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Translating High Hopes Into Tangible Benefits: How Incumbents in Supply Chain and Logistics Approach Blockchain

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ABSTRACT Blockchain is expected to have a transformational effect on supply chain and logistics due to its promise to improve the information flow between the supply chain partners. However, despite their high hopes, incumbent companies from supply chain and logistics are still struggling to deliver on this promise. In this explorative, qualitative interview study, we identify how incumbent companies try to make use of Blockchain in supply chain and logistics and we also analyze the barriers hampering them. The analysis of twenty-four semi-structured expert interviews and extensive secondary data collates a comprehensive picture of incumbent companies' activities around Blockchain adoption. We find that companies use Blockchain to drive digital transformation, constitute new business models and unify the industry through consortia. The main barriers to such solutions are a lack of technological usability and long-term uncertainties. The results of our study provide evidence for theoretical constructs and guide managerial practice.

INDEX TERMS Blockchain, decision making, logistics, supply chain management, technology management.

I. INTRODUCTION

Supply chain and logistics (SC&L) represents the backbone of economic systems. Managing supply chains is all about supply and demand management within and across companies, starting from the source of the raw materials through different production and distribution stages to a product's end customer [1], [2]. Information is a core resource when it comes to managing the physical supply chain processes [3]. Effectively sharing information, e. g., about demand changes and inventory levels of the different supply chain tiers, allows for improving the competitiveness of the entire supply chain [4]. Also, since supply chains are multi-tiered and interconnected, the effects of disruptions cascade through the entire supply network, calling for quick and well-informed reactions [5]. For example, the Great East Japan Earthquake in March 2011, ultimately resulting in the meltdown at the Fukushima nuclear power plant, severely disrupted supply chains in different industries [6]. Also more locally confined natural disasters and even unexpected demand changes necessitate an instant overview of inventory levels, production volumes and goods in transit in order to decide on countermeasures or activate backup solutions. Currently, such a tightly integrated flow of information is still a pipedream for most supply chains [7]. For example, the documentation of a freight transport from East Asia to Europe involves around 30 actors, and causes 15% of total shipment costs [8], [9]. The relevant information is exchanged through specialized platform providers, or directly from one company to another via physical documents or electronic interfaces, thus, creating different versions of the same record in various places [9]. In case of a disruption, a quick overview of where goods in transit are and when they might arrive at the next supply chain tier is not possible. A well-executed information flow is also important beyond disruptions, as it is considered to be a key-enabler for closed-loop supply chains and, ultimately, the circular economy [10]. Taken together, a seamless flow of information can benefit supply chain performance, but is far from reality in most industries.

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Blockchain could be a game-changer for the information exchange in supply chains and could provide a ledger for the decentralized recording of immutable, verified transaction data. A central promise is the creation of a single point of truth, allowing all network members to read or write to its ledger. Consequently, the technology is considered to be a natural fit for the SC&L domain, as it might enable the long sought after supply chain transparency. For that reason, many consider Blockchain to be a disruptive change for SC&L [11]–[13]. Since early 2017, the number of Blockchain trials or even only announcements of such trials by SC&L companies have exploded [14], ranging from tracking lettuce in the food industry to international shipping's paper trails [9]. Two years later, the numbers of actual use cases and successful projects beyond the piloting phase are surprisingly scarce, although the potential for SC&L is well-recognized in the academic literature [11], [15], [16]. As the Bitcoin-fueled hype has faded, the adoption of Blockchain seems to have matured. Start-ups in this domain depend on collaboration with incumbent companies as they provide technical solutions for the incumbents' transactions. Incumbents themselves also work on solutions, even though most have toned down their rhetoric.

Considerable literature has accumulated on Blockchain in SC&L. Due to the early age of the field, most authors naturally focus on establishing the ''what'', i.e., application opportunities and the ''why'', i.e., possible benefits rather than the ''how'', i.e., adoption processes [17]. In general, investigating the contingencies and approaches of Blockchain adoption is considered an important field for further inquiry [11], [15], [16]. Thus, in this study, we set out to explore the process of Blockchain adoption in the SC&L industry. Specifically, we are interested in how incumbent companies try to translate their high hopes on Blockchain into tangible benefits for their processes or customers. We address two research questions:

1) How do incumbent companies make use of Blockchain in SC&L?
2) Which factors are stopping incumbent companies from making use of Blockchain in SC&L?

We address these two research questions with an exploratory Grounded Theory approach, with an aim to contribute to the fast-growing literature body on Blockchain in SC&L.

The remainder of the paper is structured as follows: First, we provide an overview of the current literature on Blockchain in SC&L, followed by an introduction to the research methodology, and an overview of the qualitative interview study's results. Subsequently, the practices and barriers identified during the interviews are discussed and distilled into research propositions. The paper concludes with a description of limitations and an outline of future research initiatives.

II. LITERATURE REVIEW

Blockchain is a tamper-resistant, distributed digital ledger of transactions owing to the use of cryptographic methods and distributed consensus algorithms [18], [19]. In short, a solution using Blockchain technology is decentralized, verified, and immutable. Blockchain has spawned many ideas for SC&L applications—both in practice and theory. Most early contributions from the SC&L literature focus on the benefits of the technology and use them to derive and investigate application opportunities. Specifically for supply chains, the increased transparency that Blockchain could provide, might enable further supply chain optimization, the tracking and tracing of goods, as well as digital documentation [11], [14], [20]. The opportunity to amass data points along the entire supply chain could provide a basis for optimization algorithms and machine learning—perquisites for the industry 4.0 era [13], [21]. Ultimately, this data will enable better reactions to upstream events in a supply chain that are beyond the individual companies reach [22]. Similarly, Blockchain users can analyze the data to provide their customers and trading business partners with information to track goods or to ensure that they have provenance records [16], [23], [24]. Customers, in particular, are provided with a trustworthy way of checking food manufacturing certificates or identifying counterfeit medicine or products [24], [25]. Blockchain could also serve as a way of documenting the correct storage and handling of goods [23] by allowing an investigation down to the end-customer, possibly increasing client retention [26]. Combined with the right IoT devices and sensors, this documentation could be very detailed [27]. Moreover, issuers and authorities can both digitally sign digital document's hashes, which is a way of improving performance while maintaining the shared information's integrity [9], [16]. Overall, the hope is that Blockchain in SC&L will help to streamline processes and that the efficiency gains will yield lower costs [28]–[30].

Current literature reviews on Blockchain in SC&L illustrate that most contributions from the literature are of conceptual nature, whereas empirical investigations are comparably scarce [11], [16]. Table 1 provides a description of relevant empirical work published in major scientific journals. Of note, the table is meant to give an overview of the field and does not result from a systematic literature review process.

Taken together, only a few empirical contributions focus on the SC&L industry's overall perceptions of and general approaches towards Blockchain. Most focus on specific supply chain segments, logistics functions or business cases, and not on the overall shift that Blockchain could cause in SC&L. Since the ''what'' and the ''why'' of Blockchain adoption in SC&L have been covered by many contributions, we focus on the ''how'', i.e., the practices SC&L incumbent companies employ to adopt Blockchain for the benefit of their processes.

III. METHODOLOGY

We chose an explorative, qualitative Grounded Theory approach to explore how companies deal with Blockchain in SC&L. The application of Grounded Theory is feasible, whenever ''researchers have an interesting phenomenon without explanation and from which they seek to discover theory from data'' [37]. Through a set of techniques and

TABLE 1. Overview of empirical contributions.

Article	Data source and analysis	Focus	Key Findings
Behnke and Janssen (2019) [31]	Expert interviews (n=16) in four supply chains; case analysis	Dairy supply chains	Blockchain is a useful tool for tracking and tracing of dairy products. Boundary conditions for successful implementation exist that might require organizational change.
Gausdal et al. (2018) [32]	Expert interviews (n=7); case analysis	Norwegian offshore industry	Blockchain offers benefits for the management of assets, finances and documents. Implementation in the focal industry is mainly cost-driven, but could also reduce corruption risk.
Korpela et al. (2017) [33]	Focus group workshops (n_1=18, n_2=18, n_3=31); case analysis	Finnish business consortium	Blockchain provides useful functionalities beyond legacy systems. Integration of Blockchain with IoT and B2B ERP software or cloud solutions is possible.
Perboli et al. (2018) [34]	Case analysis using business process modeling	E-commerce food retailing	Blockchain can save costs by reducing waste and improving the availability of information. All supply chain members have to be involved in realizing these gains.
Petersen et al. (2018) [14]	Case analysis (n=49) and online survey (n=152)	SC&L companies	Tracking, tracing and supply chain finance are major application areas for Blockchain in SC&L. Companies start first experiments to explore possible benefits.
Queiroz and Fosso Wamba (2019) [29]	Survey data (n=738); partial least squares structural equation modeling	SC&L companies in the US and India	Blockchain adoption is still in an early stage. Differences in awareness between India and the US exist. Performance expectancy predicts the intention to use Blockchain. There is also a reluctance to exchange data with supply chain partners.
Sander et al. (2018) [24]	Expert interviews (n=12) and consumer survey (n=141); partial least squares structural equation modeling	Meat industry	Blockchain could improve track and trace systems in the meat industry. Customers hope to gain a better overview of certifications and supply chains. Professionals are mainly concerned about the cost implications.
Thiruchelvam et al. (2018) [35]	Online survey (n=66); descriptive analysis	Burundi coffee supply chains	Burundi coffee industry lacks adoption of digital technology in general. Implementing Blockchain could help them leapfrog to a process that could ensure fair trade, security, sustainability, transparency and traceability.
Tönnissen and Teuteberg (2019) [36]	SC&L use cases (n=10); case analysis	SC&L companies	Blockchain service providers increase the complexity of a process formerly driven by centralized platforms. New solutions require governance and compliance audits. Need for involvement of many different parties complicates Blockchain adoption in SC&L.
Wang et al. (2019) [30]	Expert interviews (n=14); cognitive mapping and narrative analysis	SC&L companies	Blockchain benefits are expected, such as provenance and secure and well-structured data transmissions that lead to more efficient SC&L operations. A range of barriers like cost, privacy, and administrative issues complicates adoption.

procedures, Grounded Theory allows us to record, interpret and abstract subjective experiences into theoretical statements about the phenomenon under research. Fig. 1 gives an overview of each step of our research process and how we constructed a Grounded Theory from data. In the following sections, we will elaborate on each of the steps we took to collect and analyze data to derive robust and relevant findings. Of note, the activities are presented in a linear fashion despite the fact that the research process was characterized by iterative phases of sampling, data collection and analysis. Several measures were taken throughout data collection, data analysis and construction of theory that address the validity of the research process and the quality of the findings as proposed by Mayring [38] and Flint *et al.* [39].

A. RESEARCH QUESTIONS

As stated in the introduction, our research questions are centered on Blockchain adoption by incumbent companies from the SC&L industry. Our data sources have to be geared towards this focus. In principle, collecting useful data for Grounded Theory studies can include a wide variety of sources. Researchers are advised to work with anything that helps to illuminate the research question [40]. We decided to collect data by means of interviews with Blockchain experts from the SC&L industry and amend this rich primary data with extensive secondary data to collate a comprehensive picture of how incumbent SC&L companies approach Blockchain technology. For the expert interviews, we devised a three-part semi-structured interview guideline. The questions were derived from our insights gained during previous studies and from current empirical literature, as outlined in the previous section. For Grounded Theory, it is advised to start with only a few open-ended questions to invite the participants to share their unbiased perception of the topic [41]. Later, relevant issues can be discussed in more detail. For this study, we started by exploring the expert's first encounters with Blockchain. Next, we focused on how companies are currently applying Blockchain solutions and making their business decisions regarding Blockchain. In the third part, we asked the experts about Blockchain's overall implications for SC&L.

B. DATA COLLECTION

We conducted 24 interviews between June 2017 and January 2019, which lasted between 21 and 118 minutes (mean: 59 min, median: 56 min) and were conducted in person (10/24) or over the phone (14/24), in either German (14/24) or English (10/24). The first interviews were held

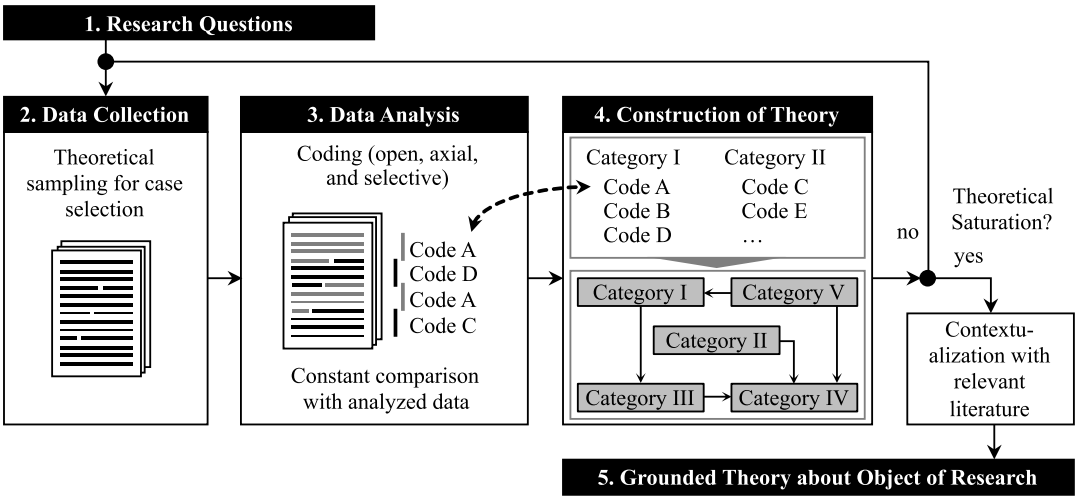

FIGURE 1. Research process: constructing a grounded theory.

with an initial sample of three experts with broad industry knowledge to test the interview guideline and obtain an overview of the topics. Thereafter, we recruited other experts by following a theoretical sampling procedure in keeping with the explored topics [40]. When contacting potential interviewees, we made sure that they had at least one year of relevant Blockchain experience and preferably were involved in proof of concepts or development projects. Table 2 provides an overview of the sample. Following the explorative nature of a Grounded Theory study and established best practices, we slightly adapted the guideline four times to address specific aspects uncovered during the interviews [41]. The final version of the interview guideline was used from Interview #7 onward. In two cases, we went back to early participants to discuss specific aspects that surfaced only after their initial interviews.

We collected extensive secondary data like technical white papers, consultant reports and reports on Blockchain activities by established companies to triangulate the findings derived from the interview data. Since data collection started, we also visited around 60 conferences, meetups and other events relevant to Blockchain adoption in SC&L to keep up with the ongoing market and technology developments, as well as to discuss our preliminary findings with other experts beyond the interview sample.

C. DATA ANALYSIS AND CONSTRUCTION OF THEORY

The interviews and the secondary data sources were transcribed and coded in parallel with the interviews [40], [41]. This coding process yielded close to 1,100 codes, each summarizing the core statement of a data fragment in English (i.e., a line of text from the interview transcripts). Subsequently, codes containing a similar statement were grouped. After that, we went back and forth between the separate interviews and compared the findings with each other. We wrote memos throughout the data analysis to capture emerging ideas and

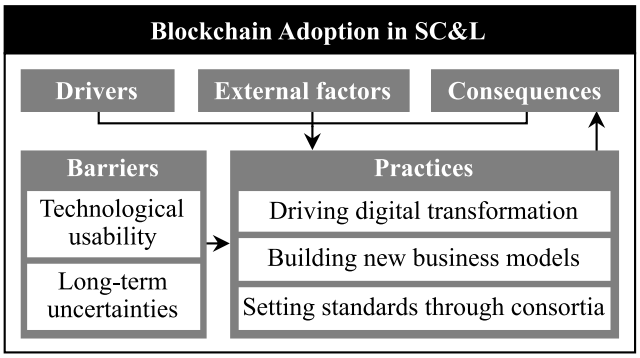

FIGURE 2. Concept map of the findings.

interpretations. To improve the presentation, we grouped our constructs into categories adopted from the Corbin and Strauss's [40] coding paradigm, which yielded the categories "Drivers," "External factors," "Barriers," "Practices" and "Consequences," ultimately providing theoretical propositions grounded in data.

IV. FINDINGS

The various companies we sampled through selecting interview partners deal with our phenomenon under study (i.e., Blockchain adoption in SC&L) in different ways – as the concept map of our findings in Fig. 2 shows.

For the following presentation of our findings, due to space limitations, we will focus on the two most important aspects for Blockchain adoption: the actual practices incumbent companies in SC&L are found to employ, as well as the barriers inhibiting Blockchain adoption. Drivers, external factors and consequences are also important; however, as they essentially inform companies' practices, we decided to focus on practices and barriers and present and discuss them in more detail. They are introduced in the next sections. In keeping with established practices for empirically grounded

TABLE 2. Sample of interview respondents.

#	Respondent Position[a]	Company	Employees	Level of Experience[b]
1	Director of Development	IT Solutions Provider	1–10	Very High
2	Consultant	Consulting Company	1 001–10 000	High
3	Business Developer	IT Solution Provider	10–100	Very High
4	Consultant	Logistics Consulting Company	1–10	Very High
5	Blockchain Analyst; Blockchain Identity Expert	Bank	>10 000	Very High
6	Director of Business Intelligence	Logistics Authority	1 001–10 000	Medium
7	Head of Supply Chain Innovations	Semiconductor Manufacturer	>10 000	Medium
8	Director of Blockchain Team	Logistics Service Provider	>10 000	Very High
9	Engineer	IT Solutions Provider	>10 000	Very High
10	Director of Blockchain Team	Electrical Utility Company	>10 000	Very High
11	Head of Supply Chain	IT Solutions Provider	10–100	Very High
12	Director of Business Development	IT Solutions Provider	101–1 000	Medium
13	Head of Supply Chain Operations	Logistics Service Provider	10–100	Very High
14	Head of Legal Department	Insurance	>10 000	Medium
15	Head of Digital Technology R&D	International Trade Organization	1 001–10 000	High
16	Senior Developer	Manufacturer	>10 000	Very High
17	Business Intelligence Analyst	Logistics Service Provider	>10 000	Medium
18	Head Manager	Telecommunications Equipment Manufacturer	>10 000	Medium
19	IT Manager	Logistics Service Provider	1 001–10 000	Medium
20	Chief Operations Officer	Logistics Service Provider	1–10	Very High
21	Business Development Manager	Automobile Manufacturer	>10 000	Very High
22	Chief Executive Officer	IT Solutions Provider	1–10	Very High
23	Chief Procurement Officer; Chief Financial Officer	IT Solutions provider	1–10	Very High
24	Researcher	University	>10 000	High

[a] (multiple experts of the same company separated by semicolon) [b] (Medium: investigates use cases, High: has own proof of concepts, Very High: Blockchain is part of the core business or has conducted extensive projects)

research, we present illustrative proof quotes along with our findings [42].

A. PRACTICES OF BLOCKCHAIN ADOPTION

Driven to use Blockchain for their supply chain or logistics activities, incumbent companies use different practices with respect to Blockchain adoption. As emerged from our data analysis, one practice is to use Blockchain as a lever to drive digital transformation in a company. Introducing the technology requires extensive technical readiness and, ideally, an interaction with a digital twin in each step of the process. A second practice understands Blockchain as a new business case and subsequently develops solutions for new business models or inclusions in products or services. A third practice is to join or found a Blockchain consortium to unify the industry and set standards. We introduce each practice in more detail in the following. Of note, the practices are not necessarily mutually exclusive.

1) DRIVING DIGITAL TRANSFORMATION

According to our experts, recording each activity related to a product on its way through the supply chain is a central Blockchain use concept. This process does not allow for any manual step or media discontinuity. Every action originally executed via telefax, phone, email or XML file transfer now requires a suitable twin step to create a corresponding transaction record on the Blockchain. Blockchain's properties allow a new approach to digitalizing a process. Blockchain can, therefore, be used as a lever to compel companies along the supply chain to innovate and incorporate digitalized processes. However, from a technological perspective, Blockchain is often not considered new, as this interviewee points out:

> We try to communicate that it is a database with special properties. Blockchain is not really complex IT. In itself, it's relatively simple. It doesnt offer business logic or features like that—you can do a lot with it; we could do all of that before—but it failed. (#8, Logistics service provider)

Our experts make it very clear that merely superimposing Blockchain on any process is not going to realize its full potential:

> Digitizing a broken process with a Blockchain solution doesnt help much. Even if a process already is fully digital, Blockchain solutions should always question the underlying process. What you often try today is to take processes that already exist and transfer them 1 to 1 to Blockchain. I don't think this is the right approach. Then you have merely exchanged technology, which is, sometimes, more or less useful, but you can only obtain the real benefit if you adapt the processes. (#2, Consulting company)

Additionally, the experts consider Blockchain as a valuable tool to revisit known problems. Since media discontinuities will hardly be possible in a Blockchain-based process, companies are forced to do their homework first and to align their processes and digitalize them as a minimum requirement.

Blockchain can serve as a platform replacement, allowing the participants to maintain their own data's visibility, and connect their company's systems. However, it should be kept in mind that the scope of a Blockchain approach needs to be broad – a process using Blockchain does not unfold its true potential if it is limited to just a few companies.

2) BUILDING NEW BUSINESS MODELS

A second practice frequently pointed out by our experts is the design of new business models enabled by specific Blockchain properties. The design of business models built on Blockchain has to keep the growth of an ecosystem in mind. All of a Blockchain platform's participants provide the infrastructure themselves, ensure visibility and provide access to data all the time, thus creating a shared ecosystem. This ecosystem serves as a mutual basis that no single entity governs, but still provides the required trust mechanisms. A Blockchain can, therefore, be the common basis for a trading platform or a service for the verification of documents. However, our experts cautioned that companies need to consider their business strategy carefully. They believe it is unlikely that the business value will lie in providing access to a Blockchain solution that a single entity operates and governs:

> There are a lot of people who all of a sudden think they can build a business on the back of Blockchain by using the old model: There is a trusted organization in the middle which you have to pay a fee to. (#9, IT solutions provider)

Specifically, the IT solutions provider experts already experience a shift in their role from providers of platform software to providers of an infrastructural basis and enforcers of collaboration:

> As for us, that was just to get those institutions and companies to test our technology, and now we're running workshops with them to see who is interested in building something because this is an ecosystem technology. So you perhaps need a number of different companies and institutions to collaborate on solutions. It doesn't make sense for one company to do it alone. (#11, IT solutions provider)

Thus, the value of a Blockchain solution lies in creating a shared ecosystem that has to be open to any company, even to competitors. This open ecosystem will then provide companies with a basis on which to build additional business models, for example, supply chain flow optimization, supply chain risk assessments or microinsurance.

3) SETTING STANDARDS THROUGH CONSORTIA

In existing IT solutions, data is stored and processed locally in the companies' data centers or centrally through a platform provider. As outlined above, many of the experts like to think of Blockchain as an ever-growing open ecosystem providing a ledger that all parties of a SC&L process can access. While simple solutions, like Bitcoin, function without centrally organized governance, the experts mostly assume that ecosystem solutions would require precisely this: an industry consortium that governs the Blockchain solution. In the trade sector, consortia such as the R3 LCC consortium, the Marco Polo Network or Tradelens exist. Our experts point out three aspects of how consortia might yield benefits for their members: (1) creating a shared organizational framework, (2) providing an addressable entity that solves problems and conflicts, and (3) accumulating power to set and propagate industry standards.

For setting up a consortium, the experts consider an organizational framework a necessity to undertake the first development steps toward Blockchain architecture and create initial traction for the proposed Blockchain solution:

> Blockchain in SC&L will initially be an issue for consortia. Industry sectors and sub-sectors can agree to approach a cooperative platform that maps the basic processes of the industry. The participants can then create their own services on this platform. This is the first step that we see as gaining traction in SC&L. (#4, Consulting company)

Setting up a consortium requires extensive planning and consideration. Our experts express the concern that too many or the wrong partners, or approaches that are too bureaucratic to create consortia, would hamper the development speed or eventually create solutions that are not useable. In fact, many interviewees attach higher importance to sorting out governance issues than to addressing technical issues:

> Who should govern it? It should, ideally, be a collective governance. No single entity should govern it. [...] If you have everybody governing something, it doesn't ever move—it becomes too bureaucratic. (#15, International trade association)

Our experts consider a consortium as a required neutral party or platform to manage conflicts between the users, correct administrative errors, and take care of system maintenance. However, they also note that this could lead to an unintended accumulation of administrative power. The experts had observed this in, for example, the automobile industry, where suppliers are obligated to connect to their customers' ERP systems.

On the other hand, powerful consortia can be a driver of a common Blockchain platform, establish standards for specific processes and, thus, attract new members. The experts regard joining a consortium as a first step toward using Blockchain in SC&L. However, they also note that the price to pay for this is having less influence on the development:

> Of course, you can join any consortium sometime later. Everyone is happy, because the bigger the consortium, the more powerful it is. However, you will join with different conditions; you have to pay a certain price. The most important argument is that you're not part of the core consortium that takes the lead. However, that's where you want

> to be. You want to control the development, and, if you're in the lead, you have the possibility to do so. Otherwise, you're just an appendage going with the flow. (#5, Bank)

B. BARRIERS TO BLOCKCHAIN ADOPTION

Blockchain is a fast-evolving technology whose use companies are still exploring. It is no surprise that especially incumbent companies face several barriers when trying to make use of Blockchain in SC&L. The barriers the experts found to be most severe can be subsumed into two groups: (1) technological usability barriers related to the technological newness and immaturity, and (2) long-term uncertainties about regulatory implications and the lack of meaningful reports from practice.

C. TECHNOLOGICAL USABILITY

The usability barriers named by the experts all relate to the technical difficulties that companies face when adopting Blockchain solutions. Limited technological usability can be a deal-breaker, not only because it can disrupt daily operations, but also because it prevents goals from being achieved efficiently. When discussing Blockchain's technological usability, the experts share their perception of implementation barriers like the (lack of) connectivity to the surrounding IT systems. The discussion reveals that integration into other business software is not easy. The existing software and platforms that many companies use are especially feature-rich; for example, current ERP systems have a decades-long development history and are capable of managing complex product workflows through user interfaces and API. Current Blockchain solutions, on the other hand, require manually built software for tasks as simple as querying information. The experts note that, in some cases, this complexity is a clear indicator that Blockchain should be an infrastructure tool for large corporations, i.e., a ledger only containing signatures of the current state, while the upstream suppliers continue to use the existing API to provide their data.

Technological usability also pertains to feeding sensor data into the Blockchain—an aspect especially important given the fast-growing amount of IoT devices. There are sensors and labels on the market that can provide asymmetric encryption, and two experts note that their companies were actively working on enabling their sensor products to work with Blockchain implementations. The creation of such devices is caused by another usability barrier, i.e., the difficulty of creating trust in physical objects and off-chain data. These solutions usually require the Blockchain data to be correct. The possibility of tampering with the physical link (i.e., tampering with the label or RFID chip before writing the data to the Blockchain), would render the whole solution useless. The same occurs if a solution requires access to external data feeds that can be tampered with. Although all follow-up records might be correctly signed, the overall record would be incorrect or assigned to the wrong good:

> It is said that Blockchain is immutable—and I am convinced that once the data are on the Blockchain, they are immutable and tamper-proof. But who can guarantee that the data that enter the Blockchain are correct? [...] At the moment, a lot of possibilities to manipulate data remain, and these data remain on the Blockchain forever. That is a problem that the Blockchain cannot fix. Blockchain will only be secure if the data that enter the platform are also tamper-proof. (#5, Bank)

Besides the connectivity problems and issues regarding the link to the physical world, experts generally agree that general teething troubles, most notably, the limited write speeds, but also the Blockchain software developers' overall lack of experience plague Blockchain solutions' path into practice. Even the Blockchain solution providers themselves hurry to emphasize that there is a long way to go:

> It is important to understand that we are in a beta phase. (#11, IT solutions provider)

D. LONG-TERM UNCERTAINTIES

Taking the long-term consequences of decisions made during the deployment or development of Blockchain solutions for SC&L into account, is challenging. Uncertainty around regulatory and technological developments hamper the decisions required to use a Blockchain solution in SC&L practice.

The lack of a regulatory definition of a Blockchain and the recognition of its features in laws and regulations pose a problem, in particular, when considering the consequences of data's decentrality and immutability. The possibility of being unable to comply with future changes makes the use of Blockchain a problem for companies:

> It is always possible that laws change and the idea of eternal storage could then turn out to be a problem, [...] because even if you use pseudonyms, it is still possible to identify the actual user. (#2, Consulting company)

The problem also pertains to public bodies:

> We are a public institution, is it appropriate or legal [for us to] decentralize sovereign activities and maintain that we are a neutral, central intermediary; that we contribute this to a technology? (#6, Logistics authority)

The immutability of Blockchain data might mean that companies cannot comply with future legal and regulatory changes, let alone with case-specific court orders. In particular, embargo and data protection laws will be the focus here. The implications of an embargoed country participating in a Blockchain transaction are just as unclear as the implications of privacy-compromising data traces found in the future.

SC&L solutions built on a global Blockchain also have to comply with the laws and regulations of the intended target countries. These regulations might be incompatible with one another if the same Blockchain solutions are used in multiple countries:

> Then there are the regulations that put a spoke in the wheel. In logistics, you have to think globally: Brazil only accepts printed freight documents. Everyone else is okay with electronic ones—Brazil is different. To always pass the buck to the authority is also wrong—there are customs authorities in Blockchain projects—they want them. (#8, Logistics service provider)

Another aspect holding companies back from embracing Blockchain solutions is found to be the surprising lack of well-documented use cases and experiences from the field. Having no examples makes it hard to evaluate the long-term consequences of Blockchain projects:

> You have to be clear: each business case is fake news. All the parameters are very unclear and have a vast range. When will the technology appear on the market? (#10, Electric utility company)

Usually there is little helpful information available on how Blockchain trials turned out. Moreover, the experts point out that the use cases outlined in theory today might not be as easy to adopt in practice as it sounds. For example, during the discussion of the failure of a cold-chain container, a freight insurance expert notes:

> Every once in a while, it is said: Just put a temperature sensor in the container, and when the temperature exceeds 20 degrees Celsius, the insurance pays. Unfortunately, it is not that easy. We have 20 pages of insurance conditions, which you can't describe in such a simple way. (#14, Insurance)

Many use cases are nothing more than short descriptions of proof-of-concepts, press releases or other marketing material. This lack of working examples or honest reports about failed efforts leads to a certain heedlessness and to the adoption or testing of use cases that are focused on implementing the technology instead of addressing an application case.

V. DISCUSSION AND IMPLICATIONS

The first research question concerning Blockchain adoption approaches by SC&L incumbents yields three main practices. As noted before, these practices are not mutually exclusive and, due to the nature of SC&L, involve companies of different sizes, abilities and at different stages of the supply chain. In the following, we mirror our findings with the available literature, discuss them and derive research propositions.

Our results show that incumbents consider Blockchain to be a useful approach to enforce digital transformation in their companies. In fact, Blockchain has been recognized as an ''application for the digitalization of the entire international trade'' [22], and as a way to establish digital electronic management systems that supersede manual human-driven systems and accelerate cross-company digitalization [33]. Furthermore, the current literature finds that Blockchain yields the largest benefits where end-to-end data continuity in SC&L is required [11], [16]. A qualitative study investigating Blockchain application in the Norwegian offshore industry similarly finds that the ''intention to work more efficiently using modern information technology opportunities'' is one of the drivers of Blockchain in practice [32]. A change from, for example, an entirely paper-based to a Blockchain-based process, will require companies to rebuild processes in practice. These companies will have to experiment with the technology and rethink each step to achieve continuity, both of which are primary drivers of digitalization in general [7]. While this process can be complicated, it can also be a way toward a new era; consequently, we suggest the following research proposition:

Proposition 1: Blockchain development is a way to enforce redesigning processes toward digital data continuity and, thereby, drive digital transformation.

Our results also suggest that incumbent companies trying to design new business models aim to create or participate in ecosystems. Among our participants, it is established that Blockchain has few benefits if it is merely a replacement of a single actor's API or platform. For example, if a grocery retailer replaces its purchasing interface with a Blockchain solution, it only means that the suppliers need to serve yet another digital interface. A consortium that jointly sets up and uses a Blockchain ecosystem on the other hand might be able to significantly reduce transaction costs. Many conceptual contributions describe how such ecosystems should work overall, for example, for the players in supply chains of diamonds, meat or pharmaceuticals [24], [43]. Wang *et al.* [16] note that Blockchain solutions should, in keeping with Perks *et al.* [44], become value platforms. However, although they discuss possible business opportunities for consortia operating a Blockchain solution, they also find that merely operating it is not a business case. A Blockchain solution should instead be the underlying infrastructure, and the business models should be built on this. Analyzing the data available on the Blockchain and providing relevant learnings could drive business cases [11]. The literature also recognizes that the opportunity to openly access a Blockchain solution is a benefit and a major driver of an ecosystem, not only for the transportation sector [22], but given that the data needed to lead to ''new forms of interactions between consumers, producers and processors,'' [45] also by implication a driver of providing consumers with direct access [22], [45], [46]. Tradenlens, the joint venture set up by Maersk and IBM, aims at digitizing international shipping documentation and is an example of the importance of this openness. Tradenlens' lack thereof is considered a key reason for the project not gaining more traction [9]. Consequently, we put forward two further research propositions:

Proposition 2: Blockchain solutions need to be designed to work for open ecosystems rather than for single companies.

Proposition 3: Business models need to be built on a Blockchain solution, not as its integral part.

Further, we found that an overarching supply chain solution requires a body of companies to form an understanding of the functionalities and usage of the Blockchain solution. Product provenance solutions for food, diamonds, or spare

parts [23], [24], [47], for document-securing processing in cross-border supply chains [11], [14], [16], or for the inclusion of IoT [11] will not work if there is no mutual agreement among the participants. While application scenarios are usually widespread, the use of a Blockchain solution forces a certain standardization of the supply chain data. The ''open standard'' that some authors expect [16] will fail if no parties use it; on the other hand, the larger the consortium, the more difficult it might be to progress. Jabbar and Bjørn [9] describe different organizational approaches, depending on the technologies used when tackling Blockchain, as part of an ''infrastructural grind.'' They outline that, due to their limited extent, different consortia could only move beyond specific points. Wang *et al.* [16], among others, found that a small, but versatile, group of companies with aligned objectives is more effective and can easily add more participants later while maintaining its first-mover advantage. The following research proposition emerges:

Proposition 4: Blockchain solutions for SC&L require an effective consortium minimally representing all of the chain functions to serve as a low-level entry point for SC&L companies.

With respect to the second research question, we identify two major groups of barriers for Blockchain adoption in SC&L. The technical perspective remains a barrier for both large enterprises and medium-sized companies. As outlined in the results, feature-rich software systems are found in practice, and Blockchain solutions' limitations are troublesome, even for professional implementers. The literature also mentions this weakness or lack of maturity. Nevertheless, many of those issues are considered solvable in the near future. Among them are frequently cited challenges like high energy consumption due to proof-of-work consensus algorithms, a low number of transactions per second, high complexity, difficult usage for some groups, and the associated high development costs [11], [22], [48], [49]. From a theoretical perspective, Blockchain users in SC&L can be considered innovators with respect to Roger's Diffusion of Innovation theory [50]. They are willing to take on the risk of adopting a technology that might ultimately fail. However, with respect to the overall SC&L sector, we suggest:

Proposition 5: Current Blockchain solutions are not mature enough for the majority of companies to use them in a productive SC&L environment.

Specifically in SC&L, the need for a physical pairing between a logistical object and a Blockchain entry raises the technical usability barrier even more. The initial pairing and maintenance of this connection during transit are, however, problematic, because the original association depends on a single writer, and there is no guarantee along the supply chain that the entity making the entry in the Blockchain indeed had physical custody of the item [16], [51]. Solutions for the textile or food industry may require this link even for a single object; for example, a shoe or a mango [13]. Current solutions like barcodes or tagging are costly, and either not tamper-proof or challenging to deal with along the supply chain [24], [43], [51]. We therefore suggest:

Proposition 6: A physical pairing between objects and Blockchain datasets is an important prerequisite for SC&L and requires solutions that are cheap and easy to use.

Stakeholders beyond the companies' reach often drive the identified long-term barriers. In terms of the first proposed long-term barrier, legislation is such an outside body. Despite having been around for ten years, Blockchain is still a very new technology, and governments worldwide are working on its legal definitions and the relevant laws. However, due to the global spread of almost every supply chain, Blockchain solutions in SC&L have to be international, which means that assessing the consequences of new laws (e.g., targeting privacy, trade barriers, and other national restrictions) is challenging. In the literature, this question is often discussed with reference to cryptocurrencies, but also the SC&L community notes the lack of compliance requirements and legal fundamentals [49]. The fear of not being able to comply with future regulations, because a decentralized network currently has the data and/or power to decide, leads to companies being cautious about implementing Blockchain solutions in SC&L. Consequently, we suggest the following:

Proposition 7: Inconsistent or non-existent local legislation hampers the adoption of Blockchain solutions for international supply chains.

The second long-term uncertainty is somewhat of a hen-and-egg problem: Companies note that there are too few well-described use cases from which they can learn. Currently, most projects are marketing-oriented proofs-of-concept or first trials with a limited scope. The results do, however, reveal that positive decisions to explore the Blockchain space would increase considerably if there were blueprints, large-scale working examples or reports about failed projects from practice. The literature refers to this as the lack of a ''large quantity of robust case studies'' [52], which is often reduced to a lack of any empirical evidence [16], [48], and not to a barrier that prevents long-term Blockchain projects. However, our results verify the latter. The final research proposition thus suggests:

Proposition 8: Blockchain solution deployment requires more described use cases incorporating experience from practice.

VI. LIMITATIONS AND FURTHER RESEARCH

The research approach chosen in this study has some limitations that have to be taken into account when evaluating the results. The analysis revealed distinct practices and barriers and how they interact. However, it should be kept in mind that the goal of the study was to uncover these practices and barriers and not to test them empirically. The sample, obtained through a theoretical sampling approach, provided useful insights, but is not necessarily representative of an underlying population. Furthermore, it is possible that the interviewees withheld information due to the public's immense interest in the topic and the consequences that their statements might

have. Volatile markets make those experts working with cryptocurrency tokens in their daily practice specifically cautious.

The research propositions put forward warrant further qualitative and quantitative inquiry. Propositions 1 to 4 should be investigated further to outline how they could be effectively implemented in managerial practice. With respect to propositions 5 to 7, quantitative inquiry could reveal further interacting factors. Proposition 8 warrants extending current conceptual research to the field to investigate if and how the proposed use cases are actually implemented. In general, our findings provide numerous starting points to further investigate Blockchain's implications from a theory-based perspective. It has already been shown that especially principal-agent theory, transaction cost analysis and network theory provide valuable lenses and can help explain certain aspects of the phenomenon of Blockchain adoption in the supply chain context [17].

VII. CONCLUSION

This paper explores the practices and barriers of Blockchain adoption by SC&L incumbents. A total of 24 semi-structured expert interviews shed light on the ways in which companies deal with Blockchain and the barriers they face when doing so. We identified three types of practices and two groups of barriers, with the practices showing that Blockchain can be a major digitalization driver in SC&L. Actual Blockchain deployments in SC&L require an open ecosystem and not a business-driven basis to provide the infrastructure. Consortia need to build and drive these ecosystems to ensure the solutions have sufficient momentum. Barriers holding companies back from pursuing one or more of the outlined adoption practices are either rooted in the still complicated technical usability due to missing out-of-the-box interfaces and the lack of easy-to-use consumer solutions, or in long-term uncertainties, which refer to possible changes in regulation and the lack of opportunity to learn from robust, well-designed, evidence-based use cases.

Adding to the available literature, we find that Blockchain solutions are a new type of market platform that will only work when designed as open ecosystems. Managers and decision-makers tasked with deploying Blockchain in their company can benefit from this research by comparing their plans with the outlined practices and addressing possible barriers early on. Overall, Blockchain solutions for SC&L are a promising concept addressing the old idea of a worldwide ledger that allows one to follow the complete history of a product and its parts. While current technological limitations apply, the impacts of Blockchain solutions can already be observed in companies—whether as a driver to revisit long-standing problems, as a way of addressing a new market or as a silent bystander in a consortium.

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