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Application of Blockchain Technology in the Manufacturing Industry

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The following paper shows both the high potential of blockchain for the manufacturing and machine tool industry in the future, as well as the challenges that occur with that technology. Several use cases of blockchain technology will be presented and discussed in this paper. Furthermore, we want to show the conditions under which blockchain solutions might be most beneficial and if block-chain will become a key technology to transform many industries.

Introduction

Recently, the cryptocurrency Bitcoin was at an all-time high, being worth more than 7,000 USD, which is six times the value at the beginning of the year. The hacker attack WannaCry from May, which used Bitcoin as a medium for the victims to pay the ransom, brought the cryptocurrency back to the public attention. Digital currencies, however, not only show their strengths in the criminal world, but their potential is also recognized by large banks.[1]

Bitcoin, as well as other digital currencies, are built on a technology called blockchain. Blockchains store data decentral and immutable, without a central authority. The financial and related industries already know the

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disruptive potential of the blockchain technology and its applications. There are several use cases besides digital currencies from foreign exchange transfer to identity management. Blockchain can also be applied in other industries, e.g. for travel management or intellectual property rights in the media industry.

However, it is still unclear if and to what extent the manufacturing industry is impacted by blockchain technology. Therefore, this work explores potential use cases for the manufacturing industry by conducting a market survey of existing blockchain solutions. Desk research is enriched with interviews with scientific and industrial experts in the field of blockchain technology.

Blockchain use cases in various industries – which might also be transferred to the manufacturing industry – will be illustrated before we focus specifically on use cases linked to manufacturing. The results of the market survey and the seven interviews are then used to discuss and evaluate future potentials of blockchain specifically in the manufacturing industry. This part begins with assessing the current maturity phase of blockchain using the Gartner Hype Cycle. Following, we evaluate potential applications in the manufacturing industry and therefore present a newly constructed matrix before giving an outlook into future developments.

Blockchain technology across industries

Although a fairly new technology, blockchain has many practical use cases and new applications of the technology are continuously introduced. This development is shown by a survey from the World Economic Forum from 2015, which predicts that 10% of global GDP will be stored on the blockchain by 2027.[2]

Table 1

Overview of blockchain use cases across industries

Use case	Examples	Description
Cryptocurrency	– Bitcoin, Litecoin, Dogecoin	– Digital coin used for payments
Smart contracts	– Utility Settlement Coin	– Currency backed by cash assets of the bank, used to decrease settlement time
	– Hyperledger Fabric	– Project for implementation of confidential smart contracts
Crowdfunding	– Swarmcoin	– Direct transfer of equity to ventures
Prediction markets	– Predictious – Fairlay	– Efficient implementation of prediction markets
Energy markets	– Smart Grids by LO3 Energy	– Local trading of solar energy
	– Wien Energy	– Trading of energy between utilities
	– Innogy	– Solution for automated billing of electrical vehicle charging stations
Smart property	– Lantmäteriet – Telia – Landshypoteket – SBAB – ChromaWay	– Transfer of property rights, for assets such as land or other tangible assets, using blockchain
	– Binded – Pixsy – TinEye – Ascribe	– Storage of intangible assets, such as intellectual property, wills, art and other documents

Besides the previously mentioned Bitcoin, the very first application of blockchain, further new digital currencies, like Litecoin and Dogecoin,[3] have evolved over time but could not replace Bitcoin as the most influential cryptocurrency. Consequently, we focus in the following subsection on use cases beyond those applications. An overview of the following use cases is given in Table 1.

Smart contracts

With the introduction of smart contracts, the number of use cases increased dramatically. Smart contracts can be described as "bundles of coded logic or procedures which sit beside the entries in the ledger."[4] If the preconditions of the contract are satisfied, the agreed upon business operations will automatically commence and do not require additional human interaction.[5] The benefits of using smart contracts are numerous. Transaction costs reduction and increased transparency are two key elements achieved through increased digital efficiency by cutting out the middle man. One such application, designed to ease intra-bank settlements, has been tested by UBS with a Utility Settlement Coin, which is regarded as a currency backed by cash assets of the bank, thus different from other cryptocurrencies.[6] Reducing the settlement time will not only yield in a quicker transfer of assets, but also reduce the default risk in case the counterparty is not paying. Further development in the trading industry has been made with the help of blockchain. Nasdaq started its Linq program in 2015, allowing actors to trade unlisted securities using blockchain.[7] In addition, trading solutions for primarily illiquid assets are currently developed.[8]

A further example of smart contract usage is the Hyper Ledger framework, an open source project, where IBM is a major contributor to the code development. The project involves ABN-AMRO, Intel, JP Morgan, Red Hat, VMware, Wells Fargo and other actors.[9] There are numerous projects based on the Hyper Ledger framework, one is called Fabric, which allows actors on a marketplace to set up confidential agreements through smart contracts.[10]

Energy markets

Energy markets are faced with the shift towards a market of prosumers with decentral production. Energy microgrids based on blockchain address this challenge. LO3 Energy has developed a technology for trading of solar energy locally using a peer-to-peer blockchain solution. The first real application with 50 physical units has been tested one year ago in Brooklyn, in cooperation with Siemens. The project "Brooklyn microgrids" applies smart meters for tracking energy generation and consumption combined with smart

contracts for energy transactions between actors on the grid.[11] One key question raised is the scalability of the project. Specifically, the computing power that is needed for validating the microgrid transactions and that is increasing with the grid size is considered as one of the key challenges for scaling the project.[12]

Other actors trying similar concepts are Wien Energy, that is focusing on energy trading between utilities, and Innogy, conducting tests with blockchain to automate the billing process of charging stations for electrical vehicles. Further development in the energy sector has been made by the startup Electron, that is creating technology that enables customers to faster switch their electricity suppliers.[13]

Smart property

The registration and transfer of property rights - land or other valuable assets like cars - can be realized through blockchain in a secure and efficient way. A first application has been tested in Sweden, with actors such as the Swedish National Land Survey Lantmäteriet, telecommunication company Telia, banks Landshypoteket and SBAB, and startup ChromaWay.[14]

Not only tangible, but also intangible assets can be transferred over blockchain; for instance, intellectual property rights, wills, art and other documents, which could be stored in the immutable blockchain.[15] Current actors developing solutions for this are Binded, Pixsy, TinEye and Ascribe.[16]

Blockchain technology in the manufacturing industry

The previously mentioned applications are a brief overview of possible uses for blockchain technology in different industries. While the majority of research projects is still focused on the technology itself and applications in the finance industry,[17] the interest to exploit blockchain in the manufacturing industry is increasing. Especially the application of blockchain for supply chain management and auditing is investigated by several start-ups and large companies. In addition, the role of blockchain for

Industry 4.0 and the Internet of Things (IoT) is discussed and some companies are combining blockchain solutions with 3D printing to enable

Table 2

Overview of blockchain use cases in the manufacturing industry

Use case	Examples	Description
Supply Chain Management and Digital Product Memory	– IBM and Maersk	– Tracking of containers during the shipping process
	– Provenance	– Recording of all important product information throughout the entire supply chain
	– Everledger	– Registers certifications and transaction history of diamonds on blockchain
Internet of Things and Industry 4.0 applications	– Factom Iris	– IoT device identification over blockchain
	– Super Computing Systems	– Sensors that timestamp data on the blockchain to save them from manipulation
	– Tile Data Processing – tilepay	– Marketplace to allow customers to sell their data from IoT devices
	– IOTA	– Cryptocurrency and blockchain protocol especially developed to meet the demands for IoT applications
	– IBM Watson IoT	– Platform to save selected IoT data on a private blockchain and share it with all involved business partners
3D printing	– Genesis of Things	– Platform to enable 3D printing via smart contracts
	– Moog Aircraft Group	– Ensuring safe 3D-printing of aircraft parts via blockchain

new manufacturing processes. An overview of the use cases that are introduced in this section is given in Table 2.

Supply chain management and digital product memory

IBM and the leading shipping company Maersk tested the application of blockchain in logistics.[18] They showed in a PoC, that a blockchain can be used to track containers during the shipping process. The goal of the project was to reduce the effort and paperwork that is necessary for the shipment. Through the platform, all actors in the supply chain can access the information that is relevant for them and they can act on it. In the future, other players like shippers, freight forwarders, ocean carriers, ports and customs authorities are going to be included in the platform. By reducing the paperwork, providing important information more rapidly and preventing shipping fraud, IBM and Maersk hope to reduce the shipment costs dramatically.[19]

In an effort to capture the entire supply chain, the start-up Project Provenance Ltd. is trying to secure the traceability of certifications and other important information of products on a blockchain. The idea is that every product gets a "digital passport" that proves its authenticity and helps to determine its origin, thereby preventing the sale of fake goods. According to the company, customers know "surprisingly little about most of the products" they consume every day.[20] A lot of valuable materials are wasted after the end of the product life cycle. In addition, poor working and environmental standards exist for many products. In contrast to existing solutions, where independent third-parties certify the product (e.g. Fairtrade, Soil Association), Provenance uses a blockchain to register every step of the production process. This ensures that the transfers of ownership are explicitly authorized by their relevant controllers without having to trust the behavior or competence of an incumbent processor. For the different participants in the supply chain, different software solutions exist to access the blockchain, to extract the relevant information for this participant and to confirm the step in the production process. Afterwards, the buyer can scan the product (e.g. via QR-Code or NFC) and access the information from the blockchain to check every step of the production process.[21]

Another start-up that is trying to increase the trust in products is "Everledger". It uses blockchain to register diamonds and secure their transaction history and ownership.[22] In the future, the start-up wants to extend the application of their technology to more luxury goods. In addition,

the CEO of Everledger believes that the technology can also be beneficial to identify machines in an IoT context.[23]

Internet of Things and Industry 4.0 applications

Solving the identification problem of IoT devices and reducing the vulnerability during this process are the goals of Factom Irisy. They realized that the current form of authentication based on certificates from authorities is too expensive for the IoT and that the scalability is questionable. Therefore, they want to register the devices on a blockchain to create a digital identity of the device which cannot be manipulated. It also offers the advantage that the information about the device can be dynamically updated and added in comparison to traditional certificates.[24]

The Super Computing Systems AG published a whitepaper in which they propose the usage of blockchain to timestamp sensor data for Industry 4.0 applications. To increase the level of trust between different parties, they want to create sensors that can save and thereby timestamp their data on a blockchain. As a result, it can be ensured that the data was not manipulated afterwards and that all standards were met.[25]

Besides using Blockchain to solve problems of IoT and Industry 4.0 applications, Tile Data Processing Inc. investigates the usage of blockchain to provide access to data that is generated by IoT devices. The idea is to enable customers to sell their IoT data via the service “tilepay”, where they can register and collect their data and decide who can purchase it. Companies who are interested in the data can subsequently purchase the real-time data and make a direct peer-to-peer payment to the customer via Bitcoin.

Before exploiting blockchain for IoT applications there are several technical challenges that need to be solved, mainly the limited scalability, the low verification speed and the incurring transaction fees. IOTA, a cryptocurrency especially built for the IoT, solves those problems by using a different kind of algorithm. Instead of using a classic blockchain, a directed acyclic graph called tangle is used.[26] Every participant who wants to make a transaction first needs to approve two previous ones. In the case of

conflicting transactions, a tip selective algorithm is used and the more likely one is chosen. As every user needs to work to make transactions, no additional transaction fee is necessary, which helps machine-to-machine microtransaction to become economically reasonable. At the same time, the new algorithm increases the verification speed and allows a better scalability.[27]

To enable small and midsized companies to leverage the benefits of IoT, IBM has introduced their Watson IoT platform.[28] The platform helps companies to save selected IoT data to a private blockchain, which is used to share the protected data among all business partners involved. While the platform is open to all industries and use cases, it is especially developed for supply chain, trade lane, asset management, regulatory and compliance use cases. In addition, IBM offers a consulting service to help customers realize their projects on the platform.[29] Furthermore, other concepts for IoT platforms based on blockchain are proposed but not practically deployed yet.[30]

3D printing platforms

Blechschmidt/Stöker (2016) published a working paper on how blockchain can eliminate the overhead in the manufacturing industry, which they call the "trust tax".[31] In the paper, they introduce the project "genesis of things", which is a cooperation of several companies, including Cognizant Technology Solutions GmbH, Innogy SE and Commerzbank AG. The goal of the project is to create a platform based on blockchain to facilitate the 3D printing supply chain. As a PoC, titanium cufflinks with a unique ID and digital product memory were produced using the platform. First, the designer registers his product design on the blockchain. To protect it from plagiarism the design is encrypted. Then the design file uses smart contracts to automatically negotiate pricing, find the nearest and cheapest 3D printer and negotiate conditions with the customer and the logistic service provider. All those steps are carried out without a middleman. After the order is produced, the blockchain provides a digital product memory, which includes the entire product history, e.g. the materials used in production or the ownership of the product. This knowledge can not only increase the trust of the customers but also enables large cost savings when it comes to warranty, maintenance or recycling.

Mr. Blechschmidt, Head of CIO Advisory at Cognizant Technology Solutions, plans to extend the project in the future to include lead users as well as certification agencies. Small and midsized companies could benefit the most from using 3D printing for manufacturing. Those users are often less digitalized and afraid to use 3D printing, because they are worried about intellectual property theft. From the new platform, they could benefit the most, especially through saving inventory costs and producing spare parts. The major challenges with the project were to convince customers from the benefits of using blockchain and the technical questions regarding which architecture to use or how the payments are made. In addition, it is still a challenge to include the entire supply chain, because there are often manual production steps involved and some machines do not allow to access their data digitally.

Another company that is using blockchain in combination with 3D printing is the Moog Aircraft Group. They want to use 3D printing to enable a point-of-use and time-of-use supply chain, where aircraft parts can be printed exactly when they are needed, saving inventory, import and logistic costs. In this project, the blockchain is used to securely transfer the data to a verified 3D printer. After the production, it enables authentication of the part, helping technicians to ensure that it was not counterfeit before the installation into an aircraft. A scan of the grain structure of each part is used as a fingerprint, guaranteeing that each individual part can be identified without a doubt. In addition, they want to use the platform to produce spare parts for discontinued aircraft models. Currently, the technology is used to register conventionally produced parts, because 3D printed parts are not allowed for flying yet, but in the future the system will be upgraded to allow a decentralized production. The vision is that customers in the future will only buy digital supply items and can decide themselves when and where to produce the part on a network of certified 3D printers.[32]

An approach to determine beneficial blockchain use cases

After presenting the current use cases of blockchain technology, this section describes the conditions under which blockchain solutions might be most beneficial.

PwC developed a framework to answer the question whether applying blockchain is useful for specific use cases. Since databanks with traditional software can also fulfil most of the requirements, certain conditions need to be met so that the strengths of blockchain take effect.

A decentralized collaborative system makes only sense when multiple parties are involved that need to share or update data in a reliable manner. The middle party, which is often only a medium for verification, can be cut off. This might be a business model in itself, because these intermediaries cause costs, increase complexity and provoke delays. Due to less intermediary and trust-related actions, the duration can be reduced and the efficiency increases. In particular, if several transactions interact with each other, applying the blockchain technology might be beneficial. This framework is used to assess some applications in the manufacturing industry.

A similar model describes the functionality of blockchain as "[m]anaging and securing digital relationships as part of a system of record over a layer of the Internet".[33] Consequently, the history of digital relationships is more important than the speed of transactions. A central authority is replaced, because it is connected to security flaws or high costs of trust.[34] Trust issues between many parties involved are the predominant underlying condition for applying blockchain. Those costs are described as "trust taxes".

The conditions above also present opportunities for blockchain technology. They can create new business models like asset sharing or improve existing (internal) processes. Therefore, the blockchain technology can be used to exploit the current business or explore new business models. In manufacturing processes, the irreversibility of data might be valuable for controlling and documenting quality. This would reduce the trust tax inherent in many processes. However, until now it is often still not completely certain where the real advantages compared to commonly used technological solutions lie and before decentral and collaborative processes have been established technically and culturally, the blockchain just serves as a medium. Convincing use cases, which are enabled solely by the blockchain, are still to come.

The main challenges today are the missing standards, the unclear legal and regulatory framework, lacking confidence and technical issues. These are also cited by the practitioners. Current blockchains have trouble with scalability and latency (i.e. verification speed). As explained above, the Bitcoin blockchain is limited to 7 transactions per second, because verifying a block with the standard size of 1 MB takes approximately 10 minutes.[35] Although the Ethereum protocol already achieves much faster verification speed of 12 seconds,[36] established networks such as VISA can handle 10,000 transactions per second.[37] Consequently, the worse performance figures still prevent blockchain from large-scale industry applications.

However, this does not mean that blockchains cannot be used in the manufacturing industry with real-time and big data. Even if it cannot be used for steering, the aggregated data can be stored on the blockchain and thereby also made available to other parties. Startups like BigchainDB or IOTA work on scalable blockchain solutions suited for the industry, which differs significantly from the Bitcoin solution with other consensus and verification concepts.

This rapid technological progress is one of the largest obstacles for real solutions after the PoC phase. The dynamic infrastructure allows only to experiment and poses also the challenge to integrate two separate blockchains. These technical issues will be overcome, but although the trend goes to decentralization,[38] the recent scandals and privacy issues[39] might prevent a faster adoption of the technology.

Discussion

In this section, the future potential of blockchain in the manufacturing industry is assessed. Therefore, in the first part, the maturity of blockchain is analysed with the Gartner Hype Cycle to predict future developments of the technology. Afterwards, based on the interviews and the results of the market survey, we determine the most promising potentials.

Assessment of the maturity and adoption

To validate potential applications for blockchain technology and assess expectable future developments, the current phase of blockchain needs to be determined first. Based on this assessment one can investigate which of the challenges companies have during the implementation of blockchain solutions are typical for the development phase and in addition expected developments can be forecasted. Therefore, the interviewed experts were asked to locate the current development phase of blockchain on the Gartner Hype Cycle.

The Gartner Hype Cycle is a commonly used tool to classify the maturity, adoption and social application of specific technologies. It was developed by the information technology firm Gartner Inc. and shows the expectations of a technology over the time since the technology emerged. The cycle is divided into five phases. After the technology is triggered the enthusiasm increases dramatically and unrealistic expectations emerge. When those expectations cannot be met, the peak is passed and the expectations fall into the trough of disillusionment. Afterwards, when an increasing number of people understands the technology, the slope of enlightenment happens and finally mainstream adoption takes place on the plateau of productivity.

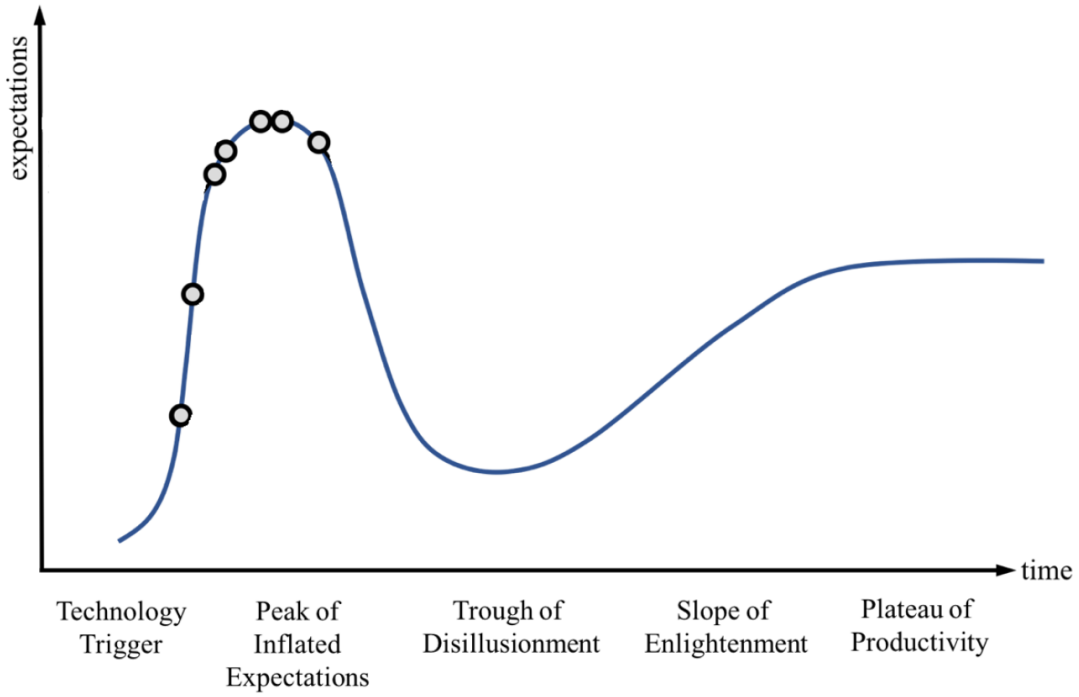
Figure 1 shows the Gartner Hype Cycle with the estimates of the interviewed experts. All agree that blockchain has not passed the trough of disillusionment yet and most think that blockchain is currently on the peak of inflated expectations or slightly before or after it. However, some believe the peak is still ahead and that the hype will increase even further in the next couple of years.

In general, the majority agrees that the hype will decrease in the medium or long-term, but one interviewee argues that it will not decrease below half of the gradient. Once companies will have implemented solutions with blockchain, they are unlikely to switch back to older technologies. In comparison, others advise to be cautious: while the hype might be real, it is noticeable that most companies still are not searching for many employees that have knowledge about blockchain, which might be a sign that the hype is not as big as many people believe. Companies that are working on or

starting new projects using blockchain should be prepared to experience setbacks and even loss of interest in their projects.

Figure 1

Assessment of blockchain in the Gartner Hype Cycle



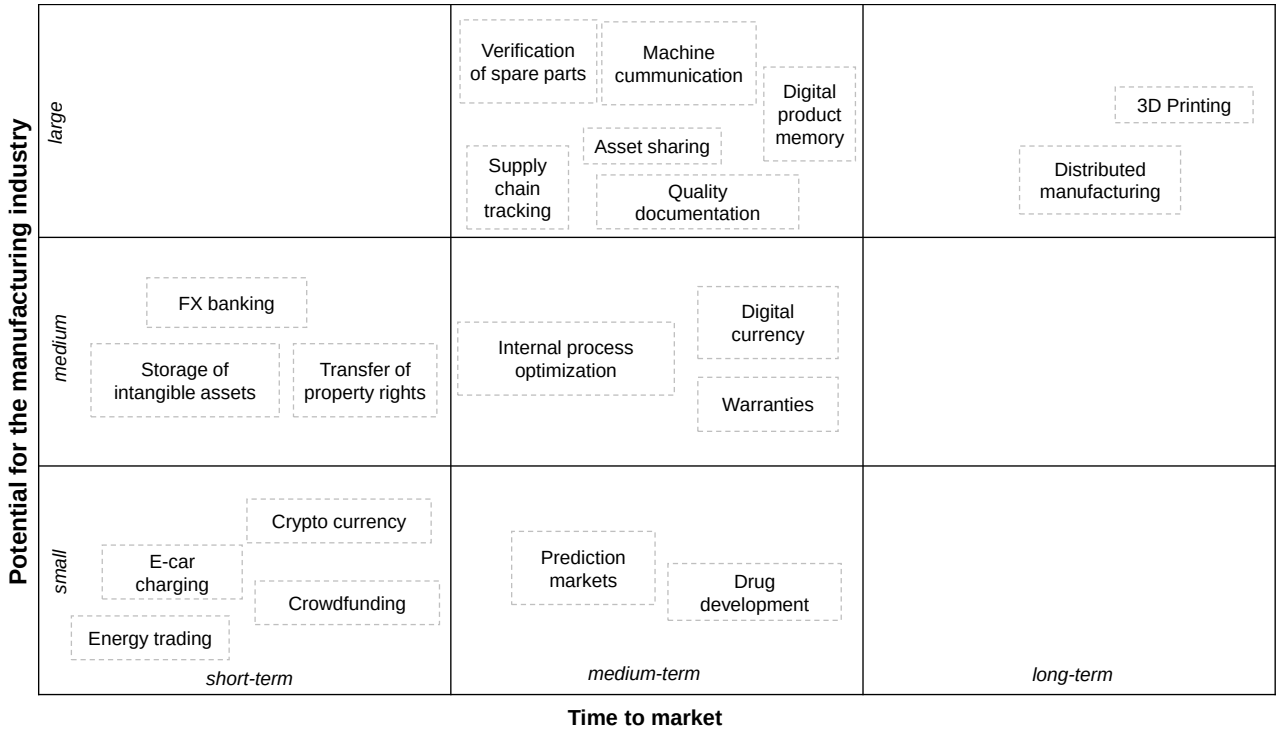
Evaluation of potential use cases

We identified several use cases of blockchain technology in the literature and through interviews with experts from science and industry. Since the existing use cases from literature were also covered by the interviews, we concentrated on insights from the latter and evaluated the potential for the manufacturing industry. For this reason, the applications were clustered according to the time horizon for market entry and their potential for the manufacturing industry (Figure 2).

These two dimensions were carefully chosen to structure the applications of blockchain. The first one is “time to market” because currently most use cases are only proofs of concept and still have to master the market entry stage. Sometimes, use cases are more driven by hype without real chances for implementation, but blockchain as a disruptive technology will develop its impact predominantly in the long-term. Most experts expect the market breakthrough in about five years.

Figure 2

Blockchain use cases and potential application for manufacturing



The second dimension in the Cross-Potential-Matrix is the “potential for the manufacturing industry”. Currently, there are not many applications specifically in the manufacturing industry and these also have different potentials for a significant impact. Sometimes, those concepts are not even in the PoC phase. However, considering the manufacturing industry in a

broader sense, some use cases might be transferred from other industries, which we call cross-potential. Asset sharing or supply chain tracking can be useful in most industries and even many use cases from the banking and energy sectors could be applied. Companies in the manufacturing industry usually have a large energy consumption and as global companies, they need a simple and cost-efficient treasury system.[40]

In the short term, most use cases are related to the finance and energy industries, because there the costs of intermediaries are most obvious. However, in the next years, the development will fasten and impact also the manufacturing industry directly, especially concerning data from the IoT and the supply chain. Distributed manufacturing and 3D printing will probably have the largest impact on this industry, but first the companies have to adapt their processes to a more open culture.

Table 3

Assessment of usefulness framework

	Multiple parties share data	Multiple parties update data	Requirement of verification	Intermediaries add cost and complexity	Interactions are time sensitive	Transaction interac-tion
3D printing	✓		✓	✓		✓
Asset sharing	✓	✓	✓		✓	✓
Digital product memory	✓	✓	✓	✓		
Distributed manufacturing	✓	✓	✓	✓		✓
Machine communication	✓	✓			✓	✓
Quality documentation	✓	✓	✓	✓		
Supply chain tracking	✓	✓	✓	✓		✓
Verification of spare parts	✓	✓	✓	✓		

Above, a framework have been presented to assess the benefits of applying blockchain technology for certain applications. Here, the PwC model is used, where four out of six criteria should be fulfilled. Table 3 presents the blockchain applications with the highest potential in manufacturing from the Cross-Potential-Matrix in Figure 2. The six criteria are applied and positive answers are signaled by checks. As a result, all potential applications satisfy the criteria of the framework. However, although they are useful and bear large potential, they will not enter the market before three to five years.

Outlook

This section gives an outlook into the near future of blockchain technology, by discussing the information and partly differing opinions we got at first hand by conducting interviews with several leading researchers and industry experts.

The interviewees consistently predict that the first successful use cases will be implemented and publicly announced within the next three to five years. As already shown above, the time to market differs significantly among the potential areas, caused by different technical requirements of the specific solution. Whereas many see the first more extensive implementations in the financial sector, other industries are catching up rapidly with their development. A good example is the energy sector, where promising PoCs, namely the cooperation project of Siemens with LO3 or the energy platform project StromDAO, have already been realized. Consensus prevails insofar that the commercialized usage of blockchain in the manufacturing industry will not be reached in this three to five-year period, mostly due to technical barriers.

Although technical challenges are the most obvious hurdles, the vast majority of experts considers them as solvable in the future. Even the limited scalability, one of the main problems and especially crucial in IoT or the manufacturing industry, seems to be effaceable with currently evolving concepts like IOTA. Besides these technical issues, the interviewees mentioned several additional obstacles that interestingly differ related to

their respective field of activity. Specifically, the energy sector seems to face regulatory challenges concerning the establishment of a blockchain-based energy platform, whereas legal issues of liability appear when it comes to 3D printing. Surprisingly, all participants agreed independently from each other that the main problem is the general openness towards this innovative technology. A lot of people seem to connect blockchain with the darknet and therefore have a negative association with it. Others never heard of the technology, or do not want to invest in a technology that could not live up to the expectations. In most cases, alternative and well-known solutions are preferred and prolongate the transition to blockchain solutions.

As mentioned above, experts predict a manageable time period to solve most of the hurdles that still prevent the industrial use of blockchain. Some interview partners see start-ups as the driving forces of this progress, rather than big and established industry companies. Nevertheless, big firms react to this development and start to increasingly invest in research, as they fear to become outdated by their competitors. Even though the impact of blockchain will firstly change internal business processes and not immediately challenge whole industry concepts, the role of established firms could change within their market.

Conclusion

This work shows the high potential of blockchain for the manufacturing and machine tool industry. Based on expert interviews and a market survey, a variety of use cases of blockchain technology in the manufacturing industry was identified. These use cases were analyzed using a cluster analysis and evaluated based on criteria for a beneficial application of blockchain. The cluster analysis assessed the potential of the use cases and the time until market entry. In addition, the cluster was used to identify cross-potentials, meaning use cases in other industries that are also relevant for the manufacturing industry. All experts agree that the first market-ready solutions that include blockchain will emerge in the next 3-5 years and our assessment of the use cases suggests that those applications will most likely be in the financial industry. According to the assessment of the interview partners and the Gartner Hype Cycle, the hype around blockchain is either already at the peak or short before. Therefore, one should expect a slope in excitement for the technology in the next couple of years. The major reason

for this development might be the technical and cultural challenges, but for the future, all experts agree that then those problems are solvable and that blockchain will become a key technology to transform many industries.

This paper focused on blockchain applications in the manufacturing industry and discloses potentials and challenges. Future research opportunities lie in a deeper analysis of the business processes in the manufacturing industry to further exploit the advantages of the blockchain technology.

If you like this article, we would be happy if you forward it to your colleagues or share it on social networks.

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