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Blockchain Technology Development as Tool for Enhancing Security in Management and Protection of Intellectual Property Rights in Additive Manufacturing

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Abstract

The purpose of the study is to analyze the capabilities of blockchain technology as a tool for enhancing the security in management and protection of intellectual property rights in additive manufacturing. The study is research-oriented and is an introduction to the use of blockchain technology for intellectual property protection. The following methods are used in the study: the analysis of documents on the use of blockchain technology in industrial asset management and the protection of content creators' rights, as well as the expert survey to assess the reliability of the selected sources. The authors introduce the term blockchain and discuss the capabilities of this technology for intellectual property protection in the field of design and production. A digital platform is proposed to enable the file exchange. Moreover, the authors describe the three main steps for developing a digital platform based on blockchain technology: the development of specialized tokens to reward users, the definition of conditions that should be included in smart contracts and the size of awards and incentives for each interested party that gains access to the platform.

Key-words: Blockchain, Intellectual Property, Intellectual Property Right, Blockchain Platform, Smart Contract.

1. Introduction

The decentralized nature of additive manufacturing (AM) ensures flexibility in the production process. According to SmarTech Publishing, the size of the global AM market (including software,

materials and services) amounted to USD 9.3 billion which is 18% more than in 2017. When comparing by sector, according to the Wohlers Report, the revenue from the metal materials market for AM grew by 42%; the market in construction is to grow from USD 70 million in 2019 to USD 40 billion by 2027 [1] At the same time, there are wide discussions of the piracy issue in AM, although no exact statistical data is provided, perhaps, due to the difficulty of measuring this phenomenon.

Therefore, the main issue related to the products created through AM is the protection of intellectual property (IP) rights. AM is characterized by a unique type of decentralized piracy where fake products can be easily manufactured. The owners of 3D printers can easily buy licensed patterns for 3D printing but there is a chance that owners will print products protected by IP rights without obtaining the necessary rights [2].

V. Petrovic et al. [3] discussed how AM could become an issue for stopping the violation of IP rights. The researchers have discussed how one could scan and print out the original item and then distribute it for other items that would be used for printing. S. Mellor et al. [4] presented a detailed discussion of IP rights associated with AM. The authors discussed how digital files could be easily distributed and altered, bringing up the crucial issues of IP that the current patent system of the USA might not be able to solve. The study on IP conducted by X. Liu et al. [5] revealed that 65% of design files uploaded on the Internet had no licensing scheme associated with them and, therefore, no IP rights. Cloud manufacturing also faces problems with IP protection. Y. Lu and X. Xu [6] proposed strategies to prevent the leaks of IP from the cloud platforms and noted that in such an environment, the best way to protect IP rights was to exchange as little information as possible. Therefore, it is evident that advanced manufacturing carries a serious risk of IP leaks or IP rights violations. Thus, there is a need for a technology that could protect IP rights, especially in the case of products manufactured with the help of additive technologies.

The joint use of a project online allows several organizations to access the asset, alter it and utilize it. Although sharing project data on the Internet ensures the benefit of accessibility for multiple users and manufacturing equipment connected through the cloud and the easiness of file exchange complicates IP protection.

The current situation with IP in the project sphere and the processing industry is currently as follows. The resource created by the designer is available to different types of users. However, there are various situations when a designer is not compensated for their work because other users can easily share the work online.

The article deals with the concept of the digital platform based on blockchain technology for IP protection in the field of design and production.

We focus on the AM industry for three main reasons: 1. AM is more subject to the issues of IP protection due to the potential public access to the features of 3D printing, 2. 3D printers can be connected to cloud digital platforms and have unique identifiers registered on digital platforms that make checking and monitoring more practical, 3. the existing cloud-based business models in the AM industry offer the chance to monetize blockchain platforms and facilitate their development.

2. Literature Review

This section deals with the key features of future production systems and the concept of blockchain that can be utilized to support IP rights in future manufacturing systems.

The key features of the future manufacturing systems are 1. decentralized manufacturing, 2. global manufacturing and manufacturing on-demand and 3. digital manufacturing [7].

In a decentralized manufacturing environment, the product is manufactured as close to the consumer as possible which makes the process sustainable. This allows one to meet the requirements of the local customer and reduce shipping times and logistical costs. Product personalization which is clients' key need combined with market fluctuations could be efficiently processed by the decentralized manufacturing environment [8]. D. Mourtzis et al. [9] demonstrated this in their work where the researchers proposed the optimal manufacturing network for producing individualized machines with computer numeric control (CNC).

According to researchers [10], AM can similarly play an important part in the decentralized manufacturing environment as projects and requirements can be transferred digitally, reducing logistical costs and environmental impact. Another reason for resorting to decentralized production in the future is that such production not only facilitates manufacturing but also contributes to regional growth and social welfare of people in the areas where the manufacturing environment is created, especially in developing countries.

The concept of global manufacturing has been significantly developed in recent years due to the reduction of transport and communication costs which led to the creation of transnational manufacturing networks [11]. This enabled developing countries to be part of the manufacturing chain where instead of manufacturing the whole product, countries can manufacture certain parts in the manufacturing process [12].

The high cost of spare part obsoletion in warehouses makes AM the best choice for on-demand manufacturing. M. Gebler et al. [13] discuss in their work how AM can stimulate the demand for spare parts and limit the number of parts stored for future use.

Digital manufacturing is a rapidly developing technology which can reduce product development time and the cost of the product. Moreover, digital manufacturing can help to improve the quality of the product and react to the changes in the market. It enables one to directly produce items without planning the process and can be used for direct manufacturing of the final product required by the consumer. AM is seen as the key technology of digital manufacturing and has been significantly developed in recent years [14].

With the development and integration of the Internet into everyday life, everything including design and manufacturing is moving towards digitalization. There is a high chance that these systems will be more Internet-dependent compared to modern systems; as a result, serious problems related to IP rights might arise [15,16]. It is here that the concept of blockchain which we discuss hereafter can play an important part in IP protection.

There are multiple approaches to understanding the essence of blockchain technology (Table 1).

Table 1- Various Approaches to Understanding the Essence of Blockchain Technology

Approach	Essence of blockchain technology	Source
Legal status	the technology that is used as the basis for many new cryptocurrencies	[17]
	the technology of an integrated space with no intermediaries	[18]
	the technology which is a decentralized ledger of information on completed transactions based on cryptographic algorithms that protect it from tampering	[19]
Legal approach	a decentralized database of all confirmed transactions made in relation to a specific asset	[20]
	a digital account of receipts and expenditures, storage of information on rights or an automated business process	[21]
Organizational and technological approach	a digital ledger where all actions on the Internet are recorded chronologically and publicly	[22]

Therefore, blockchain is a decentralized system for storing information or the so-called digital ledger of transactions, documents, deals and contracts. The main feature and significant advantage of blockchain technology is that the register is not stored in one place but is distributed among a large number, in particular, from several hundred to several thousand computers around the world. Any user can have free access to the required activated version of the register, which makes it fully transparent to all participants.

However, according to D. Kraft [23], blockchain is vastly different from traditional registers. First, because subjects that take part in informing a chain of blocks have equal rights and interact

based on the principles of social consensus, good faith and mutually beneficial cooperation. Second, blockchain ledgers can be not only a means of storing and transmitting synchronized, automated, encoded information about any property that is characterized by its widespread use and consumption. Third, the availability of technological capabilities for the transfer and exchange of digital codes between the copyright holder and the consumer generates the commodity value of the object which is determined by the agreement of the parties and the demand which is expressed in the number of users of the digital code. Finally, the current ledgers of intangible assets involve the presence of one person responsible for updating and storing information. Therefore, any operations of the copyright holders with the objects in the ledger should be brought to the attention of the entity that performs the administrative functions (for example, the use of contractual methods of exercising the rights to software, invention, utility model, industrial design, trademark or selection achievement). Such an organization requires the owners of rights to information about IP to trust the entity that administers the ledger.

The global market for blockchain technologies is steadily growing. For example, according to the analytical company Research and Market, the global market of Blockchain as a Service (BaaS) in 2019 was estimated at USD 420.5 billion and is expected to have reached USD 982.8 billion by 2025 given the average annual growth rate of 15.2% during 2020–2025. BaaS includes the solutions that allow users to create, deploy and use their own blockchain applications, smart contracts and blockchain functions through cloud services [24].

At the same time, according to the analytical company CB Insights that specializes in studying the venture funding market, the volume of investment into developers of blockchain technologies at the corporate level reached USD 434 billion in 2019 which is 62% more than in 2018 [25].

According to the October 2020 analysis by PwC, blockchain technologies could drive up the global economy by USD 1.7 billion by 2030. PwC identified five key blockchain applications and assessed their potential for value creation using economic analysis and industry research – tracking and tracing; payments and financial services; identity management; contracts and dispute resolution; interaction with clients. The PwC report also notes that blockchain technology can be used in a wide range of industries, from heavy industry to fashion labels. According to analysts [26], the most profitable application of blockchain is in such industries as government, education and healthcare. PwC estimates that by 2030, revenue growth in these areas will amount to USD 28.5 billion, which will also benefit wholesale and retail trade, communications companies and the media and a broader range of business services [26].

The purpose of the article is to analyze the capabilities of blockchain technology as a tool for enhancing security in the management and protection of IP rights in AM.

Research Objectives

- To establish the basic elements defining the digital blockchain platform for IP;
- To justify and provide a detailed characterization of the elements that define the digital blockchain platform for IP.

Research hypothesis: a digital platform built on blockchain to track the use of product design drawings allows for the management and protection of IP.

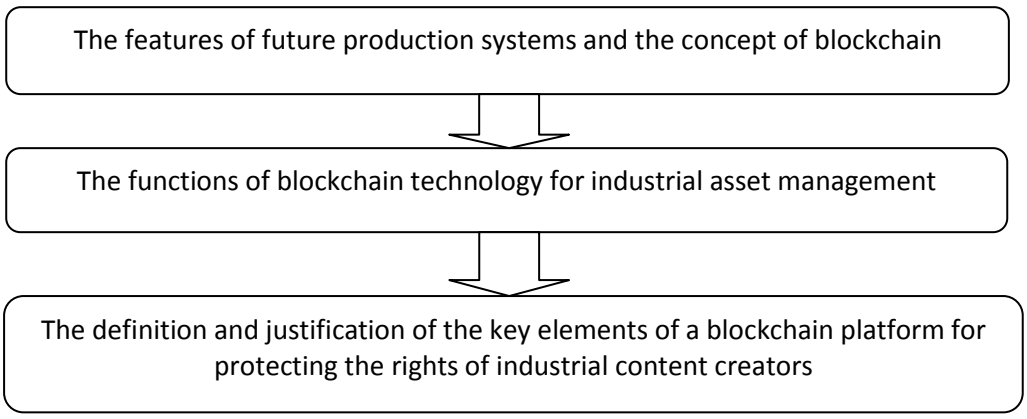
3. Methods

Based on the proposed hypothesis, we identified the following research methods: analysis of documents on the use of blockchain technology in the management of industrial assets and protection of the rights of content creators, as well as an expert survey to assess the reliability of selected sources.

Blockchain technology is a relatively new area subject to a strong influence of innovation. Therefore, in the absence of reliable comprehensive methods for assessing the prospects of developing a blockchain platform for managing industrial assets and protecting the rights of content creators, the document analysis method allows one to collect a variety of information in a large number of organizational and technological ideas. Considering the existing limitations in the application of the document analysis method (the quality of the selected sources, their completeness and the subjective stances of the authors), we conducted an expert survey to assess the reliability of the selected sources.

Structurally, the study consisted of a gradual analysis of the features of future production systems and the concept of a blockchain, the functions of blockchain technology in the management of industrial assets, identification of the main elements of a blockchain platform for protecting the rights of creators of any content, as well as their detailed justification. The documents for research were selected based on the availability of characteristics of the key features of future production systems, a detailed analysis of the blockchain concept, as well as an analysis of the main elements that define a digital blockchain platform for IP in industrial production (Figure 1).

Figure 1- Stages of Selecting Information for the Study



At the first stage of the study, the selected information was grouped by document type.

The first group featured statistical information from analytical companies Research And Market, CB Insights and PwC, indicating the source of the data obtained. The second group of documents included research on the characteristics of future production systems, including the features of AM, as well as research on blockchain technology (articles from scientific peer-reviewed journals indexed in Scopus and Web of Science over the past 10 years).

At the second stage of the study, we contacted 12 experts in the field of blockchain technology and AM. The selection criteria for experts were that they had at least three articles on this topic published in journals included in the Scopus or Web of Science citation databases. We compiled a questionnaire that contained 10 questions to assess the documents selected for the study. The experts used the Harrington scale [27] for assessment. Two questions were open-ended and the experts could make proposals for increasing/decreasing the number of important sources and comment on their answers. The results of the experts' answers are summarized in Table 2.

Table 2- The Summarized Results of the Expert Survey on Assessing the Reliability of the Selected Documents

N	Main characteristics	Result
1	Number of proposals sent to experts	12
2	Number of questionnaires received from experts	9
3	Average results on the reliability of statistical information	0.78 points
4	Average results on the reliability of research/expert information	0.71 points
5	Number of new documents added by experts to increase reliability	11

The experts were sent the same questionnaire at a time and were given an equal number of consecutive days to fill it out. Three experts cited business and declined to answer. The limited time frame and simultaneous mail-out allowed for equal conditions for the experts. On average, the experts

rated the selected documents high (according to the criterion of assessment on the Harrington scale, the "high" value starts from 0.64-0.8).

At the third stage of the study, we processed the collected information, distributed it by the degree of significance, created a blockchain platform model for IP in AM and tables and interpreted the results.

4. Results

In this study, we are particularly interested in the capabilities of blockchain for solving IP problems in product design and manufacturing. In view of this, we will examine the elements of a blockchain-based digital platform to track the use of product design drawings as third-party Internet users can create unauthorized copies of copyrighted, patented or trademarked products.

The main characteristic of companies that will suffer from the appearance of counterfeit good printed on a 3D printer is that their profit margins depend on strict adherence to IP rights. Besides the toy industry, another such market segment is the automotive spare parts industry. Major car manufacturers control this market by using design patents to prevent competitors from producing cheaper universal versions of bumpers and other parts. Thus, the market research company Gartner forecasts that by 2021, businesses will lose more than USD 100 billion a year due to theft of IP using 3D printing [28].

In response to the proliferation of 3D printing technologies, the toy company Hasbro recently partnered with 3D Systems to co-develop a website where children can create and print their own plastic Hasbro toys [29]. In this way, companies can add value to existing products or encourage customers to pay more for quality-assured genuine products and will use 3D printing to enrich the user experience. It is for this that blockchain technologies and blockchain platform created on their basis to track the use of product design drawings can be used.

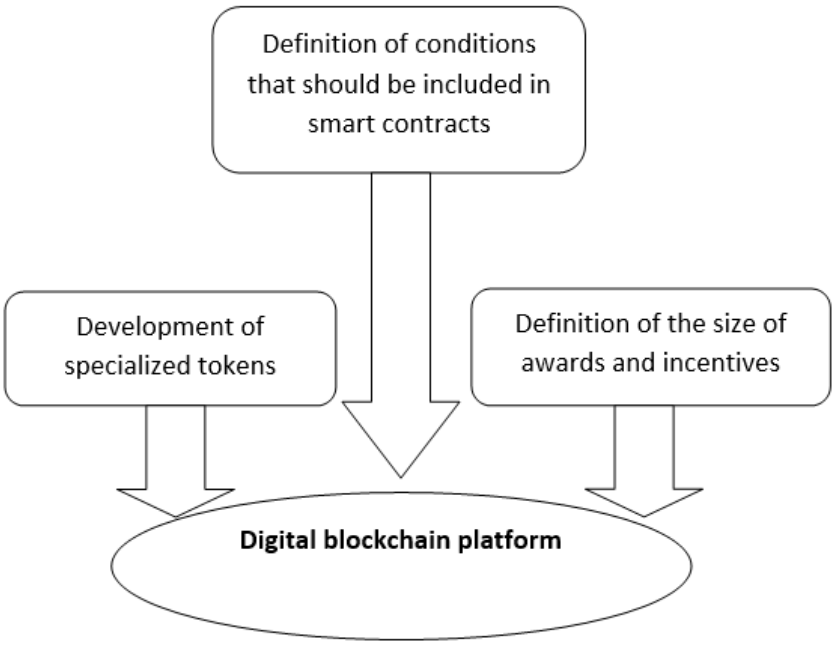
Blockchain offers many possibilities, among which we would like to highlight the following three functions:

1. Reducing the cost of verification and the cost of network interaction;
2. Asset tracking to facilitate monitoring of the use of design drawings;
3. Ensuring fair compensation for various users on the network.

Thus, the proposed blockchain platform for the management and protection of patents and design drawings requires the definition of three main elements, as shown in Figure 2. These three elements include:

1. The development of specialized tokens to award users,
2. The definition of conditions that should be included in smart contracts,
3. The definition of the size of awards and incentives offered to users in peer-to-peer (P2P) networks.

Figure 2- Three Key Elements that Define a Digital Blockchain-based Platform for IP in AM



When developing specialized tokens to reward users, one must remember that the concept of initial coin offering (ICO) or token sale is widely used in the industry by startups and enterprises to crowdfund the development of blockchain platforms. Developers of digital blockchain platforms use ICOs to fund the development cost of blockchain platforms with the pre-sale of access to future products and services offered on the platforms. Tokens potentially act as a medium of exchange (payment mechanism) on blockchain platforms and token holders will be able to access the services offered on the platform easier and faster [30].

When designing a digital platform to protect the rights of content creators, it is necessary to define a service token that can act as local money or a medium of exchange on the platform. The question arises whether it is possible to use digital currencies and cryptocurrencies instead of utility

tokens. Cryptocurrencies can also be used, but crypto is very volatile [31] and may not perform well as a stable exchange medium, at least for now.

When discussing smart contracts and their potential for IP management, it must be emphasized that various authors discuss significant advantages of smart contracts – from confidentiality and the absence of the need for an intermediary [32] to self-protection and trust [33].

The number of smart contracts is constantly increasing. At the same time, the growth in the number of new smart contracts largely depends on the cost of placement. Thus, according to data from Dune Analytics, the number of new smart contracts on the Ethereum network in March 2020 reached 1,971,632. The average monthly growth for the year is 670,000. Now, on average, developers need about USD 11,600 to release their smart contracts [34].

Smart contracts allow developers to decentralize their services to improve confidentiality [35] and gain economic incentives due to their work. The ability to copy a design drawing creates unwanted risks for designers, such as data confidentiality, authenticity and lack of control over their properties.

To develop a blockchain system for awarding acceptable asset use behavior, startups, designers and companies must be prepared to answer questions such as what behavior to incentivize, how much to charge certain users and what to include in smart contracts. It makes sense that the course of action taken by users on the platform should not only be legal behavior but also benefit the economic aspects of the business and the designers. However, it is imperative to address any inconsistency between the business objectives of blockchain platforms and the ultimate conflicting IP issues. For example, some of the terms included in smart contracts (for example, asset delivery terms, payment terms, etc.) can be time-stamped to stimulate specific collaboration opportunities between different businesses and user groups.

Therefore, the proposed platform is a digital platform that connects designers through a decentralized auditable system, promoting fair, designer-led operations. The agreements included in such systems come from various interested parties and users of the network/system.

In the proposed concept, the designer establishes a smart contract connecting a computer-aided design (CAD) file, the license to use the file and a payment wallet on a blockchain platform. Various organizations that want to use the CAD file make a request to use the file and offer to pay the developer using the wallet. As soon as the payment is made to the wallet, it will launch a smart contract to activate the license for the file, which can thus be used by the licensed entity. Each organization can provide different payments depending on its status. For example, a student can use

an industrial product design hosted on the platform for free, the university will have to pay a minimum fee, while the content hosted on the platform will be the most expensive for a multinational company.

5. Discussion

Overall, blockchain platforms offer some useful capabilities for asset management [36]. These capabilities have been redesigned for the industrial asset management case as follows:

1. Anonymity: platform participants (for example, the buyer and sellers of design drawings) can be completely anonymous while the asset is transferred from one agent to another, given that the buying agent can pay for the asset. Sellers do not need to know the identity of the buyers.
2. The transfer of the asset is carried out through methods determined by the owners of the assets and other participants in transactions with the asset.
3. There is no need for an intermediary so there is no need for a central entity in such a decentralized system. The smart contract will be posted online and not at a third party. In this case, the cost of verification is extremely low;
4. There is a consensus between different parties regarding the flow of assets from one party to another and an understandable model of trust emerges;
5. Anonymous communication and transaction: all transactions and communications developed on digital platforms are anonymous;
6. Reward system: each node in the network is rewarded based on a set of actions performed by the node.
7. Recorded assets, transactions and information can never be deleted or changed and are permanently stored on blockchain.

Currently, there are no specialized blockchain platforms for the management and protection of patents and design drawings, although several platforms already perform some functions relevant to the management of industrial assets and the protection of the rights of industrial content creators (Table 3).

Table 3

Platform	Function of the platform	Source
Proof of Existence	allows the creators of objects that are digitally transformed to easily prove authorship and date of the document creation	[37]
Blockai	gives copyright holders the opportunity to control the circulation of the results of intellectual activity on the Internet and conclude contracts with third parties; after registration, the creator of the object is issued a digital certificate of authenticity of rights, which allows third parties to identify the author of the object or another copyright owner	[37]
MoviesChain by TVzavr	allows the content creator and the consumer to connect directly and eliminates unnecessary intermediaries; moreover, such a technological solution will protect content from piracy	[38]
Ascribe	allows object authors to track the use of their content, as well as other content posted on the platform	[39]
Ujo Music	a decentralized database of copyright holders that pays royalties directly to content creators through smart contracts	[39]
Single depository of IP results	one can register the copyright for the object through blockchain	[40]
BaaS (Kazakhstan)	one can create and deploy corporate blockchain systems based on the distributed infrastructure of the operator's data centers	[41]

Due to the widespread use of blockchain technologies, the legal force of blockchain is being recognized around the world. For example, in the USA, the use of blockchain technology and smart contracts in electronic records and signatures is already permitted and enforceable in accordance with existing federal and state laws through the application of the provisions of the Electronic Signatures in Global and National Commerce Act (ESIGN Act) and the Uniform Electronic Transactions Act (UETA). Some US states have adopted additional laws that support the use of blockchain technology in connection with their application to enhance the security for the management and protection of IP rights (Table 4) [42].

Table 4

State	Description of blockchain law
Arizona	On 29 Mar. 2017, the Arizona Electronic Transactions Act was amended to add §44-7061, which treats "a signature that is secured through blockchain technology" as an electronic signature, "a record or contract secured through blockchain technology" as an electronic form or record, and a smart contract must be legally valid and enforceable.
Nevada	On 5 Jun. 2017, the Nevada Uniform Electronic Transactions Act was amended to specifically define "blockchain" and treat blockchain records as electronic records. Besides, Nevada has prohibited counties, cities and other local governments from imposing taxes, fees or licenses for any use of blockchain.
Tennessee	On 22 Mar. 2018, the Tennessee Uniform Electronic Transactions Act was amended to define "distributed ledger technology" and "smart contract", treat records protected by distributed ledger technology as electronic records and state that "cryptographic signature that is secured and stored using distributed ledger technology [...] must be in electronic form and be an electronic record".

In Europe, on 10 Apr. 2018, 21 EU Member States and Norway signed a Declaration to establish a European Blockchain Partnership (EBP) and to collaborate on the creation of a European Blockchain Services Infrastructure (EBSI) that will support the provision of cross-border digital government services with the highest security and confidentiality standards. Since then, eight more countries have joined the Partnership, bringing the total number of signatories to 30. Starting from 2021, the development and implementation of EBSI will be funded at the EU level through the Digital Europe program [43].

To protect consumers and investors, on 24 Sep. 2020, the Commission adopted a comprehensive package of legislative proposals for the regulation of crypto assets, updating certain financial market rules for crypto assets and creating a legal basis for the so-called Regulatory Sandbox – a tool that unites regulators, companies and technical experts to test innovative solutions and identify obstacles to their deployment. The regulatory sandbox is expected to start working in 2021/22 [44].

Crypto assets characterized as "financial instruments" under the Markets in Financial Instruments Directive (e.g. tokenized shares or tokenized bonds) have already come under EU securities markets legislation in the past. However, these rules preceded the emergence of new crypto assets and distributed ledger technologies (DLT). Therefore, on 24 Sep. 2020, the Commission proposed a pilot mode for market infrastructures that want to try to trade and conduct transactions in instruments that do not qualify as "financial instruments", such as utility tokens or payment tokens that can be used to pay for patent rights and design drawings. The Commission has proposed a specific new structure that will replace all other EU and national regulations currently governing the issuance, trade and storage of such crypto assets. This Markets in Crypto Assets regulation – MiCA – will support innovation while protecting copyright holders, consumers and the integrity of crypto exchanges [44]

In view of this, we consider it important to emphasize such a factor influencing the development of the use of blockchain technology as the attitude of the government or other regulatory bodies to operations carried out in the field of digital circulation. According to researchers [45], the quality of the development of innovative projects and the protection of IP depends on the attitude of states to the legalization of blockchain transactions, since as a result of such processes, legal rights and obligations appear, and this, and not centralized regulation, is what the participants of digital legal relations want.

6. Conclusion

Within the study, we introduce the concept of blockchain and discuss the capabilities of this technology for IP protection in the field of design and manufacturing. A digital platform is proposed to enable file sharing. The study features three main steps for developing a blockchain platform: the development of specialized tokens to reward users, the definition of conditions that should be included in smart contracts and the size of awards and incentives for each interested party that gains access to the platform. This platform will reduce transaction costs, increase the level of commercialization and ensure reliable protection of IP.

Therefore, the results of the study confirmed the hypothesis that a digital platform based on blockchain to track the use of product design drawings allows one to manage and protect IP.

The prospect of the research can be the development of a prototype of a digital platform and testing its capabilities in practice, especially in existing cloud-based AM businesses. The terms and conditions to be incorporated into these digital platforms should be determined based on extensive research. Efficient mathematical models must be developed to support consensus algorithms and smart contracts. Verification mechanisms are required to verify transactions occurring on blockchain, subject to the cooperation of certified users, moderators and platform vendors.

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