CHAPTER 4

Implementation of blockchain technologies and smart contracts as a driver of international investment activity in the post-war recovery of Ukraine

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Abstract

Blockchain and smart contract technologies are increasingly being considered as catalysts for boosting international investment activity. This study thoroughly explores how the implementation of blockchain and smart contracts can ensure transparency, trust, and efficiency in the process of restoring territories in Ukraine affected by military activities, thereby attracting foreign capital. The authors of the monograph present the genesis and potential of blockchain, describe a methodological model that includes a semantic analysis of key concepts (such as "remediation" and "revitalization"), and provide an analytical assessment of the introduction of blockchain to stimulate foreign investment in Ukraine's post-war recovery. The authors present a project model of a blockchain system developed to support transparency within a specific settlement's post-war remediation and revitalization project, with an emphasis on anti-corruption control and digital transformation of recovery efforts. Drawing on Ukrainian and international cases – from fundraising via cryptocurrencies during the war to blockchain-based land registries and procurement systems – the authors emphasize that the integration of blockchain and smart contracts can eliminate the human factor in record-keeping, ensure open access to information, and automate the execution of agreements. This, in turn, can increase the level of investor trust and open new opportunities for financing such projects (including through asset tokenization and smart contract-based funds). Special attention is paid to ensuring accountability in the use of resources for territorial recovery and to the role of blockchain in creating a transparent, corruption-resistant environment.

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Keywords
Blockchain, smart contracts, international investments, post-war recovery, remediation, revitalization, digital transformation.

4.1 Introduction

As a result of the full-scale war, a significant part of Ukraine has been left in a state of destruction, requiring unprecedented volumes of investment for recovery [1]. According to estimates by the World Bank, reconstruction needs amount to about 411 billion USD, which significantly exceeds the capabilities of the state itself. Such a large-scale post-war recovery is impossible without active involvement of international investments, donor assistance, and private foreign capital. However, the key condition for the inflow of funds from abroad is trust – the confidence of investors in the transparency and efficiency of resource utilization. Historically, Ukraine has had a high level of perceived corruption and non-transparency, which could discourage foreign partners. Accordingly, ensuring transparency, accountability, and anti-corruption control in recovery projects becomes not merely a technical task but a fundamental requirement for the success of the country's post-war development.

In this context, blockchain technologies and smart contracts appear as promising tools capable of radically enhancing trust in the investment process. Blockchain (a distributed ledger) allows recording transactions immutably without intermediaries, ensuring the invariability and permanence of records [2]. All participants of the system can access a single trustworthy version of the data, eliminating information asymmetries and possibilities for hidden manipulations. Smart contracts – programmable "intelligent" agreements that automatically execute when predefined conditions are met – make it possible to guarantee the targeted use of funds: for example, embedding in the code conditions under which payment to a contractor will occur only after confirmation of the completion of a specific work stage. Thus, the combination of blockchain and smart contracts can eliminate the human factor in the allocation of funds, reduce the risk of misappropriation to zero, and ensure "zero corruption" through process automation and transparency [3, 4].

Ukraine already has a strong foundation for implementing such innovations. On one hand, the country ranks among the world leaders in the adoption of cryptocurrencies and blockchain by the population – in 2022, Ukraine ranked 3rd in the Global Crypto Adoption Index [5].

According to various estimates, between 5 and 6 million Ukrainians use cryptocurrencies, driven by a high level of digitalization, the need for financial flexibility, and

wartime experience [6]. On the other hand, the government demonstrated openness to blockchain initiatives both before and during the war: as early as 2017, Ukraine concluded the world's largest agreement at that time on blockchain implementation in public administration (a partnership with Bitfury) to transfer state registries to a distributed ledger to enhance transparency [7].

In 2022, Ukraine joined the European Blockchain Partnership (EBP) as an observer, becoming the second non-EU country (after Norway) to participate in the pan-European project for using blockchain in cross-border public services [8, 9]. This indicates a strategic course towards the integration of blockchain solutions into the public sector and synergy with European digital initiatives. Moreover, during the war, the government and volunteer foundations effectively utilized virtual assets: within the first months of the invasion, more than 50 million USD in cryptocurrency donations were raised to support Ukraine, and the Ministry of Digital Transformation officially launched crypto-funds to assist the military and humanitarian needs. The successes of rapid and targeted fundraising through blockchain during active hostilities proved the effectiveness of this technology in establishing donor trust, mobilizing resources quickly, and ensuring their transparent distribution [10].

Thus, there is an urgent need for a comprehensive study on how the implementation of blockchain technologies and smart contracts can become a driver of international investment activity in Ukraine during the post-war recovery phase.

This research aims to identify the potential of blockchain in ensuring investment inflows through enhanced transparency and trust, analyze relevant global and Ukrainian experiences, and propose a conceptual model of a blockchain-based system for managing recovery projects, including the remediation (environmental cleanup and restoration) and revitalization (economic and social revival) of affected territories. The focus is on mechanisms through which blockchain can ensure the targeted and efficient use of reconstruction funds, improve the investment climate, and serve as a foundation for an anti-corruption ecosystem in the new Ukraine.

4.2 Genesis and analysis of blockchain potential

The Emergence and Evolution of Blockchain Technologies. It should be noted that the concept of blockchain originated in 2008–2009 with the appearance of Bitcoin – the first decentralized cryptocurrency, which was built upon distributed ledger technology. At its core was the idea proposed by Satoshi Nakamoto that participants in the network could independently verify and store transactions in a chain of blocks, thereby eliminating the need for a trusted central authority [11].

The first generation of blockchain (Bitcoin) was intended for peer-to-peer transfers of value. However, in 2015, the development of blockchain entered a new phase with the launch of the Ethereum platform, which introduced smart contracts – programmable scripts executed on the blockchain. This marked the transition to the second generation of blockchain, significantly expanding the range of its applications beyond cryptocurrencies.

It should be noted that smart contracts have enabled the creation of decentralized applications (dApps) across a wide range of domains – from finance (namely, decentralized finance, DeFi), supply chain management in transportation and logistics, to the administration of state registries. In recent years, we have witnessed the emergence of "Blockchain 3.0", focused on scalability, speed, and integration with the real sector (referring to the emergence of networks such as Polkadot, Cardano, as well as enterprise blockchain systems) (**Fig. 4.1**).

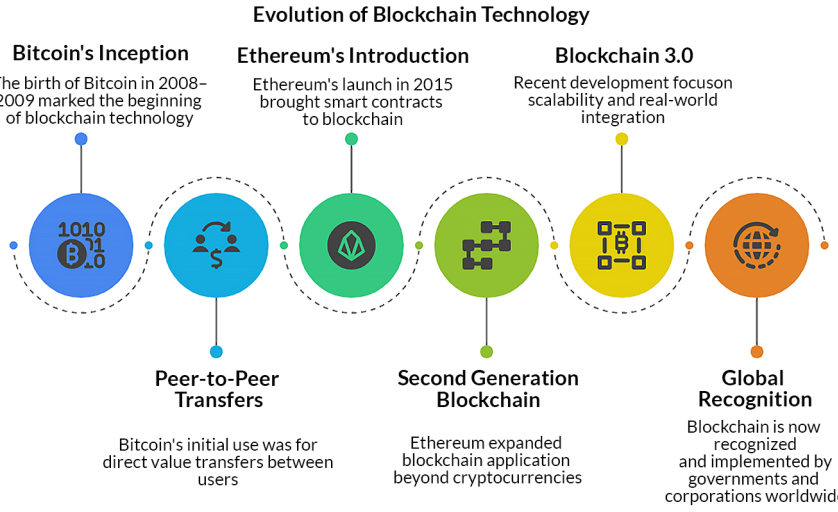


Fig. 4.1 Characterizing key milestones in the evolution of blockchain

Thus, in a remarkably short period of time, blockchain has evolved from a niche tool for crypto enthusiasts into a widely recognized innovation adopted by governments and corporations around the world.

Key Advantages and Capabilities of Blockchain. The core potential of blockchain technology is concentrated in its consistency, namely, in its decentralized nature, which ensures new levels of trust and absolute transparency. The morphogenesis

of blockchain is represented as a distributed ledger collectively maintained by all nodes in the network; each record (transaction) is encrypted and grouped into a block, which is directly linked to the previous block through a cryptographic hash, thereby forming a continuous chain. Precisely because of this, data recorded on the blockchain is virtually impossible to falsify or, for example, modify retroactively, since achieving this would require simultaneously compromising the majority of network nodes. Undoubtedly, any unauthorized attempt to alter the data would be immediately visible. Thus, blockchain creates immutable and permanent records of transactions in real time, without the need for a third party for verification purposes [2].

It is precisely this consistent property of blockchain technology that makes it possible to radically increase the reliability of record-keeping and significantly reduce operational risks. Based on this, the key and unique attributes of blockchain are transparency and verifiability: all participants (in the case of public blockchains, this can be anyone) can view the complete history of all operations. For instance, in such public networks as Ethereum or Bitcoin, absolutely all transactions are open and available for audit (however, without disclosing the personal data of address owners). In contrast to private or enterprise blockchains, where access is restricted, participants in a public blockchain network have a synchronized copy of the ledger, which eliminates the very possibility of discrepancies. Security is ensured through a combination of cryptographic methods (in this case, referring to electronic signatures and hashing) and distributed consensus (namely, the mechanism by which nodes "agree" to add new blocks – such as Proof of Work, Proof of Stake, etc.). As a result, a blockchain system is completely resistant to failures and malicious attacks, since the absence of a single point of failure and the presence of multiple confirmations for each transaction provide a much higher level of data protection than traditional centralized databases [12].

Smart Contracts and Process Automation. Smart contracts expand the capabilities of blockchain by enabling not only the storage of data, but also the execution of embedded logic. Essentially, a smart contract is a piece of program code deployed on the blockchain that automatically executes prescribed actions once the conditions explicitly specified within the contract are met. In other words, it is a digital analogue of a traditional agreement, endowed with self-executing provisions. The built-in "if-then" mechanisms allow for the implementation of tokenized targeted financing and the guaranteed fulfillment of the obligations outlined in the contract. At the same time, neither party can unilaterally change the conditions or appropriate the funds, as the program enforces compliance with the terms, and all actions are recorded immutably in the ledger [2].

Consequently, smart contracts are capable of enhancing efficiency (as they accelerate transactions and eliminate bureaucracy), as well as trust (as they remove the need to "take someone's word for it" and replace it with trust in code and the network).

Application of Blockchain: Global Experience. The authors' scientific investigation has established that, as of today, blockchain has become widely adopted across numerous industries, demonstrating its potential to solve complex problems and its capacity to transform traditional systems of stakeholder interaction. In turn, the authors have concluded that smart contracts are not merely "digital agreements", but rather integrated managerial mechanisms without analogues, which enable the automation of key processes of economic activity, namely: from application to verification; from fund allocation to monitoring and reporting; and from transparency to sustainable trust. Below are presented successful benchmarks of their application in various countries across the world.

In the domain of public administration, Estonia stands out as a prominent example and is regarded as a pioneer in the application of blockchain technology for securing governmental data. Since 2008, the country has implemented the KSI Blockchain technology to protect data in sectors such as healthcare, the judicial system, and business registries. This enables citizens to control access to their personal information and ensures transparency in public sector processes [13, 14].

Georgia is also among the first countries to have integrated blockchain technology into its property rights registration system (since 2016, in cooperation with Bitfury). As a result, the Georgian land registry system has become more efficient, and the opportunities for fraud related to property ownership have been virtually eliminated. This innovation has provided safer conditions for real estate investment by reducing bureaucratic barriers and associated business risks.

It is also important to mention the United Arab Emirates and their strategic initiative, the "Emirates Blockchain Strategy 2021". The UAE set an ambitious goal of transferring 50% of all government transactions onto a blockchain platform by the target year outlined in the strategy. This includes operations such as visa issuance, bill payments, and license renewals. An undeniable advantage is that the implementation of blockchain enables a significant reduction in paper-based workflows, cost savings, and a marked improvement in the efficiency of public services [15].

Switzerland represents a prominent example of the application of blockchain technology used for electronic voting at the local level, thereby ensuring the transparency of vote counting as well as the protection of voters' data. It should be emphasized that such a governmental initiative contributed to an increased level of public trust in the electoral process and reinforced political stability, which, in turn, attracts investment flows and stimulates economic activity [16].

Governments of several countries have also introduced similar models aimed at ensuring the safety of food and pharmaceutical products, establishing a system of transparent monitoring from the producer to the retail distributor. Notably, China was among the first countries to implement blockchain in the national food safety system. In 2016, Walmart, in collaboration with IBM, JD.com, and Tsinghua University, launched a pilot project to track pork supply chains using blockchain technology. The primary objective of this project was to enhance the transparency and safety of food products. Subsequently, Walmart expanded the application of blockchain to track other food items, including mangoes and shrimp, which enabled the reduction of product traceability time from several days to a matter of seconds [17].

The European Food Safety Authority is currently actively supporting the implementation of the Food Safety Market (FSM) program, which is aimed at transforming the food certification market in the European Union member states through the use of Big Data and blockchain technologies. The objective of the program is the establishment of an industrial-scale data platform for the digitalization of food certification processes [18].

Another illustrative example is the United States. In 2020, the U.S. Food and Drug Administration (FDA) introduced the "New Era of Smarter Food Safety Blueprint", which encourages the application of blockchain technologies to enhance the traceability of food products. As can be observed, the aforementioned examples demonstrate the growing interest and practical application of blockchain technologies by governments of various countries to ensure safety and transparency within food supply chains. Undoubtedly, the implementation of such systems significantly contributes to increased consumer trust, a reduction in counterfeiting risks, and an overall improvement in product quality [19].

In the financial sector, the emergence of digital bonds and tokenized assets opens up new opportunities for capital raising. For instance, the World Bank issued the first blockchain-based bonds in 2018 (the Bond-i project), demonstrating that major investors are willing to engage with decentralized platforms to enhance the efficiency and speed of settlements [20]. The European Investment Bank (EIB) launched the issuance of digital bonds on the blockchain. In April 2021, the EIB announced the issuance of two-year digital bonds totaling 100 million EUR using the public Ethereum blockchain. This initiative demonstrated the potential of blockchain technology in ensuring transparency and efficiency in the process of issuing and managing debt instruments [21]. It is also worth noting the experience of the Polish company Beesfund, which developed the TokenBridge platform. This platform enables the tokenization of shares, bonds, and other financial instruments, facilitating their free circulation on the blockchain. It should be emphasized that this contributes to the

democratization of investment and the expansion of access to capital for small and medium-sized enterprises [22].

It is particularly important to emphasize the role of blockchain technology in combating corruption and enhancing transparency – a factor that is especially crucial for developing economies. For example, in Colombia, blockchain is used to increase transparency in public procurement. A pilot project in Medellín applies this innovation to monitor supplier selection processes in the school meals program, thereby ensuring transparency and preventing corruption [23].

Another example of blockchain implementation concerns public procurement in Peru. In 2018, the Peruvian government agency "Perú Compras" entered into a partnership with the blockchain startup Stamping.io to develop a transparent procurement system executed by the state. This system utilizes the LAC-Chain blockchain network, initiated by the Inter-American Development Bank (IDB) for the purpose of digital registration and verification of procurement orders. Thus, it creates an immutable chain of records that guarantees the authenticity of procurement data. According to the published Decrypt report, the aforementioned blockchain system aims to prevent data manipulation and unauthorized actions during the contract conclusion process. During the pilot phase, the system processed between 500 and 1,000 orders per day, demonstrating high effectiveness and scalability potential [24].

Undoubtedly, the authors' research primarily focuses on innovative technologies applied in Ukraine. One such "weapon" against corruption is the ProZorro.Sale electronic public asset sale system, launched in the country after the Revolution of Dignity, which has become one of the symbols of transparency. In its first year, it facilitated the sale of public assets (ranging from non-performing bank loans to real estate) amounting to approximately 210 million USD, which is comparable to the total volume of privatization over the previous five years [25].

It should be noted that although the ProZorro system itself was not initially based on blockchain technology, elements of blockchain have subsequently been integrated into the system to enhance the level of trust: in particular, certain trading data is now duplicated in a distributed ledger, ensuring the impossibility of retroactively altering tender information. Despite the persisting challenges in the sphere of public procurement, the implementation of digital solutions, including components of blockchain technologies, contributes to improving the level of transparency and openness of information regarding tendering procedures. This creates conditions for the reduction of corruption-related risks and strengthens the control mechanisms from civil society and relevant stakeholders [26]. For businesses, such conditions – although they do not entirely eliminate corruption – nonetheless establish a more transparent environment and contribute to increased competition and fairness in

the allocation of public contracts, which, in turn, reduces transactional costs and broadens the pool of directly interested participants.

According to the authors' conviction, the implementation and scaling of smart contracts in Ukraine should reasonably be considered as an effective transmission mechanism (transfer factor) and simultaneously a catalyst for the intensification of economic development, particularly in the field of investment activity. Their implementation can ensure the automation of processes while eliminating the human factor at critically important decision-making points. All of the above, it is logical to assume, will significantly enhance transparency and contribute to the formation of institutional trust, which, in aggregate, will create favorable conditions for the attraction of both domestic and international capital.

Blockchain in Ukraine: Potential and Achievements. Ukraine has established itself as a technological innovator in the field of digital public services, notably through the implementation of the "Diia" system. Launched in 2020, Diia is a mobile application and web portal developed by the Ministry of Digital Transformation of Ukraine, allowing citizens to access over 130 government services online, including digital identification documents and business registrations. Furthermore, Ukraine is recognized as one of the most cryptocurrency-friendly countries. In September 2021, the Verkhovna Rada (Ukrainian Parliament) adopted the Law "On Virtual Assets", which officially recognizes digital assets and establishes a legal framework for their circulation. This law defines virtual assets, determines market regulators such as the National Bank of Ukraine and the National Commission on Securities and Stock Market, and sets conditions for the registration of virtual asset service providers [27, 28]. Although the full implementation of the law required additional amendments to the tax code, the adoption of the law itself demonstrates Ukraine's readiness and commitment to integrating digital financial instruments into its economy.

According to the authors' perspective, the war that began in Ukraine in February 2022 became a catalyst for the widespread use of blockchain: state structures and volunteers began to attract assistance through cryptocurrencies, bypassing lengthy banking procedures. Already on the second day of the war, the Ministry of Digital Transformation published official crypto wallets for financial assistance and donations, and a stream of virtual assets poured in from different parts of the world. As a result, experience was rapidly accumulated in handling large volumes of cryptocurrencies, as well as their conversion and targeted expenditure on defense needs and humanitarian projects. The acquired experience confirmed that virtual assets can facilitate fundraising and make the process extremely fast and transparent. It is also significant that initiatives for integrating blockchain into post-war reconstruction are already being formed in Ukraine. Thus, a group of people's deputies and experts

from the association "Blockchain4Ukraine", together with the public union Virtual Assets of Ukraine (VAU), developed and presented a roadmap for the implementation of blockchain and Web3 technologies in Ukraine in November 2022 [3, 29].

One of the key directions of the project is the launch of a decentralized real estate and land registry based on blockchain – as a foundation for transparent and secure handling of property rights in the process of restoring housing destroyed as a result of military actions. In February 2023, VAU and the State Service for Special Communications signed a memorandum of cooperation for the implementation of this blockchain real estate registry project [3, 29].

Another area worthy of separate mention is the Blockchain4Grain initiative, aimed at solving the problem of mined and contaminated agricultural lands in Ukraine, polluted with explosive remnants of war and other contaminants. The project involves the implementation of blockchain technologies for tracking and financing demining operations in the de-occupied regions (including Kherson, Mykolaiv, and Zaporizhzhia oblasts), as the revival of Ukraine's role as a global food supplier largely depends on this.

Thus, according to the authors' belief, the potential application of blockchain technology and the introduction of smart contracts in Ukraine appears to be quite multifaceted: from the restoration of industrial facilities and residential infrastructure to the revival of the agricultural sector, from public services (including the issuance of blockchain-based educational diplomas) to energy infrastructure (in this case, referring to the "Blockchain4Energy Project" in cooperation with the Ministry of Energy) [9].

All these initiatives are united by a common goal – the digital transformation of Ukraine's post-war economy based on the principles of transparency, openness, and trust. In the following sections of the monographic study, the authors will explore how exactly blockchain technologies can serve as a driver for attracting investment, and a project-based blockchain model will be presented to support the recovery of war-affected settlements.

4.3 Methodological model of the study

Approach and Research Methods. This study is systemic and comprehensive in nature, combining theoretical analysis, exploration of applied cases, and the development of a conceptual model. The methodology is based on an interdisciplinary approach: it involves tools of economic analysis (assessment of the influence of trust and transparency on investment activity), elements of information technology (analysis of the architecture of blockchain-based solutions), as well as methods

of content analysis of legal and regulatory documents, and secondary data sources. A significant component of the methodology was the semantic analysis of key terms and concepts related to the theme of the monographic research. This analysis allowed the identification of the key semantic nodes of the topic and the determination of the central semantic axis around which the core concepts are structured. The central axis of the study is the concept of "transparency in investment processes during the post-war recovery of Ukraine" – it lies at the core, as it connects technological aspects and economic outcomes (i.e., how technical transparency and the scaled implementation of smart contracts will contribute to economic trust and the activation of investment activity). Surrounding this axis are the following semantic nodes: Blockchain technologies; Smart contracts; International investments; Post-war recovery; Remediation; Revitalization; Anti-corruption control; Digital transformation. Each of these concepts was analyzed in terms of definitions and interrelations (**Fig. 4.2**).

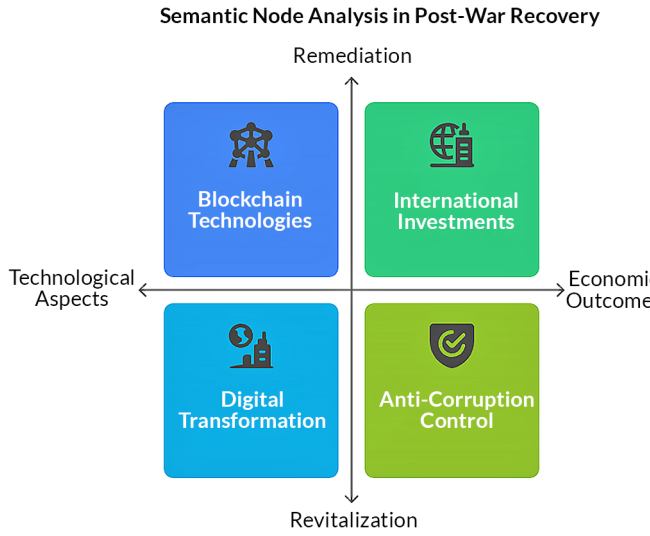


Fig. 4.2 Key semantic nodes of the methodological research model

Blockchain technologies and smart contracts represent the consistent foundation of the study, which predetermine the very fact of investment inflow. Their logical connection with investment activity is manifested through the concept of investor trust in the project and the notion of potential effectiveness, namely: implementation of these technologies → increase in transparency level → strengthening of trust

among all participants of recovery projects → growth of investment activity in the restored territory.

International investments – in the context of this study, are understood as both foreign direct investment (FDI) and donor funding, loans from international organizations, assistance from individual benefactors and Ukrainian diasporas of various types, among others. Logical linkage: international capital will be invested under the condition of a favorable climate and an established relationship system, which includes transparency at every stage of financial allocation for post-war recovery based on the rule of law.

Post-war recovery is the general context of this comprehensive and systemic study, which encompasses all types of work related to the reconstruction and restoration of destroyed economic facilities, infrastructure, housing, and social objects in territories affected by military actions. It is inextricably linked to the need for investments of a technical, technological, informational, humanitarian, and other nature, as the recovery process requires a diversity of various types of resources and technologies. The logical connection with the necessity of implementing digital technologies is driven by the need to apply non-standard solutions and modern approaches to the management of remediation and revitalization processes.

Remediation is a concept denoting a set of measures aimed at the ecological and socio-economic restoration of war-affected territories. In the context of Ukraine, it includes the elimination of military contamination, rubble removal, demining, restoration of soil, water, and air quality, as well as the reconstruction and remediation of destroyed facilities.

Revitalization, as understood by the authors, refers to the rebirth or return to active social and economic life of communities and settlements following remediation activities. It includes the restoration of social and cultural environments, infrastructural objects within populated areas, and the creation of conditions for the return of businesses and population.

According to the authors' belief, these two concepts are logically interconnected: remediation serves as the initial stage (specifically, the cleansing of the territory after the cessation of military activities and the elimination of all types of contaminants, as well as preparing the area for further revival), which is followed by revitalization – a return to normal life (economic, cultural, and social) on the recovered territories.

Logically, both stages require substantial investment and effective management of the abovementioned projects, which, in turn, necessitates ensuring transparency and control. Therefore, they are included in the semantic field of the study as crucial directions where blockchain systems and smart contracts can be employed to guarantee the targeted allocation of all types of resources.

Anti-corruption control plays the role of a critical condition necessary for ensuring investor trust. Post-war recovery projects, regardless of their potential profitability, will not attract investment if funds are embezzled through corrupt schemes and non-transparent regulation. Blockchain and smart contracts potentially serve as instruments of anti-corruption monitoring (transactions cannot be hidden or altered, contract terms are subject to automatic execution and are publicly accessible for control). Therefore, the logical sequence is unambiguous: Digital technologies → Anti-corruption control at all stages of project implementation → Stakeholder trust → Investment inflow.

Digital transformation encompasses all IT innovations and digital solutions that may be applied to address the research objectives. Semantically, it is important that blockchain fits into the general trend of the digital transformation of Ukraine's recovery governance. The logical connection is as follows: Digital tools (including blockchain) → Transparent management of remediation and revitalization of war-affected territories → More efficient and rapid recovery → Increased attractiveness for investors. It is crucial to emphasize the fact that remediation and revitalization are dimensions of post-war recovery that are critically dependent on trust and control, and therefore their analysis through the prism of blockchain technologies is of paramount importance and significance [30].

4.4 Analytical assessment of the role of blockchain technologies in stimulating international investment activity in post-war Ukraine

Financial resources required for post-war recovery of Ukraine. In order to understand how blockchain can influence investment activity, it is first necessary to outline the problem field of this process. The post-war recovery of Ukraine, in terms of its scale and required resources, is often compared to a new "Marshall Plan". However, unlike post-war Western Europe in the mid-20th century, modern Ukraine faces not only economic difficulties but also a trust deficit.

Even in the presence of a number of positive reforms (such as the ProZorro system, NABU, Diia, etc.), Ukraine continues to be perceived as a country with a high level of corruption due to a combination of factors: weak judicial institutions, oligarchic influence, low level of law enforcement, and a scandalous media environment.

According to the CPI index data presented above (**Fig. 4.3**), Ukraine, with a score of 35, is positioned below the global average, which indicates structural and persistent corruption risks.

For comparison: the Republic of Poland scored 54 points (in 2024), the Republic of Lithuania – 61, the Federal Republic of Germany – 78, the Kingdom of Denmark is the leader with a score of 90.

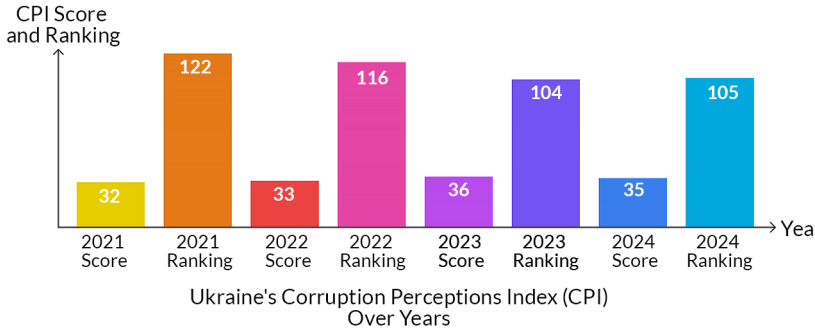


Fig. 4.3 Dynamics of Ukraine's position in the Global Corruption Perceptions Index, 2021–2024

It should be emphasized that the higher the CPI score, the lower the perceived level of corruption and the more favorable the investment and institutional environment in the country (**Fig. 4.4**). This is critically important for building trust among investors, donors, and international partners.

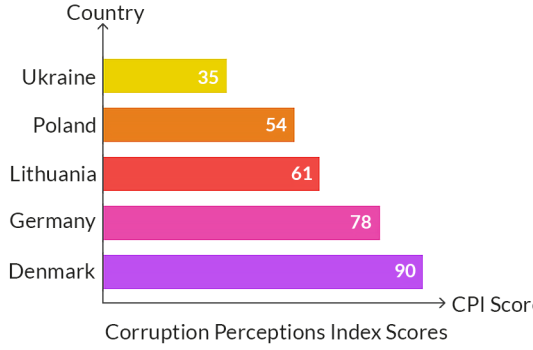


Fig. 4.4 Ukraine's place in the Global Corruption Perceptions Index, 2024

Despite the enormous international support, donors and investors expect concrete steps from Ukraine in the context of ensuring the transparency of resource utilization, as they understand that "every dollar must reach its intended goal".

Western partners explicitly link the volume of aid to the progress of ongoing reforms in Ukraine.

In this regard, it is worth highlighting the launch of the pilot project in 2023 – the Unified Digital Recovery Project Management System (DREAM platform), which is intended to ensure a full cycle of open monitoring – from the submission of project applications to tenders, execution of works, and payments – with open data available at each stage of implementation [31]. It is envisaged that the DREAM system will aggregate information from all existing sources and make it publicly accessible – something that has not previously existed in Ukrainian administrative practice. According to the unequivocal opinion of experts, it is critically important that all recovery projects be transferred into this system to guarantee maximum transparency and provide investors with a comprehensive picture of territorial remediation and revitalization [32].

Nevertheless, even in the presence of political will and implemented digital platforms, unfortunately, other persistent risks for investors still exist. Corruption may manifest not only through direct embezzlement of funds but also during the stages of reconstruction and remediation works (for example, overpricing of construction materials, collusion in tenders, failure to comply with standards, etc.). Investors are fully aware of the aforementioned risks. Historically, Ukraine has suffered from a lack of foreign direct investment (FDI), largely due to its negative reputation concerning corruption and the weakness of state institutions responsible for counteracting such phenomena.

Between 2021 and 2024, Ukraine experienced significant fluctuations in the inflow of foreign direct investment (FDI), driven by both internal factors and global economic trends. A detailed analytical assessment of the dynamics of FDI in the Ukrainian economy during this period is presented below (**Table 4.1**).

Table 4.1 Dynamics of FDI in Ukraine during the period 2021–2024

Year	FDI Volume (billion USD)	% of GDP
2021	7.95	4.1
2022	0.22	0.3
2023	4.81	2.7
2024	0.16 (Q3)	The data for the entire year has not yet been determined

Source: the data in the table was taken from sources [34–36]

As can be seen from the table data, in 2022 there was a sharp decline in the total inflow of FDI to 0.22 billion USD, which accounted for only 0.3% of GDP. This dramatic decrease in the scale of investment activity was associated with the outbreak

of full-scale war, which led to capital outflows and the suspension of already launched projects. In addition, global trends, including the rise in energy and food prices, further exacerbated the negative impact on the overall investment climate. However, already in 2023, an increase in FDI volume was recorded, reaching 4.81 billion USD (which accounted for 2.7% of GDP, factual note). It should be noted that a significant part of these investments came from reinvested earnings rather than new capital inflows. According to the National Bank of Ukraine, in 2023, reinvested earnings accounted for approximately 75% of the total volume of foreign direct investment.

The impact of blockchain on investor trust. Blockchain technologies can provide unprecedented transparency of financial flows, which will be the key to solving the challenges of attracting investment capital to Ukraine. If all transactions within investment projects are recorded in a public (or accessible to regulatory bodies) blockchain, then any interested stakeholder – from an international auditor to an ordinary citizen of Ukraine – will be able to trace the movement of financial resources from the source to the final recipient.

For instance, in the case of the above-mentioned recovery platform functioning on blockchain, the process would look as follows: the investor does not transfer funds to a regular bank account, but rather to the address of a project-specific smart contract. Then the smart contract automatically transfers these funds to specific contractors as they complete their work, and each such payment is reflected in the ledger with an indication of the amount, time, recipient, and justification for the transaction. No "hidden streams" of funds can go unnoticed, as the blockchain does not allow for payments "around the system" – every operation must be confirmed by the network. This sharply contrasts with the traditional system, in which funds may be moved between accounts of various subcontractors, offshore entities, etc., and only ex-post audit may (or may not) detect traces of misuse of resources. Essentially, blockchain enables the integration of the entire financial picture of the recovery process. According to the authors, the ideal implementation of the remediation and revitalization strategy for Ukraine's territory involves the complete elimination of the human factor in the allocation of financial and other resources – which is equivalent to the elimination of corruption.

The next equally important aspect is the enhancement of accountability. Since blockchain records are immutable, any instance of misuse of funds remains in the historical ledger and can be proven. This in itself acts as a preventive measure: knowing that transactions are open and indelible, participants are less inclined to commit violations. In addition, smart contracts allow for the codification of rules and conditions for fund utilization. For example, international partners may insist that their investments or loans be executed via smart contracts specifying clear KPI indicators. In this

scenario, funds allocated for reconstruction and remediation of war-affected territories – say, from the International Finance Corporation (IFC) – can be "unlocked" in tranches only upon the achievement of specific construction stages. These stages may be certified by an independent engineering inspection, the results of which are uploaded into the blockchain. If the conditions are not met, the smart contract may return the unused funds to the investor upon expiration of the contract term. This creates confidence among international stakeholders that their money will not disappear without trace – it will either be spent in a targeted manner or remain fully preserved. Finally, an equally critical aspect is the reduction of transaction costs and time. As is well known, international bank transfers – especially involving multiple parties – are usually time-consuming and involve significant commission expenses. Blockchain, on the other hand, operates 24/7 without borders: transfers in cryptocurrencies or stablecoins can be completed within minutes.

This is extremely important, especially in conditions where funds are urgently needed. As mentioned earlier, the war in Ukraine has already demonstrated the advantage of such a system: millions of dollars in cryptocurrency were mobilized and delivered to recipients within mere hours or days, whereas traditional aid required weeks to arrive [5].

It should be emphasized that after the end of active hostilities, the factor of time and the speed of recovery will have colossal significance. This refers to the prompt elimination of contaminants in water resources, the reconstruction of critical infrastructure facilities, or housing before the onset of cold weather [37]. In this case, rapid financing enabled by blockchain significantly increases the likelihood that projects will be implemented on time and, consequently, enhances the motivation of potential investors (as projects are not "frozen" due to funding delays and the completion of project implementation is not postponed). In addition to the aforementioned, the reduction in the number of intermediaries (such as banks, insurance agencies, etc.) substantially saves both money and time. For international investors, this means a more efficient use of their capital (in this case, a greater "return" on every dollar invested), which, in turn, encourages them to participate in a greater number of projects.

The final and most significant aspect is the emergence of innovative capital investment mechanisms and, consequently, new opportunities. Blockchain technologies introduce novel methods of investment that were previously inaccessible. One such method is the tokenization of assets. As highlighted in the study by Ukrainian economists M. Riabokin and Ye. Kotukh, Real World Asset (RWA) tokenization can serve as a powerful catalyst for attracting capital into Ukraine's economy in the postwar period [38]. The essence of RWA tokenization, as described by the authors, involves transforming real assets – such as real estate, infrastructure facilities, land

plots, and even future production outputs of enterprises – into digital tokens on the blockchain. These tokens confer ownership rights or shares in the assets and can be freely exchanged or sold to investors worldwide. For Ukraine, which possesses a substantial volume of underutilized assets with low economic efficiency, tokenization can significantly lower entry barriers for investors and enhance the liquidity of these assets. The study emphasizes that implementing RWA tokenization can become a strategic tool for Ukraine's post-war reconstruction and digital economic transformation, facilitating the creation of new investment instruments and modernizing the country's financial infrastructure.

This resembles the issuance of securities but on decentralized infrastructure, without the traditional costs and delays associated with emission. Thus, it is likely that we will soon witness the creation of new investment instruments and markets, which is already supported by successful examples in global practice (such as the operation of security token platforms). M. Riabokin and Ye. Kotukh, in their study, conclude that the implementation of RWA tokenization in Ukraine opens up new channels for capital inflows, thereby contributing to the diversification of investor portfolios and enabling access to previously inaccessible assets – a factor that will be particularly relevant and significant in the context of the post-war modernization of Ukraine's financial infrastructure.

Another mechanism that, in the authors' view, holds significant development prospects in the future is the establishment of Decentralized Autonomous Organizations (DAOs) aimed at financing post-war reconstruction projects. The concept involves investor communities or interested parties forming DAOs – a set of smart contracts – to pool funds into a common treasury and collectively decide which projects to invest in (for example, through blockchain-based voting).

Such a mechanism provides a tangible opportunity for the Ukrainian diaspora in countries like Canada and the USA to directly invest in specific projects (including the restoration of schools, hospitals, monuments, etc.) in a crowdfunding format managed by smart contracts, thereby mitigating the risks of fund misappropriation by organizers. It is noteworthy that this mechanism has been tested: in 2022, Ukraine DAO was established, which raised 6.75 million USD through an NFT auction of a digital Ukrainian flag to support Ukraine's war efforts. The proceeds were directed towards humanitarian needs, demonstrating the potential of DAOs in mobilizing resources for targeted causes [39]. According to the authors' vision, similar DAOs could be created to facilitate the reconstruction al community concerned with Ukraine's recovery.

Summarizing this analytical section, the following can be concluded: the implementation of blockchain technologies and smart contracts possesses significant

potential and a multiplicative effect in stimulating economic, including investment, activity. The direct effect of their application is the increase in trust among all participants and stakeholders, the reduction of risk levels, as well as the expansion of financing mechanisms for projects. In the context of Ukraine, their scaling across all spheres of socio-economic activity can stimulate capital inflows. The indirect effect will be the improvement of the reputational image and investment climate, which also correlates with the willingness of foreign actors to initiate partnerships and participate in reconstruction projects. For post-war Ukraine, where the demand for resources is colossal and the competition for them is high, the use of blockchain technology in all its manifestations may become a competitive advantage.

Analysis of the multi-aspect systemic functionality of blockchain and smart contracts. Based on the in-depth scientific analysis presented above, it is reasonably possible to assert that blockchain technologies and smart contracts perform a multi-aspect systemic function in the context of post-war recovery in Ukraine, especially in the direction of stimulating international investment activity. Below is an expanded and detailed characterization of their role, presented as logically interconnected provisions, namely:

1. Blockchain and smart contracts act as a *mechanism* for ensuring transparency and accountability, which allows the weaknesses of traditional project management systems to be mitigated (in our case – investment-related).

2. They represent a *method* of digital verification of actions, in which: full control over compliance with pre-established conditions is executed (through the use of software code); legal and technological justification for the distribution of financial resources is achieved; opportunities for seamless integration into project management methodology with linkage to KPIs and project implementation phases are ensured.

3. Blockchain and smart contracts are a technological *tool* for investment management and project implementation, which: allows the investor to "see" the use of their funds at each stage; increases trust through step-by-step, consistent, and immutable records; reduces transaction costs; significantly optimizes and accelerates the pace of operations; can be seamlessly implemented as a module in existing digital platforms (for example, Camunda + blockchain + Streamlit).

4. These technologies function as a *lever* for institutional changes, which: transform the principles of working with donor and investment capital; help to reduce corruption levels; strengthen Ukraine's position as a trustworthy partner; facilitate decision-making on the part of international investors, IFIs, diaspora, and the private sector.

5. Blockchain and smart contracts serve as a *transfer factor* of trust, which connects: the intentions of the investor ↔ with the implementation process ↔ with final results; legal transparency ↔ with digital immutability and, accordingly,

stability; off-chain processes ↔ with on-chain fixation (for example, DAO-investment, tokenization).

In addition, within the context of this scientific study, blockchain and smart contracts:

– form the foundation for creating digital ecosystems for the remediation and revitalization of war-affected territories (including DREAM, Blockchain4Grain, Blockchain4Energy, etc.);

– ensure infrastructural compatibility with European digital standards, such as EBSI, eIDAS 2.0;

– create new formats of institutional interaction: DAO, RWA tokenization, digital bonds (including EIB, Bond-i, Beesfund, etc.).

Thus, within the framework of the authors' monographic study, blockchain and smart contracts simultaneously function as a mechanism of institutionalization of trust, a method of digital transformation, a tool of anti-corruption control, a lever for strengthening investment activity, and a transfer factor for the transition from reputational risk to a transparent and controllable financial architecture of recovery.

4.5 Project model of a blockchain system for post-war remediation and revitalization in Ukraine

General provisions and requirements. The project model developed within the framework of this study envisions the creation of an integrated blockchain-based platform for managing recovery projects. This platform is intended to support remediation projects at the national scale with an initial pilot launch in one of the most affected settlements (including, among others, demining, environmental cleanup, ecosystem restoration, etc.) and revitalization projects (including, among others, the construction and reconstruction of housing, infrastructure, social, cultural, and household facilities for the population, economic revival of territories, etc.). The key objective of the proposed system for implementation is to ensure full transparency and accountability at all stages of the project life cycle, from planning to completion, thereby strengthening the trust of both external investors and the local community.

Justification. The war has destroyed not only industrial facilities and infrastructures but also the social life of communities that lived in specific settlements (houses, social, cultural, and household facilities, household plots, domestic farming, business facilities, etc.). Undoubtedly, revitalization is impossible without first ensuring physical security. Thus, a logical sequence of necessary actions for implementation is built: Assessment and identification of war-inflicted damage, destruction, and

needs → A set of remediation measures (demining and cleaning of territories from the consequences of military activities) → Cleared lands/territories → Restoration of infrastructure → Return of the population → New economic activity.

Project goal. The goal of the project "Smart-Invest: Blockchain-Based Remediation and Revitalization through Smart Contracts in Post-War Recovery (SIBReS)" is to create an integrated digital model for managing post-war recovery (using the example of the village of Chornobaivka in the Kherson region), which will enhance the investment attractiveness of the territory through the integration of blockchain technologies and smart contracts as mechanisms of institutional trust, transparency, and effective investment process management. The project is aimed at stimulating the inflow of international investments, including foreign direct investment (FDI), donor funding, and the participation of Ukrainian diasporas from various countries (**Fig. 4.5**).

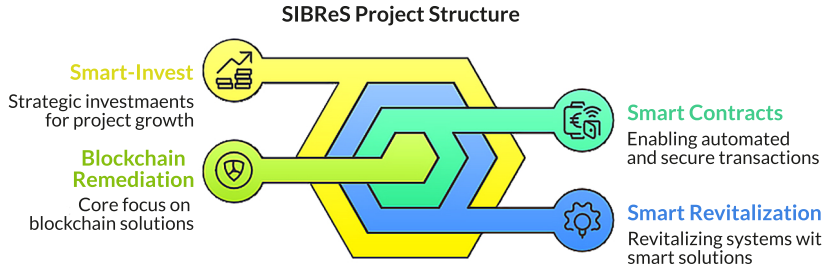


Fig. 4.5 Smart-invest project characterization: blockchain-based reconstruction and revitalization through smart contracts in post-war reconstruction (SIBReS)

Expected results. The SIBReS project will serve as a next-generation model for managing the recovery of territories affected by military activity – synthesizing advanced informational, technological, economic, and social approaches. It is expected that the implementation of this project will contribute to the formation of a new digital culture of transparency and trust, which is currently of critical importance in the context of the rapid and effective restoration of Ukraine's socio-economic development. According to the authors' conviction, the successful launch of the SIBReS project will enable the scaling of similar initiatives across the entire territory of the country, which, in turn, will have a positive impact on the investment climate and the international image of the state – demonstrating its readiness for the active implementation of innovative technological solutions.

The stages of the project are presented in **Table 4.2**.

Table 4.2 Stages of the project "Smart-invest: blockchain-based remediation and revitalization through smart contracts in post-war recovery (SIBReS)"

Stages	Component	Key Technologies/Tools
1	Assessment and Identification of Remediation and Revitalization Targets	Geo-analysis, satellite imagery, damage assessment inspections, registry of destroyed territorial assets
2	Remediation	Demining, mechanical and biological cleanup of sites and areas, environmental audit
3	Project Application, Investor Search, Donor Funding	Project creation on the platform, investor registration (FAO, EBRD)
4	Contractual Module	Smart contracts on Ethereum/Binance Smart Chain + integration with ProZorro
5	Implementation Monitoring	IoT sensors, GPS, satellite verification, IPFS storage, auditing
6	Revitalization	Reconstruction of housing, social, cultural and utility infrastructure, road and communication networks, economic reactivation, MSME development support
7	Transparent Reporting	Visualization through blockchain interface, dashboard for investors, financial donors, and local residents

Project advantages:

– *modularity:* each of the aforementioned project stages represents a separate smart contract block. The transition to the next stage will only be possible upon confirmation of the previous one (audit → validation → activation of the next tranche);

– *participation of local residents:* possibility of feedback through DAO mechanisms (including voting by residents on the platform regarding the order of implementation of recovery projects in the settlement of Chornobaivka);

– *integration with state registries:* all information on the restoration status of the settlement, including all objects, will be digitized and integrated with the "Diia" system, the open data platform data.gov.ua (for the analysis of open environmental data, namely for the monitoring of air, water, and soil pollution), the Unified State Land Cadastre platform, and others.

Starting point and rationale for selection. Chornobaivka is one of the symbolic and significant settlements in the context of the full-scale war in Ukraine. It was frequently mentioned in the media as one of the epicenters of military operations and artillery shelling, which were associated, among other things, with the location of the Kherson airport and a military helicopter unit in Chornobaivka.

Key reasons for selecting this settlement as a pilot zone Include:

– *level of destruction:* according to assessments, over 80% of the residential housing stock has been destroyed; the private sector has been decimated, and no surviving social, cultural, or public service facilities remain;

– *scale of contamination:* the surrounding fields and areas of the settlement are heavily mined; remnants of explosive ordnance, military equipment, and other hazardous elements have been recorded;

– *diversity of post-war recovery tasks:* these include a wide range of activities – from demining operations and environmental decontamination to the construction and reconstruction of residential, industrial, and infrastructural facilities, as well as the restoration of social, cultural, and public service infrastructure;

– *high potential* for multi-sectoral recovery due to strategically significant geographical localization and other favorable factors.

Development potential and scenarios for post-war revival.

Before the war, the area featured:

– a high concentration of agro-industrial production;

– a logistics zone including an adjacent airport, highways running along the settlement, and the "Chornobaivka Station" railway terminal;

– a well-developed private residential sector with high building density, along with fully functioning infrastructure for social, cultural, and public service needs.

After de-occupation (as of today):

– severe environmental and infrastructural damage has been inflicted;

– the production potential has been almost completely destroyed;

– the system of governance and resource distribution has been disrupted;

– significant destruction of residential infrastructure has occurred;

– substantial decline in population and loss of labor potential (as of July 31, 2024, the settlement had approximately 5,000 residents, compared to over 17,000 before the war) [40].

Post-war development potential:

– extensive opportunities for the development of solar energy – the southern geolocation makes Chornobaivka a promising localization zone for the advancement of renewable energy;

– restoration of the agro-industrial sector of the economy – after land remediation, implementation of programs in crop production, agro-processing, and agrotechnologies is feasible;

– opportunities for tourism development (including agro-tourism and enotourism) – development of environmentally friendly farms, ethno- and agro-tourism routes, including the implementation of tokenized investment projects;

– development and strengthening of transport and logistics potential – restoration of the transport hub as a regional and national transit node;

– development of adjacent sectors linked to the region's core specializations – primarily through support for small and medium-sized business development;

– multiplicative effect as a result of revitalization achievements – population return, revival of social and cultural life, and the full functioning of the territorial socio-economic system.

Digital platform layout of SIBReS.

The authors have structured the general layout of the project, which is presented in the tables below (**Tables 4.3, 4.4**).

Table 4.3 General architecture of the SIBReS platform

Element	Description	Role and Significance
Frontend (UI/UX)	User interface for all user categories, including a mobile version	Provides access to the platform, facilitates participation in the recovery project, and enables interaction within the system (investors, donors, contractors, citizens, etc.)
Backend	Server-side logic: routing, API, caching, embedded business rules	The core of data processing and project management, enabling system scalability
Blockchain Layer	Decentralized transaction recording and storage, smart contracts, IPFS	Ensures transparency, data protection, automation of funding flows, and investor trust
Integration Modules	Interfaces with external systems: ProZorro, Diia, UNITED24, ArcGIS, satellite data	Expands platform capabilities by enabling synchronization with analytical services and national registries
Database	PostgreSQL + TimescaleDB + + ElasticSearch for storage and analytics	Stores structured metadata and provides fast access to information and time series data

Table 4.4 Characteristics of SIBReS project integration capabilities

Platform/Service	Brief Description
ProZorro	Full-fledged digital procurement system
Diia/Trembita	User verification, access to State Registry data
eHealth, UNITED24	Collection of data on medical and social infrastructure
IPFS + Filecoin	Reliable decentralized storage of documentation
ArcGIS/OpenStreetMap	Multi-layered geospatial analytics
Documentation	Decentralized file storage system (InterPlanetary File System, IPFS) + version control + voting system for approval
AI/ML Modules	"Before/after" comparison, anomaly detection, predictive auditing of contractors

Key modules of the platform:

1. *Project Registry Module.* Essentially, this is a unified catalog of projects with their descriptions, geotags, budgets, stages, and related documents.

Role of the module – creating a database of transparent and manageable recovery projects, reflecting their relevance and progress in remediation and revitalization.

2. *Smart Contract Module*, which is a system of automatic contracts between investors, donors, contractors, and verifiers.

Role of the module – full automation of settlements, eliminating the very possibility of misuse by ensuring logical transparency in the use of resources allocated for territorial recovery.

3. *Contractor and Inspector Module*, which represents a panel for submitting tender proposals, registering participants, and forming reports.

Role of the module – creating a healthy competitive environment that promotes increased responsibility among performers, thereby improving the quality of implemented recovery projects.

4. *Monitoring Module*, which covers, aggregates, and analyzes incoming data from drones, satellites, and sensors, with verification through AI.

Role of the module – guaranteeing objective quality control of completed works, preventing falsification and non-compliance with norms and standards.

5. *Visualization Module* – dashboards with analytics and feedback channels for project participants, including visualization of the territory recovery status.

Role of the module – ensuring accessibility of information, transparency control, and full awareness of project investors, donors, and the local population.

Project Integration. It reflects the platform's capabilities for connecting external systems. Role of integration – the ability to manage data in a unified digital space by uniting the efforts of the government, citizens, and investors.

KPI and Monitoring. Mathematical formalization of the relationship between the implementation of blockchain technologies and investment activity, including the multiplicative effect of the remediation and revitalization project.

A metric of the key indicators was developed for the SIBReS project, which is presented in a summarized version in **Table 4.5**.

Mathematical model of the multiplicative effect.

The formula for the overall multiplicative effect is as follows

$$I^{+}_{intl} = f\left(T_{blockchain}, RE, E_{rev}, D_{trust}, S_{visibility}\right), \tag{4.1}$$

where I^{+}_{intl} – the increase in international investment activity.

Testing the model using the example of Chornobaivka, Kherson region, including scenario simulation for the implementation of the SIBReS project.

The authors of the study launched a pilot project in a simulation environment: Camunda BPMN + Python-based smart contract model. Using Python scripts, calculations for the indicators *RE*, E_{rev}, D_{trust}, *IAI*, and the investment multiplier were performed, and the results are presented below in **Table 4.6**.

Table 4.5 Mathematical formalization of the key indicators of the project "Smart-invest: blockchain-based remediation and revitalization through smart contracts in post-war recovery (SIBReS)"

Indicator	Formula with Detailed Components	Explanation
RE (Remediation Efficiency)	$RE = \ln(A\_clean \times Q\_ecol)/(T\_rem + \delta)$, where *A_clean* – remediated area (hectares); *Q_ecol* – ecological quality index (0–1); *T_rem* – time for remediation (days); δ – time stability constant	Measures the efficiency of land or water remediation. Uses the logarithmic relation of the cleaned area and ecological quality, normalized by time and stabilized for long-term comparisons
E_rev (Economic Revitalization)	$E\_rev = \ln(G\_value \times B\_yield)/(T\_recon + \varepsilon)$, where *G_value* – gross value added (USD); *B_yield* – business yield growth rate (0–1); *T_recon* – reconstruction time (days); ε – smoothing constant	Quantifies the effectiveness of economic recovery by integrating gross economic output and business performance gains relative to reconstruction effort and timeline
D_trust (Digital Trust Coefficient)	$D\_trust = \ln(SC\_use \times A\_audit)/(R\_error + 1)$, where *SC_use* – number of deployed smart contracts; *A_audit* – number of automated audits; *R_error* – recorded process errors	Evaluates the digital trust level based on smart contract usage and automated audit frequency, penalized for process inconsistencies or detected violations
T_blockchain (Transparency Index)	$T\_blockchain = \sum Confirmed/n(1 + F\_uncertainty)$, where $\sum Confirmed$ – confirmed blockchain transactions or operations; *n* – total registered records	Reflects the transparency of the system via the share of confirmed blockchain entries, adjusted for system-level uncertainties or non-public process elements
S_visibility (Systemic Visibility)	$S\_visibility = \ln(A\_access \times P\_publicity)/(L\_delay + 1)$, where *A_access* – open access interfaces or data channels; *P_publicity* – publicity index; *L_delay* – latency in data publication	Captures visibility and traceability of the project using the logarithmic function of open access and public awareness, adjusted for latency in publishing or interfacing data
IAI (Investment Attractiveness Index)	$IAI = (E\_rev + D\_trust) \times T\_blockchain/(1 + R\_risk)$, where *R_risk* – investment risk index (expert-evaluated, 0–1 scale)	Final aggregated index for investment attractiveness combining revitalization results, trust levels, transparency, and risk control. Serves as a key output metric for investor decision-making

Table 4.6 Results of Python model calculations

Result	Value
RE (Remediation)	0.1
E_{rev} (Revitalization)	0.665
$T_{blockchain}$	0.78
D_{trust}	0.798
IAI (Investment activity)	0.747
Investment multiplier	2.03

Interpretation of the presented table results:

RE (Remediation) = 0.1 means that approximately 90% of the contaminated area is expected to be successfully cleaned. The lower this indicator, the higher the quality and depth of the remediation;

E_{rev} (Revitalization) = 0.665 reflects the multiplier value, meaning that in this case, each dollar of investment creates 0.665 USD of economic activity (through population return, SME development, and services). A value close to 1 is considered a good result for the initial stage;

$T_{blockchain}$ = 0.78 shows that 78% of transactions were processed and verified through smart contracts. This is quite a high level of transparency, which increases stakeholder trust in the project;

D_{trust} = 0.798 demonstrates the investor trust index, which is almost 0.8, reflecting a balanced combination of transparency, successful cases, and platform reputation. This is a sufficient level to motivate international partners to invest their own capital;

IAI (Investment Activity Index) = 1.03 reflects the cumulative growth of investment activity. The calculated indicator means a potential investment increase of 103% from the baseline after the implementation of the pilot project;

Investment Multiplier = 2.03 means that after the first stage of successful remediation and revitalization, the volume of investments may double.

Streamlit prototype.

For the purpose of implementing the set task, let's proceed to the creation of a Streamlit prototype. Streamlit is a Python-based framework that allows the development of interactive web applications based on data and analytical models.

In other words, a Streamlit prototype is the first working version of a digital tool (note that this is not yet the final product), which demonstrates: how the mathematical model operates; how users can interact with it; what parameter values are assumed under different scenarios.

In our case, the significance of the developed Streamlit prototype for the SIBReS project lies in: proving the operability of the mathematical model and its practical applicability; serving as a visualization tool for "what-if" scenario evaluation; preparing for the creation of an MVP (Minimum Viable Product) of the platform; forming trust among potential international investors and donors, as they can see the transparent logic that can be managed; providing an operational method for testing hypotheses.

Application within the SIBReS system.

This chart can be incorporated into the analytical module of the recovery monitoring system for: evaluating the contribution of each parameter to the final investment activity; forming predictive scenarios; selecting priority areas for project adjustments (including, for example, strengthening *RE* or E_{rev} depending on their impact) (**Fig. 4.6**).

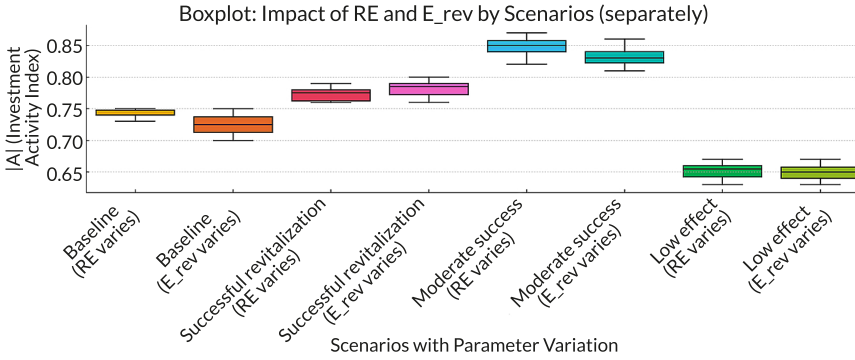


Fig. 4.6 Scenarios with parameter variation SIBReS

Let's proceed with the development of the UX layout of the SIBReS platform in the form of a schematic diagram and a prototype (**Fig. 4.7**).

The developed UX wireframe (user experience wireframe) of the SIBReS platform, presented as a visual schematic (interactive interface), reflects: the main structural blocks of the system (project registry, smart contracts, monitoring, visualization, etc.); user roles (investors, financial donors, contractors, government authorities, residents, etc.); logical connections between functional modules; data and action flows – from project registration to result verification and DAO voting.

Primarily, the UX wireframe is necessary for: further technical development of the project; presentation to investors and financial donors, as it provides a clear visualization of how the platform ensures transparency, verification, and resource distribution – the key to trust and funding; serving as a framework for the creation of

a Minimum Viable Product (MVP) with core functionality – the first step toward the pilot version of SIBReS; formalizing documentation, as it is used for grant applications, project roadmaps, and technical specifications.

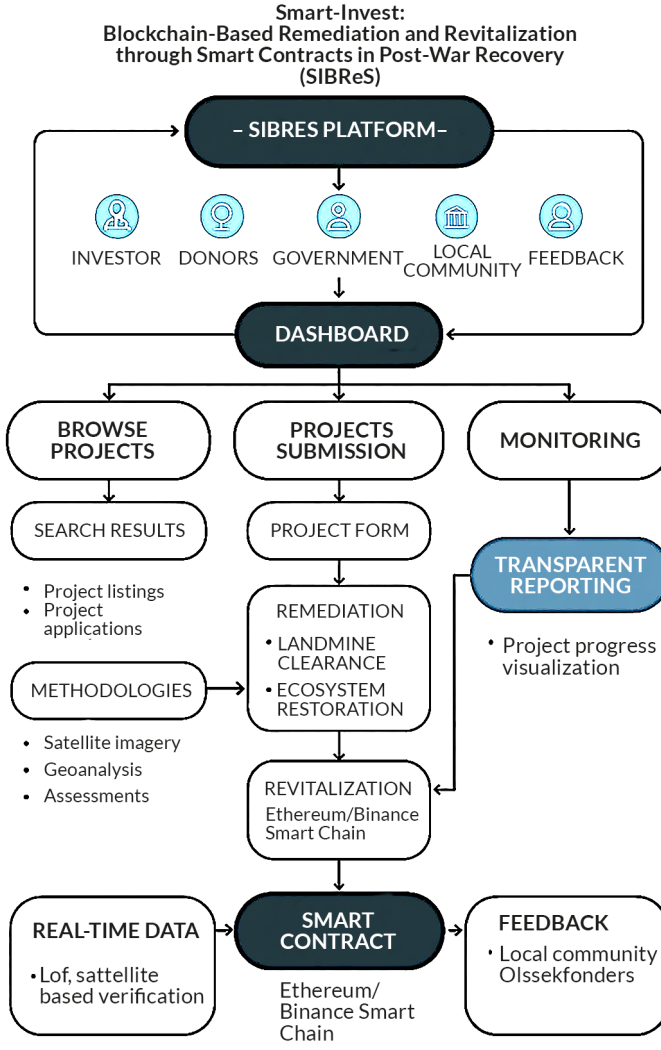


Fig. 4.7 UX layout of the SIBReS platform

The following modeling structure was used to conduct the simulation. The modeling was based on a stochastic approach using the Python programming language (specifically, the NumPy, Pandas, and Matplotlib libraries), and included 1,000 iterations per run. The purpose of the simulation was to assess the variability and resilience of the Investment Activity Index (IAI) under different economic, technological, and institutional scenarios.

The IAI was calculated using the following multiplicative formula

$$IAI = D_{trust} \cdot T_{blockchain} \cdot E_{rev} \cdot (1 + RE), \tag{4.2}$$

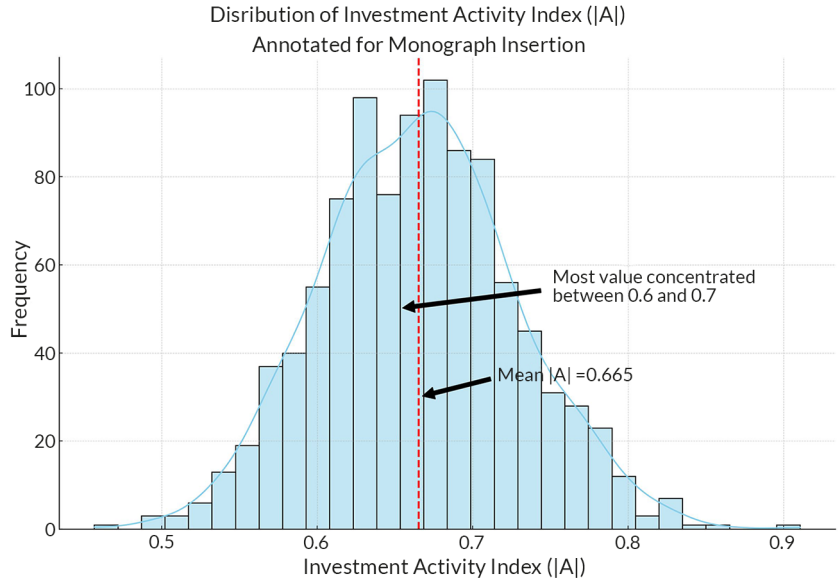
where D_{trust} – reflects the level of institutional trust (in the range 0.3–0.9, based on the Corruption Perceptions Index (CPI) and expert assessments); $T_{blockchain}$ – blockchain-based transparency index (in the range 0.5–0.95, based on open data from platforms such as DREAM, Diia, ProZorro, eRecovery); E_{rev} – revitalization efficiency (in the range 0.4–0.8, based on the modelled gross value added (GVA) return rate); RE – relative remediation effect (in the range 0.1–0.4, based on expert environmental impact assessment).

All parameters were randomly generated from uniform distributions within the defined ranges and subsequently normalized to ensure comparability. The ranges were selected based on open data from the World Bank, IMF, Transparency International, and empirical data from Ukraine's digital platforms.

Each simulation iteration generated one IAI value, which was visualized in the form of an "Investment Activity Cloud" (**Fig. 4.8**). This allowed for the observation of distribution density and general trend, confirming the overall predictive stability of the model.

This stochastic simulation made it possible to objectively analyze how changes in key parameters (such as the level of trust, remediation efficiency, revitalization effectiveness, and transparency level) influence the overall investment attractiveness of projects implemented through the use of blockchain technologies and smart contracts. The scatter plot ("investment activity cloud") of all 1,000 simulation runs, with an overlaid regression line, demonstrates that the IAI values are tightly clustered around the mean level of approximately 0.66, which confirms the high predictability and reliability of the investment process under the condition of implementing digital technologies for project management (for example, based on blockchain and smart contracts).

Thus, the previously calculated integral Investment Activity Index ($IAI \approx 0.747$) correlates with a high level of trust ($D_{trust} \approx 0.798$) and the efficiency of blockchain technology application ($T_{blockchain} \approx 0.78$), while the investment multiplier value of 2.03 indicates the presence of a strong multiplicative effect.



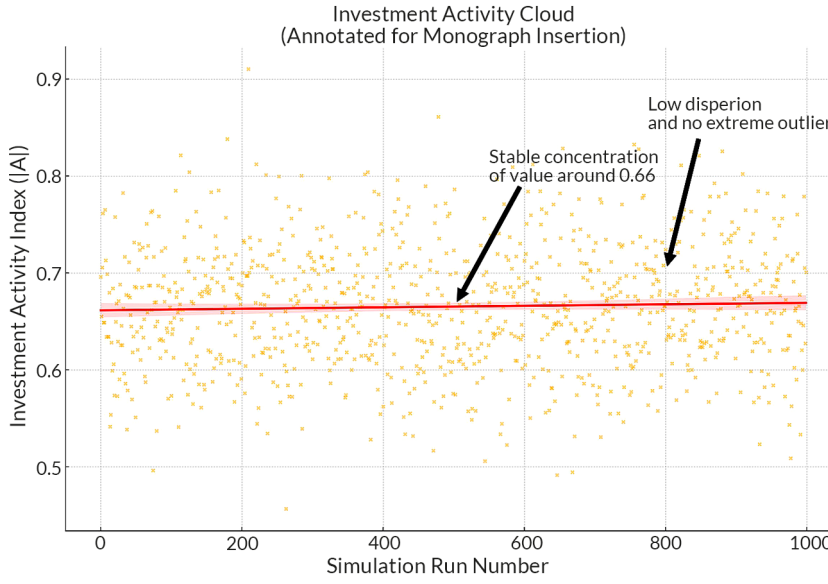


Fig. 4.8 Simulated investment activity landscape: density and dispersion patterns

The results of the conducted simulation confirm that the integration of blockchain technologies and smart contracts into the remediation and revitalization processes can significantly enhance investment activity (including international investment) during the post-war recovery of Ukraine. These findings support the thesis that digital transparency and automation are key factors for attracting capital and strengthening investor trust.

4.6 Conclusion

The conducted research has demonstrated that the implementation of blockchain technologies and smart contracts can serve as a powerful driver of international investment activity in Ukraine, which is undergoing a post-war recovery period. Transparency, trust, and efficiency, ensured by blockchain, address the key problems that have traditionally restrained the inflow of foreign investments – primarily, corruption risks and the lack of guarantees for the targeted use of funds. The analysis of the genesis and potential of blockchain has shown that this technology is mature for widespread application: its advantages in the form of an immutable ledger and automated contracts are recognized worldwide and confirmed by successful cases in both the public and private sectors. Ukraine finds itself in a unique position, where the urgent need for recovery coincides with the readiness of society and the state for digital transformations. A high level of digitalization and the experience of wartime use of crypto technologies have created favorable ground for the implementation of blockchain solutions. The international community, in turn, is interested in ensuring that every dollar provided to Ukraine is used as efficiently as possible – and therefore the openness of a blockchain platform will resonate with partners and donors. The project model of the blockchain system for recovery management developed in this work has concretized exactly how the principles of transparency can be implemented "in hardware and code": through a public project registry, smart contracts tracking the execution of works, asset tokenization to attract grassroots investments, and the direct involvement of citizens. The platform SIBReS, developed by the authors, represents a digital bridge between remediation, revitalization, and investments, combining technological efficiency, social justice, financial transparency, and adaptive management, exemplified through a specific territory, with the potential for successful scalability. It is capable of becoming the core of the digital management system for the country's post-war recovery process. From the perspective of international investors, the proposed model significantly reduces entry risks into the Ukrainian market, while ensuring an unprecedented level of

control and transparency, thereby offsetting traditional concerns related to jurisdiction. Within the framework of the research, a Python simulation with 1,000 runs was conducted and an investment activity cloud was constructed to objectively assess the resilience and variability of investment activity when applying blockchain technologies and smart contracts. The obtained results confirmed that these solutions can significantly reduce investment risks, strengthen trust, and contribute to the stabilization of international capital inflows. The investment cloud clearly demonstrated that the use of innovative technologies serves as an important driver for enhancing transparency and efficiency in the recovery of affected territories, which is particularly crucial for eliminating crisis phenomena and could be relevant for other countries (e.g., in cases of disaster recovery, natural catastrophes, technological accidents, etc.). Moreover, the creation of such a system effectively sets a new standard of investment openness, capable of attracting not only funds for recovery but also direct investments into related sectors such as IT, fintech, and consulting. In other words, blockchain can become part of the brand of the new Ukraine – a country striving to overcome corruption through progressive technologies and to become an attractive and reliable place for doing business.

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