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A CONCEPTUAL DIGITAL BUSINESS MODEL FOR CONSTRUCTION LOGISTICS CONSULTANTS, FEATURING A SOCIOMATERIAL BLOCKCHAIN SOLUTION FOR INTEGRATED ECONOMIC, MATERIAL AND INFORMATION FLOWS

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SUMMARY: *In this paper, a new digital business model for independent construction logistics consultants, which features the conceptualization of a sociomaterial blockchain solution for integrated information, material and economic flows, is proposed. Theoretically, we offer an understanding of the economic flow, stress the optimization of construction logistics through flow integration, analyse current approaches to understanding blockchain, adopt sociomateriality to envision a suitable blockchain solution, and consider the way blockchain can constitute part of the value proposition of a related digital business model. Methodologically, we systematically reviewed the literature on blockchain-related construction research, and conducted empirical studies on independent logistics consultants in the Swedish context for more than a year. On the one hand, the literature review reveals that core blockchain properties can generate value for construction logistics (e.g. shared ledger structure and reduction of accounting rework) – however, apart from visions and prototypes, there currently exist no use cases, and potential implementational constraints and security issues are limitedly considered. One the other hand, the empirical findings show that independent construction logistics consultants in the sociomaterial Swedish context are suitable candidates for the proposed digital business model. By combining the literature and empirical insights, a permissioned private proof-of-authority blockchain solution integrating the supply chain flows in a generic sociomaterial setting is conceptualized. This solution is then embedded in the value proposition of a digital business model for an independent construction logistics consultant. The proposition includes, among others, improved process management and increased productivity, while the consultants' competitive advantage through innovation is facilitated. Other business model segments, like key resources, are also updated via the blockchain solution, while some, like channels, are not significantly affected. To not hinder the realization of this digital business model, issues like the lack of blockchain awareness, and the existing power balances within sociomaterial constellations, have to be addressed.*

KEYWORDS: *Construction logistics, blockchain, value, digital business model, independent logistics consultants.*

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1. INTRODUCTION

The integration of flows within construction supply chains, has long been identified as crucial for the optimization of logistics and the overall success of construction projects (Palaneeswaran et al., 2000; Love et al., 2004). Titus and Bröchner (2005) had identified the information flow (the bidirectional flow of prompts and requirements received and released by a construction supply chain partner), material flow (the flow of physical goods), and financial flow (the flow of financial transactions), noting that their integration is critical for effective construction supply chain and logistics management. Nonetheless, such an integration should be preceded by defining these flows in connection to their realization in an actual setting – something especially challenging for, particularly, the so-called "financial flow". This term has been primarily associated with the exchange of assets (Titus and Bröchner, 2005) and entities like operational cost (Panova and Hilletofth 2018). Moreover, such a flow has also been termed "cash flow" (Pryke, 2009; Lundesjö, 2015), regarding cash transactions, and "money flow" (O'Brien et al. 2009), reflecting monetary exchanges. However, it can be considered that these terms ("financial", "cash" and "money") are not precise enough and only partially describe a flow that, in construction supply chains, does not have to be carried out in cash (e.g. in the Swedish context), and is not only associated with assets, cost entities and monetary exchanges; but rather, in addition to the aforementioned, it also pertains to transactions containing integrated data on prices, billing and invoices (e.g. of materials). Therefore, to encompass the above, we denote such transactions as *economic transactions*, and the flow they represent as the *economic flow* – which complements the material and information flows.

Throughout the years, there has been a number of studies not only showing ways a single flow can be realized (e.g. the information flow in Obonyo and Anumba, 2011), but also partially exploring the possibility of flow integration. This includes investigations on integrating the information flow (emanating from tracking technologies) with the material flow to increase the overall visibility of the supply chain network (Ikonen et al., 2013), the utilization of building information models (BIM) and geographic information systems (GIS) to integrate the material and information flows within the construction site and connected remote areas (Deng et al., 2019), and a network design formulation integrating the material and information flows to choose the best location of on-site temporary facilities (Golpîra, 2020). However, the integration of the economic flow (as it is understood here) has not been investigated as rigorously; the aforementioned studies are examples of a general focus on the integration of just the material and information flows. Nonetheless, it can be envisioned that the fluid integration of all three flows could be event-driven; such events can include the release of invoices and payments to the associated actors (e.g. suppliers) via direct peer-to-peer information exchange after successful material deliveries, correct on-site component placement, and completion of work packages (Wang et al., 2017). However, the actual benefits, framework, technology, and implications of such an integration, have not been adequately explored. In addition, the associated value proposition – realized through a new digital business model (DBM) for the specific actors that could propagate such an integration – has not been investigated.

Given the aforementioned considerations, the research question of the current study is the following: how could a solution for construction logistics, in which the information, material and economic flows are integrated in an event-driven way through the appropriate technology, be conceptualized and incorporated into a new DBM – and what would the characteristics of this DBM be? The aim of this paper is to answer this research question by proposing such a new DBM, which is dedicated to independent construction logistics consultants within the Swedish construction context, and features the conceptualization of a solution for integrated supply chain flows via the use of blockchain technology. Blockchain is often described as a digital ledger technology for peer-to-peer transactions, which are kept in a historical record that is updated through consensus (Singhal et al., 2018). The potential value of such a blockchain solution, will be investigated through the theory of sociomateriality (Orlikowski and Scott, 2008,2016). The insights drawn from the theoretical background and a literature review focusing on construction-related blockchain research, will be combined through a sociomaterial lens, in order to conceptualize the blockchain solution, its value proposition, and its embedding in the new DBM. This conceptual DBM will then be particularized and verified in a case study featuring a particular Swedish construction logistics consultant firm.

The paper is structured as follows. First, the theoretical background of the study will be elaborated on. Second, the research method will be delineated. Following, the results of the literature review will be showcased. Afterwards, the conceptual schema of the blockchain solution will be drawn. Then, the solution will be incorporated in the conceptual DBM, depicted in a business model canvas. Subsequently, the particularization and verification of this

DBM, will be exhibited. Finally, a critical discussion on the study's results and limitations, the conclusions, and recommendations for further work, will be offered.

2. THEORY

2.1 Basics of sociomateriality

Sociomateriality is a sociotechnical approach which emphasizes the way technologies are co-shaped with practices (Orlikowski and Scott, 2008) – also applying to digital technologies (Orlikowski and Scott, 2016). According to sociomateriality, the material and social aspects of digital technologies are inseparable and fused in practice (Orlikowski and Scott, 2016). This is reflected upon the agency of the actors utilizing the digital technology, since actions cease to be exclusively human properties, and come to be performed through interactions between humans and non-humans (Moura and Bispo, 2019). This sociomaterial co-shaping can affect the way in which the structure of an organization (or a constellation of actors) is realized (Moura and Bispo, 2019; Kohtamäki et al., 2020).

Central in understanding sociomateriality are the notions of entanglement and performativity (Orlikowski and Scott 2016). Entanglement holds that the material and social aspects should not be merely realized as being progressively intertwined (which would require their initially separate existence), but actually understood as lacking an independent, self-contained state (Barad, 2007; Orlikowski and Scott, 2008,2016). Performativity refers to a world being reshaped through ongoing reconfigurations (Barad, 2007; Orlikowski and Scott, 2016). This position sharply contrasts the more dominant one featuring a world made up of self-standing entities with a priori properties (Orlikowski and Scott, 2008,2016); instead, sociomateriality poses that the performativity of a technology emerges through social practices (Orlikowski and Scott, 2008).

While Orlikowski and Scott (2008,2016) offer a central understanding of sociomateriality, there have also been other approaches to the theory. Among them, Leonardi's (2013) understanding differs significantly from Orlikowski's and Scott's (2008,2016). In particular, Leonardi (2013) postulates that the material and social aspects of technologies are not isomorphic, but materiality is rather preconfigured and only gets gradually fused with the social aspect through imbrication over time. However, in this study we adopt Orlikowski's and Scott's (2008,2016) approach to formulate our understanding of a sociomaterial blockchain solution for construction logistics, since we follow the argument that the inseparable entanglement of the material and social aspects is particularly suitable to describe the reconfigurations of work practices brought about by the introduction of a digital technology (Orlikowki and Scott, 2016).

2.2 A sociomaterial take on blockchain for construction logistics with integrated flows

There are different definitions of blockchain in the literature, according to the research orientation of each study (Wamba et al., 2020). On the one hand, there are definitions that could be described as economic flow-oriented, focusing on the digital ledger aspect of blockchain (Lamb, 2018). On the other hand, there are information flow-oriented definitions, focusing on the data exchange properties of blockchain (Verhoeven et al., 2018). These approaches are further elaborated on, correspondingly, the following two paragraphs. It should be noted that there can be a blending of these foci in some studies attempting to define blockchain (e.g. see Dobrovnik et al., 2018; Li et al., 2019).

The definition given in the Introduction is an economic flow-oriented example. Elaborating more on it, blockchain can be described as a peer-to-peer system for value transaction (through a shared and decentralized digital ledger replicated across different nodes (Lamb, 2018)), where the need for in-between verification, security and settlement of the transactions through trusted third-party intermediaries, is claimed to be partially or completely redundant (Dannen, 2017; Singhal et al., 2018). Its digital ledger databases (Gausdal et al., 2018) are append-only; every entry is permanent and immutable, with the new ones reflected on all database replicants hosted in the nodes (Singhal et al., 2018). The way such nodes are set up leads to different digital ledger architectures in accordance with the privacy settings in the blockchain, from public permissionless systems to private permissioned ones (Chong et al., 2019). In permissioneless blockchains, network nodes can be set up anonymously and without oversight (Chong et al., 2019). On the contrary, permissioned blockchains are operated by a central authority; authorization is required for setting up network nodes, which are selected according to predefined compliance criteria (Chong et al., 2019). In some studies, even when the term "digital ledger" is not explicitly mentioned, the focus on the economic flow is accentuated by noting the use of blockchain in economic transactions involving cryptocurrencies (e.g. in Barima, 2017).

Described in a more information flow-oriented manner, blockchain is a technology to store and access information in a decentralized and transparent way, by facilitating data transactions kept in a historical record (Verhoeven et al., 2018). Each “block” of this record stores finite data; then these blocks are connected in a fixed order or “chain” (Verhoeven et al., 2018). Thus, by determining the dataset through following the chain and resolving the block transactions, the blockchain not only holds the present transactional information, but also the complete history (Verhoeven et al., 2018). Throughout the nodes, such a history is shared and can only be updated through consensus via certain validation methods, such as “proof-of-work”, “proof-of-stake” and “proof-of-authority” algorithms (O’Leary, 2017; Verhoeven et al., 2018; Rossi et al., 2019). Such an information flow-oriented approach can account for more diverse blockchain uses than just economic transactions (Scott et al., 2017; Kshetri, 2018), such as controlling quality (Chen et al., 2017) and data integrity (Lemeš and Lemeš, 2020).

The diversity regarding the definitions of blockchain, along with its potential application-wise versatility, can be partly attributed to it being an emergent general-purpose technology (Filippova, 2019). While blockchain was initially introduced to support Bitcoin – as described in Nakamoto (2008) – its application potential has grown extremely (Konstantinidis et al., 2018). For construction supply chains and logistics in particular, there have been so far studies focusing on the streamlining of a single flow (e.g. the information flow in Nanayakkara et al., 2019), or on the integration of the material and information flows (e.g. see in Lanko et al., 2018, and Wang et al., 2020). The utilization of blockchain for the integration of all logistics flows has yet to be investigated. This corresponds with the general lack of research on the integration of all three flows within construction logistics, as mentioned in the Introduction.

We hereby argue for a sociomaterial take on blockchain as a solution for construction logistics, with a key element being the integration of all flows. Sociomaterial understandings of blockchain are relatively few, with the current ones postulating that:

- Blockchain is intertwined with the social world in both its protocol and application level (Rossi et al., 2019). Thus, the agents’ social motives, incentives and issues of governance are critical, not only regarding the consensus mechanisms of the operation protocols, but also the framing and constraints of the technology in its application (Rossi et al., 2019). This framing also shapes the understanding of trust, information privacy, scalability, security, user behaviour, disintermediation, and environmental sustainability, among the actors in the blockchain constellation (Rossi et al., 2019). It can also lead to blockchains with different privacy settings (Rossi et al., 2019).
- Blockchain can bring about a complex sociomaterial system among actors, by digitalizing the value chain, integrating various flows, shifting routines and capabilities, and reconfiguring existing sociotechnical infrastructure (Kohtamäki et al., 2020).

Building on a combination of the economic flow- and information flow-oriented definitions of blockchain, and the aforementioned sociomaterial postulations, we sociomaterially define blockchain for construction logistics with integrated flows as a permissioned private digital ledger for partially decentralized peer-to-peer information and economic transactions across a project-specific networked constellation of supply chain actors (e.g. clients, contractors, logistics consultants, and suppliers). Its digital ledger databases are append-only, permanent, stored and accessed in a historical record updated through consensus, and shared across all network nodes reflecting the stakeholders of the constellation. As a permissioned system, it features a reduced but existing need for in-between verification, security and settlement of the transactions, and is based on a proof-of-authority algorithm, where consensus features identity as a stake and is agreed between the authorized participants (Verhoeven et al., 2018). In addition, it creates power shifts within the constellation, in line with the sociomaterial autonomy-control paradox (Bader and Kaiser, 2017). The economic transactions are event-driven and event-inducing, i.e. they are triggered when certain events in the information flow (e.g. sending purchasing orders) and/or the material flow (e.g. successful on-site material delivery) take place, and can trigger themselves events (e.g. issuing invoices when transactions are completed). Thus, the economic, material and information flows become integrated.

Through this sociomaterial understanding, a blockchain solution for construction logistics with integrated flows can be the central value-adding aspect for a new DBM implemented by the suitable actors; in the course of the current study, we will argue that such actors can be the independent logistics consultants in the Swedish context.

2.3 Digital business models and the potential of value proposition through blockchain

A DBM is a digitally supported set of processes to create, deliver and capture value (Schneider and Spieth, 2013). A crucial aspect of a (digital) business model is value proposition, namely the creation of novel value for clients willing to pay for it, thus converting it into turnover and profit for the firm (Andreini and Bettinelli, 2017).

In rapidly evolving times, firms can respond to and incorporate new sources of value in their business models (Schneider and Spieth, 2013). Such value may come from new technologies; however, it might be difficult to utilize a new technology, and as such, the interested actors should re-evaluate and expand their business models in order to frame and capture that value (Chesbrough, 2010). Particularly for blockchain, it is rational to start small, identify the implementation objectives, take precautions, and consider issues of security and regulatory challenges (IBM Institute for Business Value, 2017a). IBM Institute for Business Value (2017b) identified three basic concerns in the deployment of a DBM utilizing blockchain: the involved project stakeholders need to receive some economic benefit, trust among them must be facilitated, and they should be early adopters of the technology. A number of studies have built on these considerations and have presented value-adding benefits of blockchain implementation, drawing mainly from the leveraging of the technology's core capabilities. Indicatively, Dobrovnik et al. (2018) identified the facilitation of origin tracking, transaction cost reduction, advanced actor activity overview, process compatibility, reduction of transaction complexity, user-regulated participation and information-sharing, and facilitated transaction observability. Moreover, O'Leary (2017), Scott et al. (2017), Wang et al. (2017), Dobrovnik et al. (2018), and Kshetri (2018) noted the streamlining of transparent and accountable processes, while Veuger (2018) described the facilitation of trust and collaboration among the actors in the blockchain network. Paper-heavy processes can be mitigated, and the shared digital ledger reduces the need to reconcile local ledgers, thus shortening confirmation times (Verhoeven et al., 2018).

Curiously, the culmination of these (and other) value-adding benefits into the actual value proposition of a DBM is often not researched in the related literature (Risius and Spohrer, 2017). A notable exception is the effort by Chong et al. (2019), who study five Chinese companies implementing different DBMs with blockchain solutions. For each of the five cases, the value creation logic takes one of the following roles: platforming, disintermediating, mediating, transforming, and co-innovating (Chong et al., 2019). However, none of the investigated companies was itself (or cooperated with) a firm within the construction sector (Chong et al., 2019).

This lack of explicitly identifying the value proposition of blockchain for DBMs, is also apparent in the case of construction logistics. However, it has been shown that in developing DBMs for construction logistics, a simultaneously integrated and agile approach is needed (Thunberg and Fredriksson, 2018). The digitalization of (or enhancement of already digitalized) business models through blockchain, can optimize their efficiency and lower costs (McKinsey Global Institute, 2017). Blockchain properties also align with the utility of viewing such DBMs in an inter-organizational context within supply chains (Vendrell-Herrero et al., 2018).

3. RESEARCH METHOD

In order to attain the research aims set in the Introduction, and following the theoretical preparation above, this study unfolds methodologically through: (a) a targeted literature review for the selection of research material according to certain criteria, (b) the collection of empirical data, (c) the combination of the literature review results and the empirical data to attain the final research outcome, and (d) the verification of this outcome.

For the targeted literature review, the concept-centric framework augmented by units of analysis (Webster and Watson, 2002) was used. The units of analysis emerged during the review itself, facilitating the iterative revision of earlier conceptions. This iterative revision followed the abductive reasoning of qualitative research (Bell et al., 2019). Moreover, the references-of-references and "snowballing" techniques (Greenhalgh and Peacock, 2005), and the conduct of a comprehensive search to avoid a narrow sample (MacLure, 2005), were implemented.

Specifically, within this literature review, the following steps were followed and abductively iterated:

1. Source selection (e.g. books, journal articles, consultancy reports, conference papers, and theses).
2. Identification of broad keywords fitting the research aims (e.g. blockchain, supply chain, logistics, logistic flows, sociomateriality, business models, and value creation). The search was conducted on a number of library engines covering a range of publishers. After filtering out the results in terms of relevance, a total of 188 literature sources were kept. 23 of them were chosen as the current study's

backbone in theory and research methodology, and are mainly featured in the current and the previous sections. The remaining 165 sources were treated as described in steps 3 and 4.

3. Identification of targeted keywords fitting the research aims (e.g. sociomaterial blockchain, construction supply chain, construction logistics, construction logistic flows, smart contracts, cryptocurrencies, decentralization, digital business models, value proposition, independent logistics consultants, Swedish construction context). The corresponding sources amounted to 100 out of 165, with the ones finally selected being 53.
4. Inclusion of studies not directly related to construction, but with the potential to offer insights suitable for construction, as they elaborated on topics tangentially applicable to the research aims. The corresponding sources amounted to 65 out of 165, with the ones finally selected being 19.

It should be noted that while the literature sources were broadly categorized as previously, there can be found contextual overlaps among them. The criteria for finally selecting the 23+53+19=95 references were the sources' particular relevance, high quality (with regard to their impact and number of cross-references), methodological rigorousness, clarity of results, and sound basing on previous research output. Furthermore, since blockchain-related research is developing very quickly, our review was iterated several times between November 2018 and October 2020.

Regarding the collection and elaboration of field qualitative data to couple the results of the literature review, the co-authors focused on the Swedish construction sector context; this methodological choice was made to account for the national institutional and socioeconomic forces impacting and making each industry unique (even if it can share interfaces with others). In the particular context of Sweden, at least until the recent COVID-19 pandemic outbreak, an intense urbanization had been taking place, despite a very uneven distribution of urban and countryside areas. Such an activity and its associated complex processes, especially within densely populated places, could result in logistics-related issues (e.g. delayed deliveries, complicated supply chain coordination, and low productivity) (Dubois et al., 2019). One Swedish business practice to counter such issues, is clients employing independent logistics consultant firms, in order to coordinate and handle complex, recurrent and conflicting flows (e.g. deliveries of materials and arrival of incoming goods) (Gustavsson, 2018). These firms facilitate such a coordination across the supply chain by suitably connecting the related actors (e.g. clients, material suppliers, main contractors, and sub-contractors) (Gustavsson, 2018). This practice is particularly emerging in the case of public clients in central urbanization projects.

In this context, we combined the following sociomaterial qualitative techniques described in Moura and Bispo (2019): observations, interviews, participant mapping, and photo elicitation. These techniques were implemented (in various combinations) during the following three sessions:

1. The introductory study (December 2018 to July 2019) of eight firms offering independent logistics consultancy exclusively or in combination with other services (LogTrade, Myloc, Prolog, Servistik, Svenskt Byggdialog, Svenskt Bygglogistik, FM Management, and Ramirent). The sampling of these companies followed their characterization as prominent in their field by Swedish construction periodicals (e.g. Byggindustrin, Byggvärlden), as well as the field expertise of one of the co-authors as an observer of such firms' business activity in the Swedish construction sector since 2013.
2. The in-depth collaboration with Prolog and another independent logistics consultancy firm wishing to remain anonymous. The sampling of these two companies followed the preparation of the previous step and was furtherly consolidated after the co-authors' personal communication with them. In the case of Prolog, one of the co-authors visited its former offices in Stockholm twice (in December 2018 and January 2019), and its offices in Malmö once (in January 2019); the offices in Malmö were visited again by both co-authors in January 2019. In these visits, we observed the company's operation processes and discussed with its consultants for their respective roles – resulting in the design of a participant mapping in early 2019, which was then disseminated to all relevant colleagues. Moreover, from November 2018 to March 2020, we held regular (almost biweekly) Skype meetings with Prolog; these meetings were not recorded, but each time notes were taken and then disseminated to all participants. In the case of the anonymous firm, and apart from the construction site visits (see next step), one of the co-authors held a number of telephone conversations with one of the company's

founders in October 2019; notes from these conversations were taken and used as a preparation for the interviews described in the next step.

3. Visits to three construction sites where the anonymous firm operated; one featuring the expansion of a hospital in Helsingborg, Sweden, and two (for which the firm wished the disclosure of no project information) in Copenhagen, Denmark. In the visit to Helsinborg (October 2019), both co-authors and a research colleague interviewed the aforementioned company founder and partner, as well as another of the partners, for about four hours. The semi-structured interview, first taking place in the on-site firm's premises and then in the site itself, was recorded and transcribed. The two sites in Copenhagen were both covered in a single visit (December 2019). In the first site, one of the co-authors interviewed the same company's founder and partner for about two hours. In the second site, both co-authors continued interviewing the same interviewee for about three hours. This two-part semi-structured interview was recorded, and noted on its most useful parts were taken. In both cases, the interviews took place in the firm's respective on-site premises, and then in the sites themselves. During the interviews, we also observed the company's consultancy processes and took notes. Moreover, the interviewee introduced the co-authors to on-site firm partners, which then helped us design a participant mapping for each construction site. Furthermore, in all three site visits (in Helsinborg and Copenhagen), photographs from the company's workflow charts, as well as their actual on-site coordination, were taken. All of the interview transcriptions, notes, observations and site photographs were compiled into a short report which was then disseminated to all participants.

The sum of this material was used to inform all empirical findings in Section 5 (note: for Fig. 4, only material pertaining to Prolog was utilized). Also, ethical considerations about data and corporate confidentiality were accounted for; only the information allowed by all involved actors is disclosed in this study.

The literature review findings and the field data were combined to (a) realize the sociomaterial understanding of blockchain for integrated construction logistics, (b) conceptualize the blockchain solution, (c) understand its value creation for a new DBM, (d) select the independent logistics consultants in Sweden as a suitable candidate for the implementation of this DBM, and (e) conceptualize such a DBM. For these, the sociomaterial study framework by Moura and Bispo (2019), the ten-step decision path to determine when to use blockchain technologies by Pedersen et al. (2019), and the business model canvas tool by Osterwalder and Pigneur (2010), were used.

Finally, for the verification of the DBM, a case study was conducted with Prolog. The firm particularized the previously formulated conceptual DBM canvas in its own context. The use of case studies for verifying conceptualizations in a sociomaterial context is exemplified in Rossi et al. (2019) and Moura and Bispo (2019).

4. LITERATURE REVIEW

There has been research noting the need for transparency in the access and management of information in construction supply chains (e.g. in Čuš-Babič et al., 2014), as well as new approaches to procurement (e.g. in Eriksson and Lind, 2016). Since these aspects can be coupled with capabilities of blockchain (described previously), it can be considered that they have paved the way for investigating blockchain solutions for the construction sector. It has been claimed that, while possibly overhyped, blockchain has indeed a credible potential within construction (Perera et al., 2020) – despite concerns regarding its applicational immaturity and the inertia of the sector in adopting it (Perera et al., 2020), as well as it being considered more fitting in a process-based, rather than the dominant project-based, approach within construction (Sharma and Kumar, 2020). Considered to be among the enablers of Construction 4.0 (Maciel, 2020), blockchain for construction is still in the very early stages of technological readiness and commercialization (Gerber and Nguyen, 2019; Nguyen et al., 2019), and the corresponding research output has been this far relatively limited. However, such an output is constantly growing, and can be broadly categorized into studies approaching the construction industry and the related potential for blockchain implementation more holistically, and studies with a differentiated scope, which distinguish and focus on specific niches and/or processes of the sector.

First, the studies with the more holistic approach will be elaborated on; with their wider focus, these efforts have tried to provide overarching insights.

Specifically, Barima (2017) wrote about leveraging the basic Bitcoin blockchain for transactions in construction, albeit he proceeded to investigate the potential of altchains, sidechains, and cryplets. Barima (2017) also noted that using cryptocurrencies can alleviate currency fluctuations across borders, thus streamlining the exchanges for international construction projects. Li et al. (2019) introduced a sociotechnical framework for the implementation of blockchain in construction, featuring conceptual models that considered the dimensions of technical architecture, process management, social impact, and policy. Hunhevicz and Hall (2020) focused on the digital ledger aspect of blockchains, and proposed a framework to decide whether there is a need for a digital ledger, determine its design (public or private, permissionless or permissioned), and note the associated use constraints (e.g. throughput, data storage, interoperability, privacy, and cost structure). Perera et al. (2020) extrapolated the insights gained by implementing blockchain in other industries (e.g. financing, identity protection, agriculture, and healthcare) to construction, and concluded that blockchain can be especially useful for industry-wide processes, such as file sharing and property and document management. Finally, Yang et al. (2020) investigated the potential of public and private blockchains within construction, pointing to challenges emanating from business variations, node identity issues, cost and complexity of adoption, and system scalability, vulnerability and security.

Following, the studies with the differentiated scope will be presented; by focusing on specific niches and/or processes of the construction sector, these efforts aimed at offering more targeted insights. As will be shown, some studies focused on one niche (e.g. Mason (2017)), while others investigated more than one niches (e.g. Penzes, 2018, and Gerber and Nguyen, 2019).

Specifically, Cardeira (2015), Lamb (2018), Penzes (2018), Das et al. (2020), and Hamledari and Fischer (2020) emphasized the utilization of smart contracts (namely, computer protocols for the facilitation, verification, or enforcement of contract and clauses (Cuccuru, 2017)), as well as the peer-to-peer transactional properties of blockchain, for the automation and facilitation of contractual agreements (including progress and interim payments). Mason (2017) looked into smart contracts for the commercial bargains between construction stakeholders. Piraquive et al. (2017) focused on the implementation of blockchain in the knowledge management of construction projects. Heiskanen (2017) and Kochovsky and Stankovski (2018) researched the integration of blockchain and the Internet of Things (IoT) for the enhancement of construction productivity and performance during production, claiming that such an integration can expedite processes, simplify data flows, and reduce issues of messy and untrustworthy data due to multiple sources and formats. Graglia and Mellon (2018) wrote about utilizing blockchain for strategic innovation in real estate management. Klyukin et al. (2018) emphasized the utility of distributed digital ledgers for the purposes of urban planning. Lemeš and Lemeš (2020) noted that the integration of blockchain with Computer Aided Design (CAD) can facilitate the distribution and validation of digital designs. Integration blockchain with BIM (Penzes, 2018; Hargaden et al., 2019; Di Giuda et al., 2020) – sometimes also using IoT network data as input for BIM (Arthur et al., 2018) – has been claimed to facilitate trust among stakeholders, resolve data-related issues (e.g. data confidentiality, provenance tracking, disintermediation, non-repudiation, multiparty aggregation, traceability, inter-organizational record-keeping, change tracing, data ownership) (Turk and Klinc, 2017), mitigate workflow bottlenecks by increasing visibility and predictability (Woodhead et al., 2018; Nawari and Navindran, 2019), and scaling collaboration to multiple agents via the use of smart contracts (Dounas et al., 2020). Ghaffarianhoseini et al. (2017), though, have criticized the integration of blockchain and BIM, stating that blockchain would be more useful just as a tool for automated document handling and auto-invoices. Gerber and Nguyen (2019) and Nguyen et al. (2019) have discretized the construction sector into five markets (cities, energy, property, transport, and water), and then presented blockchain visions and prototypes for five subcategories in each market, like, indicatively, circular economy (cities), renewable certificate tracking and trading (energy), lease agreements and automated payments (property), freight tracking (transport), and utility contracts and billing (water). For each subcategory, Gerber and Nguyen (2019) and Nguyen et al. (2019) focused on specific blockchain attributes that were deemed more suitable, and primarily digital distributed ledgers and smart contracts. Elghaish et al. (2020) developed a blockchain framework to facilitate integrated project delivery (IPD) by automatically executing financial transactions among the core project team members; as such, they coded reimbursed costs, profits, and cost savings, as functions of the IPD smart contracts. Fu and Zhu (2020) showed the applicability of public blockchains as a potential infrastructure for trusted data networks in the context of smart cities. In the questionnaire survey by Kim et al. (2020), which considered the applicability and anticipated impact of the technology, blockchain was deemed suitable for project cost/change management, contract bidding and formation, and procurement evaluation. A literature review by Kiu et al. (2020) showed that leveraging the core blockchain properties points to construction supply chain management, facilitation of BIM, contract management, electronic document management, real estate management, and funding management, as potential areas of application within construction. Finally, Zhong et al. (2020) showed that smart contracts can be used for compliance checking to regulation requirements of construction products, thus aiding in quality management.

Of particular interest for the current study are the efforts with a differentiated scope focusing centrally on the potential of blockchain for construction supply chains and logistics. More specifically, Cardeira (2015) noted that digital distributed ledgers can mitigate disarrays due to changes in the construction supply chain strategy, thus reducing the suppliers' uneasiness connected to withheld payments or other insolvencies. Wang et al. (2017,2020) and Nanayakkara et al. (2019) wrote that the information flow in downstream supply chain segments can be improved due to the facilitation of transparency and traceability through blockchain. Lanko et al. (2018) have studied the improvement of on-site logistics through the integration of blockchain with data collected from on-site RFID sensors. Penzes (2018) claimed that blockchain-induced transactions can result in dynamic and instant payments for suppliers, transporters, and subcontractors, as well as better communication with the main contractor. Moreover, the visibility of the complete transactional history across the construction supply chain and the consensus requirement for the block updates, are exemplified for tackling the tampering with past logistics data (Penzes, 2018) and issues of productivity and efficiency (Shemov et al., 2020). Furthermore, blockchain is envisioned to reduce administrative rework (e.g. matching data among different ledgers for multiple deliveries) and data errors and outages across the supply chain, thus leading to time and cost savings, better change management, better planning, and instant delivery notice for the contractors (Penzes, 2018). Rodrigo et al. (2020) investigated the utility of blockchain in estimating the embodied carbon emissions along construction supply chains, by making the relevant data transactions transparent and immutable. Tezel et al. (2020) emphasized, through a SWOT analysis, that preparing construction supply chains to accommodate blockchain would require the conceptualization and development of operational processes that align with the roles and responsibilities of the supply chain actors. Finally, Qian and Papadonikolaki (2020) have postulated that blockchain, by providing solutions for data tracking and contracting and transferring resources, can mitigate the opportunistic behaviours of supply chain actors, thus shifting the trust from relational to system- and cognition-based.

The literature review shows that while some blockchain studies approach the construction industry as a whole, most focus on specific niches and processes of the sector. In each case, there are conceptualizations, visions and some prototypes of blockchain solutions, but no actual use cases yet. On another note, the core properties of blockchain, such as peer-to-peer transactions, record immutability and a degree of decentralization, are generally described as beneficial for construction, and generate the majority of the stated value-adding benefits. Most studies elaborating on these properties and benefits, approach blockchain in a blended economic flow- and information flow-oriented manner, although there are efforts (e.g. the ones about integrating blockchain with BIM) where the information flow is more pronounced. Regarding specific blockchain aspects, the digital ledgers and smart contracts are generally the ones considered to have the biggest potential for construction, and they are investigated across various blockchain visions and prototypes.

The studies particularly focusing on construction logistics generally adopt the previously discussed themes as well, i.e. investigation on a largely conceptual level, a blended economic flow- and information flow-oriented approach, value-adding benefits mainly emanating from the core blockchain properties, and a focus on digital ledgers and smart contracts. Nevertheless, Tezel et al. (2020) and Qian and Papadonikolaki (2020) have also considered social issues, such as the facilitation of trust across the supply chain. However, no construction logistics-related studies elaborate explicitly on the simultaneous integration of the information, material and economic flows. In addition, no construction-related studies adopted sociomateriality. Notably, Li et al. (2019) have used a sociotechnical approach. However, this study did not explicitly focus on construction supply chains and logistics, and as its focus was not on the co-shaping of the technology with its practical implementation, it is not considered sociomaterial.

Finally, the potential constraints and security issues regarding the implementation of blockchain, two topics that are quite widely researched outside the field of construction, are only limitedly considered in a few construction-related studies (e.g. in Barima, 2017; Perera et al., 2020; Sharma and Kumar, 2020; Shemov et al., 2020; and Yang et al., 2020). To expand this limited consideration, we investigated blockchain-related studies outside the field of construction. Regarding implementation constraints, Kshetri (2018) wrote that for supply chains and logistics, blockchain can only be adopted if it can lead to the achievement of strategic objectives, such as cost, quality, speed, dependability, risk reduction, sustainability and flexibility. Furthermore, Verhoeven et al. (2018) identified the limited engagement with technology, limited seeking of technological novelty, limited context awareness, limited cognizance of alternative technologies, and anticipation of technological alteration, as strategic factors that can impede the adoption of blockchain for logistics. Considering security, a number of studies (e.g. Underwood, 2018; Veuger, 2018; Chong et al., 2019; Rossi et al., 2019) highlight two common denominators. The first is a presumptive mistrust in the potential of blockchain as a viable technology investment. The second is the possible abuse of the properties of blockchain; the anonymity of the distributed node network could lead to illicit activities, the use of cryptocurrencies to losing grasp of the actual value of fiat currencies, and the inflexibility of the automated transactions to tensions among the actors in the blockchain network.

5. DIGITAL BUSINESS MODEL FOR INDEPENDENT LOGISTICS CONSULTANTS

5.1 Empirical findings

Through our empirical studies in the Swedish context (described in Method), we found that there are variations in the approach and level of digitalization for the coordination procedures the logistics consultants carry out. Their use of IT support (such as planning software, site gate control systems, and tracking applications) varies and is reflected on the firms' different business models. For example, firms like Prolog outsource their digital solutions to specialized IT consultants, which can differ in each project; firms like LogTrade and Myloc deploy an in-house IT infrastructure; and firms like Ramirent (which is predominantly a construction equipment supplier) have adjacently entered the construction logistics field and present an approach to logistics solutions which echoes the business models of Swedish firms offering miscellaneous construction services (e.g. Buildsafe, Loop Rocks, Ene Golv, and Edvirt). However, while all approaches entail that the independent logistics consultants collaborate interactively with on-site contributing parties and key suppliers, evidently no approach features blockchain.

It was found that a common practice by independent logistics consultants (as well as other practitioners) in Sweden, is the implementation of area disposition plans (namely, drawing-based material and storage management plans (Cooke, 2015)). Such plans have often been claimed to be dynamic, but are practically rather static. They are rarely translated to an uninterrupted on-site space usage for provisional storage, and scarcely exhibit a continuous integration between the logistics planning, its included information and material flow control system, and the material registration, placement and installation. In some cases, there is also a difficulty in efficiently regulating the delivery entries at the construction site, as a suitable gate control system may be either absent, or suboptimally integrated with the information flow (e.g. when deliveries are manually assigned in a ledger, and then communicated to the logistics consultants via phone calls). Moreover, on-site physical placement is rarely tied to any implemented digital solutions facilitating information exchange. However, even in the presence of such ties (depending on the digital systems used), the economic flow remains disintegrated with the information and material flows. This is evident in the decoupling among the deliveries and transportation services, the corresponding payments, and the fees released for the implemented logistics solutions. Consultants are usually burdened with justifying the value-for-money for their services (commonly paid on an hourly wage), as the communication of their results to the clients is mainly done in parallel to the actual construction supply chain and logistics setup, and the clients do not participate in the information flow too actively. Independent logistics consultants strive to solve such problems while tackling delivery failures, unprecise data retrieval, time delays, withheld payments, and inefficient intra-systemic flows and data transfers.

To confront these issues, an event-driven blockchain-induced flow integration across all phases of the related processes, i.e. from the issuing of purchasing orders until the completion of the on-site deliveries, can be a feasible solution for logistics consultants. Envisaged value-adding aspects of this integration can include the holistic overview of construction supply chain, an increased value-for-money perception via tightened work-payment coupling (even when the consultants are paid on an hourly wage), the fostering of trust, transparency and traceability in transactions, the offer of quicker and more efficient services, the quicker collaboration with the main contractor, and the leveraging of the automation of processes to commit fewer human and material resources on the more tedious parts of the logistics plan (thus focusing on more convoluted issues and being more useful to the client). Notably, while some of these value-adding aspects (e.g. offering quicker and more efficient services) can be brought about by centralized IT systems (already developed and/or implemented by some of the independent logistics consultants) working in conjunction with each other, there is currently no solution that can address them simultaneously in the way the proposed blockchain solution can. In addition, all other current IT solutions require some form of third-party intervention, while a blockchain solution can facilitate the direct peer-to-peer interaction of the participants in the blockchain network, and furtherly reduce time and resource waste.

Thus, it can be derived that when it comes to the operation and challenges of the independent logistics consultants, the Swedish sector presents a fertile and suitable sociomaterial context to accomodate a DBM for construction logistics with integrated flows through blockchain. However, and in accordance with the autonomy-control paradox, the logistics consultants have also to consider the power shifts among the supply chain actors as soon as the integrated flows (and particularly the economic flow) change with the implementation of blockchain. Through our collaboration with the logistics consultants (and especially Prolog), we have found that the main contractors, already losing some of their control over the supply chain when the client hires independent logistics consultants, are not very keen to relinquish more of their power in a setting that gets even more decentralized due to blockchain.

5.2 The conceptualization of the blockchain solution in the Swedish context

By combining, through a sociomaterial lens, insights from the theory, the literature review and the empirical findings, the blockchain solution offered by the independent logistics consultants can be conceptualized into being implemented on the economic flow involving the client, the main contractor, and suppliers, and coupled with events on the material flow (e.g. successful on-site deliveries) and the respective data exchanges on the information flow. It should be noted that the suppliers can be interchangeable with transporters and/or subcontractors, or can be different entities altogether; in the case of the simplified example we offer below, as well as many real projects, the suppliers, transporters and subcontractors are one entity.

Initially, in Fig. 1 we present a swimlane process flow diagram depicting in a simplified and generic way the situation before implementing the blockchain solution; namely, the initial form of the construction supply chain and logistics setup segment which the independent logistics consultants are hired to facilitate.

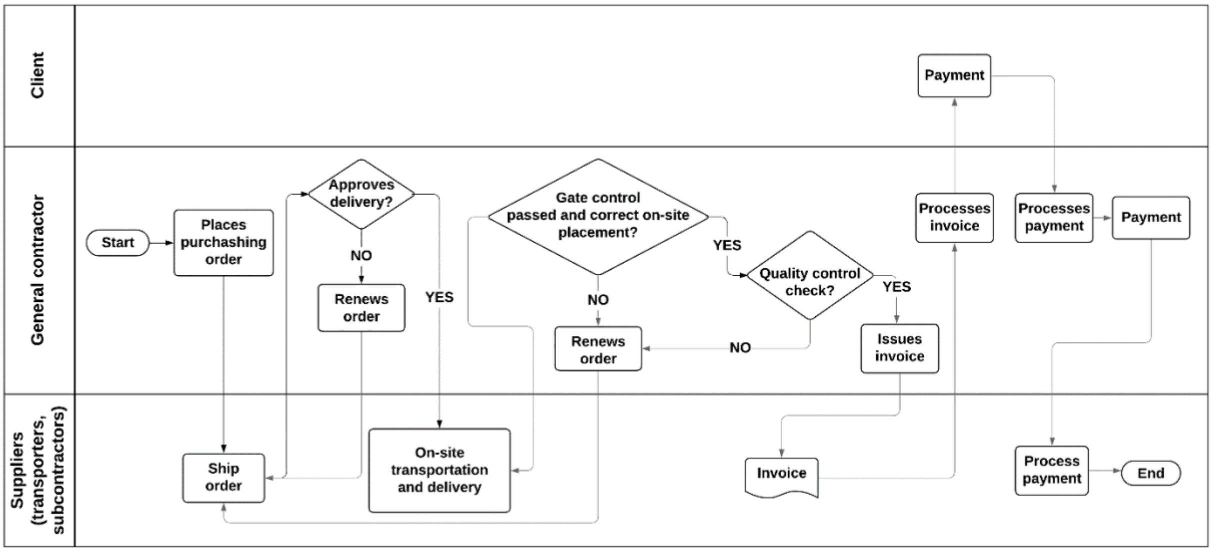

FIG. 1: Swimlane process flow diagram depicting the construction supply chain and logistics setup segment which is facilitated by the independent logistics consultants.

This segment of the supply chain is usually preceded by many other steps, like e.g. the specification of the suppliers by the clients or the architects, the obtainment of the supplier quotes by the general contractor, the approval of the supplier submittals, and other. However, in the generic case, the facilitation offered by the independent logistics consultants usually starts when the suppliers have been chosen, and the purchasing department of the general contractor issues the purchasing order (economic flow). Then, the ship order is issued by the suppliers and prompts the approval of the delivery by the contractor (information flow). If this approval is denied, then the order is renewed (information flow); if it is accepted, there is a clearance for the on-site transportation and delivery (information flow). Then, the transportation and delivery itself takes place (material flow). As soon as the goods arrive on site, a series of checks is performed (gate control, on-site placement, quality control); if these checks fail, the orders are renewed (information flow), and if they succeed, the issuing of the invoice is prompted (information flow). The invoice is sent to the suppliers and then processed by the contractor’s accounting department, which prompts the payment by the client (economic flow). Finally, after the final processing of the payments by the contractor’s accountants, the payment is released to and processed by the suppliers (economic flow).

On this segment, the independent logistics consultants strive to facilitate, accelerate and coordinate the recurrent and conflicting flows, connect the client, the general contractor and the suppliers, and counter the decoupling of the delivery and transportation services with the corresponding payments. However, the current setup makes such a facilitation difficult. The general contractor seems to retain power over most business-critical supply chain aspects, and large parts of all three supply chain flows remain separated and disintegrated – thus making the client and the suppliers more "passive", especially in their role in the economic flow. Moreover, the checks of the on-site deliveries and physical placement of goods are sometimes not implemented, or are done with distance in time, thus separating the information and material flows. Furthermore, the information communicated to the client is not shown in the diagram, as it is not strongly connected to this setup, but rather runs in parallel, thus accentuating the burden of the consultants to justify the value-for-money for their services.

Then, in Fig. 2, we present a swimlane process flow diagram conceptualizing in a simplified and generic way the situation after the independent logistics consultants implement the sociomaterial facilitation offered by the blockchain solution. In Fig. 2, such an implementation is shown to simplify and integrate the flows, thus accelerating processes and countering issues of delivery failures, unprecise data retrieval, time delays, withheld payments, multiple ledger structures, and faulty intra-systemic data transfers. Moreover, it enhances the transparency and traceability of the whole setup by actively involving all actors in the consensus checks of the smart contracts. In particular, the placement, approval and renewal of the orders (economic + information flows) can be done directly through the blockchain (e.g. with the storing of hashes of files pertaining to each of these transactions), and trigger the on-site transportation and delivery (economic + information + material flows). Finally, through the blockchain, the successful on-site checks of the deliveries are codified and stored (information + material flows), the issuing of the invoices are triggered (economic + information + material flows), and the payments are released (economic + information flows).

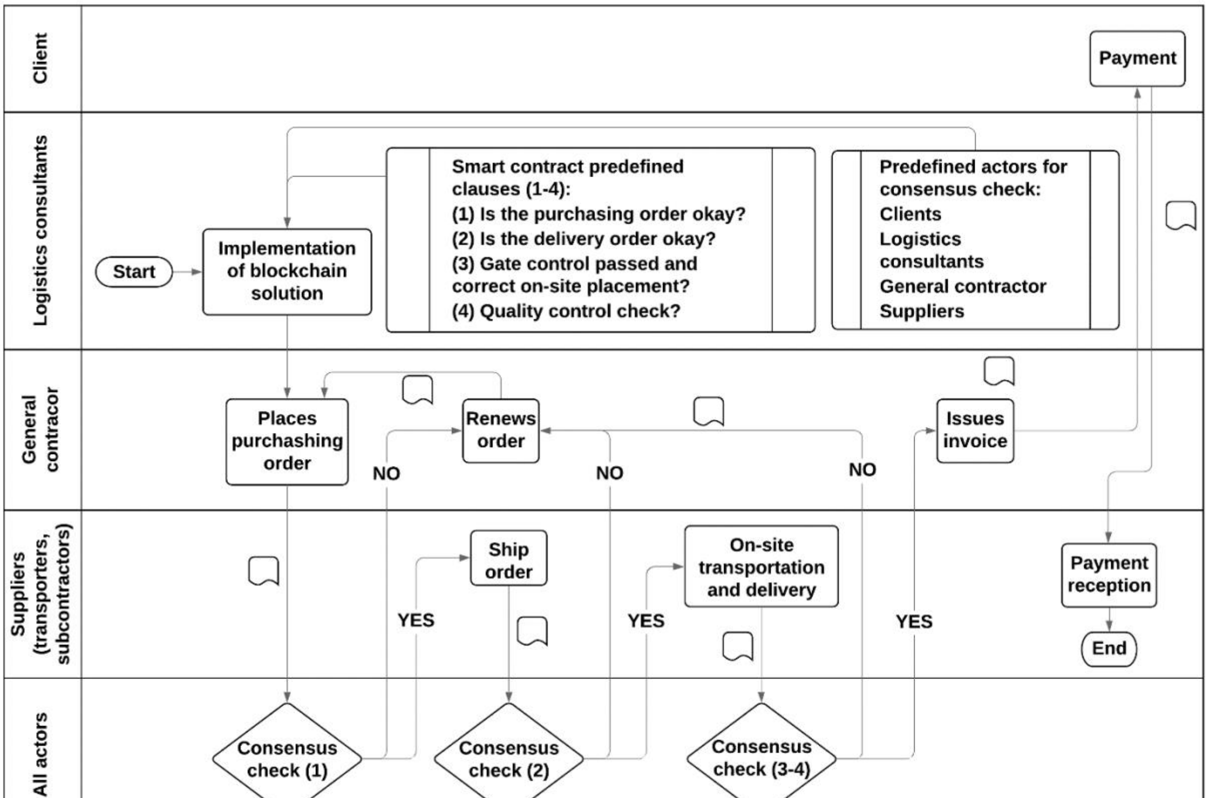

FIG. 2: Swimlane process flow diagram conceptualizing of the construction supply chain and logistics setup with the sociomaterial facilitation offered by the blockchain solution.

In this setup, the client and the suppliers are centrally involved in shaping the flows, and thus assume a much more active role – which allows them to have a better and more transparent overview of the construction supply chain.

Moreover, the independent logistics consultants do not simply facilitate the various flows and notify the client "in parallel"; but rather, they too participate in the active shaping of the flows with the implementation of the solution, foster accountability through the consensus checks, and justify their value-for-money as a measure of the solution's performance. However, it should also be noted that in line with the sociomaterial autonomy-control paradox, the general contractor may lose a lot of their power over the supply chain – power which is diffused, through the consensus checks and the automated processes of the blockchain, to the client, the suppliers, and the logistics consultants themselves.

5.3 Digital business model canvas: conceptualization and verification

By combining, through a sociomaterial lens, the previously illustrated conceptual blockchain solution, and the relevant insights from the theory, the literature review and the empirical findings, a new DBM for independent logistics consultants can be conceptualized. This conceptualization, based on the tool by Osterwalder and Pigneur (2010), is provided in Fig. 3.

<table>
<tr>
<td rowspan="2"><u>Key partners</u>

- Other consultants
- Material and equipment suppliers
- Transporters
- Subcontractors
- Professional associations
- Academia
- Specialized IT consultants (optional)</td>
<td><u>Key activities</u>

- Coordination of complex, recurrent and conflicting flows
- Coordination across the supply chain by connecting the main stakeholders
- Interactive collaboration with on-site contributing parties and key suppliers</td>
<td rowspan="2" colspan="2"><u>Value proposition</u>

- Offered services: quicker, more efficient, and upgraded in terms of project overview
- Justified value-for-money and increased productivity
- Acceptance of the new professional role by the clients
- Automation and improvement of traditionally cumbersome logistics processes
- Smoother communication and collaboration with the main contractor
- Commitment of less human and material resources in the more tedious parts of the logistics planning
- Crude switches between different supply chain strategies during the project production can be smoothened out, or mitigated
- Economic friction points within the logistics process can be minimized</td>
<td><u>Customer relationships</u>

- Interactive collaboration with on-site contributing parties and key suppliers
- Automated-dynamic transactions using cryptocurrency
- Peer-to-peer transactions</td>
<td rowspan="2"><u>Customer segments</u>

- Project owners / clients
- Main contractors and developers: accounting, purchasing, project planning, services related to the work of suppliers / transporters / retailers
- Project managers (e.g. structural, facilities, HVAC)
- Representatives of the suppliers
- Representatives of the transporters
- Representatives of the subcontractors</td>
</tr>
<tr>
<td><u>Key resources</u>

- Monetary: fees paid by the client
- Human: logistics consultants
- Human: specialized IT consultants (optional)
- Digital assets: blockchain system
- Material assets: offices and on-site working facilities (e.g. as parts of a logistics consolidation center)</td>
<td><u>Channels</u>

- Business reputation (new and potentially disruptive solution offered)
- Customers
- Social media
- Industry events</td>
</tr>
<tr>
<td colspan="3"><u>Cost structure</u>

- Service cost paid by the client (included in the logistics fees)
- Business and asset costs
- Reduction of interaction and accounting costs (economic data)
- Less rework with the accounting figures</td>
<td colspan="3"><u>Revenue streams</u>

- As created by the operation of the blockchain nodes
- Decentralized, secure, transparent, resulting through instant transactions
- Initial utilization of cryprocurrency → then translation into fiat currency depending on the system used</td>
</tr>
</table>

FIG. 3: DBM canvas for logistics consultants: blockchain solution with integrated flows for construction logistics.

The proposed conceptual DBM canvas involves all the known elements of a business model. The value proposition emanates from a combination of the literature insights regarding the potential of blockchain for construction logistics, the embedding of the previously illustrated blockchain solution, and benefits envisaged during our empirical study. In the key resources, the blockchain system is added as a digital asset that can be offered by the logistics consultant as an IT solution. As mentioned earlier, a core aspect of this digital asset is that it can be a single system and not a bundle of IT solutions working in conjunction. Customer relationships are also altered due to transactional properties of blockchain. More specifically, the direct peer-to-peer transactions can offer more transparency and traceability, make payments more dynamic and expedite the consultants' collaboration with the project clients and on-site partners. Notably, a permissioned private blockchain can allow for the retainment of the aforementioned benefits, while still keeping the solution accessible only to project-specific actors – which, according to our empirical insights, was a security requirement by all project stakeholders willing to accept a blockchain solution offered by the logistic consultants. In that sense, the permissioned private system would allow for a better positioning of the logistics consultants as the sole providers of a solution that is not subjected to the possible jeopardies of permissionless public systems. In the cost structure, the positive impact of blockchain on the accounting processes is mainly reflected on the reduction of interaction costs and accounting rework, mainly due to the shared ledger structure of the proposed solution – instead of multiple actors' ledgers which the logistic consultants would need to align. The revenue streams are now integrated with the blockchain network – also due to the possible use of cryptocurrencies – and are both facilitated and expedited due to the direct peer-to-peer transactions of the blockchain solution. The key partners, key activities, channels, and customer segments remain largely unchanged in comparison to the current situation of logistics consultants, since during our literature review and empirical study we found no indication that these business elements would alter in case the consultants start implementing a blockchain solution.

To verify this canvas, a single case study was conducted with the independent logistics consultant firm Prolog. Prolog was founded in 2001, is staffed by 13 employees, and currently has offices in Malmö (previously also in Stockholm). During its years of work, it has consulted around 400 clients, and has successfully offered its services in around 1560 projects, including ones situated in Norra Djurgården and the Jarfälla municipality in Stockholm. Within our 17-month-long collaboration with Prolog, its consultants were able to customize our generic conceptual business model canvas shown in Fig. 3, into one especially befitting Prolog (shown in Fig. 4).

It can be observed that the elements constituting the partitions of the customized canvas, are either similar to, or particularizations of the ones featured in the initial conceptual canvas (as e.g. in the case of the value proposition). As such, most of the expected benefits in the key resources, the customer relationships, the cost structure, and the revenue streams, can be carried over in the specific case of Prolog. However, some aspects of the DBM partitions were deleted during the customization (e.g. within value proposition and customer segments), which was to be expected, since the conceptual canvas was developed to be as generic as possible for the general case of independent logistics consultants.

<table>
<tr>
<td rowspan="2"><u>Key partners</u>

- Other consultants (e.g. Svensk Bygglogistik)
- Material and equipment suppliers
- Transporters
- Subcontractors
- Specialized IT consultants
- Associations (e.g. Byggherrarna)
- Academia (e.g. universities and students)</td>
<td><u>Key activities</u>

- Coordination of complex, recurrent and conflicting flows (incl. managing processes and change)
- Coordination across the supply chain by connecting the main stakeholders
- Interactive collaboration with on-site contributing parties and key suppliers (e.g. through workshops, analyses, and competence development)</td>
<td rowspan="2"><u>Value proposition</u>

- Efficiency development
- Unique facilitation of the logistics planning and integration of flows
- Improved situational leadership
- Improved change management
- Improved process management
- Effective digitalization and streamlining of processes
- Increased productivity</td>
<td><u>Customer relationships</u>

- Interactive long- and short-term collaborations
- Peer-to-peer transactions
- One-time deliveries</td>
<td rowspan="2"><u>Customer segments</u>

- Project owners / clients, like municipalities (e.g. Järfälla Kommun, Stockholms Stad)
- Facilities (e.g. VA Syd, Traffikverket)
- Developers / contractors (e.g. JVAB, Skanska, NCC, Veidekke, Bravida, Assemblin)
- Facility managers (e.g. Riksbyggen)</td>
</tr>
<tr>
<td><u>Key resources</u>

- Reference projects
- Monetary: fees paid by the client
- Human: logistics consultancy employees
- Innovative assets: blockchain system
- Material assets: offices and on-site working facilities (e.g. as parts of a logistics consolidation center)</td>
<td><u>Channels</u>

- Present and former customers
- Word-of-mouth
- Social media
- Industry events</td>
</tr>
<tr>
<td colspan="3"><u>Cost structure</u>

- Fees paid by the client through the blockchain system
- Staff salaries (e.g. consultants, project leaders, salespeople)
- Office rent
- Reduction of interaction and accounting costs
- Less rework with the accounting figures</td>
<td colspan="2"><u>Revenue streams</u>

- Fixed-priced consultant service fees payment throught the blockchain system
- Variable-priced consultant service fees payment throught the blockchain system</td>
</tr>
</table>

FIG. 4: Particularization of the DBM canvas for Prolog.

Thus, it can be understood that the canvas customized by and for Prolog is a particularization of the generic conceptual canvas. Therefore, we could verify through Prolog that our conceptualization of the DBM can be applicable in the case of a real independent logistics consultant firm. More elaboration of the most interesting parts of the canvases is featured in the Discussion.

6. DISCUSSION

This paper proposes a new DBM for independent logistics consultants, which utilizes a sociomaterial conceptualization of a blockchain solution for the integration of the information, material and economic flows within construction logistics. The discussion goes through the arguments we have formulated throughout our study. In particular, it elaborates on the results of the literature review, our insights regarding our choice of sociomateriality, critical comments on the most interesting parts of the two DBM canvases, and concludes by drawing attention to the barriers for adopting a construction logistics solution featuring blockchain.

The literature review on blockchain for the construction sector shows that the core properties of blockchain, such as peer-to-peer transactions, record immutability and a degree of decentralization, are generally shown to generate the majority of the potential value-adding benefits. While some blockchain studies approach the industry as a whole, most differentiate by focusing on specific niches and/or processes of the sector. In both approaches there are conceptualizations, visions and some prototypes of blockchain solutions, but no actual use cases yet. It can be argued that the differentiation into niches can be instrumental for moving the development and application of blockchain closer to actual use. However, it may also imply that this general-purpose technology is dispersed into a number of dissimilar applications, where construction logistics is only just one – and not widely researched yet.

The choice of sociomateriality for our own conceptualization reflects not only our theoretical considerations on the way blockchain, a general-purpose technology, can be properly contextualized within construction logistics setups in Sweden – but also our empirical understanding of the real-life function of such setups. Rather than viewing the respective actions as technical choices among rationally discernible operational models, which is recurrent in the operations management and business economics approaches, we interpret them as different sociotechnical solutions involving characteristic distributions of power. This evidently means that the investigated operational framework is not limited to knowledge exchange (Gustavsson, 2018), but also constitutes a type of a political game which is co-shaped along the utilized technological frameworks. Moreover, the sociomaterial approach leads to the understanding of mutual trust as a crucial issue of security in blockchain implementation (see also in Woodhead et al., 2018). Since large urban building sites can suffer from theft and shrinkage in material supplies, at least internal trust among participants in a decentralized blockchain network, should be cultivated. However, supporting an outright permissionless setup can be difficult. Thus, the proposition of a permissioned private system that can establish procedures to protect the blockchain network both from external threat and internal instabilities, is informed by existing sociomaterial conditions. Furthermore, integrating the new technology would probably involve technical interoperability issues, as well as changes in the work practices, social setups and organizational structure of the participating companies. Through our sociomaterial understanding, the tackling of such issues and changes can initially place the blockchain solution on top of an information infrastructure consisting of different accounting, project planning, site planning, quality control, and access control systems; then, the adoption of common standards for the structuring of ledgers would ensue.

Regarding the DBMs, the canvas in Fig. 3 represents the more generic version, where the central value proposition consists of the automation and optimization of several aspects of construction logistics. However, in the canvas showing the customized DBM for Prolog (Fig. 4), the central value proposition consists of the facilitation of logistics planning and the integration of the economic, information and material flows. The difference between the value propositions mirrors the actual positioning Prolog's DBM depicted in Fig. 4, which emphasizes consultancy over automation. Another interesting differentiation between the two canvases is found in the customer segments section. While the way of facilitating construction logistics with blockchain can address many customer segments, Prolog focuses more on the construction clients, who in the Swedish context are typically public. When it comes to key resources, the "digital asset" in Fig. 3, is addressed as an "innovative asset" in the case of Prolog. This can reflect not only Prolog's opportunity to position itself as a possible innovation leader in the field of construction logistics, but also as a statement of evolving their business practices (from currently outsourcing digital solutions to offering an integral, in-house system). Finally, in the revenue streams, Prolog has rejected the use of cryptocurrencies, opting for a crypto-free system. This might show prudence, as from our interviews with Prolog we have understood that the firm deems current sociomaterial constellations in Swedish construction logistics to be too inert to adopt crypto-transactions.

The hindrances and barriers in adopting the solution, can be attributed to current issues in construction supply chains that need to be overcome – such as data unavailability, lack of blockchain awareness, and the existing power balances within sociomaterial constellations. These issues can also present challenges in the specific case of Prolog – especially the upsetting of the existing power balance in a sociomaterial construction logistics setting, in which the contractors have a dominant role. Prolog has so far been a neutral (in terms of interactions and power distribution) strategic consultant for the facilitation of logistics flows, a role signified according to the clients' prerogative. However, with the implementation of the blockchain solution, Prolog may shift the power setup, since the contractors will have to relinquish a degree of control over e.g. the economic flow.

Despite blockchain's potential, its value can be speculated when data availability and quality cannot be guaranteed (Lamb, 2018). However, while a number of actors in some national industries appear to suffer from a relative lack of awareness and required skills (Büyüközkan and Göçer, 2018), it can be observed that actors in sociomaterial constellations of construction supply chains in other national industries, such as in Sweden, are becoming increasingly more competent in data capturing and storage – thus potentially mitigating the aforementioned speculation. This can present an opportunity for Prolog, since it can complement its role as an early blockchain adopter and/or solution provider and allow it to get ahead of the competition.

Another consideration regards the challenge of transitioning from physical documents (e.g. shipping fulfilment orders, invoices) to digital ones (e.g. smart contracts), which could jeopardize the value proposition (Loklindt et al., 2018). This challenge could be tackled by being prudent when implementing blockchain, in order to leverage its potential benefits, rather than push for a publicity-pressured adoption (due to the current use of blockchain as a hyped buzzword) which could result in ill-fitting applications (Verhoeven et al., 2018; Perera et al., 2020).

Coupling the aforementioned critical points, our own field experiences indicate that to realize the value of this technology (which is claimed to be disruptive) through a relative DBM, certain aims need to be attained. These aims include the development of an understanding within our sector of what blockchain can offer, the improvement of the realization of its claimed potential in the limited existing visions and prototypes, and the mitigation of the aversion towards changing the autonomy-control status quo of the existing power relations within the sociomaterial construction supply chain and logistics constellations – for example, through proprietorial solutions with permissioned systems, rather than entirely permissionless systems as the blockchain hype would suggest. However, there is optimism that attaining such aims will be successful, as studies on blockchain for construction gain more traction (Hunhevicz and Hall, 2020).

7. CONCLUSIONS

This paper addresses the research question of whether a solution for construction logistics, in which the information, material and economic flows are integrated in an event-driven way through the appropriate technology, can be conceptualized and incorporated into a new digital business model (DBM). In particular, it proposes a new DBM for independent logistics consultants, which utilizes a sociomaterial conceptualization of a blockchain solution for the integration of all three flows. The blockchain network, with the main construction supply chain actors as nodes in a sociomaterial setting, is envisioned to have the ability to trigger immutable automatic transactions and payments (through smart contract protocols), when specific events (e.g. the on-site delivery of incoming goods) have taken place and the corresponding information packages have been exchanged.

The literature review on the studies researching blockchain for the construction sector, which mostly have a differentiated scope and focus on specific niches and processes of the industry, showed that the core properties of blockchain can generate value-adding benefits for construction. The research on, specifically, blockchain for construction supply chains and logistics, also delineates a number of such benefits (e.g. the reduction of administrative and accounting rework); however, no studies have adopted a sociomaterial lens, and there has been no specific focus on either the integration of all three supply chain flows, or the operation of independent logistics consultants in particular.

In our empirical work within the Swedish context, we tried to couple the insights and address the shortcomings of the current literature, in order to conceptualize a construction logistics solution featuring blockchain for integrated flows, and then embed this solution in the value proposition of a digital business model canvas for independent logistics consultants. The Swedish construction sector encompasses a well-established set of independent logistics consultants, and it was thus considered suitable to accommodate such a value proposition. As such, the conceptual solution culminated into an event-driven, blockchain-induced flow integration across all phases of the related processes, i.e. from the issuing of purchasing orders until the completion of the on-site deliveries. The envisaged benefits of the solution included (among others) the streamlining of logistics processes and the improvement of productivity, and were embedded in the value proposition of a new DBM for independent logistics consultants. However, certain issues (mostly tied to the wider construction context) have to be addressed, so that the realization of such value will not be hindered; such issues include, among others, data unavailability, lack of wide blockchain awareness, and the existing power balances within sociomaterial constellations.

The delimitations of this study include the choice of a particular context (i.e. Sweden) and of a particular actor (the independent logistics consultants) in a specific construction logistics setup, for which the presented blockchain solution and DBM were conceptualized. The main downsides of this choice are that the same conceptualizations cannot be easily replicated for other construction sectors unless new context-specific analyses are first conducted, and that within Sweden itself, the dominant setup (in which the main contractor internalizes the logistics services) is not hereby investigated. However, we believe that our choices of context, actor, and solution, complement each other into a concise proposition for the improvement of construction logistics in Sweden.

Recommendations for future work include the conduct of further sociomaterial field studies, the development of the prototype application connected to the blockchain solution, and the pilot testing of such a prototype in at least one real construction site. It is hoped that the investigation within this context will not only contribute to the improvement of construction supply chains and logistics in Sweden, but also impact on other contexts where independent logistics consultants are active.

Blockchain has the potential to play a positive role within the ongoing digitalization paradigm shift in, generally, the construction industry and, particularly, construction supply chains, and can complement well-established technologies such as BIM, and/or other currently investigated cutting-edge technologies, such as IoT. We hope that our study will push research and development in that direction.

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