications yet. Moreover, no model that provides insights on quantifying blockchain application development costs, cost-effectiveness, cost-benefits analysis or sharing gains strategies have been developed. Therefore, this research has the following original contributions.

The experience and the literature review show that even when supply chain stakeholders are shown the cost-effectiveness of blockchain-based solutions, stakeholders networks still do not incline to accelerate its adoption. The reason is that, due to different operational cost-structures, not all stakeholders involved in a data exchange network reach cost-effective solutions at a certain transactions volumes. A response to this shortcoming is the calculation of cost-effectiveness at each individual stakeholder and apply gain-sharing scenarios.

The latter pin-points the returns that can be shared, from stakeholders that have better gains towards the ones with less gains, for faster successful adoption of a solution. To cover this instance, the present paper develops an analysis framework and applies it on a concrete case study. The analysis framework combines an industrial-economic approach and gain-sharing scenarios. The newly developed framework of analysis is flexible enough to treat the transaction and development costs as input variable allowing further custom analyses. The literature (e.g. [20] has shown as well that blockchain solution developers must carry relatively heavy financial investments, next to investments in talent and knowledge acquisition, training and education. Moreover, these elements are fundamental in determining the individual cost structures that each stakeholder in the supply chain has when adopting blockchain-based solutions. These elements are addressed in the present paper and are fully customizable in the newly developed model for further analyses development.

With reference to the empirical part, the focus of this paper is thus set on the phytosanitary certificate and applying the newly developed cost-effectiveness model on a specific network of stakeholders related to one port. This empirical exercise is in line and relates to other publications that analyse supply chain where the goods traceability and trust is key. For example, the research of Bumblauskas et al. [21] explores a use case blockchain is deployed in food distribution, specifically related to eggs. Similarly, Howson [22] focuses practically on a similar issue, namely the build of trust in the supply chain management and the traceability of seafood provenance, and Saurabh and Dey [19] put forward a case study considering the grape wine supply chain. They conclude with stating that a cost-effective blockchain architecture is a driver for faster adoption. Previous research has put forward case studies from the airport industry, such as the one of Li et al. [23]. Their research concludes that digitalization management remains the most influential factor positively affecting the intention to adopt blockchain and could effectively promote digitalization in the aviation industry. Yet, no economic model is linked to these research initiatives. Therefore, the present research sets new borders in the literature dealing with blockchain applications. The newly developed framework is transferable and has the potential to be used in applications in different industries than the maritime supply chains and ports.

The following section presents the conclusions and limitations of this research. Equally, it provides remarks concerning future potential development tracks.

7 Conclusions and final remarks

This paper presents an analysis of a DLT-based application to be purchased and implemented in the maritime supply chain. This application addresses the vertical flow of information related to the transfer and handling of the phytosanitary certificate (PHC) as a new research topic. The approach taken by this paper consists of both desk research and interviews with logistics stakeholders. The desk research provides an overview of the state-of-the art research about the blockchain topic and the industrial-economic approach applied by academia to evaluate the decision of implementing innovation. Moreover, the desk research observes a gap in the literature with regard to models and applications development that show the costs and benefits of DLT (or blockchain) in the maritime supply chain. Based on this research and by using a dedicated framework to quantify the costs and benefits of ICT innovation in the MarSC, a cost-effectiveness analysis is further conducted. Doing so, it answers the main research question: *What is the cost-effectiveness of vertical data integration application regarding the transfer of the phytosanitary certificate that makes use of a blockchain-enabled application?* The interviews with the logistics stakeholders allowed validating the formulated framework, giving input with regard to the cost elements that should be considered and proposing several strategies to be tested by the cost-effectiveness analysis. The following conclusions are formulated.

Firstly, through the framework of this research, it is observed that the stream of data passes three MarSC actors vertically positioned in the supply chain. Each of these stakeholders has individual cost structures with regard to the handling of the PHC, thus the resulting operating costs and the cost of implementing a DLT-based solution are different. In this context, the decision to purchase and implement the DLT-based innovation is individually taken by each of the supply chain stakeholders. Hence, this decision is dependent on the minimum amount of PHC handled through the entire chain that financially justifies the implementation of the ICT tool. To provide this justification, two working practices (scenarios) are analysed for each stakeholder: the manual handling of these certificates and the use of the DLT-based solution.

Secondly, this research identifies that the cost of implementing the DLT-based solution has three main components for its users: the cost of developing the DLT nodes, the software acquisition cost that covers the setting in practices of a set of conditions on validating new transactions (also known as the consensus algorithm), and the pay-per-use fee. The benefits generated by this type of solution are linked to the labour saved from activities like sending, receiving, correcting, searching information or broadly receiving network updates with regard to the status of the PHCs.

Thirdly, the following findings are formulated by analysing the three proposed purchase and implementation strategies. The first strategy assumes that the development costs are individually covered in full by each of the application users. The freight forwarder is pointed out as the stakeholder that benefits the most from the implementation of a DLT-based tool to handle the PHC and requires the least PHC to flow through the informational chain to justify the implementation of a DLT-based tool. However, the consignee is the stakeholder that sets the limiting margin with regard to the amount of PHC necessary to flow through the chain in order to prove the cost-effectiveness of the DLT-based tool. The second strategy considers a gain-sharing approach for the system's user to accelerate the tool's adoption necessities. Exploiting this approach, the user can benefit from the gain that the other stakeholders (involved in the chain) obtain and pursue the adoption of a DLT-based tool with cost-effectiveness of 23 to 44%. The final strategy considers that an authority covers parts of the above-mentioned costs motivated by its desire to gain an overall efficiency of the supply chain. In this strategy, the supply chain stakeholders could anticipate purchasing and adopting the DLT-based solution and achieve a cost-effective outcome sooner.

The results of this research are relevant for academia, industry, financial institutes and policymakers. Apparent theoretical aspects concerning the cost structure of MarSC stakeholders for handling documents such as the PHC are put forward. Academia and researchers might use the same framework to conduct further in-depth research on similar or derived applications. Moreover, the industry now benefits from a hands-on tool with reference to types of cost and benefit elements necessary to determine the cost-effectiveness of implementing a DLT-based solution. Further, the conditions to purchase and adopt an ICT innovation from a gain-sharing approach perspective in a vertical supply chain are also shown. Given the increased contemporary attention to DLT and its potential, MarSC stakeholders could now benefit from a tool that allows them to assess the effectiveness of implementing such a technology. Moreover, financial institutes receive a tailor-made sector tool that points out the costs and benefits of MarSC stakeholders that could benefit from their financial services. Moreover,

policymakers and authorities benefit from a methodology that allows them to assess when the sector needs their support and the cost-effectiveness they achieve.

One should be aware that some conditions still need to be considered when generalising these findings. The results of the numerical application are valid for the case study considered in this research. The input elements used in this model are provided from the perspective of stakeholders active in that port and ICT tools developing firms providing solutions to these stakeholders. Developing, implementing and using an ICT tool might vary in function of the use case, depending on the market, timing, actors involved in the network etc. To provide reliable results for another framework of analysis, the model offers possibilities for replicability, however new data for the input variables need to be collected and validated with the industry.

A critical view on the new developed analysis reveals the following limitations. Previous research has pointed out that theoretical concepts should leave the opportunity open so that economic models can easily incorporate qualitative elements or the lobby support offered by communities, senior management and consultation. Equally, other research initiatives have been also investigating the blockchain transactions and the implication they have on the computational cost. The later concepts are not considered in the present research developing a cost-effectiveness framework or economic simulation, and it is to be research more detailed in follow up applications.

This initial research regarding the cost and benefit aspects of a DLT-based solution opens thus several opportunities for further investigation as follows. The analysis framework developed through this research can be easily transferable to other ICT and DLT-based solutions that facilitate the transfer of documents in the MarSC, such as B/L, customs documents, CMR, etc. In theory, a wider span of benefits can be considered as well, but since further concepts with regard to the DLT are still to be developed, this issue remains uncertain (and may drag on for years). Another opportunity is to conduct a comparative study of already implemented systems across ports to point out the success and failure factors of implementing a DLT-based solution for the handling or the ownership track and trace of other documents. Equally, further research to investigate the cost-effectiveness of different DLT-concepts used to set the governance rules in a chain is also of interest.

Appendix: Interview design with regard to the PHC flow in the MarSC and its handling costs

Part A. Questions with regard to PHC handling

What is the flow of the PHC in the supply chain? Who emits the PHC? Which stakeholders receive it firstly? To which stakeholder is passed over?

Which information is exchanged throughout this process? How many people come in contact with the PHC?

Which of the people have to read the content, who is checking the content and when? How long does it take for each action to happen?

What is the procedure to correct errors when they occur? Is there an extra fee? What are the costs generated when an error occurs? Who is responsible in that case for the extra costs?

What is the amount of cargo for which a PHC is usually emitted for a pallet? For a container? Or for multiple containers? Is there a minimum/maximum cargo volume for which a PHC is released?

How many PHCs are handled in the port of Antwerp?

From each MarSC's perspective: what are the costs of handling one certificate? How much time is spent in checking/handling one certificate?

How long does it take to complete, check, send and receive a PHC?

What is the profile of a person doing this job? What are the job profile and his hourly costs?

How many people are working on PHC handling?

Are there other activities (handling of other documents) that are done by the same person?

Part B. Questions with regard to DLT (blockchain) technology

What are the features and functionalities an IT solution should have to be used to facilitate the transfer of the PHC?

Does blockchain fulfill these conditions, and does it offer enough functionalities? What are the other options that could be used for the same purpose?

What are the cost components when developing a DLT-based application?

How long does it take to develop each component? What is the hourly cost of a person developing such a system?

Are there technical or capacity limitations in using a DLT-based solution for facilitating the transfer of the PHC?

Which actors should be involved in developing such a system? What role would they have, and how strong should their involvement be?

What are the barriers and disadvantages in using each technology/IT system for a TG system? How could these barriers be overcome?

Part C. Questions with regard to strategies to purchase and implement a DLT-based solution?

What are the costs covered by the users of a DLT-based solution?

Which options are feasible to divide costs or the benefits in a DLT-based application?

Which type of stakeholder has an interest in partially cover the costs of developing such a solution? Which costs can be covered?

Which strategies do you think are feasible in implementing and sharing the costs/benefits of a DLT-based solution? And why?

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