CHALLENGES AND BENEFITS OF BLOCKCHAIN IMPLEMENTATION IN SUPPLY CHAIN

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Abstract

This article presents the challenges and benefits of blockchain implementation in the supply chain. In a broader context, the article addresses how technology facilitates digitalization in a traditional industry, with no shortage of ideas and controversies. The findings are drawn from a case study of a Romanian tech startup. The empirical investigation uses interview and direct observation methods to show how the startup under study implements Industry 4.0 solutions based on blockchain technology. The findings demonstrate the feasibility of the technologies, the benefits for customers, and the challenges associated with them. So, it can be said that tech startups are real ambassadors of innovation and are able to change the status quo faster and easier. Their solutions and products have the potential to disrupt the industry and evolve into integrated platforms for artificial intelligence.

Keywords: blockchain, Industry 4.0, supply chain, tech start-ups

JEL Classification: L23, L26, M13, O33

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1. Introduction

Blockchain is one of the most widely used terms nowadays, both in academia and in the business world. The Blockchain system is an innovation that disrupts the level of established and traditional business processes, as applications or transactions can be decentralized with certainty. The blockchain is a data structure that is reproduced within the network and distributed between participants.

The amount of research in the field of blockchain systems is impressive, especially in relation to Bitcoin and other cryptocurrencies. The applicability of blockchain technology can also be observed in other fields of activity, such as: the Internet of Things, medicine, software engineering, logistics, banking, etc. However, popular virtual currencies are not the only application of blockchain technology. In the context of this paper, it is of great interest to see how this technology is also entering the supply chain sector.

According to Kim and Kinra (2019), blockchain technology is positioning itself as a digital innovation in the supply chain and, in particular, within the concept of Industry 4.0. In a complex yet comprehensive definition, Industry 4.0 "is the creation of self-optimizing cyber-physical systems by building upon various technologies, starting from the broad application of Information and Communication Technologies (ICTs), sensors, and robotics, through additive production, Internet-based uninterruptible communication and interaction, simulation and virtual modelling, cloud-based services, augmented reality, data mining, and artificial intelligence, as well as machine learning" (Kovacs, 2022, p.29). The definition attempts to capture all aspects of Industry 4.0, from hardware to software, and from visibility to predictability to improvement and optimization. In a nutshell, the author perfectly describes a smart/intelligent factory as a future paradigm for the manufacturing industry. The concept is also revisited in the 3rd part of this paper.

However, the blockchain concept and especially its applicability in manufacturing are still controversial. Business and academia are still looking for success stories that prove the feasibility of the concept through research and real-world implementation. We believe that the study contributes to this goal and is relevant for the literature and practice.

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The paper presents the challenges related to blockchain implementation in the relevant field, highlighting its benefits and the associated barriers. The article starts with the literature review, then presents an overview of the problem, and shows, through a case study, how this innovation was implemented by a Romanian tech startup focused on Industry 4.0. We conclude that the potential of blockchain in the supply chain is impressive, and it will be the task of startups to put it into practice.

2. Literature review

Blockchain or Distributed Ledger Technology (DLT) works with a technology based on an infrastructure and registers (Scheau and Zaharie, 2018). The nodes of the network, called miners, connect in chronological order the blocks that contain the hash of the previous block to create the blockchain (Crosby et al., 2016; Fran et al., 2018), keeping all transactions performed in a register. Thus, based on computer systems (located in separate places), transactions are confirmed and also different records are updated and synchronized in a network, through this technology based on an infrastructure and registers (Scheau and Zaharie, 2018).

Therefore, blockchain technology is similar to "a distributed registry based on cryptography" (Taylor et al., 2020, p. 147) which allows various transactions between participants who do not trust the network. The architecture of the blockchain system has several features, such as security, robustness, transparency, and auditability (Christidis and Devetsikiotis, 2016; Fran et al., 2018), which can bring both advantages and disadvantages.

The scale of this system and the popularity of its spread have demonstrated its lasting impact; its unique and safety features have made it a subject of great interest and the subject of numerous scientific studies (Taylor et al., 2020). Wang, Han, and Beynon-Davies (2019) examined how blockchain technology would influence supply chain policies and practices. The authors initially defined the technology similarly to Kim and Kinra (2019), but with the addition that there are two types of blockchain-public, where access is allowed to all participants in the system, and private, where there is an entity or group of entities that control access. There are also mixed blockchain systems that combine the characteristics of the two approaches. Based on an extensive literature review, the authors identified the main factors influencing the adoption of blockchain technology in the supply chain (Table 1).

Table no. 1. The main factors that influence the adoption of blockchain technology in the supply chain

Factor	Comments
Trust: reliability and security of information	The trust that blockchain technology brings is mentioned as the most important factor. This is possible due to the secure and anonymous nature of the transactions facilitated by the new technology.
Reducing the complexity of the supply chain	In today's world, supply chains span multiple continents and include numerous actors. A registry integrated with the blockchain allows all of these actors to connect in a secure and anonymous way.
Safety, authenticity, and legitimacy of products	Secure and anonymous transactions are a good guarantee that the associated products and services are also secure. Particularly in the food industry, this requirement is extremely important.
Public security and the fight against corruption	Last but not least, all the above elements contribute to a more open and safer society.

Source: adapted from Wang, Han and Beynon-Davies (2019)

Trust and transparency are also cited by Ghode et al. (2019) as the most important factors that impact the implementation of blockchain technology in the supply chain. The authors identified eight relevant challenges and even propose a ranking, accompanied by a grouping of the challenges. It is also worth noting that the authors do not limit themselves to technological and operational challenges, but also introduce themes with social and organizational connotations (Table 2).

In a recent research, Shoaib, Lim, and Wang (2020) identified 48 factors that contribute to the success of blockchain implementation in the supply chain. In line with previous research, the authors point to transparency, trust, disintermediation, and security as the main factors. As a novelty, the research also

brings into the discussion the idea of customer satisfaction and simplification of operational processes, as well as the aspect of sustainability. The social dimension of blockchain implementations in the supply chain is also highlighted by Francisco and Swanson (2018). The authors have correlated the behavioral intention with the anticipated performance and effort and, in particular, with the trust generated by the new technology.

Table no. 2. Challenges of Blockchain adoption in supply chain

Challenge	Purpose	Category	Place
Inter-organizational trust	Overcoming mistrust between business partners in the supply chain network	Organizational	1
Relational governance	Achieving cooperation between the different parties involved in the supply chain	Organizational	3
Transparency of data	The balance between data transparency and confidentiality in the blockchain to achieve maximum profit	Technological	4
Immutability of data	Restoring or correcting data in case of wrong entry, due to unexpected events and to avoid hacking	Technological	5
Interoperability	Sharing information of manufacturers, suppliers, customers, and other actors in the supply chain	Operational	2
Type of product	Avoiding fraud by eliminating the intermediary in different types of supply chains	Operational	7
Social influence	Certification of socially responsible production methods	Social	8
Behavioral intent	Assessing the behavior of stakeholders in the supply chain towards blockchain adoption	Social	6

Source: adapted from Ghode et al. (2019)

After reviewing the main factors that determine the adoption in the supply chain, it is also time to look at the key benefits and applications of the technology. Wang, Han, and Beynon-Davies (2019) have presented a number of benefits without claiming to provide an exhaustive list (Table 3). The authors note that, given the early stage of the technology, blockchain applications in the supply chain are expected to explode in the coming period.

Table no. 3. The main benefits of blockchain technology in supply chain

Benefit	Comments
Extended visibility and traceability of products	As mentioned above, the trust brought about by the new technology is probably the most important aspect. By its nature, every transaction along a blockchain supply chain is fully auditable, and every block in the system is traceable and transparent.
Digitalization and disintermediation of the supply chain	Currently, the integrity of transactions in the supply chain is generally usually ensured by a specialized intermediary. In the new paradigm, the entire network ensures this integration, eliminating the need for an intermediary.
Improved data security for information exchange	The data in the blockchain is considered immutable because the transaction sequence is saved in chronological blocks of nodes broadcast to all other nodes. This prevents any possible falsification of the data by any participant in the network.
Smart contracts	A smart contract is defined as a computerized transaction protocol that automatically executes the terms of a contract on a blockchain. This benefit has direct effects on complex transactions in the supply chain, as it minimizes human intervention and secures the execution of contracts. For this reason, many authors value smart contracts as the most important benefit of blockchain technology.

Source: adapted from Wang, Han and Beynon-Davies (2019)

A study conducted by Kim and Kinra (2019) also showed that the benefits of blockchain technology in the supply chain are found, in particular, in terms of data availability, immutability, and consistency of data. Transparency, coordination, and visibility of the supply chain are also among the benefits, as

well as increased security and reduced errors. Last but not least, these authors also mention smart contracts as the main benefit of blockchain technology in the supply chain. The same benefits are also mentioned by Cole, Stevenson, and Aitken (2019), with a new focus on data immutability and smart contracts. The authors also presented potential applications and case studies of blockchain technology in the supply chain, including:

- Increase the safety and security of products by providing safety test records. Case study – pharmaceutical industry
- Improve quality management by providing visible and easily accessible batch information, supporting recalls, and improving services. Case study – automotive industry
- Improving and automating contracts and reducing the need to develop trusting relationships within the supply chain. Case study – food industry, in particular related to food safety
- Improving stock management. Case study – any industry
- Reducing the need for intermediaries, thereby reducing the complexity of the supply chain. Case study - removal of certification bodies
- Accelerating the design and development of new products by improving efficiency and ensuring greater transparency between teams. Case study – any industry
- Reducing the cost of transactions through automation, enabling real-time auditing. Case study – smart contracts

The review of blockchain implementation in the supply chain together with the associated technologies revealed some common and important aspects. Firstly, they are still in their infancy, where ideas are clarified ideas and controversies. The application of these technologies is also questionable; many of them can be categorized as solutions waiting for problems to be solved. Second, however, their potential is very large and only implementation in practice (as we will see in the next chapter) can truly validate this technology. Finally, it should be stressed that these technologies work together and that their implementation is part of a larger effort to digitize entire processes.

3. Overview of the problem

The supply chain industry, including production and manufacturing, has a large amount of information. On the other hand, there is constant pressure to increase performance and track traceability. Especially the last aspect is also critical for customers, who are becoming more demanding under the current conditions. Therefore, the main problem for production companies is therefore how to use this data to increase productivity and customer service.

The technologies used in the past did not allow us to reach high standards in this field. The explosive development of recent times allowed the emergence of new technologies integrated by tech startups. One of these technologies is Blockchain, which in combination with other technologies (e.g., IoT) has given rise to the phenomenon of Industry 4.0.

Industry 4.0 is the current trend of automation and data exchange in manufacturing technology, which creates the so-called smart factories. A smart factory is a leap forward from traditional automation to a fully connected and flexible system that can use a constant flow of data from connected operational and production systems to learn and adapt to new requirements. In this context, Blockchain technology is the backbone that ensures a streamlined flow of data and information. Technology is nothing new in manufacturing. Since at least 1913, when Henry Ford's assembly line was widespread, factories have incorporated the latest technologies to make products faster, better, and cheaper.

However, manufacturing productivity appears to have reached a plateau, despite notable advances in factory equipment, new software, and manufacturing processes. Labor productivity developments continue to be a concern for most producers, with annual growth of around 0.7% between 2007 and 2018, in stark contrast to the average annual growth rate of 3.6%observed between 1987 and 2006. Simply put, production levels are strictly correlated with the number of hours worked, rather than increasing as has been the case for most of the past seven decades (Deloitte and MAPI - Smart Factory Study - 2019).

All manufacturers face common challenges:

- Performance is influenced by several different business or environmental variables, not all captured accurately or in real time.
- Only a small part of the data captured in production is analyzed.
- Performance analysis is not done in real time, causing delays in critical decisions.
- Complex analysis of process events in a certain context is almost impossible when modelled in Excel or any other internal software package.
- Operators use expensive machines that can suffer damage and downtime due to workload, personnel rotation, and potential handling errors.
- Existing software solutions on the market can usually be implemented in months and sometimes depend on complex customization and / or interfaces.

The same Deloitte and MAPI study cited above estimates that the manufacturing industry produces about 16% of the EU's GDP and that the total market dedicated to the Industry 4.0 phenomenon may reach 185 billion euros by 2025. Over the next few years, European industrial companies will invest €140 billion annually in Industry 4.0 initiatives. By 2025, more than 80% of companies will digitize their value chain. Deloitte's study also argues that 86% of manufacturers think that smart factory initiatives will be the main driver of production competitiveness in 5 years. Finally, the study presents two stages of adoption of new technologies: Phase 1 (2019-2024) is a relatively slow but steady adoption, while in Phase 2 (2025-2030) we will have accelerated adoption.

As can be seen, the study was developed before the COVID-19 pandemic. In our opinion, the identified trends clearly remain real and valid, but we can notice that their adoption is much faster and more comprehensive. Most likely, the Phase 2 mentioned in the study is already underway.

4. Methodology

The research findings are presented through a case study of a Romanian tech startup focused on Industry 4.0 called KFactory. The start-up was founded in 2019 by two engineers with significant experience in both manufacturing and information technology. Their vision is to become a recognized brand for deep-tech Industry 4.0 solutions for advanced manufacturing in the world and catalysts for the irreversible digital transformation of operational processes.

KFactory is part of the first wave of Industry 4.0 startups that disrupt the manufacturing industry and innovate a specific core process in production line performance management. The company is integrating new technologies such as blockchain, IoT and machine learning into the manufacturing process, transforming a classic process into a new one where industrial equipment, commands, operators and support departments are actors in a well-orchestrated digital process. Integrating artificial intelligence components into the process is a revolutionary process in which KFactory understands the behavior of performance components in relation to the production process. The company's vision is to help factories solve complex problems in a simple and intelligent way using industry knowledge and technology.

Yin (2014) mentions that the case study is an empirical investigation that becomes the preferred method when three conditions are met: 1. A contemporary phenomenon (the case itself) is investigated in a real context; 2. The researcher has little control over the events; 3. The answer to questions such as how or why is sought. Based on these conditions, the main advantages of the case study as a research method are: the investigation is deep and thorough, the analysis of the phenomenon is continuous, it allows comparisons with other studies, and provides a general increase in knowledge. Nevertheless, the method also has certain disadvantages, such as limited representativeness, an inherently subjective approach, and the possibility of bias and error.

The information contained in the case study was obtained from a variety of sources, both primary and secondary.

As regards to primary sources, the studies were conducted using semi-structured qualitative interviews according to the systematic methodology described by Rabionet (2011). First, the appropriateness of semi-structured interviews as a rigorous method of data collection on the research

topic was evaluated. In order to obtain valid data, we decided to directly interview the experts in the field in order to obtain empirical evidence on the studied area. For this purpose, a qualitative analysis based on a semi-structured interview could be the best method. In fact, the format of the interview consisted of a set of predetermined open-ended questions, as well as additional questions that emerged from the dialogue between the interviewer and the respondent. Therefore, the use of a semi-structured interview format provides deep insight into the research topic. The interview with the founders of the start-up was conducted according to the framework presented in Annex 1.

As for the secondary sources, the documentary research was also carried out by analysing various documents to identify the components of the company. This category includes the start-up's website, press appearances by the founders or collaborators, financial statements, and internal reports, as well as other materials provided by the company.

5. Results and discussion

KFactory combines industry knowledge with the latest technologies to generate value and results. The system collects data from multiple sources and analyzes it in context, finding answers to questions like *Why did my performance drop that day*? *What will be the impact of the production of command X on car Y on period Z*?

As described in the methodology, the start-up was founded by two engineers who have different roles within the company; one co-founder is responsible for commercial and business development, while the other co-founder is responsible for product and technical development. Therefore, the semi-structured interview took this distinction into account.

According to the statements of the commercial leader, the business proposition of KFactory is based on two levels of analysis:

- the *hot* analysis component that handles the process in real time and detects anomalies or a combination of variables that can lead to a risk in the process, signaling the process manager on multiple channels (e.g., real-time SMS).
- advanced analytics components, which include scenarios, behaviors, and predictions of the future.

As a result, the key features of the platform can be summarized in the following points:

- It is built on the best practices of the industry worldwide and can be used by any production company.
- Fast user adoption, easy to use.
- Very short implementation cycle.
- Software as a service (SaaS), subscription type – no implementation fee, no investment in software development, operating cost model based on subscription.
- Agnostic industrial equipment – any type of industrial equipment can be connected and monitored in KFactory.

The main benefits for customers come from the platform's features, as listed below. The commercial leader mentioned during the interview that the startup is continuously working on enhancing these benefits and, most importantly, adapting them to specific industries. He stated very clearly: “We had our initial customers in the automotive sector, which is one of the top industries in Romania. However, we need to look further to new verticals and new geographies if we really want to become a global player”.

- Increased productivity from the first day of use. Current customers have seen productivity gains of more than 20% in the first months of use.
- Reducing operational costs by automating the data collection and reporting effort.
- Complete visibility over the process, real-time performance tracking.
- Fast return on investment thanks to the SaaS model.

The interview with the technical leader focused more on characteristics of the product and future roadmap. With all the advantages offered, according to the statements of the technical leader, the

solution represents a first step in the digitization of supply chain processes. KFactory's vision is much broader and is aimed at the sustained and adequate development of real artificial intelligence processes, called virtual engineers.

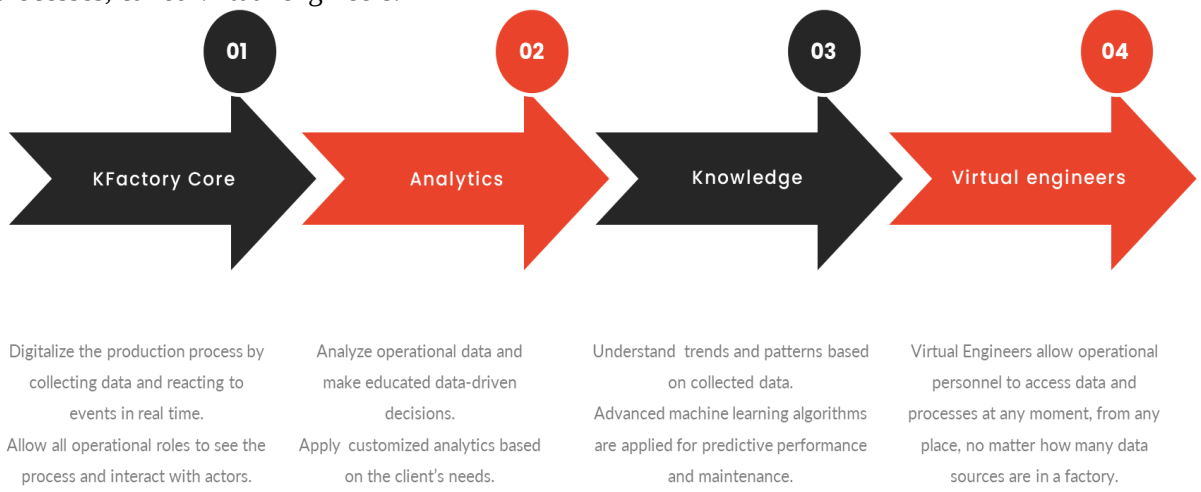

Fig. no. 1. The digitization process in KFactory's vision
Source: adapted from the KFactory strategy

KFactory Core enables real-time control of the manufacturing process and detects deviations from the production plan, as well as undesirable behaviour of operators or support teams. Smart notifications enable managers to act before losses occur, maximising production time. It also monitors energy use in real time using data collected by sensors.

KFactory Analytics is the ideal tool for comprehending production outcomes and making data-driven decisions.

KFactory Knowledge goes far beyond to identify trends and patterns in your operating processes and predict maintenance needs, reducing maintenance costs and downtime and increasing machine uptime.

The Virtual Engineers Team serves as an extension of the physical factory staff, offering suggestions and advice to management. Virtual engineers are extremely valuable because they have access to all data in a factory via blockchain technology, manage processes, and perform administrative tasks, allowing the human engineer to be better used elsewhere in the factory. Virtual engineers know everything about a factory's operations and help drive the adoption of digital systems without having to deal with the difficulties and complexities of integration projects. The technical leader stated: "We know that the core product is very good and meets the needs of customers. But the concept of virtual engineers will really set us apart as an artificial intelligence platform and change the status quo in the industry."

The key features of the concept are listed below:

- Technology enables virtual engineers to access and inform everything related to operational processes;
- Virtual engineers manage improvement plans, maintenance interventions, quality issues, and meeting reports;
- When a forwarded meeting or message is required, a virtual engineer can do it, saving time.
- Virtual engineers use Microsoft Teams chat to communicate;
- The dialogues are conducted in natural language, using more than 35 different languages.

The virtual engineers can be deployed in any process or department in a factory. The roadmap presented by the team is comprehensive, but a particular focus is on the virtual quality engineer, which simplifies the work of quality assurance personnel by providing real-time data, integrating multiple systems, and alerting them to problems as they occur. This feature has already been

implemented in several Romanian factories and has been very well received by customers. Another add-on is the Green Virtual Engineer, which helps companies achieve 100% compliance with EU regulations in terms of carbon emissions.

6. Conclusions

Transparency and automation of supply chain processes is a key area of business innovation supported by emerging technologies such as blockchain. In reviewing the literature, it was found that these concepts are still controversial and their feasibility is debatable. Combined with the ease of implementation and use, KFactory's solutions can bring important benefits to companies in this area and have the prospect of evolving into integrated artificial intelligence platforms. We expect that the future will bring large-scale partnerships between innovative technology startups and medium and large supply chain companies. The results of the study add to the findings in the literature and fill the gap with a concrete example of the successful implementation of blockchain technology in the supply chain.

The paper has certain limitations in that it is a single but representative case study. However, there is a legitimate question as to whether the conclusions drawn for the entire ecosystem can be generalized. Yin (2014) believes that there are two types of generalization: statistical and analytical. Statistical generalization is not applicable to case studies because they are laboratory studies rather than sampling units. Therefore, the case study method is suitable for analytical generalization. In a different context, but in the same vein, Schumpeter (1954, p. 281) states that "analytic generalization can arise from observation triggered by concern for practical problems.

In order to overcome these inherent limitations, we intend to deepen the research by focusing on the processes and improvements achieved by these technologies through quantitative data and statistical analysis.

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Annex 1

Guide to the interview with the founders of KFactory

Activity	Comments/Questions	Approximate Time
Purpose of the interview	Identifying and understanding the main aspects and key components of your start-up.	
Introduction	Thank you for agreeing to participate in this interview. We interview you to better understand your ideas and opinions related to your company's business model. There are no correct or wrong answers to any of our questions, we are interested in your own opinions. Participation is voluntary. The interview should last about an hour, depending on how much information you want to communicate. All responses will be shared with members of the research team and we will use the information received from you to build a case study for teaching purposes. You may refuse to answer any questions or stop the interview at any time and for any reason. Are there any questions about what I just explained?	5 minutes
Establishing the Quality of the Interviewee	Before we begin, it would be useful if you could tell me a bit about yourself and your position/role in the company.	5 minutes
Structured topics	**1. The idea of the business** Can you tell me how the idea of this business took shape? • What inspired you to start? • What were the fundamental initial elements that led you to hit the road? • Can you outline the directions in the original business plan? How many of these are still valid? • Please highlight the key moments in the evolution of the organization since its appearance to the present. **2. Business model in general** Can you describe the main activities of the business? • What is the operational component of your business? • Can you present the key tasks? **3. Business model** Can you elaborate on the specific business concept? • From your point of view, what do you think is the main	50 minutes

Activity	Comments/Questions	Approximate Time
	differentiator? • Do you think your business has can sustain this differentiator in the long run? • Please outline the limits and risks, but also the opportunities and challenges of the business model. **4. Partners and key resources** We would like to discuss the partnerships and resources needed to run your business. • What are the material and human resources involved? • Can you detail the financial resources needed to start your business? Were external funds involved? • What can you tell me about essential partnerships? How do you select the suppliers and partners you work with? **5. Market served** How would you describe the market your business serves? • Can you define persona buyer? • What are the target customer segments? • How would you define the value proposition of this business? **6. Future plans** Is it convenient for you to discuss future plans? • How do you plan to develop the product? • Has the pandemic had implications for the company's plans? • Do you think that the product is adequate for external markets? • Can you provide us with insights on the financial situation of the company?	
Closing the interview and final considerations	Are there other things you want to add?	10 minutes