City logistics: Towards a blockchain decision framework for collaborative parcel deliveries in micro-hubs

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ABSTRACT

The growth in e-commerce has led to increased pressure within the courier, express and parcel (CEP) sector to tackle the ‘last-mile’ issue and come up with solutions that not only satisfy the customers, but also other stakeholders such as city councils and other regulatory bodies. Scholars have highlighted micro-hubs and the associated horizontal collaboration as a possible solution, which might help alleviate problems associated with last-mile logistics in inner-city centers. However, trust and data exchange issues are considerable barriers to the introduction of horizontal collaboration, in particular between CEP carriers. To address the lack of trust and the issue of data exchange between carriers, the use of blockchain technology may present a solution, but existing research so far is limited concerning frameworks that specifically discuss blockchain technology in the context of micro-hubs and last-mile deliveries. In response, this paper presents a blockchain decision framework for a horizontal collaboration between CEP carriers based on key characteristics of existing blockchain decision models and relevant related research in the area of logistics and last-mile distribution. This is the first study that specifically addresses the use of blockchain technology for horizontal collaboration in the context of micro-hubs and last-mile deliveries.

1. Introduction

The growth in e-commerce has led to an increase in a door-to-door, same-or next-day delivery services within the courier, express, and parcel (CEP) sector, in particular for home deliveries (Esser and Kurte, 2006; Hesse, 2002; Kim and Chang, 2014; Weltevreden and Rotem-Mindali, 2009). This development has increased the pressure within the CEP sector to tackle the ‘last-mile’ issue and come up with solutions that not only satisfy the customers, but also other stakeholders such as city councils and other regulatory bodies (Gevaers et al., 2011; Menge and Hebes, 2011; Patier and Routhier, 2008). In particular, CEP companies are looking for ways to improve the efficiency of the last-mile, while at the same time looking for solutions to respond to the higher demands from consumers regarding ecological sustainability (Anderluh et al., 2020; Hemmelmayr et al., 2012; Herold et al., 2019).

One possible solution is the collaboration between CEP carriers, which aims to optimize the last-mile delivery networks in inner-city regions to solve the problems caused by the increase in commercial vehicle movements, thereby providing a potential solution to optimize workload, routes and efficiency (Allen et al., 2018; Brown and Guiffrida, 2014; Herold and Lee, 2019; Park et al., 2016). More specifically, studies have shown that collaboration between CEP carriers may lead to reductions in distance-based costs by up to 16 per cent (Juan et al., 2014, 2016), environmental cost by 24 per cent (Verdonck et al., 2013), and volume increases of 25 per cent for cooperating partners (Quak et al., 2016; Quak, 2012).

From a horizontal collaboration perspective, an often proposed approach is a two-stage delivery system, where a so-called city- or micro-hubs in the inner city are used as distribution centers for the last-mile (CRAINIC et al., 2009, 2010; Van Duin et al., 2016). In a collaborative micro-hub, two or more CEP carriers share their efforts to achieve a common logistics and transportation objective which involves physical exchange of shipments between collaborating partners, sharing material and immaterial resources in the form of logistics facilities, vehicles, information as well as planning and optimization methods (Gonzalez-Feliu and Salanova, 2012).

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One pre-requisite of a logistics collaboration with shared risks and shared rewards is mutual trust (Pomponi et al., 2015). So far, these trust issues have lowered the CEP carriers’ willingness to participate in horizontal collaboration to 16–18 per cent (Holguín-Veras et al., 2008; Regan and Golob, 2005). One way to address these trust issues is through blockchain technology (Dobrovnik et al., 2018; Kummer et al., 2020; Mikl et al., 2020), which may also support an efficient data exchange (Hackius and Petersen, 2017; Treiblmair, 2019). However, existing research so far is limited concerning a blockchain decision framework for CEP carriers with which horizontal collaboration can be evaluated and possible solutions can be outlined. In response, this paper presents a blockchain decision framework for a horizontal collaboration between CEP carriers based on key characteristics of existing blockchain decision models and relevant related research in the area of logistics and last-mile distribution.

As such, this study contributes in three ways: First, there is still limited literature on horizontal collaboration from a city logistics perspective, in particular in the context of CEPs and its relation to trust and inter-organizational data exchange. Second, by developing a blockchain decision framework for horizontal collaboration between CEP carriers, we expand and link current blockchain literature to the area of city logistics, thereby providing a theoretical foundation for further research into micro-hubs and last-mile deliveries. Third, by reviewing and using real-world blockchain applications, our blockchain decision framework is practice-oriented, thereby not only expanding the body of knowledge in theory, but also aims to spark discussions and projects among logistics and blockchain managers.

The remainder of the paper is structured as follows: in the next section, we present and discuss the underlying factors behind horizontal collaboration in city logistics and its link to blockchain technology, in particular with regard to trust and data exchange. This is followed by an outline of the methodology and a description of the qualitative approach and the data. Next, in the results section, we list and discuss the most relevant characteristics of blockchain decision frameworks and outlines the most appropriate blockchain type for CEP collaboration. We conclude by summarizing main insights and contributions as well as outlining scientific challenges and opportunities for future research.

2. Background

The growth in e-commerce as well as the ability to receive goods within a matter of hours after ordering has placed considerable pressures on the logistics industry to deliver more efficiently within cities. Moreover, city councils are concerned about the increase in parcel deliveries by CEP carriers and are looking for sustainable solutions to reduce traffic and congestion (Esser and Kurte, 2006; Hesse, 2002; Kim and Chang, 2014; Weltevreden and Rotem-Mindali, 2009). One possible solution highlighted by scholars are urban consolidation centers or so-called ‘micro-hubs’ (see e.g. Ballare and Lin, 2020; Janjevic and Ndiaye, 2014; Macharis and Kim, 2017) based on a two-stage delivery process. The first stage comprises the delivery of goods from outside the city to the respective micro-hub, followed by the second stage of last-mile distribution to end consumers (Anderlhub et al., 2020). Existing research found that the use of micro-hubs in cities for last-mile deliveries does not only have the potential to minimize trips and miles (Allen et al., 2018; Anderlhub et al., 2019a; Brown and Guiffrida, 2014; Iwan et al., 2016; Taniguchi et al., 2016), but the close proximity to end consumers allows a more environmentally friendly means of transport (e.g. electric cargo bikes), thereby alleviating congestion and reducing carbon emissions output (Allen et al., 2012; Anderlhub et al., 2019b; Herold and Lee, 2017; Taniguchi et al., 2020).

In addition, carriers and local authorities see the concept of horizontal collaboration as an opportunity to reassess how they can best operate in urban centers to still meet customer demands whilst maintaining or even reducing costs and has received increasing interest in recent years (e.g. Basso et al., 2019; Mason et al., 2007; Pan et al., 2019; Pereira et al., 2014; Pomponi et al., 2015; Rodrigues et al., 2015; Sheffi et al., 2019; van Lier et al., 2016). In particular, horizontal logistics collaboration and the concept of the ‘carriers-carrier’ has been thoroughly studied and discussed by both scholars and practitioners (Park et al., 2016; Raue and Wallenburg, 2013; Schmoltzi and Wallenburg, 2012; Steinnicke et al., 2012), where it has been referred to as a critical factor (Lindawati et al., 2014; Naessens et al., 2009) for logistics competitiveness, but it is now being actively pursued by some parcel carriers (Allen et al., 2017). Studies show that horizontal logistics collaboration between carriers can be of a wider benefit through (1) higher utilization rate of delivery vehicles (cube and weight fill), (2) lower number of kilometers driven in the transport network (especially empty ones), (3) lower number of receptions at the gate of the warehouse (lower cost of labor), (4) lower inventory levels (higher inventory rotation), (5) higher customer service level (faster deliveries and small drops), and (6) positive impact for society (reduced traffic) (Allen et al., 2017). In short, horizontal collaborative practices may lead not only to lower shipping costs and quicker delivery service, but also allows companies to reduce the environmental impact of their distribution activities (Jian et al., 2014).

Within research in horizontal collaboration in the context of logistics, the CEP industry remains a neglected topic, in particular regarding micro-hubs. The so-called ‘collaborative micro-hubs’ aim to identify and achieve win-win situations (e.g. improved optimization, load capacity and asset utilization between CEP carriers), where CEPs exchange parcels among each other for more efficient final deliveries due to either the geographic location of their depot infrastructure or their fleet characteristics (e.g. using electric vehicles, which may be better suited to the task where preferential access and parking conditions are available for environmentally-friendly vehicles) (Allen et al., 2017).

These CEPs may or may not be competitors operating at the same level of a supply chain. More specifically, horizontal collaboration in the context of micro-hubs can be classified according to their relationships, which comprises competition, co-opetition and cooperation (Bengtsson and Kock, 2000; Crujissen et al., 2007). Competition refers to an ‘action-reaction’ pattern where firms depend on same or similar suppliers and target the same consumer, while co-opetition is characterized by jointly stipulated goals, mainly for non-core activities (Zissis et al., 2018). In contrast, cooperative relationships are characterized by tight bonds and the pursuit of common goals including core activities. With regard a micro-hub environment, a full cooperation for last-mile deliveries can be regarded to have a strong relation to the concept of a ‘white-label’-hub, where the hub is operated by a neutral party and all CEPs are treated as customers (Prandstetter et al., 2019; Puftahl et al., 2020).

However, logistics collaboration between CEP carriers involves trust and potential data sharing to optimize routes and capacities (Wei et al., 2012), in particular in a ‘white-label’ micro-hub environment. Pomponi et al. (2015), Daudi et al. (2016) and Leitner et al. (2011) found that key information and knowledge sharing can be seen as critical form of trust in logistics collaboration and highlight that a lack of trust may jeopardize jointly agreed objectives and represent a main cause for collaboration failure. In other words, trust, information sharing, and data integration are crucial aspects in a horizontal collaboration between CEPs in a micro-hub environment for last-mile deliveries.

In this paper, we argue that blockchain technology presents a solution to address the collaboration and trust issues as it has the potential to record all transactions in the micro-hub and the involved carrier verifiably and permanently (Francisco and Swanson, 2018; Iansiti and Lakhani, 2017). And although research about the application of blockchain technology for last-mile deliveries in its infancy
In order to answer the research questions, this paper presents a blockchain decision framework specifically for horizontal CEP collaboration. The blockchain decision framework is based on an extensive review of the most popular blockchain decision frameworks and their specific characteristics with regard to last-mile deliveries and the CEP industry.

3. Methodology

In order to answer the research questions, we adopt an qualitative research approach (Yin, 2014) to seek to reach understanding through interpretation of the complex processes behind blockchain decisions and to further develop a blockchain decision framework for horizontal collaboration between CEP carriers in a micro-hub environment (Nordqvist et al., 2009). To achieve this aim, we followed a three step process: First, we identified relevant blockchain decision frameworks in the literature, thereby focusing not only on academic literature, but also specifically looking for models outside academia that are built for practice and which can be used in the specific context of blockchain. Koens and Poll (2018) identified in their literature review 30 different blockchain models, which we subsequently used to design a blockchain decision framework to identify the most appropriate blockchain for horizontal CEP collaboration in micro-hubs. An overview about the 30 blockchain decision framework can be found in Table 1.

As a second step, we reviewed and evaluated the blockchain characteristics regarding their suitability for horizontal CEP collaboration in micro-hubs. In particular, the blockchain decision frameworks have been examined according to their (1) graphic design, (2) solution granularity, (3) question types, (4) addressed topics as well as (5) inconsistencies between blockchain decision frameworks (Koens and Poll, 2018). Third, using our findings, we created a decision framework, which is also based on sequential steps. Within this steps, questions are asked that logically combine a sequence of simple tests and compares a nominal attribute against a set of possible values, which makes it easier to interpret and understand (Kotsiantis, 2013).

4. Results and the development of the blockchain decision framework

4.1. Blockchain decision framework characteristics

The 30 blockchain decision frameworks were analyzed according to the (1) graphic design, (2) solution granularity, (3) question types, (4) addressed topics as well as (5) inconsistencies between blockchain decision frameworks. Regarding (1) graphic design, the majority of the decision models are designed as a flow chart, only 5 out of 30 are designed as a questionnaire. Concerning (2) solution granularity, the system solutions proposed in the examined schemes mainly differ in their granularity and the authors categorized the models accordingly. Some schemes focus on whether blockchain technology should be used (yes/no/maybe answers), others differentiate between different blockchains such as public or private and public or private permissioned blockchains (Koens and Poll, 2018).

With regard to (3) question types, the questions in the schemes are usually framed as yes/no questions and are exclusion criteria to evaluate the suitability of a scenario for the use of blockchain technology. The posed questions depend on the focus of the decision models but similarities between them are visible. In particular, the questions mainly focus on:

- Need a database? (19)
- Can you use a TTP? (20)
- Shared write access? (18)

Table 1

| No | Source | Title | Source | Title |
|----|--------|-------|--------|-------|
| 1  | Lin et al. (2017) | Blockchain: The evolutionary next step for ICT e-agriculture | 16 | Quindaz (2018) | Do you really need a blockchain? |
| 2  | Meuser (2018) | Will blockchain solve my business problem? | 17 | Cooke (2018) | Blockchain technology |
| 3  | Pahl et al. (2018) | A decision framework for blockchain platforms for IoT and edge computing | 18 | Gardner (2018) | Do you need a blockchain? |
| 4  | Peck (2017) | Blockchain world-Do you need a blockchain? | 19 | Lixin (2017) | Blockchain part 2 |
| 5  | Suichies (2016) | Why blockchain must die in 2016 | 20 | Meunier (2017) | When do you need blockchain? Decision models |
| 6  | WEF (2018) | Blockchain beyond the hype | 21 | Nandwani (2018) | Do you really need to use blockchain for your application? |
| 7  | Wüst and Gervais (2018) | Do you need a blockchain? | 22 | PwC (2018) | Blockchain: The $5 billion opportunity for reinsurers |
| 8  | Greenspan (2018) | Avoiding the pointless blockchain project | 23 | Verslype (2018) | Betalingssmodel: Wanneer blockchain gebruiken? |
| 9  | DHS (2018) | Most companies don’t need blockchain | 24 | Birch et al. (2016) | Towards ambient accountability in financial services |
| 10 | IBM (2018) | How to decide when to use blockchain | 25 | Saiko (2018) | Blockchain technology |
| 11 | Lewis (2018) | Blockchain cheat sheet v0.1 | 26 | Hackernoon (2018) | The blockchain test |
| 12 | Xu et al. (2017) | A taxonomy of blockchain-based systems for architecture design | 27 | Chand (2018) | Do you need a blockchain |
| 13 | Deloitte (2018) | Blockchain A new model for health information exchanges | 28 | Sarem (2017) | Blockchain decision path. |
| 14 | Henkel (2018) | Beginning blockchain: Key questions to getting started | 29 | VerifiedICOs (2018) | Is a blockchain really required? |
| 15 | Mavll et al. (2017) | Distributed ledger technology: Applications and implications | 30 | CapGemini (2018) | Cap Gemini - SAI trends |
• Public transactions? (17)
• Participants trust each other? (13)
• Participants known? (13)
• Participants interests aligned? (10)
• Where is consensus determined? (9)
• Need to control functionality? (8)
• Do you need high transaction throughput? (8)

Moreover, Koens and Poll (2018) categorized all questions according to a) whether they help determine which Blockchain type is suitable, b) whether they address current Blockchain limitations, c) system design aspects or d) process aspects, thereby focusing on the technical perspective and thus forgo process and design questions.

With regard to (4) addressed topics, the following categories are mostly discussed (Werner et al., 2018):

• Participants: This category considers the number of participants in the system and their relation to each other (awareness and trust)
• Third parties: Questions posed examine whether a trusted third party (TTP) can be used for data management and voting function. Even if a TTP is already used, Blockchain might allow to eliminate this middlemen and result in efficiency gains and / or cost reduction.
• Data storage management: deals with questions such as whether data needs to be stored at all, shared data management is actually needed and if so, whether traditional databases can be used. Other questions consider whether modification or permanence of data entries is required.
• Transactions: The relationship between transactions is considered, such as whether they build on each other or are viewed separately. Likewise, the transaction speed is considered.
• Other criteria: Some models also consider other aspects such as which intention is to be achieved with a Blockchain (i.e. cost reduction, market-oriented approach, publicity, insufficient solutions with current technologies)

Last, the most (5) inconsistencies and contradictions between decision models are found between the schemes. These inconsistencies result from differences in granularity of the described solutions or because of vague solution descriptions. For example, the scheme from (IBM, 2018) highlights a complex business logic and is seen as a reason to use blockchain technology, whereas Verslype (2018) sees complex logics as a barrier, indicating different mindsets behind the frameworks (Koens and Poll, 2018).

4.2. The blockchain decision framework for CEP collaboration

Based on the findings above, a blockchain decision framework is developed which uses a questionnaire instead of flow chart and is based on question-by-question sequences (see Fig. 1). The framework is constructed in a way that it ‘asks’ questions that logically combine a sequence of simple tests and compare nominal attributes against a set of possible values, which makes it easier to interpret and understand (Kotsiantis, 2013). The questions are a based on the identified characteristics (1) writing access, (2) control over functionality, (3) reading access, (4) third party, (5) transactions, (6) known writers, (7) trust and public verifiability, (8) immutability, (9) data transparency, (10) process automation, (11) throughput, (12) data storage and (13) potential benefits. In particular, the blockchain decision framework consists of the following questions:

Question 1 – Writing access: In the proposed use case all CEP partners in city- or micro-hubs should have equal writing access as each partner needs to enter shipment information for the transportation leg they are responsible for.

Question 2 – Control over functionality: In this use case the involved participants are first and foremost competitors and they cooperate only in cases which benefit them. Hence, if one organization should control functionality the other participants would likely show resistance to use the system of a competitor. When a Blockchain is used and when functionality such as rules on how database permissions are set or how the database can be queried might need to change over time, all participants will need to agree to proposed changes. The answers to question 1 and 2 thus lead to the exclusion of a central database.

Question 3 – Reading access: Parcel tracking is a standard service offered nowadays in the market and direct customers as well as parcel recipients expect to have information where their parcels are. Especially commercial parcel shippers want to have timely access to the status of a parcel shipment in order to know if a customer order is completed.

Question 4 – Third party: The question is not easy to answer from an external perspective. It might be possible that the CEP partners agree on a trusted third party. For example, it could be assumed that city councils can fulfill this role as it is in its interest to consolidate last mile delivery shipments in order to reduce negative externalities. Furthermore, the government may include further functionalities that can be used for other purposes, such as transport statistics and analysis. If this is the case, a shared database with a tailored user right system could be implemented. It is also possible to encrypt sensitive data so also the third party cannot read, for example customer and recipient specific information. However, even with anonymizing procedures companies are still likely to be reluctant to share integral company information with third parties. To answer this aspect satisfactorily, it is necessary to interview delivery service partners regarding the questions a) whether they are in principal willing to use a third party, b) who they view as an appropriate third party and c) which conditions would have to be met. Depending on these answers a shared central database maintained by a third party might be sufficient. The question which benefits might be achieved through disintermediation is not applicable for this use case as no third party is used.

Question 5 – Transactions: CEP collaboration transaction data clearly depends on each other as the tracking of the shipment flow is sequential. Delivery service companies require information from their partners as soon as parcels have to be transferred from one partner to another. Currently each company has its own database and data is exchanged via EDI. This means that the partners do not access the same data and discrepancies may occur. Transaction interaction is one of the main reasons that blockchain technology might be a beneficial solution.

Question 6 – Known writers: From a city- or micro-hub perspective it would be beneficial to screen new participants and allow access based on defined criteria. For example, only delivery service companies shipping parcels within the city could participate. It should be considered some carriers contract a high number of subcontractors that might also deliver parcels to the city- or micro-hubs. In this case, they should also be registered as participants. Nevertheless, the number of CEP companies is limited and thus all writers would be known. As a consequence, a public permission blockchain is not necessary. Alternatively, a distributed ledger such as Corda might be sufficient (Koens and Poll, 2018).

Question 7 – Trust and public verifiability: As mentioned, the participants are competitors and therefore do not trust each other. It can be assumed that they do not want to give any insight to competitors into their business and are thus only willing to share data necessary for the transfer of parcels in the network. Blockchain types with different user roles and user rights can be defined in a permissioned blockchain, so that only the transaction partners can view their respective transactions. Regarding the question of public verifiability, the goal of the blockchain implementation in this use case is a more efficient collaboration between the delivery service partners and not public transparency. Thus, a private permissioned Blockchain is a sufficient solution. The aspect of public verifiability is more important in cases
| I. Central control | 1a. Should multiple parties have writing access? | No: If it is enough that only one party has writing access, then a central database is sufficient, leads to less complexity and will offer better performance. |
| | 1b. Which parties should have writing access? | Yes: Changing functionality is difficult in a blockchain as all partners need to give consent to all the changes. In this case a shared central database is more suitable. Controlling database functionality may include setting the rules on how database permissions are set (such as create, store, delete), how the data is stored in the database (a relational database or an object oriented database), or how the database can be queried (e.g. SQL). |
| | 2. Is it necessary to control functionality? | No: If a third party can be used, but multiple writers need access than a shared central database is sufficient. However, if disintermediation results in significant improvements a different system might still achieve added value. |
| II. Disintermediation | 3a. Can a third party be used, which maintains a shared central database? | Yes: If the involved parties do not trust each other to maintain a system owned by one of the parties, then a third party may be able to take over this role. For example, banks act as a third party between account holders who transfer money between each other. The system is maintained by the financial institute and includes various security checks, such as verification of identity when an account is set up. Bitcoin became famous among other things because through this system a third party is not necessary anymore. |
| | 3b. What benefits can be achieved through disintermediation? | No: In this case a distributed database (i.e. Storj) is likely better. |
| III. Transactions | 4. Do transactions depend on / interact with each other? | Yes: This is where Blockchain can offer value. When data is generated by different parties and this data needs to interact, then a distributed ledger, with or without blockchain, may result in faster interactions than with a conventional database. |
| | 5. Are all writers known? | No: If not all writers are known and the limitations of blockchain do not pose a problem, a public permissionless blockchain can be suitable. |
| | 6a. public permissioned blockchain: All writers are known, but not all should have the same user rights and public verifiability is important. | Yes: If all writers are known, transactions interaction takes place and a third party should not be used, then a distributed ledger such as Ripple or Corda is an option. Nevertheless, a blockchain could also be useful. |
| | 6b. Private permissioned blockchain: All writers are known, but not all are trusted and public verifiability is not required. | Question 6 helps to identify whether a private or public blockchain is better suited. In general: If not all writers are trusted user rights can be restricted by using a permissioned blockchain. |
| | 6c. For which users should user rights be restricted and in which way? | 6d: If public verifiability is not required, all writers are known and also read access should be restricted, then a private permissioned blockchain is suitable. |
| IV. Participants & Trust | 7. Data should be saved permanently and be immutable. | A private blockchain has fewer performance issues than a public blockchain. 6c: This question supports clarification but is not strictly needed to assess whether a blockchain can be used. |
| | 8. Data should be transparent | Note: If all writers are known and trusted, then the question arises why Blockchain Technology should be introduced in the first place. In this case other solutions are more efficient, for example a centralised database with web-based access for multiple writers which are located at different locations. |
| V. Immutability & Transparency | 9. Can the transaction process be performed autonomously (following given rules)? | This is one of the main characteristics of a blockchain. If data should be changed ex post or deleted, then a different solution should be found. |
| | 10. Describe the involved transaction process shortly | However, if this characteristic is important blockchain can add value. It should be noted that depending on the consensus mechanism, changes are still possible, but may be hard to achieve. |
| VI. Process automation | 11. Is high throughput important? (scale) | Data is stored in an encrypted form and thus cannot be read by parties without a private key. Nevertheless, each party has a complete ledger of all data in the blockchain and if one should obtain the private key of another party it could encode their data. |
| | 12. Will large amounts of data be stored? | This aspect is not strictly necessary to decide whether blockchain is a suitable solution, but when smart contracts can be used this adds value as process automation can increase process speed and efficiency. |
| VII. Performance & Capacity | Storage of large data (Terabytes) poses currently a problem for blockchains. The entire Bitcoin database needs currently 243 GB of storage space (Status: 03/2019). One has to take into account that the needed storage space increases with each year. |  |

Fig. 1. The blockchain decision framework.
where the goal is to increase consumer trust in the quality of an end product (i.e. FairTrade production of coffee). In these cases, a public Blockchain would be a suitable solution.

Question 8 – Immutability: Historic transaction data of parcel shipment flows should not be changed. In case mistakes happen, information can be corrected with an additional transaction, similar to booking corrections in accounting. As it is not as crucial as for example the transfer of ownership rights the box ‘important’ was checked.

Question 9 – Data transparency: As described before trust is low and thus transparency should be restricted to data which is crucial to working together. If parties fear that encrypted data might be encoded or that by analyzing the volume of transactions it might be possible to draw conclusions additional safety measures can be implemented into a Blockchain.

Question 10 – Process automation: For horizontal collaboration between CEP carriers, a parcel ID is generated and at various locations such as transshipment facilities, the parcel barcode is scanned automatically to allow location tracking. Therefore, it is known when, such as transshipment facilities, the parcel barcode is scanned automatically into a Blockchain.

It is possible to draw conclusions additional safety measures can be implemented.

Question 11 – Throughput: To answer this question, delivery service partners need to be interviewed as they should be able to estimate how many transactions are needed per minute. For this paper it is assumed that throughput is important, but not crucial.

Question 12 – Data storage: As a rough estimate it is assumed that 300 characters are needed per transaction. As one character equals one byte, approximately 62 GB of storage are needed per year for an entire country such as Austria. If the use case is limited to parcel shipments in Vienna, then roughly 19 GB are needed (based on the year 2016 in which 62 million parcels were shipped). In comparison, the entire Bitcoin database needs 243 GB (Crosby et al., 2016). As the parcel shipment is estimated to grow quite strongly, the storage space needed will grow as well. However, as it is assumed that only data for parcel shipments, where cooperation between different partners is needed, would be added to the Blockchain the storage requirements would be drastically lower.

Question 13 – Potential benefits: The most basic advantage, that can be gained through the introduction of blockchain technology is the fact that partners will access the same data base, reducing data inconsistencies, thus leading to improved data quality and reduction of errors made based on false data. As data is available to all concerned partners as soon as information is added by one partner to the shared ledger, information exchange is likely to be faster than with current systems where information is first added to the individual systems operated by each partner and then shared. An additional function, which can be implemented are smart contracts. The previously described payment process automation can lead to efficiency increase and cost reduction. To evaluate the potential benefits the current payment process, the rate of problems caused by data inconsistencies and the current information exchange process should be evaluated, including the process time. It is likely that the evaluation of the real-world processes will show further benefits.

5. Conclusion

The aim of this paper was to develop and present a blockchain decision framework for a horizontal collaboration between CEP carriers in a micro-hub environment. Based on the key characteristics of existing blockchain decision models and relevant related research in the area of logistics and last-mile distribution, we proposed a blockchain decision framework that retained granularity while at the same time guiding the reader towards suitable blockchain types or presenting alternative cases instead of blockchain technology. In particular, by reframing the flow charts into a questionnaire, the usability was improved for practical use as well as for documentation purposes. As such, one of the main advantages of the proposed framework is that it is being able to point readers and users towards different solutions due to a sequence of questions. In the case of a horizontal collaboration between CEP carriers, we found that a private permissioned blockchain presents the best solution order to improve the information flow, shared data quality and transparency. Additionally, smart contracts for the payment process automation can be implemented to improve the process efficiency and reduce personnel costs.

By developing a blockchain decision framework for a horizontal collaboration between CEP carriers in a micro-hub environment, the contribution of this study is threefold: First, we expand existing research on horizontal collaboration on a city logistics perspective, in particular in the context of CEPs and its relation to trust and inter-organizational data exchange. Second, by linking current blockchain literature to the area of city logistics, we provide a theoretical foundation for further research into micro-hubs and last-mile deliveries. Third, by reviewing and using real-world blockchain applications, our blockchain decision framework is practice oriented, thereby aiming to spark discussions and projects among logistics and blockchain managers. As far as the authors are aware, this is the first study that specifically addresses the use of blockchain technology for horizontal collaboration in the context of micro-hubs and last-mile deliveries.

However, our proposed blockchain framework has to be viewed in the light of its limitations. First, the questionnaire form makes it difficult to show an immediate solution. And although an explanation for each question has been presented, we ask future researcher to find ways to combine questionnaire and flow chart approaches. Second, so far, the blockchain framework has not been tested in practice. Apart from the fact that blockchain technology is relatively new in the logistics sector, a key challenge would be to convince CEP carriers to participate. Therefore, it would be useful for future researcher to evaluate the benefits and risks involved with the substitution of a current system with blockchain technology. The alternative of using a shared central database maintained by a trusted third party exists, and another angle could also be investigated, i.e. whether the delivery service partners would be ready to use a third party and under which circumstances.

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CRediT authorship contribution statement

Marko Hribernik: Supervision, Conceptualization, Writing - original draft, Writing - review & editing. Kathrin Zoro: Conceptualization, Writing - original draft, Methodology. Sebastian Kumer: Supervision, Writing - review & editing. David M. Herold: Writing - original draft, Writing - review & editing, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
