Blockchain in Maritime Industries

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This white paper is published by Center for Logistics and Collaboration based on the project 'Maritimt Block-kraft' funded by the Danish Industry Foundation. The white paper summarizes findings from studies of blockchain potentials and challenges across three supply chains identified in port industrial areas. The project has been managed by Center for Logistics and Collaboration with participation from the Freight Transport Research Group and the Danish Center for Environmental Assessment at Aalborg University.

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Preface

Maritimt Block-Kraft is dedicated to investigate the compatibility and possibilities of integrating blockchain technology in businesses located in port industrial areas with a special focus on SMEs. In recent years, the awareness on blockchain technology has increased, and the usability in businesses, particularly across supply chains, is increasingly acknowledged. In this white paper, we introduce current applications and future potentials of blockchain technology in three different supply chains affiliated to port industrial areas.

The awareness of blockchain technology and the changes it can and will create in many industries is growing rapidly. As evidenced by the diverse Blockchain projects funded by the Danish Industry Foundation, we have seen businesses that initially turned down the idea of blockchain, suddenly conforming to the technology and starting to implement it. Therefore, we thank the Danish Industry Foundation for creating the possibility to explore and disseminate knowledge on blockchain technology which represents an essential step in creating digital transformation in Danish SMEs.

Significant gratitude goes towards the participants in the project and companies in the participating ports for sharing their time and knowledge of the industries. This includes Port of Aalborg, Hirtshals Port, Hanstholm Port, Strandby Port, and other participants including especially Dansk Havne, Erhvervsnetværk 9220 and Erhverv Norddanmark. The project could not have been completed without their involvement.

The white paper has been developed in cooperation with Aalborg University, specifically the Freight Transport Research Group and the Danish Center for Environmental Assessment. As the contributions from these groups address different supply chains, the presentations of blockchain technology differ based on the context and the professional form and content of each industry. In addition, the purposes and potentials of blockchain technology application reflected in the three sections are very diverse. These findings reflect the diversity and challenges in terms of transferability between business cases.

This white paper is aimed at business actors with some prior knowledge of blockchain technology. For a less technical introduction to blockchain, we will refer you to the Danish version of this paper that is aimed at SMEs and business actors who want to learn more about blockchain and how it can benefit their operations.

Contents

Executive Summary

Introduction

This white paper shows how small and medium sized companies (SME) involved in supply chains affiliated to the maritime industry and port industrial areas are challenged by the diffusion of technologies and managerial principles associated with Industry 4.0 with a special focus on blockchain technology. Blockchain technology creates potential for added value through transparency and auditability of data flows that arise through system decentralization, where intermediary parties such as a central authority will not store data or verify transactions. Instead of conventional workflows, the technology brings new approaches to collaboration by combining multiple parties with equality of data ownership. In doing so, blockchain technology challenges conventional rules of data ownership.

While attention on blockchain technology has been increasing, most blockchain projects are still under development. However, the technology gained ground in areas such as healthcare, governance, and supply chain management. This white paper focuses on the potentials and challenges of blockchain technology in maritime related supply chains.

Based on a discussion of industry preparedness for Industry 4.0, a taxonomy of blockchain adoption is presented. The taxonomy is based on two dimensions including: (1) the digital complexity of internal activities and (2) the degree of value chain integration between actors in the supply chain. The dimensions encompass four archetypes of behavior on blockchain adoption that are applied in the following analysis.

The potential for blockchain technology is increasingly evident in supply chain logistics and manufacturing that is often located in industrial areas such as ports. By studying blockchain potentials in Danish maritime SMEs, the findings reflect the currently limited insight into blockchain technology from the point of view of business actors. As shown in the study of three Danish supply chains, containers, seafood and recirculated plastics, there are low-hanging potentials to be realized through changes to the current technologies and systems in application.

Blockchain for Container Supply Chains (BCS)

This section explores blockchain technology for container supply chains. It shows existing blockchain initiatives in the maritime industry and provides an overview of how these blockchain projects align with the development strategies of Danish maritime ports.

Maritime ports and logistic hubs are efficiency drivers of the global economy. Sea-based transportation involves dozens of parties: shipping brokers, liner operators, terminal operators, customs, shipping agents, port authorities, freight forwarders, etc. Often, these parties do not interact with each other, and for this reason data sharing is limited. Parties at the port, accordingly, do not possess information about the cargo's place of origin, goods type, corresponding documentation, and other in-

formation that is relevant for customs, port operators and receivers. This lack of information complicates container checks for customs and can create time delays. In short, the maritime industry is overdue for communicational upgrades.
Establishing connectivity between all parties in a supply chain is the next step for time-efficient, secured deliveries. This connectivity can be created through blockchain technology that can ensure transparency and auditability of information flows. Within such a widespread distributed network as shipping, this is extremely relevant.
Prior to the introduction of blockchain technology, there have been attempts of creating communication upgrades through Port Community Systems. The aim of developing the Port Community System was to address many of the challenges that current blockchain-enabled solutions are dealing with. The Port Community System followed similar goals to digitize port document handling and speed up port communication. However, the concept has not received full support due to data ownership concerns and partners' unwillingness to change business routines and organizational structures. Nevertheless, the concept of community systems is crucial for understanding the motivation behind current blockchain initiatives.

A review of existing research on blockchain technology and blockchain projects reflects three categories of blockchain technology application in the maritime industry: 1. Document flow management, 2. Financial processes, 3. Device connectivity. These three categories address significant areas of development for container document handling and tracking possibilities.

The section is concluded by a discussion of the potentials and challenges of blockchain technology in container supply chains based on interviews in six maritime ports in Denmark. Medium-sized ports in Denmark prioritize land expansion and equipment optimization above IT innovation. In addition, major communication gaps between port authorities and terminal operators challenge optimization and data handling. These aspects are crucial to address prior to introducing decentralized communication like blockchain technology.

Blockchain for Seafood Supply Chains
This section explores blockchain technology for seafood supply chains by using current experiences with blockchain technology in other food supply chains.
The drive towards blockchain technology in seafood supply chains is driven by two forces, i.e. the expectations from consumers that the origin and quality of food products become more transparent, and forthcoming EU legislation regarding a more transparent documentation of the same issues. Two cases of companies currently implementing blockchain technology through the IBM Food Trust platform are introduced. IBM Food Trust Platform supports the implementation of blockchain technology in seafood supply chains through a permissioned, permanent, and shared record of food system data stored on a blockchain.

Based on the experiences from existing cases of blockchain technology in seafood supply chains, the remainder of this section explores cases of SMEs affiliated to 'Maritimt Block-Kraft' and shows how SMEs can gain a competitive advantage from the potentials explicated in the cases.
Previous attempts of digitalization in the seafood supply chain includes the SIF (traceability in the fisheries sector) system, which was operated by the Danish Fisheries Association. However, due to technical challenges, the system has not been successful and central stakeholders have abandoned the system. Instead, the supply chain consists of a multitude of systems with a low degree of convergence, which necessitates extensive manual entries. The level of digitalization and use of automation technology observed in the industry is not particularly high. Nevertheless, the strong coalition of actors across the supply chain might reflect a potential for the Danish seafood supply chain to become blockchain frontrunners.

Blockchain for plastic supply chains
This section explores blockchain technology for plastic supply chains with a focus on plastic recirculation. The port hinterland is a natural connection for transport of materials, and hence, ports are often hubs for the circular economy. One of the focus areas for the circular economy in Denmark, as well as in the EU, is plastic recirculation. There is a need to improve the quality and value of recycled plastic, and one way to achieve this is by ensuring that information of origin and composition follows the plastic. Blockchain technology holds the potential to support this as shown in the blockchain solution 'Circularise'. Circularise is a platform partly funded by the EU Horizon program that supports transparency and sustainability of the plastics industry. However, the platform is built to be used in major companies with large capacities in terms of knowledge and digital readiness. For this reason, this section elaborates and discusses potentials and scenarios for how blockchain technology might improve plastic recirculation from an SME point of view. The scenarios have been developed with assistance from stakeholders in industry, public authorities and experts in blockchain technology.

Central challenges in this supply chain include uncertainty on origin and safety of recycled plastics as well as low volume/economy for individual 'suppliers' of plastic. The main questions driving this exploratory process is thus how blockchain technology may assist in improving the circular economy of plastics, as this technology holds potential for reducing transaction costs while increasing transparency of material flows. Generally speaking, the industry of post-industrial and post-commercial plastic is made up of many small, independent recyclers with a low degree of digital maturity. In addition, the marked is yet to reach a price point where the feasibility of plastic recycling does not depend on fluctuating oil prices.

Blockchain technology holds the potential of changing this situation, both by reducing collection cost of smaller fractions, facilitating higher quality of the collected material, and by adding value through traceability. Recycled material has higher value, independently of technical characteristics, when the origin of the plastic is traceable and verifiable.

The recommendation here is to build a system tailoring existing initiatives in Europe to the specific needs of the Danish industry characterized by SMEs that are typically situated downstream to the companies producing the plastic polymers.

Introduction

Industry 4.0 may be described as a set of new technological opportunities based on how Internet-of-Things (IoT) enables new methods of communication and collaboration between technology and humans within and across organizational boundaries. Collaborative activities can be based on artificial intelligence, machine learning and automation to the extent where machines coordinate with machines, and systems with systems, without human interference. Similarly, problem solving and decision making can be undertaken automatically. In most cases, however, problem solving and decision-making take place at the interface between technology and humans, often involving the processing of data by technological systems, where human interference is focused on exceptions from standard cases. Industry 4.0 provides opportunities for economies of scale, since data on products, processes and quality can be integrated across organizational boundaries throughout the supply chain, e.g. stimulating just-in-time activities and build-to-demand production systems.

Many small and medium sized companies (SME) are challenged by the diffusion of technologies and managerial principles associated with Industry 4.0. The reason for this is that the implementation of Industry 4.0 requires IT skills and preparedness that in many cases are more complex than the current state of affairs in Danish SMEs. The implementation and use of blockchain technology, which is one of the technologies associated with Industry 4.0., poses similar challenges to SMEs. In consequence, when analyzing the preparedness of firms for adopting Industry 4.0, the same line of reasoning can be applied to the case of Blockchain. This is the approach adopted in this white paper.

In the following, the technology of blockchain and the development in blockchain application is presented. Following this, industry preparedness for Industry 4.0 is discussed specifically concerning blockchain technology to develop a taxonomy of behavior on blockchain adoption. This is applied in an elaboration of blockchain recognition in Danish industries and following this in the exploration of blockchain potential in three Danish supply chains in a maritime context.

What is Blockchain and what are its uses?

The technology called blockchain represents a decentralized database. From 2016-2020 blockchain technology has been projected into a wide range of industries and business cases, especially amongst big business and government. It is considered a significant part of Industry 4.0 and fully integrated manufacturing (Tsiulin et al, 2020a; Casino 2019).

Initially, blockchain technology was used in financial markets and traditional banking services for ‘reinventing’ payments, financial services and economics. Although it is often presented as a trendy technology with a short history, its origins are in the 1990’s and dot-com era. Even though “Ecash” (e.g. electronic wallet and digital coins) was implemented in real transactions in USA and Europe, it shares plenty of similarities with today’s cryptocurrencies. Unlike bitcoin, E-cash did not survive with credit cards and ever-larger banks (Tsiulin et al, 2020a; Wright 1997; Hwang et al. 2001).

Since gaining media attention in 2018, blockchain is seen as a powerful tool for transforming many industries: supply chain and logistics, healthcare, governance, data management, data security provision, etc. Fundamentally, blockchain represents a distributed network with information combined into blocks. Seebacher and Schüritz (2017) defines it comprehensively as a distributed database based on peer-to-peer network, which:

Consists of a linked sequence of blocks, holding timestamped transactions that are secured by cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity.

A key aspect of implementing blockchain is transparency and auditability of data flows. The qualities of auditability and transparency are achieved through system's decentralization. Decentralization excludes any intermediary party, meaning a central authority that keeps all data, verifies and authenticates transactions. In contrast to centralized systems, all permissioned actors are allowed to verify the state of the database, i.e. that it was changed according to protocol, and all actors have the same views of the storage (Reyna et al, 2018; Antonopoulos, 2015; Tsiulin et al, 2020a). Blockchain establishes a direct connection between selected final users, providing communication as well as post factum actions.

The technology is considered as the main tool that could shift out-of-date document management and decision-making processes to fully electronic formats and thus create trackability. All transactions are confirmed by participants, and once a block is completed, it is prevented from any further changes. Confirmed transactions represent timestamps, providing required information regarding when and how a particular transaction was completed. In storage, each block keeps the data history of finished transactions (Tsiulin et al, 2020a; Hawlitschek et al, 2018; Seebacher and Schüritz, 2017). The risk of falsification is at a minimum due to storage decentralization and overall block dependency on each other. The security is achieved through synchronization of blocks by hash algorithms — each new block always refers to the hash of the previous one.
The blockchain varies by the type of access granted to different parties. It ranges from being either fully open for all parties or so-called "permissioned" with a closed network able to access the database. The second type monitors the flows of stored data to unauthorized users, which prevents data from leakage and ensures confidentiality (Tsiulin et al, 2020a;).

To broaden the functionality, new blocks might be created through an automatic logic agreement approach, called smart contracts. Smart contracts are automated self-verifying, self-executing and self-response algorithms in accordance with predefined logic that gets "activated" once predetermined circumstances are met. A smart contract approach is built on "If – Else" basis, i.e. for any action there is a sequence of conditions to be checked by the algorithm. Then, depending on the checked result, the transaction is completed or declined. Upon completion, the system transfers the transaction to the ledger (Tsiulin et al, 2020a; Narayanan et al. 2016; Yuan and Wang 2016).

Certain blockchain projects are based on tokenization. Tokens represented shares (similar to corporate stocks) of the project and simultaneously played the role of working units for the system to remain functional. Initially meant as a tool for tracking "who owns which assets" and raising funds for projects during its lifecycle, it has been developed further into a “token-monopoly”. That means the system stays non-functional unless transactions are supported with a certain amount of “digital fuel”. Tokenization creates a dependence on units which then becomes an unnecessary supplement for a particular project’s algorithms. Considering that most governments regard tokens as unregulated currency, it creates extra challenges for such systems to being legally accepted. Strict dependency on tokenization has received a great decline since 2019, where tools such as Hyperledger started looking into decentralized applications with minimal or zero dependencies on any internal currency. Consequently, it softens block-chain for law and data usage regulation and distinguishes it from cryptocurrency (Tsiulin et al, 2020a).

Development in Blockchain uses

Nowadays, the majority of distributed database projects are ‘in development’ or ‘in active testing’. As for solutions, running applications mainly work as e-voting platforms or databases, expanding the usability to a wide range of domains including especially healthcare, governance and supply chain management. These three areas match the fundamental requirements of blockchain: a high number of scattered, diverse actors with lack of trust between each other, a low level of co-integration and significance of third parties in data processing (Casino 2019; Swan 2015; Tsiulin et al, 2020a).

As reflected in the three areas of implementation, blockchain technology holds great potential for governance services, such as e-citizen services, national income distribution, dispute resolution, and any kind of document registration e.g., marriage contracts, land agreements, etc. (Tsiulin et al, 2020a; Casino, 2019). Moreover, there is an increasing potential for the usage of blockchain in healthcare, with electronic healthcare records that allow patients to access their records regardless of the treatment center they were inputted through (Hald and Kinra, 2019). It does not only provide access, but a right for the patients to decide where the record information can travel. In this case, the entire control shifts from an institution to the patient, who is able either to delegate it or to move to another organization.

Despite the increasing scientific attention, the technology is still poorly examined in practice. For this reason, the technology is still considered new and is continuously developing. Studying and helping to solve practical challenges of blockchain implementation, as in the multiple blockchain projects funded by Industriens Fond, can lead to the development of best practices that can potentially shift the progress of blockchain development to a new level (Tsiulin et al, 2020a).

In the following, the degree of blockchain maturity is discussed and a taxonomy for blockchain adoption behaviour is proposed to inspire the adoption process and potential challenges in Danish SMEs.

Blockchain maturity

Preparedness for adopting Industry 4.0 technologies such as blockchain depends on how advanced the firm is in its use of IT and the extent to which IT is integrated with various dimensions of the socio-technical system.[1] In most cases, the relevant dimensions of the socio-technical system are the products that the firm produces, the processes by which the products are produced, the people that are involved in production, the financial procedures by which investments and operations are controlled, and the strategy that frames the activities of the firm.[2] Depending on how elaborate these dimensions are, the firm can be characterized as more or less mature for adopting Industry 4.0 principles and methods. Several models on maturity levels can be found in the Industry 4.0 literature, all of them spanning from some kind of novice or embryonic level to some kind of expert or mature level.

The level of maturity will normally be characterized in terms of the number and variety of technologies and systems applied, the degree by which IT-based systems are integrated in various activities within the firm, and the extent to which activities are digitally coordinated across organizational boundaries, i.e. encompassing customers and suppliers (Köhler & Pizzol 2020). This means that maturity covers both internal and external dimensions of the firm's activities, where the internal dimensions are understood in terms of the digital complexity of the firm's activities, while the external dimensions are understood in terms of the extent to which activities along the supply chain are integrated.

These dimensions are captured by the taxonomy in figure 1 that combines (1) the extent to which internal activities are more or less digitally complex and (2) the degree of supply chain integration. The taxonomy represents an aggregated version of more elaborate classifications of various levels of maturity where the internal and external dimensions are laid out in details. The aggregation allows a parsimonious analysis classifying firms in four archetypes. Furthermore, the archetypes are inspired by the model on long term diffusion of technology that has been suggested by Iansiti & Lakhani (2017) and applied to Blockchain technology. They argue that blockchain technology is a foundational technology, i.e. a technology that "has the potential to create new foundations for our economic and social systems" (p. 120). In order to analyze the potentials involved in blockchain technology and the time horizon by which these potentials are likely to occur, they compare the future diffusion of blockchain technology with the historical pattern by which TCP/IP[3] was introduced and diffused

[1] The socio-technical system may involve various degrees of interaction between technology and humans, and also determine the extent to which humans are excluded from work processes, see Neuburger, R. & Fiedler, M. (2020), "Zukunft der Arbeit – Implikationen und Herausforderungen durch autonome Informationssysteme", *Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung*, forthcoming, Springer Professional. https://doi.org/10.1007/s41471-020-00097-y, published online 18 September 2020.

[2] These dimensions are suggested by Mittal, S., Romero, D. & Wuest, T. (2018), "Towards a Smart Manufacturing Maturity Model for SMEs (SM3E)", Moon, I. et al. (eds.), *Advances in Production Management Systems. Smart Manufacturing for Industry 4.0*, Springer: IFIP International Federation for Information Processing, pp. 155-163.

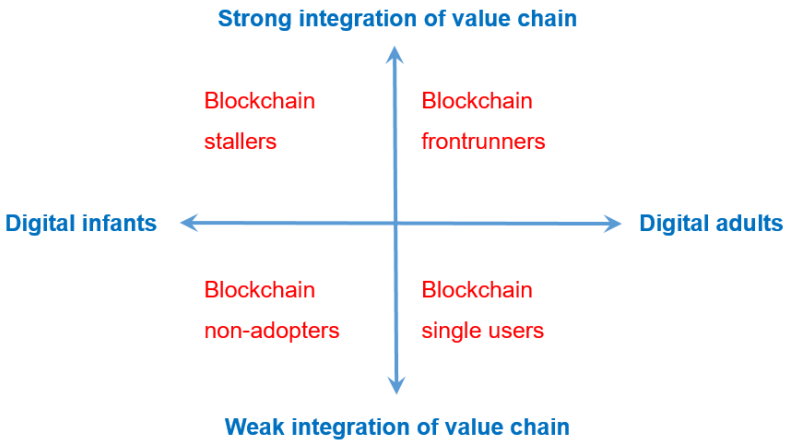
[3] TCP/IP is an abbreviation for "transmission control protocol / internet protocol".

throughout the economy. The application of TCP/IP started as e-mail, typically applied by *single users* as an alternative to conventional forms of communication in terms of telephone, fax, and snail mail. The degree of novelty was rather low in this type of use, and the complexity of use was low because it did not require extensive coordination with other users. As more and more users became aware of the low-cost opportunities in TCP/IP, the technology caught on and became a foundation for local private networks within firms and organizations. While this *localized use* implied some degree of novelty and complexity, it was relatively easy to apply because it did not involve a large amount of users and thus a high degree of coordination. With the advent of the World Wide Web, TCP/IP became a platform for services and applications that could be applied across a large amount of different firms and organizations, where it substituted existing services and applications. While this *substitution* became extensive, the technology solutions were, nevertheless, rather straightforward in the sense that they were based on "existing single-use and localized applications", but were, however, "high in coordination needs because they involve broader and increasingly public uses" (p. 125). In the long run, new business models occurred, creating a *transformation* of how value is created and captured, both as processes of exchange and in the form of the advent of new digitally based firms. These are:

> *novel applications that, if successful, could change the very nature of economic, social, and political systems. They involve coordinating the activity of many actors and gaining institutional agreement on standards and processes. Their adoption will require major social, legal, and political change (Iansiti & Lakhani, 2017: 126).*

Following this line of reasoning, the taxonomy presented in figure 1 suggests four types of behavior on blockchain adoption. *Blockchain non-adopters* are firms that are digitally immature and operates in circumstances where integration across the supply chain are less important. For this kind of firms, blockchain technology is neither an option, nor a potential source of value. *Blockchain single users* are digitally mature firms that operate in a supply chain context similar to the non-adopters. While they have no need for coordinating across organizational borders, they may benefit from adopting blockchain solutions within the firm. *Blockchain stallers* are firms that operate in circumstances where integration across the supply chain is needed and may even be a source of competitive advantage. However, being digitally immature they do not contribute to the diffusion of blockchain technology, although they might benefit from adopting the technology. These are firms that are not likely to invest much in blockchain development on their own accord but could be stimulated to adopt blockchain technology if user-friendly solutions were to appear in some abundance at the market. Finally, *blockchain frontrunners* are digitally mature firms that need strong integration across the supply chain and pursue digital solutions to that effect.

Figure 1. *Four types of blockchain adoption behavior*



Based on this taxonomy, the following section elaborates on blockchain recognition in Danish SMEs. Throughout the three supply chains, the taxonomy will be revisited and discussed to elaborate on potential blockchain adoption pathways for supply chain actors and the inherent challenges and limitations to this process.

Blockchain recognition in Danish Industry

The present exploration of blockchain potentials in Danish maritime SMEs reflects that the knowledge of the blockchain technology is still in its infant stages and often associated with cryptocurrency. There is little knowledge of blockchain in connection with other instances such as supply chain management, and a low number of companies and business are considering implementation of the technology. However, the awareness of the technology is increasing which means that the need for information and knowledge sharing about the technology along with its potential uses is at the most critical stage right now.

As reflected in the report on "The economic impact of blockchain on the Danish industry and labor market" from Frauenhofer both micro-sized and large companies have the same degree of knowledge around blockchain while middle sized companies have the lowest degree of knowledge. In addition, large companies have better chances of succeeding with blockchain initiatives as they have the resources and time for significant changes. However, as the exploration of the three Danish supply chains shows, the demand of resources should not be the major barrier for SME in terms of blockchain adoption. A lot of SME's have opportunities to make changes to the technologies and systems they apply. While it will often require hardware investments such as scanners and sensors, the blockchain system can easily be controlled through a web browser. There are a significant number of start-ups focusing on blockchain where they offer SaaS (Software-as-a-Service) which can assist in imple-

menting blockchain, which means that blockchains are made for servicing and helping physical processes in businesses. These exist alongside more established organizations, such as IBM and Atea, who have created platforms readily available for businesses of all sizes to join. As stated in the Fraunhofer report other EU countries have initiated large-scale public sector initiatives to create an ecosystem for blockchain and blockchain-clusters. The current initiative from Industriens Fond can be viewed as an initiator for Denmark in this regard.

Prior to deciding whether or not to partake in the development of blockchain platforms, industry actors must continuously question the individual and collective need for data transparency and auditability of data flows that can be created through distributed ledger technology (DLT)/blockchain technology. One approach to do so is by going through the Gartner decision tree as developed by Litvan (2019).

As discussed in the previous sections, the potential for blockchain technology is increasingly evident in supply chain logistics and manufacturing that is often located in industrial areas such as ports. To explore these potentials further, the remainder of this white paper shows three industry supply chains that to various degrees are associated with the maritime sector in Denmark. These include the supply chains of: containers, seafood and recirculated plastics. In these three chains, the current cases of blockchain usage, the blockchain maturity and the future potentials of blockchain application are presented and discussed.

Blockchain technology for container supply chains

Maritime port terminals and distribution logistic hubs are main efficiency drivers of global turnover and economy. But with the rising market of innovative technologies, the maritime industry is overdue for operational and especially intra-port communicational upgrades (Tsiulin et al, 2020; Francisconi, 2017).

In the maritime industry, issues concerning lack of accurate and complete information affects the coordination along the transportation route – both through lack of communication between goods receiver and sender as well as shipping parties along the way (Groenfeld, 2017; Kshetri, 2018). A standard vessel shipping of a twenty-foot equivalent container involves dozens of parties (terminal operators, customs, shipping agents, port authorities, freight forwarders etc.), with multiple rounds of confirmations and regulations between them. A central issue is caused by the lack of awareness of upcoming arrivals and transportations, which includes notifying parties along the supply chain about time of arrival, cargo type, place of origin, corresponding documentation and other relevant information for customs and receiving parties (T-Mining, 2018; Tsiulin et al, 2020a). This lack of information regarding specific containers increases the probability of delays during customs check, pick-up by freight forwarders and repositioning of goods at the port site. Consequently, these issues complicate the planned delivery and the subsequent payment processes and can thus increase costs for the companies. This creates uncertainties for both the recipient and the sender, that is also affecting efficiency of ports operations at the container yard and during customs checks (Tsiulin et al, 2020a; Smart Port, 2018).

Port Community System

Prior to the introduction of blockchain, the maritime industry attempted to solve the recurring challenges of outdated document handling and communication delays across supply chain parties by introducing the ‘Port Community System’ (PCS). As visualized in figure 2, PCS is a central information hub that connects maritime stakeholders (port authority, importers and exporters, freight forwarders, customs, consolidation centers) to enable intelligent exchange of information and documents (Baalen et al, 2008; Rodrigue, 2020; Francisconi, 2017; Tsiulin et al, 2020c; 2020a).

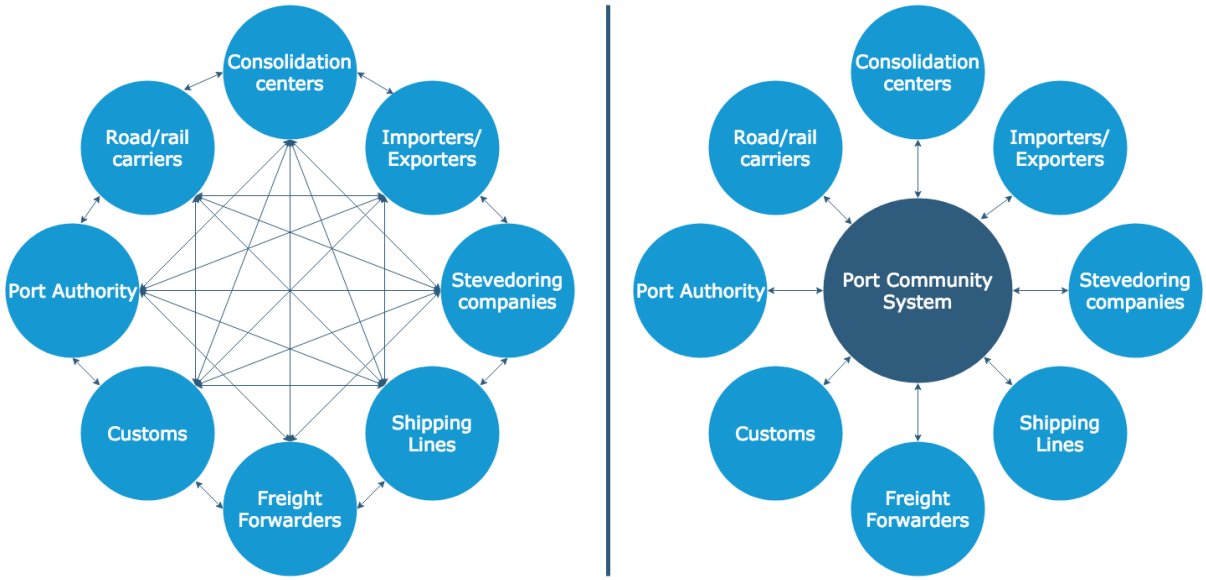


Figure 2. Communication between shipment actors without (left) and through (right) the Port Community System
Source: (Tsiulin et al, 2020a)

PCS has been the first conceptual attempt to shift document management, cooperation and decision-making processes to electronic format (Tsiulin et al, 2020c). However, even though the system conceptually showed potential and wide support from industry actors, it faced fundamental challenges in terms of ownership and data security. As presented in figure 2, the system presupposed one centralized privileged third-party that could regulate the information flows and aggregate data from the port actors as data-owner.

Despite the overall attractiveness of potential benefits, implementation attempts of the concept have been hindered by the unwillingness of network partners to share information. This included a reluctance to adjust paper flows to new standards. The Port Community System has been tested through different platforms in a variety of international ports including Port of Valencia, Port of Antwerp and Port of Busan (Carlan et al, 2016). The platforms, however, did not succeed to cover other parties along the supply chain and connect senders, ports of origin and producers. The main inconsistency in agreements was due to data security concerns as the third-party structure imposed risks of data or confidential information leaks.

Current cases of Blockchain usage

Since 2018 both media attention, academic communities and business initiatives have shown an increasing interest in blockchain applications in the maritime industry. In contrast to centralized databases like the Port Community System, blockchain has been promoted as a solution to the abovementioned issues related to communication, data security, elimination of the role of central gatekeeper, establishing point-to-point communication with transactions visibility and permissioned transparency (Tsiulin et al, 2020a). Based on the complex interconnection of different supply chain actors in the

shipping process, the blockchain features of transparency and trackability have fueled the industry awareness of blockchain technology.

To address the low maturity of applied blockchain technology, the current lack of implementation experiences and the recently emerged academic interest, the following section of the report presents how various blockchain projects relate to and intersect with each other. Through a systematic review of projects and academic publications representing recent blockchain initiatives, the following section highlights central supply chain blockchain projects with a particular focus on port and shipping activities (Tsiulin et al, 2020a).

The review is based on academic publications and commercial projects covered in public media, including start-ups, commercial projects, press-releases and white papers. Based on a search of databases, 33 academic publications and 23 projects have been examined[4].

As shown in figure 3, the review revealed that supply chain projects related to the sea-shipping industry can be classified into three categories (Tsiulin et al, 2020a). These include: i) Projects designed to simplify and speed-up document workflow (Document Workflow Management; DWM), ii) Projects designed to speed-up financial transactions throughout the delivery after goods arrival to the terminal (Financial Processes; FP), and iii) Projects designed to improve communication at the maritime port area and to connect all supply chain parties starting from the place of product's origin (Device Connectivity; DC).
However, in general, the insight into blockchain potentials in maritime port management and shipping is limited and mostly presented as a supply chain sub-topic.

[4] For further elaboration on the methodology behind the review see (Tsiulin et al, 2020a).

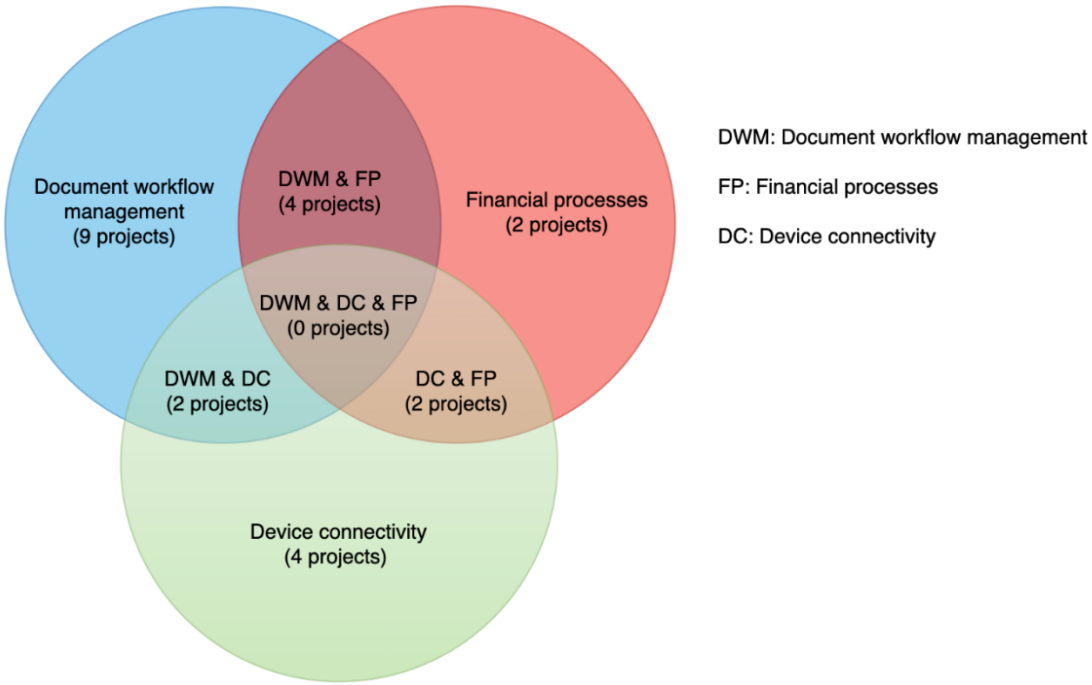


Figure 3. Distribution of projects across the conceptual frameworks
Source: (Tsiulin et al, 2020a)

Figure 3 illustrates the three categories of reviewed projects and their associated areas. As implied by the overlapping of circles, the review showed clear interlinkages between the blockchain categories at play, and often the projects could be classified into more than one category. However, none of the reviewed projects considered all three areas at once.

The main part of projects identified relate to the categories of Document Workflow and Device Connectivity while only two projects focus exclusively on financial processes. This division implies a commercial interest in projects that combine the digitization of paper workflow and financial transactions into one single application thus underlining that the financial aspects of blockchain cannot exist without a well-functioning document transaction basis (Tsiulin et al, 2020a; Tsiulin and Reinau 2020b).

The three central categories identified are elaborated in the following sub-sections.

Three categories of blockchain projects in the maritime industry

1. *Document workflow management*

The category of document workflow management directly relates to the issue around the lack of accurate and complete information and consequent coordination along the transportation route that is described at the beginning of the section.

When integrated the process of data transfer to the blockchain can be executed digitally instead of the conventional physical flow. Involved parties are becoming internal nodes, and, according to blockchain fundamentals, have identical copies of the database, and are able to contribute to the process by approving the documentation online. Approvals are seen as timestamps throughout the process, and show the exact time, place and condition of the transaction. Once the required approval has been received, smart contracts, as an internal logic, can send documentation to the next parties automatically. The history of document handling is visible to all parties while also being indefeasible to unauthorized changes (Tsiulin et al, 2020a; Tradelens, 2019; Swan, 2015).

The fundamentals of blockchains such as transparency of actions and consensus algorithms can increase the overall attractiveness and trust between partners and help to decrease the occurrence of fraud. Trust and flexibility are achieved through the possibility to track all changes in the ledger in real-time. Any suspicious actions are automatically rejected by the nodes through the overall chain connectivity.

The category of Document Workflow Management is well-illustrated by TradeLens - one of the largest blockchain initiatives launched by the Danish shipping company Maersk in collaboration with IBM. The aim of TradeLens is to speed up supply chain and paper-based processes by tracing goods more efficiently and reduce the volume of overall point-to-point communications. The system, having a digitalized workflow, tracks end-to-end shipments, and eliminates frictions as well as uncertainties in real-time. For example, once customs sign shipping documents, they are transferred to the database along with their digital signature. It is planned that digital signatures will fully replace their physical analogues. This certifies a completed process to all involved actors, including Maersk and government representatives, which in turn simplifies work with disputes (with blockchain, transactions are unchangeable after confirmations) and furthers communication (Tradelens, 2019; Tsiulin et al, 2020a).

2. *Financial processes*

The category of financial processes involves the payment to a consigner bank so a container can be released from the terminal area. Financial flows could be easily generalized as each shipment is attached to a chosen Incoterms regulation, i.e. an obligation of buyers and sellers in foreign trade contracts. Depending on the chosen regulation type, certain parties could be restricted from collecting goods until the consigner bank clears the payment in accordance with a Letter of Credit that goes along with the cargo. The goods leave the terminal area only when information is clarified and payments are cross-checked. This procedure typically causes delays since the consigner bank does not belong to a port's internal community or communicational system, and thus cannot be notified of the status of the container in real-time and receive the relevant documentation (Francisconi, 2017; Tsiulin et al, 2020a).

The blockchain potential in this category is to enable trusted and secured information flows between the consigner bank and the port network. In this case, once notified regarding the unloading of a container, the consigner bank, being one of the nodes in the network, can initiate a cross-check of all required documentation, keeping to a minimum the number of point-to-point communications thus speeding up the pick-up for a freight forwarder. In this case, payment orders can be automated through smart contracts that notifies the client regarding the status of goods. Moreover, the ability for other parties to track the approval of payment documents and follow the process in real-time can impact the total processing time. (Kshetri, 2018; Tsiulin et al, 2020a).

3. *Device connectivity*

The category device connectivity shows that Internet of Things and global device connectivity is among the key concepts addressed by the reviewed projects. Gradually, the whole transportation and supply chain process shifts towards transparency and traceability as a way to better demonstrate the quality of the product and its origins. In addition, detailed transportation history might be applied in dispute resolution between supply chain parties. Once embedded, Internet of Things functionality provides a broad list of trackable real-time characteristics: location, temperature, capacity, movement and damage (Tradelens, 2019; Provenance, 2018; Tsiulin et al, 2020a).

In the category of device connectivity, blockchain can function as a database that is updated in real-time by multiple actors. Goods transportation records are automatically added to the blockchain as timestamps when checkpoints are passed. It collects the precise location, condition and other needed parameters in order to monitor goods during transportation. In addition, the embedded logic is able to define whether sensor-recorded parameters exceeds the required level and create a report accordingly. In this case, the information is stored automatically without any manual user input and is visible to affiliated parties in the network. By knowing exactly when and where each action occurs, this approach can prevent fraud and reduce the time spent on resolving disputes.
Smart contracts promote the utilization of automatic logic for creation of self-made reports and notifications for all parties involved. The end result will not only facilitate transparency improvements and a reduction in the average time spent on resolving disputes but also increase end-customer trust. A great number of projects demonstrate continuous location tracking as a main new feature for the end customer to ensure knowledge about product quality (Tsiulin et al, 2020a; Casino et al, 2019; Kshetri, 2018).

Summary of blockchain categories

The review of existing blockchain projects in the supply chain of port and shipping showed that both existing actors and start-ups are interested in creating tools for tracking goods and product data. Blockchain projects in the maritime industry are often applied to global supply chain transportation, mainly as a tool to obtain a larger degree of control over cargo handling and transportation times. This creates value in supply chains that are often characterized by inaccurate and incomplete information handling along the way, i.e. lack of notification on cargo's arrival, type, origins, and other

relevant information for customs and other parties e.g. maritime port or terminal that receive the cargo (Tsiulin et al, 2020a).

For the majority of applications within the maritime and supply chain domain, blockchain represents a global ledger for tracking the whole transportation process from start to end. Being able to identify the country of origin, transportation time, time spent in warehouse and temperature requirements creates credibility for both partners and end customers. (Kshetri, 2019; Tsiulin et al, 2020a; Reyna, 2018).

Table 1. Summary of three blockchain categories

Block chain category	Potential
Document Workflow Management	Shift document exchange between shipping parties to digital format, unify documentation, eliminate unnecessary interactions between parties, simplify approvals to a digital signature, automate paper flow and notifications, track approvals and unauthorized logins
Financial Processes	Integrate shipment-related financial enterprises and banks into the port community to speed-up information updates on cargo, automate payments and hence reduce time-delays
Device Connectivity	Organize a system of nodes throughout a particular supply chain, trace the place of product's origin, track the product in real-time, integrate technical sensors (physical and damage sensors), automate self-made condition reports and pre-arrival notifications, track approvals and unauthorized logins

Potentials and challenges for container supply chains

To further explore the potential of blockchain categories for the maritime industry, a series of interviews were conducted with representatives of central Danish maritime ports including the port authorities of Aalborg, Hirtshals, Aarhus, Fredericia, Copenhagen-Malmo and Esbjerg as well as two terminal operators.

The aim of these interviews was to understand blockchain feasibility from the practical viewpoint of port authorities and terminal operators. This included questioning how blockchain technology is aligned with the long-term development strategies of ports, the relationships with other actors at the port site including SMEs and the possibility to integrate those in a blockchain system (Tsiulin and Reinau, 2020b).

Port roles and SMEs

Maritime ports in Denmark vary by the model of ownership that consequently affects their development. The majority of Danish ports are owned by a municipality and managed as public self-governing ports. The Port authority (PA) functions as a regulator and landlord while being restricted from managing physical operations with cargo. Port authorities lease areas to companies that manage cargo handling and all accompanying operations. Therefore, terminal operators (TO) that operate cargo are

represented only as tenants that do not have a possibility to reorganize the port infrastructure by removing/adding new facilities or significantly changing the operational flow. Such internal changes occur either following a mutual agreement with the port authorities, or at the initiative of the port authority (Tsiulin and Reinau, 2020b). However, in recent years the priority regarding the development of port areas has turned towards territorial expansion rather than intra-port optimization.

SMEs that base business and operations within the port site vary by their degree of connectivity with the ports' logistics operations. Most of the time, the port authority, as a landlord, has limited information about the activities and operations of geographically close SMEs. The low awareness on the land side has motivated port authorities to explore the possibilities of collecting data and understanding inner-port supply chain flows. By analyzing and understanding these data, port authorities can create value for their tenants through logistics optimization, which can reduce logistics costs and make the port site appealing for new industries. By doing so, port authorities can generate business opportunities by assisting terminal operators in asset optimization and by creating extra port logistics services. However, it needs to be questioned how integrated SMEs can and should be in a port community system based on blockchain technology. Port-based SMEs might find it difficult to relate to blockchain due to the overall collaborative potential. Therefore, port authorities must emphasize the importance of collaboration with SMEs to explore the potential for each particular enterprise and how its logistics chain is connected to and can be further integrated into the inner-port flow. This created opportunities for port authorities through logistics value-added services, better communication over port clusters, optimization of traffic, fleet capacities etc.
As Danish ports are primarily focusing on container and trailer yard expansion, the collection of data flows and internal information regarding HR monitoring, scheduling, equipment breakdowns etc. plays a secondary role. The main motivation for data collection is to ensure management flexibility, real-time updates of operations and human resource utilization at the yard. That involves booking, online-monitoring and expansion of port extra-service which create flexibility to the customer and make it possible for port authorities to attain information on the upcoming cargo.

The majority of respondents including port authorities, terminal operators and SMEs emphasize that current approaches to document processing are outdated, regularly completed using e-mail, telephone call, fax or ERP modules. Across the paperwork stages in transportation, the risks of the human factor, falsification, miscommunication, and delays increase (Tsiulin and Reinau, 2020b). The respondents are all aware that the digitalization of workflows will be implemented, whether it will be a blockchain or other technological advances. When questioned, port authority respondents reacted positively to certain blockchain concepts (Tsiulin et al, 2020a) that emphasize better monitoring of document workflow ("Document Workflow Management") and communication ("Device Connectivity").

Currently, the biggest concern is how to incorporate customs into such an information-sharing system. Most delays happen during customs checks, so the participation of customs and their willingness

to contribute in the platforms network (i.e. blockchain) is crucial. Most respondents expect that customs will be willing to use the system but without contributing or supporting the workflow (Tsiulin and Reinau, 2020b).

Another concern is posed by blockchain potentially becoming a "turnkey solution" from major industry actors and global shipping liners. Respondents are generally fearing that a blockchain solution could later be transformed into a solution where agreements and rules are decided by a central developer. They experience this risk as it *"could turn towards, for example, shipping liners creating one end-to-end solution. Decentralized values and digital democracy could limit the scope of actors in the future and lead to the emergence of monopolies"*. Being aware of such risks, blockchain startups propose the concept of transferring the rules for maintaining or amending unified documents to state organizations, such as a port authority or local municipality (Tsiulin and Reinau, 2020b). However, the current restriction within the Danish port law might hinder such solutions.

Blockchain for extra services

Despite the skepticism of blockchain categories in "Financial Processes" described earlier, the concept nevertheless holds potential as a database for port's extra services, e.g., port gate monitoring, and notification systems for container status along the transportation route. This includes for instance, photos of the container going through gates after being picked up by the forwarder. For port authorities, such transparency between port actors could optimize the logistics and make the actors more proactive in planning over container yard and stacking, as well as keep better track of post-factum payments between cargo sender and receiver (Tsiulin and Reinau, 2020b).

Another possibility is to use blockchain for port area security e.g. to prevent cargo pick-up errors. When the container yard is not automated, the freight transporter that picks up cargo is navigated by the container number or a parking slot number at the yard. The situation is poorly controlled at the gate when driving out with no cross-checks. Consequently, that leaves room for human errors whether intentional or not. Port authorities in Denmark see such a scenario as a way to create an extra value added around the existing services. Automated port gates, scanning documents in and out and automated control over truck drivers can ideally eliminate human errors and reduce the number of pick-up errors and stolen containers (Tsiulin et al, 2020a; Tsiulin and Reinau, 2020b; T-Mining, 2018).

Future perspectives

Due to port law restrictions, all infrastructure development outside the port operational area is to be managed by commercial companies. The development within port areas in Denmark might lead to a shift from area expansion, port equipment modernization, and towards better communication between port authority and terminal operators. While attention is increasing, port community systems as well as blockchain projects are a secondary priority.

For future perspectives, Danish port authorities should be regarded as information flow participants in the logistic chain. The roles of the port authority in industry clusters within the port site and interaction with SMEs are likely to expand as well. For this reason, tighter collaboration becomes a central approach to reach more cost-efficient optimization of the port facilities. Blockchain represents a potential platform for establishing such a port community network.

Implementation of blockchain requires resource planning and certain technical requirements. In addition, challenges arise at the stage of network creation and integrity. As mentioned among the key challenges when implementing or shifting between various IT systems (not necessarily blockchain), establishing efficient cooperation between several independent companies or institutions is a challenge despite of the industry. This includes to engage required parties towards joining the system and continuously contribute to its updates, usage, expansion, etc. A closer look at similar business cases, especially implementation experiences of such concepts as Port Community System can solve the lack of knowledge and lead to the development of best practices to shift the progress of blockchain development towards the industry and port site in particular (Tsiulin and Reinau, 2020b).

A central constraint towards the implementation of blockchain is the reluctance of industry actors to change their business routines., even in industries where the existing means of communication are outdated and operations are based on conventional workflow schemes. In such cases, blockchain could lead to reduced HR, IT-support, and support-related costs. Moreover, integration with currently existing document processing systems could reduce the general reluctance in adjusting the working process to new, digitalized standards.

Many large companies have excellent showcases of blockchain-related projects, such as IBM, Maersk, and Amazon. However, it has proved increasingly complicated for SMEs to translate these examples from major industry players into their own contexts and processes. In order to identify the potential of blockchain technology in SMEs, it is essential to consider the degree of blockchain maturity. This maturity depends on both the SME level of digitalization and the level of integration found in the supply chain. These aspects are elaborated in the following.

Following the blockchain maturity matrix shown in figure 1, both the review of existing blockchain projects in the maritime and port supply chains and the empirical studies of Danish ports show a low awareness of blockchain technology and its capabilities in regard to the port network, port site development and port community systems.

In relation to the SMEs involved in these supply chains, they are often aware of the technology as well of its technical possibilities and limitations, though less motivated to implement the technology due to poor connectivity with major ports logistics operators.
While they currently represent block-chain non-adopters, the role of port authorities might, in the future, be to leverage the blockchain stallers and reduce the fear from opportunism by collaborating

with suppliers of blockchain databases to offer a port solution for Document Workflow Management across supply chain partners, Financial Processes in and around the container yard and Device Connectivity.

Blockchain technology for seafood supply chains

The supply chain of seafood represents a central chain that affects many actors in the maritime industry. This section explores the current cases of blockchain usage within the seafood industry and future potentials for blockchain application.
This exploration is based on interviews of key actors in the seafood supply chain in the port of Hanstholm, the port of Hirtshals as well as in the privately operated fishing port of Strandby in Northern Jutland conducted from the second half of 2019 till mid-2020.

In 2020, the *Food and Agriculture Organization of the United Nations* published a report entitled "Blockchain Application in Seafood Value Chains" to raise governmental and international awareness on the role of blockchain in the seafood industry. As stated in the report: *Key points highlighted throughout the document point to regulatory concerns that arise with global trade, appropriate use cases for blockchain and challenges — such as scalability and interoperability — that need to be addressed in order for mainstream adoption of blockchain to occur.* The FAO report advocates for a broader approach to the application of blockchain technology, and as this section concludes, a sector wide approach where the full supply chain is involved and included in the introduction of a new digital traceability system, can be the source of competitive edge both for the supply chain as a whole and the individual companies involved.

One of the driving forces for implementing digital technologies such as blockchain technology in the seafood supply chain is the need for documenting traceability and fish story lines to address food safety concerns. As stated in Cointelegraph[5]: "It's been said that up to 40 percent of fish in the world doesn't come from where it's labeled….". This reflects the concern of many actors in the food industry. For example, COOP is now using blockchain to track canned goods products so customers through QR codes can check the route from production to store. This reflects a customer focus on transparency, which alongside the increasing focus on e.g. sustainable produce and organic food can be improved through blockchain technology.
Similar challenges are evident in the seafood industry represented by the Marine Stewardship Council (MSC) certification. This certification represents products that complies with international best practice within fisheries, which means the customers that buy products with MSC labels will know it is a sustainably produced product. Blockchain can support the transparency of seafood products and thus the ability to adhere to the MSC certification standards.

The blockchain project Provenance (Provenance, 2018) started as a pilot for the fishing industry to allow users to monitor the date of catching, transportation chain and storage conditions, so the customer could estimate the product quality and its freshness. In general, the industry development re-

[5] Kvarøy Arctic also joining (Norwegian Seafood Sector partnered with IBM) https://cointelegraph.com/news/from-sea-to-table-norways-seafood-industry-hooks-into-ibm-blockchain

flects an inclination towards digitalized tracking of correspondence and device connectivity with assistance of IoT technology. These initiatives can be implemented with or without blockchain depending on the scope of the value added.

As presented in the following, blockchain technology is gaining foothold as an important tool for addressing the challenges, mentioned below, in the seafood industry.

Current cases of Blockchain usage

The following section presents a number of current cases in the seafood industry that has applied blockchain technology to their operations. The cases presented throughout this section is based on the IBM Food Trust Platform that supports the implementation of blockchain technology in seafood supply chains. This platform has evolved from IBMs initial tracking of lettuce. The knowledge gained in this process reflected a potential to alleviate several issues in the seafood industry as well. Through digitalization of transactions, IBM Food Trust could create more efficient ways of working across the entire seafood supply chain by providing immediate access to data, all the way from the fishermen or fish farms to the consumers. By collecting the data history and tracking individual food items certifications are available in seconds once uploaded onto the blockchain. IBM Food Trust is using a permissioned, permanent and shared record of food system data stored on a blockchain. The functionality of this blockchain is evident in the cases that are included.

Table 2 shows the activities and technologies in two specific cases of blockchain application the seafood sector:

Table 2: Blockchain application in seafood companies

Seafood Case / **Highlights**	Raw Seafood (IBM Food Trust)	Kvarøy Arctic (IBM Food Trust)
Core Activities	Scallop production	Salmon Production
Technology (Hardware)	Printer attached to weight QR Codes	QR Codes
Blockchain	Permissioned Blockchain	Permissioned Blockchain
Benefits	Immediate access throughout supply chain	Immediate access (Scan QR at point of receipt)
Problems solved	Seafood fraud (Fear of fish) Transparency	Seafood fraud (Fear of fish) Transparency

The first case is Raw Seafoods, a company located in New England, United States that catches and distributes scallops. In RAW three major challenges have been addressed by introducing blockchain technology. These challenges include:

1. Seafood fraud: the lack of transparency and tracking means that there are knowledge gaps in the origins of fish as well as known issues of mislabeling products and thus potential seafood fraud
2. Transparency: Mislabeling along with various different import places causes unknown products, and vague efforts in trying to correct this causes issues in terms of transparency
3. Fear of fish: a general lack of competences to prepare a meal with fish and food safety concerns from lack of tracking.

Currently, Raw Seafoods operates with a printer attached to their scales when unloading and packing the scallops. As the finished pack is weighed, the printer issues a tag with a QR code that contains the necessary information along with time of packing, down to a time stamp of seconds which is also entered into a computer system. This process continuous through the chain where the scallops are processed and packed into the final containers. The data about the individual package is stored on a shared database that is entrusted by all users. This creates transparency, so that the purchaser who buys scallops can track down the vessel and instantly provide feedback on the product.

The second case is Kvarøy Arctic, a salmon production company, that has signed a contract to begin cooperation with IBM Food Trust, announced 4th of June 2020. Their goal is to add QR codes that will contain the relevant data for the consumers. Each member of the chain will be able to use an application to scan each salmon at the point of receipt. Kvarøy Arctic is the controller and can grant access to the permissioned blockchain for all collaborating partners, and therefore, choose which data are visible. Atea is the IT infrastructure provider for the system.

Potentials for the Seafood Industry within the participating ports

As evident in the previous section, the possibilities in IBM Food Trust has attracted a number of prominent companies within the industry to adopt the technology. It is, however, still crucial to explore how SMEs can gain a competitive advantage from the potentials explicated in the cases. This is shown through a deep-dive in central stakeholders that have been a part of 'Maritimt Block-Kraft'. As highlighted above, the advantages and potentials include product value increases, lowering of production times and reduction of the physical paper trails.

Until the end of 2020 a SIF (traceability in the fisheries sector) system was operated by the Danish Fisheries Association. SIF introduced RFID tags into the Danish fish boxes that are used by all central actors when fishing in the North Sea, including transporters, auctions, middlemen and fish processors. The SIF system has been in progress since before 2010 and over the years the utilization of the database solution for SIF has been decreasing, reportedly due the to the gradually declining speed of the database which has led to many of the key actors to abandon the system. Instead, the Danish fish

auctions in the participating ports have started to use their own system Fiskeauktion.dk. Fiskeauktion.dk is a common platform for the auction houses and they are cooperating with the website and database to transfer data from different ships and online auctions. This platform demonstrates a general readiness in parts of the supply chains. The fact, that stakeholders in the industry coalition are willing to and interesting in gathering around a digital initiative with the purpose of enhancing their business processes and a potential value addition, reflects the receptiveness needed to embark on new technology implementation. The possible introduction of a blockchain technology platform would create a more decentralized system in comparison with the centralized SIF system. While both systems can function in this industry, a decentralized system could create benefits as stakeholders could have ownership of their data and share them with stakeholders that benefit from it. By doing so, each actor can control their data in a distributed system and be a part of a larger database. Furthermore, the increased data security will also add positive effects for the stakeholders, along with transparency within the supply chain.

By utilizing the established industry coalition, it would be possible to create a prototype project of the future blockchain system. This would be a great advantage as one of the big challenges is the lack of trust and lack of interest in cooperation between different stakeholders, when it comes to introducing blockchain technology. Furthermore, by starting with a prototype project, the effects can potentially be realized earlier than would be the case in pursuing a full implementation of the technology right from the start.

Blockchain technology in seafood

In the following, the cases explored in the seafood industry in Northern Jutland are presented. The cases represent different but typical companies within the Danish seafood sector. As shown in table 3, the cases represent different levels of technology application and systems that they are currently using to highlight the level of digitalization in the industry along with issues that they are experiencing.

Table 3: Case companies from the seafood industry in Northern Jutland

Seafood Case / **Highlights**	Processing Company 1	Processing Company 2	Fish Auction
Core Activities	Processing seafood	Processing seafood	Distributing seafood
Technology (Hardware)	Documents / PC	QR Codes & Scanners	QR Codes / RFID / Scanners
Blockchain (Software)	Relational Database / Excel	Relational Database / Excel	Relational Database / Excel
Issues	Excessive time on data collection	Data collection is local (Time used to conform data)	Data collection is local (Time used to conform data)

In table 3 above, selected cases gathered through interviews at different ports are presented. The purpose of the interviews was to explore the activities, operations and technologies utilized at each supply chain actors. Based on the current technological level, the aim was to introduce and discuss blockchain technology to obtain a stakeholder perspective on the potential of the technology.

In general, the seafood supply chain under study showed a general application of traditional databases in combination with local relational databases. For this reason, blockchain technology might prove a favorable choice when industries are mainly using data in order to comply with legislative measures. The EU has advised that in the future EU regulation it will be compulsory in order to be able to demonstrate traceability on a digital platform within the seafood sector, hence a blockchain solution could provide just that.

Generally, the level of digitalization and use of automation technology observed in this industry is not particularly high which could pose a challenge when attempting to implement blockchain technology. Similarly, digital competencies among key staff members is also expected to be a challenge and improved skills will be required for the industry to fully utilize the possibilities within blockchain technology.
One common denominator for all the three cases described in the above table is the excessive time used to perform data collection and conform the data to local standards. Even though much data is encoded into systems to eliminate paper trails, the data is fitted and validated by individual systems, hence each company encodes and registers data individually thus adding to a large total use of time for data handling and for documenting traceability from catch to consumer. Companies are using common systems and databases such as relational databases and a centralized system; hence they must conform the data to fit their own needs and structure. For example, the fish auction receives data from multiple sources, such as two different systems and sometimes voice messages. So, fish auctions receive data from three different sources, after which they encode the data into their own system as the data received cannot be used to compile and generate the data needed by the fish auction. Generally, there is a lack of data standards in the industry, along with low trust as some companies do not want to share certain information that could have relevance and be applied to improve the daily operations. For instance, if the fishermen shared the real-time data on the amount and location of fish caught, the companies in the ports could improve the coordination of their efforts to cope with the soon-to-arrive catch. The auction houses could prepare storage areas and better flow into the site if they were aware of the exact amounts of products entering the next day or in the coming days.
The transparency, security and storytelling could potentially be facilitated by the introduction of blockchain technology,

The Danish Seafood sector still has an opportunity to become a first mover in utilizing a blockchain platform as a sector standard and ensuring sector wide application, with the potential to harvest a competitive edge when comparing to other EU members and possibly Norway and the UK as well.

where every stakeholder can be held accountable for their information. This adds to the potential to both tell and document the full story of the fish from catch to consumer and vise-versa if retraction of products due to food safety concerns occur. The Danish Seafood sector still has an opportunity to become a first mover in utilizing a blockchain platform as a sector standard and ensuring sector wide application, with the potential to harvest a competitive edge when comparing to other EU members and possibly Norway and the UK as well. This, however, depends on the joint action and timeliness of the Danish Seafood sector.

Based on the strong integration of the supply chain, the expected legislative changes and the individual interest in adopting a system to reduce time spent and flawed entries, this supply chain might represent a potential to become blockchain frontrunners.

Blockchain technology for plastic supply chains

Ports are industrial areas that contain a multitude of different industries. In the industrial park located at the Port of Aalborg, central stakeholders are exploring the potentials in recirculation of plastics. The following section identifies the challenges of plastic recirculation from the point of SMEs that through production are left with plastic waste, transporters, recyclers and public authorities, it shows the potentials created by introducing blockchain technology in plastic recirculation. The section is based on interviews conducted with central business stakeholders in and around the Port of Aalborg and a national digital scenario workshop on blockchain in the plastic industry.

Current cases of Blockchain usage

There is a large untapped potential for improving the circularity of the Danish, as well as the European and global plastic economy, as thoroughly described by the Ellen McArthur Foundation and the European Commission (see e.g. Ellen MacArthur Foundation 2015, 2017; European Commission 2020; Andersen et al. 2019). The potentials arise from addressing a number of challenges such as plastics from industries and businesses not being collected, uncertainty regarding the origin and usability of recycled plastics, and unstable supply of plastics for recycling. These challenges imply that it is difficult to create the volume of recyclable plastic that is necessary for viable value creation in plastic recycling.

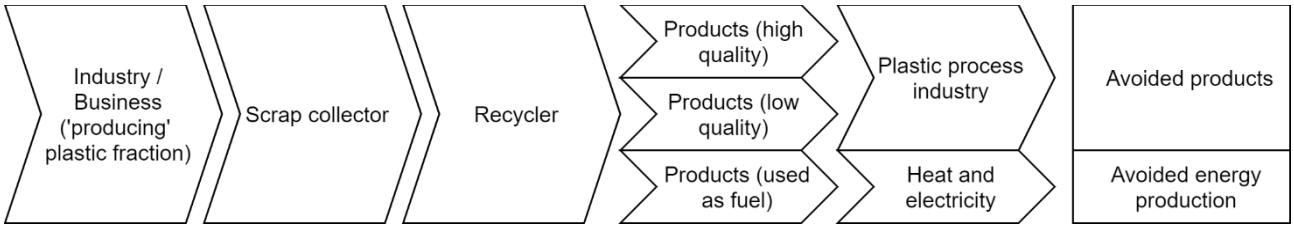
The exploration of the potentials of blockchain in the recirculation of plastics is relevant to both post-industrial and post-commercial plastic. Currently, the potential is limited in post-consumer plastic due to impurities and related low recyclability. However, the technology may hold potential also for post-consumer plastic through the creation of more diversified and quality optimized flows, and through increased transparency of the fate of recycled post-consumer plastic.

The main questions driving this exploratory process is how blockchain technology may assist in improving the circular economy of plastics, as this technology holds potential for reducing transaction costs while increasing the transparency of material flows.
Generally speaking, the industry of post-industrial and post-commercial plastic is made up of many small, independent recyclers with a low degree of digital maturity. In addition, the industry is yet to reach a price point where recycled plastic of less clean fractions become really interesting. Furthermore, waste carriers/scrap dealers are showing a limited degree of interest in changing the degree of digital maturity, mainly because the current business models do not require more detailed information. However, increased digitalization could hold the potential to change the dependency across the supply chain, which can create shifts in the value proposition. There is a need for incentives to increase input quantity and quality and thereby make the related stakeholders see a potential value capture. Increased quality and quantity will increase the usability of the recycled materials, but beyond this, the limited use of recycled materials indicate that there might be a need for incentives

beyond price and quality, pushing for increased use in production. Through interviews, several companies stated that the recycling of (plastic) materials only makes sense from a branding perspective, as the volumes and values/revenues typically are very limited compared to the core business activities.

The following generic flowchart inserted below illustrate how there is a need for focusing not only on the waste flow but also the information flow across central actors in the supply chain, where blockchain technology may assist in creating increased value. Specific pathways will vary, as the main part of high-quality products are based on waste feedstock traded directly between industries producing the plastic waste and industries recycling and selling on the market or returning the refined plastic product to the first industry. This relationship is characterized by a high level of trust between the involved stakeholders. The full generic flow as outlined typically involves products that crosses country borders, as many more difficult-to-sort mixed materials are often processed in Sweden, Poland and Germany. Prior to the Chinese waste import ban, much of this waste was exported out of Europe.

Figure 4: Generic flow of plastic waste



The main challenges for the plastic recycling supply chain (or network) is the difficulty of utilizing the plastics that come in smaller volumes, which until recently has been incinerated. It has to be said, that incineration with the high level of high-quality energy recovery, which characterizes the Danish waste sector, has been a fairly good solution, as the produced heat and electricity has been leading to a decrease in coal consumption for heat and electricity production. However, with the current and especially the near future technology mix in Danish heat and electricity production, incineration is an inefficient and polluting solution.

The blockchain solution 'Circularise' holds potential for resolving some of the challenges identified above and which plastic recycling faces. Circularise is a platform based on open standard (open source data) with the purpose of enabling transparency and sustainability of the plastics industry. The start-up project has been partly funded by the EU Horizon program and is currently exploring implementation together with European industries, including Borealis, Covestro, Domo Chemicals and Porsche. The concept is that every product leaving the factory is followed by information on production, which may include data that can be used to calculate life-cycle impacts, alongside data on composition, possible impurities etc. Through this, downstream users can retrieve data that can be essential to understand a given material or mixture of materials without compromising eventual production

secrets. The system is a decentralized information storage and communication platform building on a combination of blockchain technology, peer-to-peer technology and cryptographic zero-knowledge protocols. The advantage of the system is that it is already developed and documented. But as discussed in the following, the challenge is that the system is built to be used in major companies with large capacities in terms of knowledge and digital readiness, whereas the characteristics of Danish SME companies may require a more tailored and maybe modest system approach.

Potentials and challenges

Overall, the future potential users of recirculated plastics are the primary drivers for the potential of blockchain in plastic recirculation. The industry is currently challenged by a low demand for recirculated plastics. This is in part due to the low economic value added of using recycled plastic, which are only slightly cheaper than virgin plastic materials. There are also examples of recycled plastic in strongly branded products with prices exceeding virgin plastics. Furthermore, the cost of recycled plastics are related to handling-costs, whereas the cost of virgin plastics is strongly influenced by oil-market price. The implication of this is that the profitability of recycled plastics is as volatile as the oil marked.

Supply

The supply of plastics for recirculation is still rather uncultivated and many production companies handle their plastic waste as small combustibles. However, existing transportation of other waste streams creates potentials for including the transportation of plastics for recycling without significant additional costs. The pooling of scrap iron and plastics has created a focus on the potential for reusing plastic waste even though this waste type is less valuable than others. For this reason, it is pivotal that the sorting process of plastics does not create additional activities or incur additional costs on the side of the producer, otherwise it will not be incorporated in the process in the organization. These sorting processes, in addition, also represent challenges for many producers as employees find it difficult to sort the waste properly, e.g. in distinguishing between plastic and rubber.

For the suppliers of recycled plastics traceability is central and can be a selection point when choosing which recycler to collaborate with. This can create a brand value, so the value creation is not just located at the end user. In the (near) future, this might become a competitive lever in the industry, as it becomes a part of being a frontrunner.

While there is generally found to be a low digital maturity in the supply of recycled plastics there is a potential to add the waste flow to existing ERP solutions.

Demand

A central barrier for the demand of recirculated plastic is found in the need for producer guaranties advanced by customers. Many purchasing industries of plastics have very specific and high standards for the plastic quality and while these vary across industries it generally creates a legislative barrier that is difficult to alter. Thus, the potential for blockchain in the plastics industry is high if it can address the need for control of material quality. Actually, numerous industry actors expect that EU in

the coming years will advance legal document requirements on plastics, which can create a joint incentive for implementing processes with a higher degree of transparency and tracking.
The stability of supply is a central barrier for the demand and use of recycled plastics in production. Large fluctuations in the supply occur which makes it too unstable for producers to rely on.
Furthermore, there is still a barrier for producers to integrate recycled replacement materials in their production often because purchasers do not know which materials they can use. For this reason, matchmaking of materials is central when it comes to including more replacement materials.

Blockchain technology workshop

Blockchain technology does hold potentials for enhancing traceability and related corrective actions in the supply chain that may lead to higher quality of material and related higher value of waste products. In addition to this, blockchain technology also holds the potential to increase transparency while – when needed – keeping specific product properties or origins confidential (Licht et al. 2019). Specifically, to the Danish context several challenges currently stand in the way for unleashing this potential. These challenges were explored during an online participatory development workshop[6] that included main stakeholders in the plastic supply chain and block chain experts (for further description see Pizzol & Løkke 2020). Examples of statements from stakeholders in this domain collected during the workshop support the existing challenges, for example:

> *"Although many are interested in Blockchain there are not many situations where it is used in practice"*,
> *"It is not transparent as to where a waste stream comes from and ends up. It's an imperfect and immature marked"* and
> *"The value of recycled plastic is low, it can't pay for blockchain technology"*

Throughout the online workshop, a number of drivers were identified as important for the value added of blockchain technology in the plastic circular economy:

- Regulation. For example: "increased state requirements for recycling of plastic", "EU regulation", etc.
- Technology development. For example: "better and more mature blockchain", "development of blockchain infrastructure".
- Market. For example: "Prices for plastic", "Use of tokens", etc.

[6] On June 16th, 2020 DCEA organized an online participatory scenario workshop with 12 stakeholders related to the Danish blockchain and plastic industry. The participants in the workshop included representatives from industries that use, produce or process plastic and plastic waste, companies working with plastic waste logistics, the National Plastics Center, the Plastics Industry, and experts in blockchain technology from academia and the consultancy sector. The purpose of the workshop was to explore scenarios to be used in connection with the Maritimt Block-kraft project. More specifically, the purpose of the workshop was to derive scenarios that explore opportunities and barriers to the use of Blockchain technology in supporting increased and improved recycling of plastics, with a focus on post-industrial and post-commercial plastics, and on both SMEs and larger companies.

- Consumers. For example: “perception of consumers towards blockchain”, “consumer choices regarding sustainability”, “catastrophes affecting consumer perception”
- Strong actors. For example: “lead company models”, “strong interest organization”

The identified drivers were ranked according to their *importance* and *uncertainty* levels. Based on this, two types of drivers stood out as the most important if blockchain technology is to play a role in the improvement of plastic circular economy. These drivers reflect the technological maturity of the supply chain and the degree of institutionalization across the supply chain.
The first driver concerns the overall technological maturity of the supply chain in plastic recirculation. Here two technological developments are important. Firstly, improved technologies for identifying plastic materials, as the value of information collected in the blockchain on the materials needs to be checked and validated. Secondly, specific blockchain applications meeting the needs of the current and future SME infrastructure.
We stress that this driver does not concern the technology development in the blockchain domain itself, which was described as a separate driver: "(technological) development of better blockchain solutions". This was assessed of high importance but very low uncertainty. As stated by a participant: *"I am quite sure there will be development in this area* [blockchain, ed.]*, there is a lot of work in this area, I don't think this is where the problem is, although there is still a need for further development"*.
The second driver concerns leading markets players as strong actors and first movers that function as a "Leading example: a value chain uses blockchain and others are "forced"" to institutionalize block-chain as the primary data platform. This driver was ranked of medium importance and high uncer-tainty, as once triggered it becomes very important, but the possibility of it being triggered is currently unlikely. A leading example actor for blockchain technology in plastic recirculation could be a region, state, large retailer chain, or company, e.g. the example of Tradelens was mentioned*: "If Mærsk says either you use our system or you don't get any products then we are forced to jump in"*.

As such, the potential for enhancing value creation and capture through the supply chain by block-chain technology implementation requires identifying other missing actors:

- Municipalities might have some potential in guiding a focus on local waste recycling and plastic recycling.
- Newer platforms for plastic resale: Block-chain would be a significant value added to the plastic resale platforms, if they could more clearly specify the origin of the recycled plastic. However, the willingness is also low from the manufacturing companies where plastic is a by/waste product. This will, most likely, require an EU standard focusing on the reuse of waste fractions.

The challenge in the current system is large fractions being incinerated, a large fraction being recycled as low-quality materials, and too few products being suitable as high-quality materials. To improve this situation, communication and transparency is needed throughout the supply chain, and this com-munication needs to live up to two criteria: trust and low communication costs or efforts.

Blockchain technology seems to hold the potential for unleashing some of these preconditions for a functioning circular plastic economy, resolving challenges with the current lack of knowledge of how waste plastics move, and corresponding lack of transparency of where recycled plastics come from (the exemption is high quality industrial plastic waste where transparency and traceability in general is good).

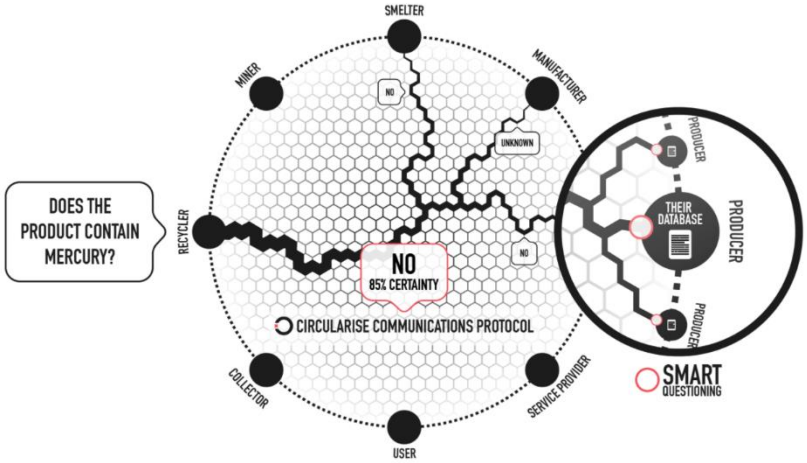
A block chain technology system will enable communication up and down the supply chain and will thereby enable the corrective actions (marked driven or otherwise) necessary to increase the quality of collected plastics to become part of the (future) circular economy.

Block chain technology in plastic recirculation

In principle all companies use plastic in some form. Using blockchain technology in circular plastic requires that all industries connect to the same network, using an interchangeable data format. The large challenge is to secure that data enter the system in a trustworthy way.

The approach suggested in the existing concept, Circularise, does to a large extent fulfil these needs, but will need to be supplemented by an approach tailored to the specific challenges here identified in Danish SMEs. Circularise is, from a supply-chain perspective, designed to be driven by data from the producers of basic chemicals and plastics, enabling downstream users – both primary, secondary and so forth users. The concept is that the primary producer of the plastic through the Circularise system, without disclosing full product recipes or other protected or proprietary knowledge, can disclose relevant information to users downstream. There are four key properties of the Circularise concept, namely that 1) product data is fragmented, in the sense that no single stakeholder holds all information, 2) exact properties of supply chains are often secret, 3) the information required is unknown, as the need occurs after the product is produced and information enters the system (future innovations and destinations of the materials are unknown), and 4) centralisation of data is not an option as open sharing of data may compromise competitive advantages (Circularise 2020). Circularise solves this, as mentioned in the previous section, with a combination of blockchain technology and cryptographic zero-knowledge protocols, as shown in figure 5:

Figure 5: Circularise concept
Source: (graphics reproduced from Circularise *(2020)* with consent from founder of Circularise, Mesbah Sabur)



An SME-tailor-made additional solution should bypass supply of data from suppliers of basic plastics and polymers. In principle this relates to the first system design property above i.e. '1) product data is fragmented, in the sense that no single stakeholder holds all information', but focuses on the need to work with imperfect data, and with the enabling of mechanisms for evaluation of data quality, and product quality. This leads to adding three *working criteria* to the four key properties mentioned earlier:

5) data may enter the product-chain at any level of the cascaded supply chain

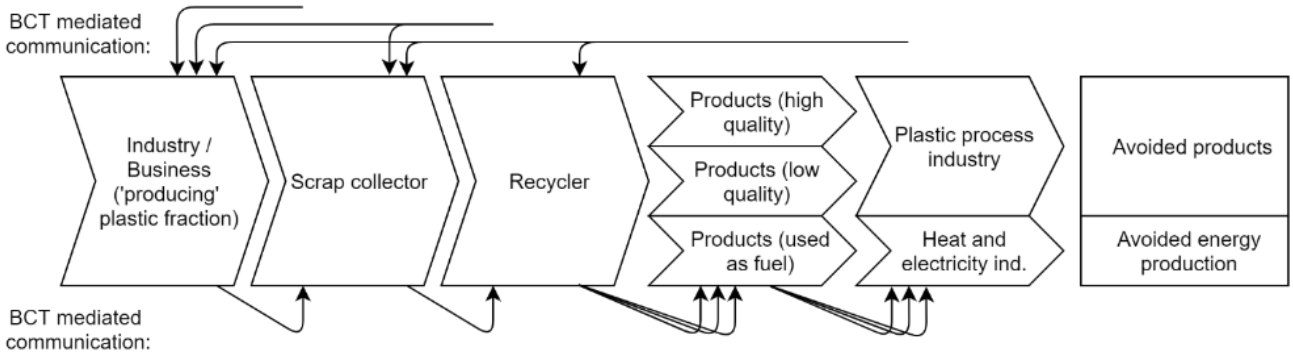
6) data may be incorrect or incomplete and traceability shall make it possible to give feedback to data-entry point

6a) product quality may be low e.g. due to impurities

7) data must be evaluated by spot-checks evaluating agreement between actual material properties and registered properties to support feedback and system learning.

The central aspect is that the system needs to have procedures for evaluating both data and product quality and related feedback and scoring of data- and material-input points. Challenges that need to be resolved include the level of data access, and the securing of communication that both respects the need for improved knowledge of quality of recycled or cascaded materials and of production sensitive information. The needed feedback loops are outlined below in figure 6.

Figure 6: (Danish) SME-tailored BCT-concept for circular economy triple loop learning (First order: what does the BCT-labeled material contain? Second order: What should be altered in the production to ensure higher recycling quality? Third order: learning about the circular economy of plastic as input for systemic learning for system changes for circular economy?).



This system is designed to support increased value-creation in the plastic economy by enabling transparency, traceability, and learning. In the following central exemplary use-cases are outlined (see table 4), and further steps are discussed.

System development should be compatible with the Circularise system, so that materials with Circularise blockchain technology verified labels from (first) producer of the plastic can blend into the system. The point is that the system as such becomes smarter with the activity of the communication links in the system. Basically, the system must be a network, able to evaluate and qualify inputs and flows, and especially, able to deal with imperfect information. Many of the data providers will be smaller SME's so entering data into the system needs to be 'app'-easy.

Table 4: Generic supply chains involving potential for circular plastic economy and the related potentials for using block chain technology to release the potential

Plastic CE Case / **Highlights**	Industry with high volume, clean, high quality waste material	Industry with high volume, but potentially very contaminated waste material	Industry with need for take-back of sold products	Producer of products with recycled content brand
Typical core Activities	Production of products, fully or partially of made of plastic.	Production of products where plastic is an important part of production, e.g. agricultural plastics.	Production of plastic-based technical components.	Production of consumer products.
Typical main challenge	Marginal: this type of plastic is currently recycled	Marginal: these types of plastic are to some extend recycled when marked value of materials are sufficiently high (oil-price dependent).	Logistics are too complicated, as products are spatially scattered. Currently most waste plastics are incinerated	Can the end-user trust that the product is actually produced on recycled content?
Potential advantage with blockchain supported enhanced circular plastic economy.	Marginal extra value due to certifiable traceability.	Marginal extra value due to certifiable traceability. Increased value due to certifiable traceability may have large impact on recycling rate, if this can be what push the value from red to black.	Involving a third party for material collection becomes a possibility with an industry-wide registration system	Certifiable origin, Easier access to larger marked, Enhanced possibility for evaluate purchased materials

Additional benefits of the system are overall increased knowledge of plastic flows, driven by a marked-based data collection and potentially decreased transaction costs for smaller fractions. A main challenge is related to the barriers for the development of the system. A system development needs to have both national and international dimensions. As identified in this work, we see that the active engagement of central stakeholders will be essential for a sufficiently rapid development, which must be combined with an industry-wide engagement.

As evident in the 'Circularise' project, the field of plastic recycling and traceability have blockchain frontrunners focusing at improving the circularity of plastic. For Danish SMEs, jumping on this trend would require a full system implementation at European level (i.e. that the plastic materials DK SMEs receive is already registered in the system) and significantly upgrading digital competencies. This would mean that Danish companies, being dominated by SMEss, would be on the rear end of this development. deemed to become late comers in this. However, with the system proposed here, we can create a system which is independent of, but also prepared for the upstream implementation. In such a project large Danish companies will take an important place a role models, and the project will take the real-life situation of SMEs into consideration focusing at a resilient system that can handle and evaluate imperfect information. This will move Danish companies from the rear end to become frontrunners in the quest for circular plastic economy.

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