BLOCKCHAIN IN BUILDING LOGISTICS: EMERGING KNOWLEDGE, AND RELATED ACTORS IN SWEDEN

Dimosthenis Kifokeris and Christian Koch[1]

Division of Construction Management, Department of Architecture and Civil Engineering, Chalmers University of Technology, Sven Hultinsgatan 6, Gothenburg, 41296, Sweden

Large building projects involve complex on-site logistics regarding materials and subsystems, often encompassing hundreds of vehicles handling incoming and outcoming goods and requiring precise timing and space handling. Such a material flow is generally decoupled from the respective economic flow; however, the integration of the two could, among others, foster a holistic overview of the full construction project production, facilitate the collaboration of the supply chain stakeholders, and optimize constructability. Blockchain technologies can enable an integration of these flows by using the distributed ledger facility inherent in a decentralized blockchain network, as well as smart contracts. This paper aims at reviewing the emerging knowledge on blockchain in construction and identifying different constellations of companies and flows in digital building logistics. Theoretically, the paper draws on a sociotechnical approach, which views the development of digitalization as an intertwined social and technical process, where technology is co-shaped with practice. Building on a literature review and interviews and dialogues with actors active in building logistics within Sweden, at least three digital building logistics constellations with the potential to implement blockchain solutions are identified: (1) large contractors integrating building logistics internally, to overcome transaction challenges and maintain power over business-critical supply processes, (2) clients employing independent third-party logistics consultants acting as convenors of different interests in the building logistics setup, and (3) other third-party actors such as construction equipment suppliers, offering customised digital building logistics solutions.

Keywords: Blockchain, logistics, digital business models, information technology

INTRODUCTION

Viewed from a social interaction perspective, blockchain is a team technology - fostering collaboration to solve business challenges. In more technical terms, this is translated to blockchain being a shared and decentralized digital ledger replicated across unique nodes representing organisations or individuals; it is a peer-to-peer system for value transactions, where there is reduced need for their in-between verification, security and settlement through trusted third-party intermediaries (O'Leary 2017, Penzes 2018, Singhal *et al.,* 2018, Verhoeven *et al.,* 2018). Blockchain can act as a layer on top of the internet, as well as co-exist with other networking technologies (Singhal *et al.,* 2018). Its digital ledger databases are append-only, and every new entry is permanent, immutable, and reflected on all database replicants across the nodes (Singhal *et al.,* 2018). Each "block" in the chain

[1] christian.koch@chalmers.se

Kifokeris, D and Koch, C (2019) Blockchain in Building Logistics: Emerging Knowledge, and Related Actors in Sweden *In:* Gorse, C and Neilson, C J (Eds) *Proceedings of the 35th Annual ARCOM Conference,* 2-4 September 2019, Leeds, UK, Association of Researchers in Construction Management, 426-435.

stores a finite set of transaction- and system-related data, up to a pre-specified cumulative size; then these "blocks" are subsequently connected in a fixed order (Verhoeven *et al.,* 2018). Following the chain from the first to the latest block, the blockchain dataset does not only hold the present transactional information, but also the complete relative history (Singhal *et al.,* 2018, Verhoeven *et al.,* 2018). Such a history is shared across the nodes and can only be updated through consensus and validation, with algorithmic methods such as "proof-of-work", "proof-of-stake" and "proof-of-authority" (O'Leary 2017, Penzes 2018, Singhal *et al.,* 2018, Verhoeven *et al.,* 2018).

Blockchain was initially introduced as the underlying technology of bitcoin; however, its potential applications are actively being investigated in an emergent manner (Konstantinidis *et al.,* 2018), including its utilization as a process performance measurement tool (Kuhi *et al.,* 2018), and a facilitator of a digital ecosystem with the Internet of Things (IoT) (Woodhead *et al.,* 2018). For the building sector in general, blockchain solutions have been investigated both for the derivation of theoretical frameworks focusing on the re-engineering of entire processes, and for hands-on and focused practical development and implementation (see, for example, Barima 2017, Wang *et al.,* 2017, Penzes 2018, Li *et al.,* 2019, Nguyen *et al.,* 2019).

More particularly, in the field of on-site construction logistics and supply chain management, it has been considered that the identified issue of the disintegration of the material and economic flows (Love *et al.,* 2004, Sundquist *et al.,* 2018), can be potentially resolved with the implementation of blockchain solutions; such a potential has been noted indicatively, but not systematically, in Wang *et al.,* 2017, Dobrovnik *et al.,* 2018, Lanko *et al.,* 2018, Li *et al.,* 2019, Penzes 2018, and Rubio *et al.,* 2018. The aforementioned research efforts collectively identify that the integration of the material and the economic flows through blockchain, could aid in a holistic overview of the full construction project production, foster trust, transparency and traceability in the transactions within the flows, enhance the deliverables' quality appraisal, facilitate the collaboration of the supply chain stakeholders, and optimize constructability (which considers a holistic view on logistics, supply chain integration, and trusted stakeholder cooperation (Kifokeris and Xenidis 2017)). More importantly, such a blockchain-realized integration could formulate a new digital business model - namely, the digital transformation of organizations and business processes to create, deliver and capture value (Beck *et al.,* 2017, Konstantinidis *et al.,* 2018).

Crucial in the culmination of such a digital business model is the way the respective construction firms coordinate the relative flows (and especially the economic one). After the current short introduction on blockchain-related research in the construction context, this paper will identify different constellations of companies and economic flows in digital building logistics (particularly in Sweden), as well as the way their operation can be facilitated with the implementation of blockchain. The paper will theoretically draw on a sociotechnical approach, and methodologically will build on a literature review and dialogues with actors active in building logistics within Sweden. Following will be the discussion on the research findings and the conclusions.

A Sociomaterial Take on Blockchain

Blockchain is a digital technology with possible enactment in a number of building processes (e.g. see in Barima 2017, Penzes 2018, and Nguyen *et al.,* 2019). However, the largely non-systematic approach in most of these potential implementation efforts reveals that they are still rather visions than actual applications. Therefore,

researchers should commence an analysis of possible issues related to the embedding and interaction of blockchain within building process and practices. In the current effort, we mobilize the sociotechnical approach, where the development of digitalization is an intertwined social and technical process (Orlikowski 2016). We use one particular sociotechnical approach, namely sociomateriality, which emphasizes the way digital technologies are co-shaped with practices (Buser and Carlsson 2017, Orlikowski 2016).

According to the sociomaterial perspective, the social and the material aspects of digital technologies are inseparable (Orlikowski 2016). Particularizing this framing for blockchain in building logistics and supply chain management, it is derived that blockchain cannot be understood as separate from the processes themselves, nor their practical realization. Thus, the primary unit for research for blockchain in this context is not independent objects with well-delimited boundaries and properties, but rather phenomena materially embedded in practice (Orlikowski 2016).

One key aspect of the sociomaterial perspective is the discussion on the autonomy-control paradox (Bader and Kaiser 2017, Zuboff 2019). While the technological fundamentals of blockchain are claimed to generate trust and security, it may be more precise to understand this as a coexistence of control and autonomy. Blockchain provides overall transparency through generalized and decentralized control, but to the benefit of this transparency, the autonomy of the actors represented by the blockchain network nodes appears to be reduced (Bader and Kaiser 2017, Zuboff 2019).

It should be noted that while the sociomaterial approach can be suitable to investigate the potential of blockchain implementation within construction logistics, there is currently, within this field, little widespread understanding of the underlying technology, making the respectively dedicated and/or knowledgeable researchers relatively rare. Due to this limitation, the conceptualization and realization of certain frameworks and solutions may involve blockchain experts not necessarily familiar to the particularities of construction supply chains and logistics, thus potentially resulting in a partial de-contextualization of the respective research efforts.

Constellations of Digital Building Logistics in Sweden

Currently, Sweden is experiencing heated construction activity associated with complex coordinating processes, leading to a potential series of logistics-related issues (e.g. delayed deliveries, complicated supply chain coordination, and low productivity) (Dubois *et al.,* 2017). To ameliorate such issues and facilitate all associated logistics services, certain constellations of digital building logistics and their potential for integration with blockchain, can be highlighted. Drawing on the understandings of the aforementioned sociomaterial framework and its set of perspectives, the basic literature results of the introductory section, and interviews and dialogues with actors active in building logistics within the Swedish construction sector, at least three such constellations are identified - along with their primary proponents, their realization of the economic flow, and ultimately their take on a relative digital business model:

11. Large contractors integrating building logistics competences internally, to overcome transaction challenges and maintain power over business-critical processes of the material supply and its reflection on the economic flow.
12. Clients employing small independent logistics consultants, whose digital business model can then be enlarged with blockchain, and who can appear as independent conveyors of different interests in the building logistics setup.

13. Third-party players such as construction equipment suppliers, or industrialised housing suppliers, offering digital building logistics solutions.

The identification of these three business models was derived by targeted literature findings and the input of practitioners working within organizations that constitute typical examples of each of the three constellations. Such input consisted of statements, descriptions and procedural documents, and was solicited through unstructured interviews; finally, it was compared with the literature review results, and was critically scrutinized through the sociomaterial perspective. As a result, an analysis on each of the constellations is respectively featured in the following three subsections. It should be noted that these constellations are not the only ones that may act within the Swedish construction sector and building logistics; however, they appear to be the most dominant. Moreover, project governance, and institutional and cultural context, should also be considered as potentially impactful factors on the respective business models. However, due to space limitations, these factors are consciously not considered in the present paper and are left for further research work; the sociomaterial approach is utilized only in the ways previously delineated.

The Internalized Building Logistics Organization

It is often seen at large construction sites in Sweden to rely on the interaction of a range of actors, mainly contractors, purchasers, subcontractors, retailers and other material suppliers, and transporters (Sundquist *et al.,* 2018). Especially in heavily urbanized areas, a network of material and equipment storage places, local offices, retailer facilities and other infrastructure, is permanently in place in the vicinity, to support a newly specified large building site. For example, this was the initial state of the site for the project Urban Escape, namely a currently built district in Stockholm (Juhlin 2018). The way this initial state was changed by the operation of third-party actors offering digital building logistics services, is described in the third subsection.

In such an environment, most operating contractors (e.g. Veidekke Sweden) have chosen to integrate the corresponding building logistics competences and services internally. That way, they attempt to overcome transaction challenges (which would have been prevalent if such services were delegated elsewhere) and maintain power over business-critical processes of the material supply and its reflection on the economic flow and the workplace costs - namely, all costs incurred at the construction site but not directly included in the production of buildings, such as work management, machines, workstations, sanitation, construction lifts (Juhlin 2018). This approach can be characterized as relying on existing supply nodes and routes, since order release, incoming transport, on-site material placement, and even subsequent payments, are largely organised by many actors in parallel each relying on their own supply set up, with little coordination before the arrival on site. This leads to occasional congestion and bottlenecks in incoming flow, e.g. when a single road provides access to a site, or a single main gate has to be passed by all incoming transport.

The economic flow passes certain human-information system nodes, such as the client's accountant utilizing one accounting system, and the main contractor's accountant utilizing another. The corresponding ledgers are organised according to each actor's business practice, and they are rarely commonly structured along general standards. Observing the corporate-level function even within the contractor firms

themselves, there can be a discrepancy in the way the economic flow is realized and disseminated among the different business units.

In such a situation, the transition to a digital business model utilizing blockchain for building logistics with integrated material and economic flows, would mean that a generalized, decentralized and common digital ledger would be used by all the related actors, and thus the discrepancy in the utilization of different accounting systems would be significantly mitigated. While there can be different levels of blockchain integration within the economic flow-related aspects of the existent business model, the normalization of the whole process brought about by the append-only aspect of the block creation, along with the immutability of the chain itself, would give a certain impetus to at least adopt a basic level of decentralization in the relative processes.

The Atypical Use of Independent Building Logistics Consultants

To ameliorate logistics issues and facilitate all associated logistics services, an emerging business practice is the employment of independent third-party logistics consultant firms (such as LogTrade, Myloc, Prolog Bygglogistic, Servistik, Svenskt Byggdialog, Svenskt Bygglogistic, and FM Management), which coordinate and handle complex, recurrent and conflicting flows consisting of deliveries of materials, arrival of incoming goods, payments for deliveries and services, and other sub-systems. These firms are often small organizations; they embody a business model for improved construction logistics, strengthening the coordination across the supply chain by connecting the client, the material and equipment transport companies, the contractors, and the subcontractors (Gustavsson 2018).

However, there are several different approaches and levels of digitalization in the way these firms coordinate logistics. In some cases, "traditional" and/or established methods and tools are utilized, while in others there is support by advanced IT infrastructure (either in-house or outsourced to specialized IT consultants), such as planning and tracking software systems. These approaches do not have to be mutually exclusive; both can and sometimes are being used to some extent, but in a generally fragmented and disintegrated manner. However, all approaches involve interactive on-site collaboration with key suppliers and/or other stakeholders within the construction supply chain; this is important to the value proposition of the business model of such firms. At present, the parallel economic flow is often organised similarly to the model sketched in the previous subsection.

The digitalization of such a business model (or enhancement of an already digital one) through blockchain, can optimize the efficiency of these firms, and lower their costs (McKinsey Global Institute 2017). Blockchain properties align with viewing such a digital business model not as a single-company effort, but instead an inter-organizational one (Vendrell-Herrero *et al.,* 2018) - as is the case when partnering with logistics consultants. In such a context, this digital business model could involve partnerships between incumbent product-oriented firms and digitally capable newcomers, to foster the agility of supply chains (Vendrell-Herrero *et al.,* 2018).

Apart from the collaborative aspect mentioned above, digital business models for construction logistics can benefit from a simultaneously integrated and agile approach (Thunberg and Fredriksson 2018). Through such an approach, on-site space usage for provisional storage reflecting ongoing changes of spatial options and limitations could substitute the more static “Area Disposition Plan” (APD). While APD is usually referred to as dynamic, there is rarely an actual and continuous integration between

the logistics planning and flow control system, and the material registration, placement and installation. A blockchain solution integrating the economic flow and material flows, could facilitate such agility (O'Leary 2017).

Logistics consultants can also lead to the realization of the integrated and agile aspects mentioned above. However, delivery failure, unprecise data retrieval, time delays, intra-systemic inefficient flows and data transfers, and the disintegration of the on-site physical placement with any implemented digital solutions, are still hindering the consultants' efforts. Even more crucially, the economic flow brought about by these consultants is still ambiguous. Not only their coordination of the invoices to be paid after any successful deliveries and/or finished works has not fully eliminated issues of delay and complacency, but the consultants themselves are also burdened with justifying the value-for-money for their services - the disintegration of the flows is widened in the decoupling of the payments for the deliveries and transportations, and for the logistics services.

Thus, it can be derived that the current state of affairs of the logistics consultants both:

- Presents a fertile ground for a digital business model for construction logistics using blockchain to integrate the material and economic flows;
- Needs such a digital business model. Even among more digitally advanced logistics consultants, issues like on-site disintegration and of value-for-money justification, have still to be tackled.

It should be noted that the employment of these independent logistics consultants is not common. While there are clients that actually ask for them (e.g. the public clients of the whole district development in the area of Järfälla, Stockholm), in most cases the building projects are either contracted to actors already internalizing logistics services (see previous subsection), or there is a utilization of the limited services of third-party players (see the following subsection).

Third-Party Actors Offering Dedicated Digital Building Logistics Services

The placing of the tasks, as well as the organisation and management of building logistics can be set up in a larger number of ways, often with third-party actors offering unique and/or out-of-the-box solutions and digital services. Among these, a reported case is an equipment supplier, Ramirent (Juhlin 2018).

Ramirent normally leases machines and other equipment to construction sites. But in the case of the large site for the aforementioned multibuilding project Urban Escape, they offered a comprehensive concept for building logistics (Juhlin 2018). The client and developer needed a logistics solution for a congested site with many operating stakeholders and main contractors, and a concept of a temporary factory. Ramirent changed their ordinary business model and engaged in providing the entire logistics concept, including site access technologies. The site was split in six major zones, given to three major contractors Skanska, NCC and Zengun. These six zones featured different access points and transportation routes (Figure 1).

The temporary factory was a hybrid framework drawing from the contractors' way of realizing the building production, along with new suggestions and concepts brought about by Ramirent (Juhlin 2018). The function of this temporary factory was translated into a new way of planning, organizing, visualizing, performing, and invoicing temporary parts of the building that do not directly concern the construction of permanent buildings, such as taking up the responsibility for common areas and functions (e.g. reception, changing and dining rooms, cleaning), visualization of

processes in time and space with the help of Building Information Models (BIM), development of logistics plans, construction of temporary facilities (e.g. buildings, elevators, electricity infrastructure, scaffolding), waste management activities, rental of machinery, development of new digital support tools, growth of new competencies, and provision of enclosures and guards. Ramirent outsourced the individual tasks to external partners, including a BIM-competent company. This enabled the active use of visualisation in the temporary factory design, and the integration of design and production planning in 4D BIM. The temporary factory also involves a site-placed machine rental centre, which all participating contractors are supposed to use.

Figure 1: Picture of Urban Escape. Lower left and right areas - Skanska, Upper left and upper right areas, garage and Gallerian - Zengun, Upper centre area - NCC (adapted from Juhlin 2018).

Thus, Ramirent has created a market for itself and can leverage a better capital investment, as a type of a blue ocean strategy (Juhlin 2018), despite expanding to an area of lower profitability. This process can furtherly by strengthened by introducing blockchain to the respective digital business model, by streamlining the decentralized economic flow of on-site planning (already "flattened" to ease on-site congestion), along with the multiple material flows connected to the differently designated site areas and access points.

DISCUSSION

When reviewing the emerging knowledge on blockchain in construction, as well as the characteristic types of building logistics set-up in Sweden, it can be clearly understood that the processes in and around building logistics represent a possible field of blockchain implementation. The different set-ups represent different business models, and thus different modes of collaboration between the participating parties in a blockchain network. Rather than viewing these different set-ups as technical choices among rationally discernible models, which is recurrent in operational management and business economics approaches, we interpret them here as different sociotechnical solutions involving characteristic distributions of power. Where the first often seen set up would imply a "business as usual" power balance, the second introduces an apparently neutral actor, that can facilitate the logistics flow. These small independent consultants usually enter into the scene based the clients' request, and they are given a pivotal role according to the clients' power and prerogative. In the third case, the strategic movement of a machine rental company is currently stirring up uneasy reactions not only from other collaborating parties on site, but also from its own shareholders, who are worried about reduced revenue due to moving into the less attractive business area of building logistics (Juhlin 2018). So, in all of these

cases, it is evident that the corresponding operational frameworks have to do not only with knowledge exchange (Gustavsson 2018), but also constitute a type of a political game. Hence, the adoption of blockchain solutions for building logistics with integrated material and economic flows within new digital business models for the actors of each of these constellations, should also consider this dimension.

A crucial issue is security in blockchain implementation and the related need for mutual trust (Woodhead *et al.,* 2018). In terms of security, it is recurrent that large urban building sites suffer from theft and shrinkage in material supplies. As such, internal trust among participants in a blockchain network, in which there is inherently no centralized control, should be cultivated - however, it is difficult to support such an endeavour. It may be necessary to set up a permissioned system and follow a series of procedures to not only protect the blockchain network from external threat, but also internal instabilities. In addition, the matter of integration involves technical interoperability issues, as well as changes in the work practices and organisation of the participating companies. The introduction of a blockchain solution to integrated building logistics would probably place it, at first, on top of an information infrastructure consisting of a series of different accounting, project planning, quality control, access control, and site planning systems; then, the adoption of common standards, not only for building components, but also for the structuring of ledgers, will enter the agenda.

A series of further issues that cannot be covered due to space limitations, can further illustrate the sociotechnical character of the phenomena under research. In a wider perspective, blockchain is only one digitalisation technology; integration and cross-fertilization of the IoT, machine learning, digital twin, automated vehicles, augmented reality, and other digitalization technologies, will emerge as possibilities.

CONCLUSIONS

This paper aimed at reviewing, in a targeted manner, the emerging knowledge on blockchain technology within construction, and identifying some different set-ups of related actors and flows in digital building logistics, to facilitate the conceptualisation and contextualization of using blockchain solutions. Scrutinizing these findings through the sociomaterial perspective (namely, that the social and the material parts of digital technologies are inseparable), we found three main sociotechnical constellations that might be able to adopt blockchain solutions: The business as usual contractors internalizing logistics services, the independent building logistics consultants, and the unique third-party actors, as in the case of a construction machine rental company taking up logistics in a large building site. Each is characterized by its own challenges and power structures. In all cases, implementing blockchain entails a long series of negotiations, and requires the tackling of issues, such as cyber security and integration with other information systems.

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