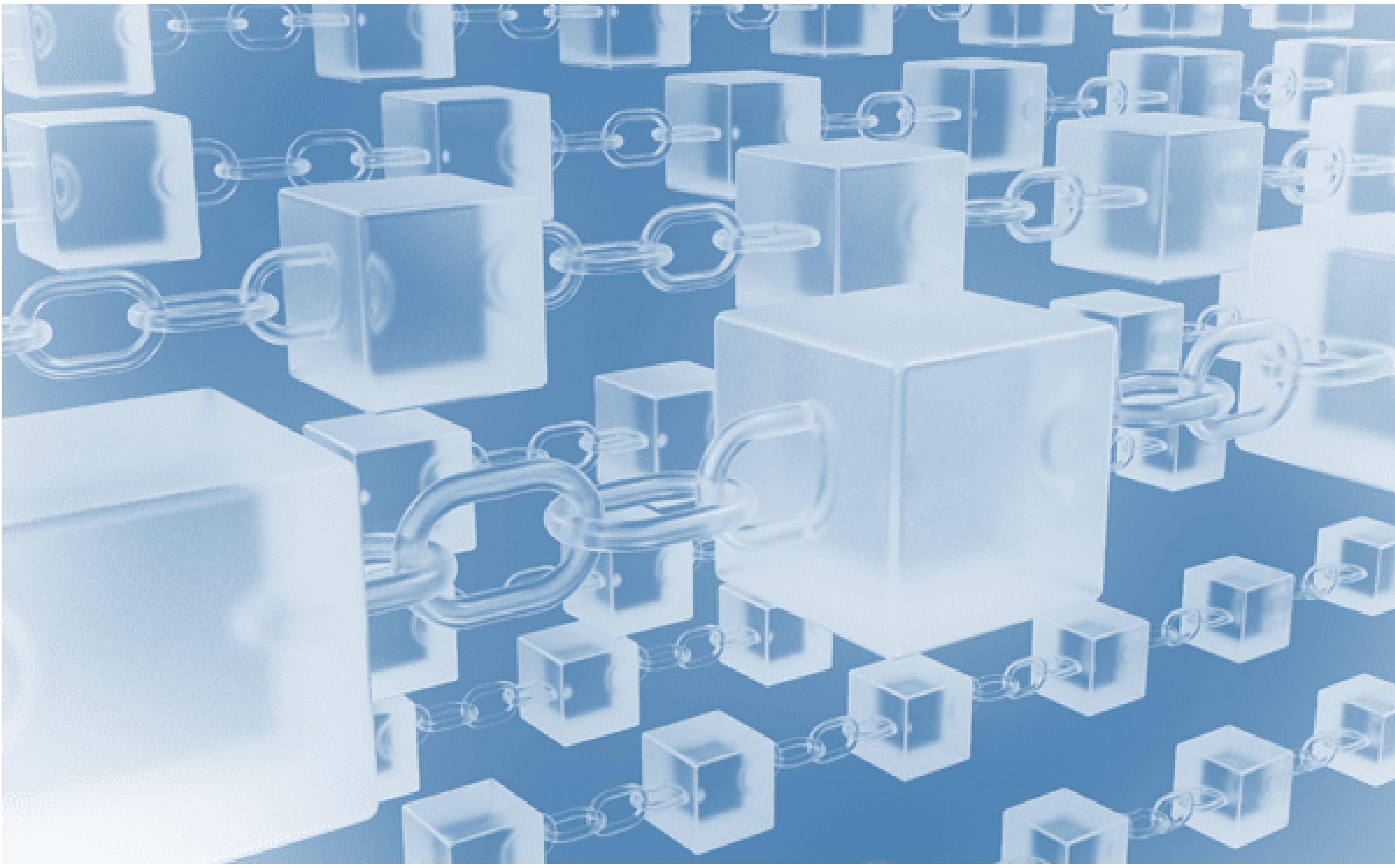
Internet of Things and Blockchain Technology for Product related use – a Literature review



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Ledelsesresume

- Denne rapport præsenterer resultaterne af et litteraturstudie indenfor forskning i informationssystemer for blockchain og Internet of Things teknologi med særlig fokus på produkter. Da rapporten er en del i et projekt, der omhandler danske designprodukter inkluderes ligeledes et studie af products lifecycle, som baggrundsviden.
- Indsigterne for hver teknologi præsenteres separat og kombinationen af de to dækkes også. Derfor er rapporten struktureret med tre afsnit - et for hver teknologi og et for det kombinerede. Dertil følger et overblik over product lifecycle mangament og metoden bag studiet
- Litteraturstudiet af blockchain teknologien påviser en stigning i et betydeligt antal af innovative ideer for anvendelse af blockchain teknologi. Et stort antal af proof-of-concept projekter har været succesfulde. For eksempel vedrørende herkomst og livscyklus fra farm til forbruger indenfor fødevarer. Der har imidlertid ikke været mange løsninger der har skaleret. Der er få af løsningerne som har leveret forretningsmæssig værdi som eksempelvis kryptovalutaer f. eks. bitcoin og transperans i forsyningskæden f. eks. TradeLens. Fire brugsscenarier indenfor produkter er identificeret: transperance, sporbarhed, autensitet, og bæredygtighed.
- Litteraturstudiet af IoT påviser et substatielt antal publikationer og et betydeligt omfang af brugsscenarier, primært indenfor elektronik.
- Kombinationen af IoT og blockchain teknologi er konceptuelt veludviklet og har været et emne for paneler ved konferencer i flere år. Imidlertid er kun få kommersielle eksempler beskrevet i akademiske udgivelser. Disse angår primært sporing af fødevarer.
- Brugsscenarierne hvor IoT og blockchain er kombineret for product lifecycle management og som er dokumenteret i forskningen, er begrænset til et par publikationer om sporbarhed i forsyningskæden - specielt indenfor fødevarer fra farm til retail og forbruger.
- Denne rapport er et af resultaterne fra projektet Avanceret Blockchain I Dansk Design, som er støttet af Industriens Fond i tæt samarbejde ml. Copenhagen Business School, DI Handel og Lifestyle Design Cluster.

Executive summary

- This report presents the results of a literature review for blockchain and Internet of Things technology used in relation to products published within the Information Systems research field. As the report is a part of the project focusing on Danish design products, a literature review of the product lifecycle is included as background knowledge to consider the whole lifespan of products.
- The results are presented for each of the two technologies separately, and their combination is also covered. Accordingly, the report is structured with three sections, one for each of the two technologies, respectively, and one section for the combination of IoT and blockchain, followed by an overview of product lifecycle management and the method used for the literature review.
- The literature review of blockchain technology reveals the rise of a sizeable number of innovative ideas for applications utilizing blockchain technology. A large number of proof-of-concept projects have been successful, e.g., for product lifecycle provenance, from farm to consumer within meat export. However, not many solutions have proven scalable. Concepts delivering value include cryptocurrencies, e.g., Bitcoin, and for supply chain transparency, e.g., TradeLens. Four use scenarios have been identified related to products.
- The literature review of IoT reveals a substantial number of publications and a considerable range of use scenarios primarily related to electronic products.
- The combination of IoT and blockchain technology is quite well developed conceptually and has been a topic for special interest groups and panels at conferences for several years. However, only a few real-life examples are described in the academic publications, especially for food tracing.
- The use scenarios, where IoT and blockchain technology are combined for product lifecycle management, which are documented in academics, are limited to a few publications about traceability in the supply chain specifically for food, from farm to retail and consumer.
- This report is one of the outputs of the **Advancing Blockchain for Danish Design (ABCD) project**, supported by the Danish Industry Foundation.

KORT OM PROJEKTET

Industriens Fond har gennem temaindkaldelsen ”Konkurrencekraft i blockchainteknologien” bevilget midler til projektet ”Blockchain i Business og Dansk Design”. Projektet er et samarbejde mellem Copenhagen Busines School, Lifestyle & Designcluster og DI Handel.

Formålet med projektet er at afdække, hvordan blockchainteknologi kan understøtte øget effektivitet, gennemsigtighed og en troværdig global forsyningskæde i handel- og designindustrien. Blockchainteknologi skal være med til at autentificere produktets ægthed og verificere, at råmaterialet kommer fra en bæredygtig kilde. Projektet ønsker at give danske virksomheder, deres leverandører og kunder kompetencer til at tage strategiske beslutninger om valg, implementering og inkorporering af blockchainteknologi i deres hovedaktiviteter. Derfor har projektet til hensigt at udvikle praktiske værktøjer til danske handels- og designvirksomheder til implementering af blockchain og IoT.

Følg med i projektet på www.blockchainbusiness.dk

BLOCKCHAIN I BUSINESS & DANSK DESIGN

INDUSTRIENS FOND FREMMER DANSK KONKURRENCEEVNE
The Danish Industry Foundation

Lifestyle & DesignCluster

DI Handel

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1. Introduction

Information technologies as blockchain and Internet of Things pose opportunities for businesses to generate business value. The latest knowledge is presented in this report, simultaneously aiming to provide an understanding of the technologies and illustrate the potential for business value creation posed by specific use scenarios.

The literature review aims to prepare for the future through understanding the past. The method used for the literature review is described in the appendix. The literature included in the review is two-folded. Firstly, the research from the Information Systems field is included, and secondly, knowledge from the industry about several initiatives containing blockchain and/or IoT technologies is also referenced.

We found 83 academic publications and thousands of industry initiatives. However, taking into account the scope of products primarily within design and fashion industries led us to a narrower focus, which reduced the number of relevant academic publications to 20.

The relevant academic publications are divided into, respectively, the ones regarding blockchain technology and IoT technology. Additionally, there are a few publications regarding combining those two technologies.

Publications	Search	Relevant to the scope of products within design and fashion industries	Focused on one technology	Combination of technologies	Business value
Academic	83	20	18	2	1
Industry	>1000	>20	>20	-	-

Table 1 Overview of the result of the literature review in the number of articles identified in academic literature published within the research field of Information Systems and in industry documents, further distributed on four dimensions.

The publications have been classified by characteristics of technology and degree of innovation (invention, prototype, proof of concept, commercially available, scaling externally, and delivering business value).

Blockchain technology is swiftly expanding its scope of potential use beyond the financial sector (e.g., Bitcoin), to include an increasing array of new areas of business value. Among these areas, supply chain management is an important one. Blockchain technology has the potential to improve the levels of transparency of supply chains in the following ways: To enhance the ability to trace products as they travel the supply chain; and to enhance their sustainability by, for instance, allowing stakeholders to verify the source of a product, and enabling the re-use of products at the end of their lifecycle (i.e., circular economy).

The design industry, defined as including furniture and textile companies, is flourishing. Nevertheless, it faces challenges in an era of digital transformation. For instance, consumers increasingly look for the possibility to verify the authenticity of branded design goods in global supply chains often challenged by counterfeit products. They want to be able to check and possibly reduce the environmental footprint of the design products. They demand that products are sourced in a socially responsible way. Danish design represents a flagship industry, and blockchain technology provides a unique opportunity to tackle these challenges and gain competitive advantages in both local and global markets.

2. Blockchain technology

The literature review of blockchain technology reveals the rise of a considerable number of innovative ideas for applications utilizing blockchain technology. Further, a large number of proof of concept (poc) projects have been successful, e.g., Walmarts poc-project and Danish Crown's poc-project for product lifecycle provenance from farm to consumer within meat export. However, not many solutions have proven to scale. Concepts delivering value include cryptocurrencies, e.g., Bitcoin, and supply chain transparency, e.g., TradeLens in the shipping industry.

Nakamoto (2008) designed the conceptual architecture of blockchain as a distributed ledger technology combined with a consensus mechanism and secured with cryptography. Blockchain is a long, ever-growing chronologically ordered logbook of timestamped events. Initially, it entailed transactional records of the cryptocurrency trade with sufficient information about transactions. The events are grouped into blocks that are hashed and linked in a cryptographic chain. A new block is distributed in the peer-to-peer network of nodes. Among the nodes that take part, they compete to calculate the most laborious cryptographic proof of work. As consensus is reached, the other nodes acknowledge the proof of work and add the block on their chain as well, resulting in every node holding an identical chain of blocks. To work, the nodes adhere to a standardized protocol for authenticating and inscribing transactions onto a block. The distributed design of blockchain, with its integrity and veracity, become protective against retroactive alteration. Altering information that has already been inscribed onto a block, requires consensus among the majority of nodes in the network to modify all subsequent blocks, which seems an almost impossible task once the blockchain network has grown sufficiently large. Therefore the blockchain is by design virtually immutable due to its resilience to manipulation.

The architecture design of blockchain provides some technological benefits of blockchain technology (Abeyratne & Monfared, 2016), which include reliability, transparency, immutability, process integrity, and more. Reliability because the decentralized network eliminates the risk that a central system unit can cause the entire system to collapse. Systems based on blockchain technology are therefore significantly more reliable than systems based on central critical components, e.g., a central database. This feature also makes it much more difficult to infect systems based on blockchain technology compared to central systems. Transparency, because every node in the network has a copy of all transactions and events. Therefore all activities are visible in real-time, increasing confidence in the blockchain-based system. Immutable, since the entire network has the same information. Since information cannot be deleted or changed but only added and everyone in the network by consensus acknowledge all additions, everyone can safely rely on the information and that it is accurate and historically unchanged. Process integrity because everything follows the open-source protocols that are executed as the code prescribes. Therefore users can be assured that actions are performed as described in the given protocol - on time and without dependence on human interaction – every event stored on the blockchain becomes fully traceable. As a result of the above, blockchains can be claimed to be more sustainable than alternative solutions.

There are many thousands of initiatives based on blockchain technology, each representing one or more use scenarios. Currently, it seems that blockchain technology is searching for use scenarios (Glaser, 2017). To cope with the number of use scenarios, those have been categorized based on the type of use scenario and target group. There have been several attempts to categorize use scenarios; some examples are given in the following. That blockchain potentially can transform organizations and economies is foreseen by Beck et al. (2018), who foresee new forms of governance and organizations enabled by blockchain. Clemons et al. (2017) foresee blockchain triggering economic changes, Mendling et al. (2018) foresee changes to business process management, Dai & Vasarhelyi (2017) to accounting, Gomber et al. (2018) to Fintech, Ølnes et al. (2017) to e-government. Cryptocurrency, as BitCoin and others, was the first successful example of solutions based on blockchain technology. Other examples of use scenarios (Schwartz & Merhout, 2019) include diamonds, wines, health care (health care), democracy (e.g., elections and polls), and social identity industry (democracy and social identity), energy (renewal energy), and food supply chain. White (2017) predicts the future applications of blockchain in business utilizing a Delphi study method resulting in a ranked list of 14 applications for use scenarios from currency to a performance management system. Only one (low ranked) use scenario relates to products being "Independent Certification of Product Quality." Further, Moyano & Ross (2017) explore the use scenario Know Your Customer (KYC), specifically within the bank sector. A Danish study (Beck et al., 2019) points to the following examples of use-scenarios that can be related to products, specifically food, counterfeit prevention, logistics, and process improvements in supplier networks; with the following examples: asset registration, asset tracking, provenance, tracking of containers, operations transactions, and insurance.

Medaglia and Damsgaard (2020) categories in four types of use scenarios have been identified related to products:

1. transparency
2. traceablity
3. authentication
4. sustainability.

Transparency includes visibility into the organization behind a product and to independent organizations verifying that the organization behind confirm to a set of regulations and standards which is documented through e.g. audits and certificates.

Traceability includes insight and possibily tracking the supply chain of the raw materials, components and the final product e.g. for valuable goods as diamonds and perishable food e.g. meat. Further, the life of the product can be traced from cradle to cradle including change of location and ownership, even the re-use and re-cycling can be included.

Authentication includes to identify the individual product is original and not a fake copy. This can involve a range of verification methods eg. embedded codes, chips and related to the products life journey from production to use and that the geographic trace is physical possible preventing fake copies easily can record events on the blockchain since time-line and trace cannot be unlogical.

Sustainability relates to transperancy into that the organizations involved are considered sustainable and can include enviromental accounting related to the product e.g. the CO^2 footprint.

For many of the use scenarios mentioned above proof of concept solutions exist. Take Walmarts poc-project and Danish Crowns poc-project, which use QR code to identify the individual box of meat[1] and link to the documentation of its provenance (without any IoT device involved). However, the prototypes and poc-projects have mainly been used to convince management/investors to provide funding for further developments; very few of these solutions are commercially available, and even fewer are scaling and successful in delivering business value. As mentioned above, several cryptocurrencies are thriving, especially BitCoin.It should be noted that within the BitCoin network, only the miners are motivated by earning for their work. Cryptocurrencies represent an alternative and can become a threat to the conventional finance sector. The disruption beyond the financial services is expected (Wörner et al., 2016). Within the supply chain, especially for container shipping, Tradelens by Maersk is commercially available. Already backed by major players in the industry that in total handle 2/3 of the world trade volume in containers, it is ready to deliver business value (Jensen et al., 2019).

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[1] https://www.industriensfond.dk/Bottom-up-blockchain-vaerdikaeder-i-foedevaresektoren
https://www.dr.dk/nyheder/regionale/oestjylland/blockchain-teknologi-skal-foelge-dansk-svinekoed-hele-vejen-til-kina

It should be noted that those two successful examples represent two different types of blockchains being permissionless and permissioned blockchain (for members only). Regardless, businesses need to evaluate the business opportunities of blockchain and when to invest, e.g., guided by Iansiti & Lakhani (2017) and Beck et al. (2018). Additionally, value creation and value capturing can be by different partners (Al-Debei and Avison 2010). Taking this into account, Chong et al. (2019) propose five different options for business models inspired by blockchain technology, and accordingly, several options for delivering business value can be further explored.

3. Internet of Things technology

The literature review of IoT reveals publication ten years back. However, the research field is sufficiently covered by Shim et al. (2017, 2019, 2020). Further, the possibilities for transforming businesses within industries are analyzed by Porter and Heppelmann (2014, 2015).

Internet of Things (IoT) consists of a device located at a thing of interest, and the device can act autonomously without human interaction. It communicates utilizing the internet (or similar communication network) whereby the things device can interact independently with other IT solutions. An example is a logistic tracking device that can be attached/included in a parcel whereby the location on its journey can be traced. The temperature, humidity, and vibration can be recorded as well if that’s supported by the IoT device. The level of sophistication can evolve significantly with rather complex architecture and advanced services.

IoT devices are being used by various industries such as transport and logistics, public sector, smart cities, industrial automation, and consumer electronics (Shim et al. 2019). The use scenarios of IoT devices for the industrial use identified in the literature review include consumer electronics, smart homes/offices, smart buildings, elderly care, gastronomy, water quality monitoring, utilities, public sector/smart cities, transportation and logistics, in airports, and industrial automation (Shim et al., 2017; Thangavel et al. 2019).

There are significant obstacles to the use of IoT devices (LeBuda & Gillespie, 2017), particularly regarding their power consumption. Since the devices need a power supply, they depend on battery power. Accordingly, power consumption becomes an essential factor. However, utilizing a low-power communication network address this, and some low-power consumption devices claim more than ten years of battery life per charge. All in all, many IoT solutions are commercially available.

One of the most successful IoT solutions is the RFID device that is attached to most products sold by retailers and similarly is used to track parcels logistically. The RFID chip originates from a mandate by Walmart and is standardized by the United Nations. It is operationalized by the not-for-profit organization GS1 standardizing European Article Number and Universal Product Code, among others delivering significant business value, especially to retailers. In food supply chains, the uses of passive Radio Frequency Identification (RFID) devices are well documented for food traceability (Cao et al. 2009).

4. Combination of blockchain technology and Internet of Things technology

The combination of IoT and blockchain technology is not well-covered by scientific publications. The knowledge about the concept is well developed and has been a topic for special interest groups and panels at conferences for several years. However, real-life examples are minimal, with only a handful of know cases available.

According to Shim et al. (2019), "…providing the transparency across different stakeholders and borders, the IoT implemented in combination with blockchain technologies can help to reduce misrepresentation and fraud in the entire supply chain." By leveraging blockchain technology, IoT devices can send data to a private blockchain-based tamper-resistant database. Thereby, only authorized stakeholders are allowed to access and contribute IoT data without the need for central control and management (Shim et al. 2017). With this setup, blockchain can become a solution to data security issues and identity management since blockchain technology can authenticate the identity of the nodes in a network. As such, it can verify that only authorized nodes can access data and maintain data privacy and access control (Shim et al., 2020).

Liu et al. (2019) propose the use of smart technologies like IoT, Cloud, and Digital Twin to Product Lifecycle Management; they propose to use blockchain technology for manufacturing in the area of Industry 4.0. Bahga and Madisetti (2016) and Liu et al. (2017) propose and build a prototype of a blockchain platform for industrial IoT. In the proposed solution, Huh et al. (2017), use the blockchain only to control and configure IoT devices. They predicted that blockchain technology with its ability to create a distributed and tamper-proof digital record system could turn IoT data traces from a security hazard into a reliable source of valuable data. Choi (2019) proposed an analytical model to study the blockchain-based supply chain operations for diamond authentication and certification process. Sidorov et al. (2019) presented an RFID protocol targeted for blockchain-based supply chain management systems.

In terms of false product identification, Alzahrani & Bulusu (2018) proposed a supply chain framework based on blockchain that can track products, detect modification, cloning, and/or tag re-application attacks. Toyoda et al. (2017) propose an RFID-attached product ownership management system which makes the efforts of counterfeiters to clone original tags redundant.

As for publications about solution(s) with the combination of IoT and blockchain technology for product lifecycle management, only one innovation has been explicitly identified for trace the supply chain for food from farm to retail and consumer. Tian et al. (2017) describe an extended concept with active sensors and the use of blockchain technology. They proposed a solution based on blockchain with IoT for traceability in the food supply chain. The solution is still in the initial stage of implementation. The use of IoT devices for consumer products is only predominant in consumer electronics, but not in any other categories. Therefore, the use of IoT devices for consumer products (such as furniture and fashion goods) is a new and emerging phenomenon.

Beyond the apparent technological challenges, the combination of IoT and blockchain convergence poses organizational adoption challenges as well, e.g., privacy protection of data from IoT sensors (Chanson et al., 2019). However, all of the above-described use scenarios are in an initial stage, hereof a few delivered proof of concept solutions. However, none of the publications report the successful creation of business value.

Given the lack of publications regarding the combined use of IoT and blockchain, it is foreseen that documenting product lifecycle in a holistic perspective (Geissdoerfer et al. 2017) to keep track of product sustainability, serviceability, and recycling can pose new business opportunities.

5. Categories of use scenarios, product-related scenarios, and business opportunities for product producers and resellers

The use scenarios described in the literature reviewed by Lacity (2018) are numerous for blockchain technology seen in the nearly 5,000 blockchain startup companies[2]. However, of the top 50 blockchains,[3] only two focus on products: ShipChain which tracks products across the supply chain, and FarmaTrust that tracks products from the point of origin through to the point of consumption to prevent fake pharmaceutical products.

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[2] https://angel.co/blockchains
[3] https://channels.theinnovationenterprise.com/articles/50-blockchain-startups-to-watch-out-for-20-1

The Danish Industry Foundation has reported [4] the economic potential of implementing blockchain for Danish SMEs and provide examples of use-scenarios that can be related to products:

1. food[5],
2. logistics,
3. counterfeit prevention,
4. process improvements in supplier networks;

specifically:

- asset registration,
- asset tracking,
- provenance,
- tracking of containers,
- operations transactions, and
- insurance.

The above examples of use-scenarios match to the categories specified in section 2 following Medaglia and Damsgaard (2020) with four types of use scenarios related to products:

1. transparency
2. traceablity
3. authentication
4. sustainability.

Outside academic publications, additional examples of blockchain-based prototypes related to a specific type of product have been identified for diamonds, wine, and luxury. Furthermore, examples have been identified related to specific characteristics of the products certified materials, sustainability, organic and fair trade. Moreover, examples have been identified that extend to the whole lifecycle of the product, including product service, product refurbishment, product resell, for example, for used cars (Notheisen et al., 2017), product donation, product recycling, and more.

[4] https://www.industriensfond.dk/economic-impact-of-blockchain

[5] Specifically for food trace based on blockchain technology a none scientifically report is published by Industriens Fond

Categories of use scenarios	Example of blockchain technology application	Example of combining IoT and blockchain technology
Finance	Cryptocurrency e.g. BitCoin following Nakamoto (2008) Know Your Customer (KYC) as described by Moyano & Ross (2017)	
Supply Chain	Containerized shipping eg. TradeLens as described by Jensen et al. (2019). ShipChain tracks products across the supply chain are described by Lacity (2018) Food supply chain use case is identified by Beck et al. (2019) For the blockchain-based supply chain operations for diamond authentication and certification process, an analytical model is proposed by Choi (2019).	Blockchain-based supply chain management system with a targeted RFID protocol presented by Sidorov et al. (2019) Trace within the supply chain for food from farm to retail and consumer with active sensors and the use of blockchain technology described as extended concept by Tian et al. (2017)
Trade	Use cases for health care and for renewal energy identified by Schwartz & Merhout (2019)	FarmaTrust tracks products from the point of origin through to the point of consumption to prevent fake pharmaceutical products is described by Lacity (2018)
Design Products	Valuable products as diamonds and wines are mentioned by Schwartz & Merhout (2019) Counterfeit prevention is described as use case by Beck et al. (2019) Independent certification of product quality is described by White (2017)	False product identification is described by Alzahrani & Bulusu (2018) and they propose a supply chain framework based on blockchain that can track products, detect modification, cloning, and/or tag re-application. For product ownership management system Toyoda et al. (2017) propose an RFID-attached which makes the efforts of counterfeiters to clone original tags redundant.

Table 2 Examples within selected industries of blockchain technology application, and of combined IoT and blockchain technology application.

Similarly, there are even more use scenarios with IoT. The most common IoT devices are related or even build into electrical/electronic products since this ensures power supply. The most successful IoT device is the extensive use of radio-frequency identification (RFID) tags within the retail industry, as described earlier.

In the scientifically documented use scenarios that utilize the two technologies combined, only two use-scenarios were singled out. Respectively, for food trace in China and supply chain for transport units (refrigerated containers in case of Tradelens) that can carry any product and with IoT devices measuring inside temperature and humidity, GPS location, and more. As Lacity, 2018 points out, "Not many enterprises have progressed their blockchain solutions beyond proofs-of-concept.". Of those mentioned above, only the Tradelens blockchain solution is commercially available and mowing towards delivering business value (Jensen et al., 2019). Maersk owns Tradelens. As Cusumano et al. (2019) point out, platforms power the world's most valuable companies, Chong et al. (2019) sketch five business models for blockchains to deliver business value.

6. Appendix: Product lifecycle

The literature review of product lifecycle reveals a long history where the producers have been the main driver and also the ones harvesting the benefits of managing the product throughout its life.

Product lifecycle was introduced in 1965 by Levitt, and Rink & Swan (1979) call for more research within product lifecycle management (PLM). Terzi et al., 2010 summarize its history and argue for a new role of PLM. Holler et al., 2016 argue for a closed-loop PLM. Stark,(2004, 2019) extend PLM to be "the business activity of managing, in the most effective way, a company's products across their lifecycles; from the very first idea for a product all the way through until it is retired and disposed of to product." A dedicated publication can be found in the International Journal of Product Lifecycle Management[6].

Product lifecycle management is an integrated part of the solution by ERP solutions by, e.g., SAP and Microsoft, and is characterized by separating the product itself from the information stored about the product. Furthermore, the information recorded is structured with a set of predefined record types sometimes annotated with versions; however, the history of the information is not visible.

[6] https://www.inderscience.com/jhome.php?jcode=ijplm

7. Appendix: Literature review methodology

The literature review has been conducted following the highly acknowledged guidance for literature review by Webster & Watson (2002), which recommends a structured approach, first identifying the relevant literature for the scope of the review. Secondly, develop the structure of the review, and lastly, submit it for publication with expected review and improvements.

The scope of the literature has been limited to the state of the art knowledge within Information Systems literature. In IS research, a set of eight high-ranking journals, also known as the Association for Information Systems' Senior Scholar's Basket of Journals,[7] is preferred.

Our approach to sort the source material for the review starts with the leading journals within the research field of Information Systems since those likely publish the significant knowledge contributions. Secondly, we looked at the leading conference proceedings[8] , especially the annual top conferences by the Association for Information Systems research, since they have a reputation for a high quality of knowledge.

Additionally, as Information Systems is an interdisciplinary research field straddling other disciplines, we searched for and reviewed literature from other research fields[9]. We have included literature covering the opportunities of use scenarios in the blockchain and IoT technologies outside the field of Information Systems.

Reading the identified articles and their citations lead to the identification of articles published earlier. Other published literature reviews, Risius and Spohrer (2017), Casino et al. (2019) represent a significant source, ensuring that all previous relevant publications are included. Furthermore, a few journals have published special issues focusing on blockchain technology, e.g., Journal of Association of Information Systems (Rossi et al., 2017)[10] and in the journal MIS Quarterly Executive (Lacity et

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[7] https://aisnet.org/general/custom.asp?page=SeniorScholarBasket
[8] Search within AIS eLibrary https://aisel.aisnet.org/ and Copenhagen Business School' library
[9] Through Google Scholar and journal databases like ABI/Inform (ProQuest)
[10] https://aisel.aisnet.org/jais/vol20/iss9/

al., 2019)[11] regarding delivering business value through enterprise blockchain applications. Further, searching for publications that cite those already identified published articles led forward to identifying the newest publications. Forthcoming articles from journals and conference proceedings have been identified, and with the approval of the authors, those have been included. The systematic approach to the search for relevant publications ensures the accumulation of a relatively complete census of relevant literature. Leading researchers have reviewed this literature review to ensure that all publications that they are aware of are included and interpreted to their understanding. Regardless if relevant publications are missing, please inform the authors of this literature review.

The speed of innovation within Information Technology is ever-accelerating wherefore it is important to understand that the literature review only represents the current status at the time of the review and the existing publications. New knowledge is expected to be published afterward. The present literature review does not express any scientific knowledge regarding predictions of the future (regardless that some researchers try to be predictive).

The structure of the literature review has been influenced by the scope given within the ABCD project, and the report reflects this. The structure is, as stated earlier, focused specifically on blockchain technology, IoT, and product lifecycle, and the combination of those. Furthermore, the focus zoom in on 1) the concept of each technology (with characteristics), 2) exploring identified use-scenarios opportunities, 3) evaluation concerning success as innovation, and 4) delivering business value. Each technology is characterized based on its premises; however, for a combination of several technologies, compatibility between them has to be considered. Based on the revealed possible use-scenarios, a set of characteristics including, e.g., organization and governance are extracted, and expected benefits and drawbacks are considered. The success of innovation is evaluated as 1) innovation 2) the internal adoption of the innovation within an organization, 3) the external scaling of the innovation among partner organizations, following the distinction of success of scaling argued by Henfridsson and Bygstad (2013). Proof of concept and associated

[11] https://aisel.aisnet.org/misqe/vol18/iss4/3/

solutions are considered as a critical milestone and typically evaluated by the innovation being used operationally within one organization, e.g., Product Information System that is governed and controlled solely by the organization and typically is expected to either reduce cost and/or improve efficiency. Generally, the investment in this level of innovation will require a favorable business calculation of, e.g., ROI. Innovations that require the usage of the innovative solution by several organizations and the business value delivered can be marginal per entity, but by scaling the business value can increase significantly, for example, when becoming a dominating platform (Gawer et al., 2019). Similarly, for blockchain solutions, five business models are sketched (Chong et al., 2019) for opportunities for delivering business value (Lacity, 2019) as, e.g., for Tradelens by Maersk (Jensen et al., 2019).

8. References

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