



Article

Digital Transformation of Public-Private Partnership Tools

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Abstract: The need for modern infrastructure as a prerequisite for sustainable development, poverty alleviation, and improvement of the quality of life of the population is a global problem that requires searching for and attracting large amounts of long-term investments. The presence of this problem in recent decades has led to the increasing implementation of complex and costly infrastructure projects through the public-private partnership (PPP) mechanism with high potential for attracting investment. This mechanism, in conditions of limited financial opportunities, allows one to combine the financial resources of the public and private parties for the implementation of major infrastructure projects. The limited use of existing tools at different stages of PPP projects and the increasing need for additional resources make it necessary to consider the possibility of using digital tools that complement traditional ones. For this purpose, the authors analyze existing financing tools, revealing their advantages and disadvantages, and identify and justify the possibility of using digital tools in the implementation of PPP projects. However, digitalization includes not only financing tools but also the development of infrastructure, including digital platforms needed to conduct such operations in the digital environment. As a result, a combined financing toolkit can be formed for each phase of project realization, including traditional and digital tools. The results of this study will become a basis for revealing the directions of the digital transformation of the PPP mechanism.

Keywords: public-private partnership mechanism; project financing tools; digital transformation; digital investments; digital financial instruments; specialized and integrated digital platforms



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1. Introduction

The state and development of infrastructure is a key factor in the economic growth, social well-being, and competitiveness of individual regions and countries. The insufficient provision of infrastructure facilities to the society leads to a significant increase in the demand for additional investment and the need to find long-term sources of financing. Resource intensity and the extremely high costs required to address the infrastructure problems have contributed to the fact that large-scale infrastructure projects have in many cases been implemented through a public-private partnership mechanism.

In many scientific sources, public-private partnerships are defined as a public-private agreement on the production and provision of infrastructure services concluded to attract additional investment, and more importantly, as a means of improving the efficiency of budget financing (Delmon 2009).

The public-private partnership (PPP) mechanism allows one to pool the financial resources of the public and private parties for implementing public projects, especially infrastructure projects, on mutually beneficial terms while sharing the risks of the implementation of the project. Thanks to this, interest in projects implemented on PPP terms is steadily growing all around the world, which is confirmed by the increasing volumes of financing by sector and the number of new participants.

For example, according to the World Bank, the number of PPP-funded projects has increased by 1.3 times over the following years, although funding has decreased by 13%, as evidenced by Table 1 data.

Table 1. Dynamics of changes in PPP projects funding by World Bank structures.

Indicators	2014	2015	2016	2017	2018	2019
Number of PPP projects, units	310	334	242	304	335	409
Volume of financing, billion dollars	111.7	111.6	71.5	93.3	90	96.7

Source: (World Bank 2019a).

However, in recent years the problems of PPP related to the institutional, organizational, and other features of traditional partnerships that do not meet today's requirements for the rapid attraction of funding for PPP projects, have been highlighted. This is confirmed by the decrease in funding, the maximum amount of which occurred in the period of 2011–2014; in 2016 the minimum was achieved, after which the amount of funding stabilized, although it did not reach the previous values. The average cost of projects accepted by the bank for financing has also reduced from USD 0.36 billion to USD 0.24 billion.

The prospects of overcoming these problems are related to a number of approaches, however, the most efficient one is the introduction of digital tools based on modern information and communication technologies into existing PPP mechanisms. The digitalization of different sectors of economic activity shows great opportunities for increasing decision-making speed, flexibility, and transparency in organization and monitoring of projects of different sizes. At the same time, questions remain as to how and what digital tools can be applicable and useful for such a complex and diverse structure of activity as is built in public-private partnerships. The answers to these questions will lead to the formation of a combined PPP toolkit that will include both effective practices of traditional mechanisms and digital tools for financing and implementing PPP projects.

The goal of the research is to analyze existing practices and determine what digital tools and technologies can facilitate the digital transformation of public-private partnerships to enhance the socio-economic impacts on the state, business, and society.

For achieving this goal, the authors of this paper outlined the following tasks:

- identifying and analyzing the current state, problems, and shortcomings of the current PPP financing mechanism;
- conducting a critical analysis of existing sources and methods of financing PPP projects based on the implementation phase;
- identifying a set of digital tools that can be used at different stages of project implementation in addition to traditional tools;
- identifying the main areas of the digital transformation of the PPP mechanism.

The results of the study are intended to be used by both the private sector, which focuses on the use of digital tools in its activities, and the public sector in the development of PPP project realization mechanisms.

The results obtained form the basis for subsequent development of an integrated platform for interaction between PPP participants.

2. Materials and Methods

2.1. Methodological Principles of the Research

The authors' article is a comprehensive interdisciplinary scientific study based on the following basic methodological principles:

1. The principle of development and analysis of practices, reflecting the continuous change and development of forms, methods, and sources of financing for public-private partnership projects in the context of the transition to the digitization of the economy.

2. The principle of determinism, associated with the identification of factors that influence the development of the digital economy instruments, depending on the mechanisms of financing projects of public-private partnerships.
3. The principle of consistency, reflecting an interconnected system of interdisciplinary approaches to the consideration of different aspects and methods of using digital technologies, the formation of digital financial instruments for funding the PPP projects.
4. The principle of objectivity, which involves ensuring the interaction of different economic subjects in the process of financing projects and understanding the need to develop digital technologies and tools.
5. The principle of system engineering, which involves the use of a methodology for creating complex systems in the design of a digital PPP platform based on the necessity to identify the needs of stakeholders involved in the project.

2.2. PPP Mechanism and Its Place in the Development of Digital Infrastructure

The concept of a public-private partnership mechanism as an efficient method of attracting financial resources for the realization of infrastructure projects has received quite broad coverage in the modern scientific literature. Many researchers have made significant contributions to the development of various aspects of this problem, which allows us to present some of them.

A number of papers present a comprehensive approach to the mechanism of organization, management, and financing of PPP projects by both the public and the private sector (Yescombe and Farquharson 2018; Gatti 2018). The sectoral and regional features of the PPP mechanism have been noted (Agarchand and Laishram 2017; Romero 2015; Chotia and Rao 2018; Asubonteng 2011; Xu and Chang 2016; Singapore Ministry of Finance 2012).

The PPP mechanism creates benefits for both the state, reducing the initial capital costs of projects and improving the efficiency of the use of private capital, and for the private party, which receives a return on investment (Berezin et al. 2018). The researchers identify the following as the most significant reasons for using the PPP mechanism: the reduction in administrative costs of the state, the reduction in budgetary constraints in the public sector, greater mobility for the private party, the ability to attract funds from various sources within the private sector, and the acceptance of a common risk by the parties (Robert et al. 2014).

The reason for employing the PPP mechanism is the lack or insufficiency of funds of the government for infrastructure spending on the one hand, and its obligation to society to build and provide infrastructure on the other. The use of the PPP mechanism reduces the burden on short-term government spending and to some extent improves the efficiency and quality of public services (Xu and Chang 2016). Some scientists note that for successful implementation of PPP projects, it is necessary to create a favorable investment environment and provide state support for the PPP management strategy for the future (Sani et al. 2018).

The PPP mechanism, as a complex multifaceted concept, includes a number of different elements and related tools: country and industry features, composition of participants, regulatory and legislative conditions, object of contract, phases of project implementation, contract forms, sources, methods and forms of project financing, procedures for reimbursement of costs, risk allocation.

At the same time, the existing toolkit, especially the financing toolkit, has certain limitations, which hinder the development of the entire PPP mechanism. Therefore, the authors propose to improve this mechanism by incorporating digital investment tools increasing the opportunities for attracting financial resources for PPP projects and bringing all the participants together. The need to digitize the PPP mechanism stems from the introduction of information and communication technologies (ICT) and digitalization in all areas of public life, including business and public administration. The level of ICT adoption varies considerably in different countries. For example, the index of business digitalization of the countries leading by this parameter varies in the range of 50 to 25

(Figure 1). On the top of the ranking are the countries where businesses actively introduce and use digital technologies, increasing their competitiveness.

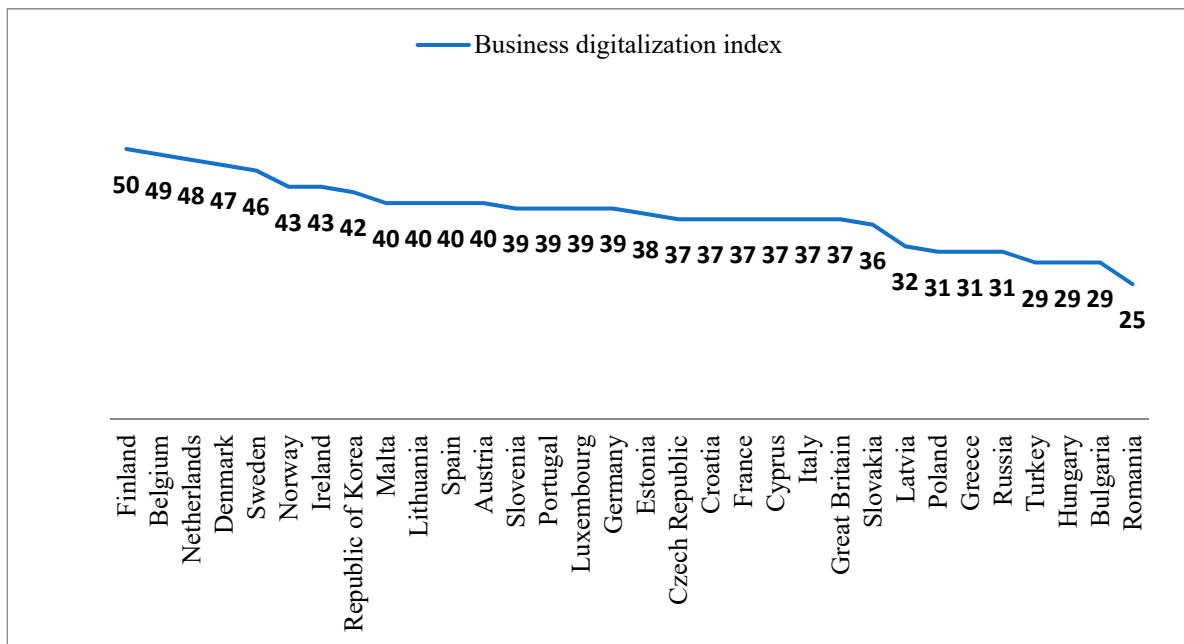


Figure 1. Rating of countries by the business digitalization index in 2018. Source: Compiled based on (Abdrakhmanova et al. 2020).

The rating of countries by the e-government development index in 2020 shows that the variation in the level of introduction of digital technologies into public administration is even greater. Figure 2 shows the top 20 of 191 countries by this indicator (UNDESA 2021).

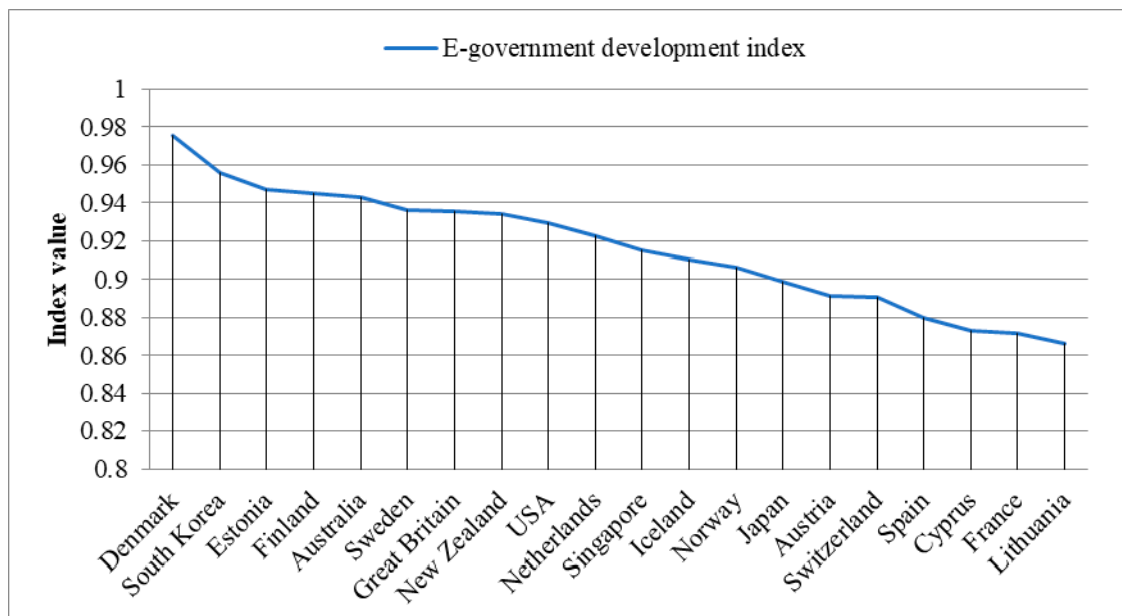


Figure 2. Rating of countries by the e-government development index in 2018. Source: Compiled based on the UN 2020 e-government development index (UNDESA 2021).

The countries in the middle of the list have an index of about 0.6 (Dominicana, India, Ghana), which is almost 1.5 times lower than the leading countries. The indicators of the

outsider countries differ from the leaders by more than 10 times (Central African Republic, 0.14, Somalia, 0.13, South Sudan, 0.08).

The private sector addresses the digitalization of the business mainly in the manufacturing sector in order to reduce costs and increase competitiveness. With regard to the digitization of the public sector, the situation is more complex. While developed countries have the financial capacity for adopting digital technologies, many developing countries do not have the means to do so. At the same time, the insufficient and often weak development of the digitalization of the system of public administration leads to deadline extensions, delay in funding, reduced quality, and other negative aspects in the provision of public services, including the provision of infrastructure. Therefore, the development of the modern system of government and the introduction of IT technologies in developing countries are supported by the World Bank structures (Table 2).

Table 2. Reserved World Bank funds by sectors of the economy in 2015–2019, billion dollars, percentage.

Indicator	2015		2016		2017		2018		2019	
	Billion Dollars	% of Total	Billion Dollars	% of Total	Billion Dollars	% of Total	Billion Dollars	% of Total	Billion Dollars	% of Total
Volume of funding by the world's macro-regions, total	42.5	100	45.9	100	42.1	100	47	100	45.1	100
including:										
Public administration	5.92	14	6.61	14	6.71	16	7.20	15	8.44	19
ICT	0.36	0.8	0.27	0.6	1.02	2.4	0.74	1.6	1.39	3.1

Source: Calculated by the authors based on the World Bank Reports of 2015–2019.

Funds provided by the Bank Group directly for the introduction of information and communication technologies and the creation of appropriate infrastructure so far are not very significant, but their volume and share in the financing structure are growing. At the same time, the cost of digitalization is also partly included in public administration expenditures, although their share is also not too high.

The PPP mechanism as a way of developing public infrastructure allows one to combine the opportunities of business and the state to solve the problems of the digital transformation of public services. Therefore, it is important to understand in what directions such development will take place, and what tools can be used.

The authors believe that the digitization of the PPP mechanism is ambivalent. First, it is the use of digital financial instruments in the process of investing in PPP projects (the financial component of the PPP mechanism), and secondly, it is the use of digital platforms to unite the interests of numerous PPP participants of projects (the organizational and communicational component). This approach allows the authors to conclude that, along with traditional organizational and financing tools, digital tools should be used in the implementation of PPP projects.

This becomes possible due to the interaction of state, municipal and private information and analytical systems, technology platforms, applied Internet services (Lutsenko 2019). In turn, the creation of a digital environment within the state and the private sector, combining open data, services, and tools for their use, forms information infrastructure for the business community, the state, and its citizens, including within the PPP. This approach allows one to facilitate the digital transformation of the PPP mechanism based on the combined toolkit, blending the traditional and digital financial instruments in the process of project implementation as well as ensuring efficient interaction of all the interested parties through the digital platforms.

3. Results

3.1. Overview of Current PPP Funding Tools

A detailed analysis of the tools used in PPP-based investment projects showed that the phases of implementation of the project, which differ from each other's goals, objectives, types of work, play an important role (Liu et al. 2015). Moreover, if the first and second stages are costly in nature, then the third and fourth ones involve the generation of income (Table 3).

Table 3. Types of work at different stages of the PPP project implementation.

	Stage of Project Implementation			
	Pre-Investment	Investment	Operation	Post-Investment (Liquidation-Analytical, Completion)
Types of work	Exploring the feasibility of the project	Detailed examination of the selected project	Construction and installation, start-up and commissioning work	Evaluation of the project results by the initiator and experts
	Pre-project and preparatory research	Deciding on the implementation of the project	Project maintenance	Assessing the project's investment experience
	Assessment of the feasibility of the project	Designing and developing a business plan of the project	Reinvestment for equipment replacement and overhaul	Post-audit
	Organizational, regulatory, and legal design of the project	Implementation of the project, reaching design capacity	Project monitoring	Reprofiling or eliminating capacity

Source: Developed and compiled by the authors.

The toolkit, including the search for sources of funding, methods of their accumulation, and use for the project, plays a decisive role in the implementation of PPP projects. Based on the intended participants and types of work, different methods of financing PPP projects can be used (Table 4).

Table 4. Funding methods used in PPP projects at different stages of their implementation.

Funding Methods	Stage of Project Implementation			
	Pre-Investment	Investment	Operation	Post-Investment (Completion)
Equity financing	+/-	+	+	+/-
Public financing	+/-	+	+	+/-
Project financing	+/-	+	+	+/-
Credit financing	-	+	+	-
Leasing financing mechanism	-	+	+	+/-
Equity or mixed financing	+/-	+	+	+/-

"+" all are used; "-" none are used; "+/-" are partially used (in a limited manner). Source: Developed and compiled by the authors.

Equity financing is the most common, though the most expensive, method used in the implementation of large-scale projects. However, often it is not able to protect the participants from project risks.

Public financing involves full or partial funding of public projects, mainly infrastructure projects, from state or local budgetary funds, as well as funds of extrabudgetary funds. Risks are associated with a reduction in revenues of the budget system and a possible decrease or freeze in project financing.

Project financing is a promising method of financing used for separate projects, which is, in fact, investment lending. It has become quite widespread in the financing of projects implemented in terms of PPP. It provides cash for the cash flow the project will generate after its completion. It involves pooling the resources of many participants, which are accumulated and distributed by a specially created project company. The risks are due to the fact that, as a traditional loan, this loan is risky and insufficiently secured, which creates high risks for the creditor banks as well.

Credit financing is a method often used in medium- and short-term investment projects with a high rate of ROI. The PPP uses project lending by individual banks, syndicated lending, financing through the issuance of infrastructure bonds, export credit financing, etc. Risks are associated with both the implementation of the project itself and possible changes in the terms of contracting and financing by investors.

The leasing financing mechanism is one of the methods of raising borrowed funds to finance projects. It is considered as one of the types of long-term loans provided by the leasing company (bank) to the lessee in a commodity form and is repaid in installments. Leasing cannot always be used in relation to social and some other infrastructure PPP projects.

Equity or mixed financing is a combination of several sources and the financing methods discussed above. This is the most common method of financing that is used in the implementation of investment projects in the infrastructure sector, primarily in the implementation of PPP projects, allowing one to smoothen out existing risks.

We should summarize that within the framework of projects implemented on the PPP basis, the choice of a financing scheme depends on each specific project and the participants' assessment of the financial benefits from participating in it.

Many regions of the world require investment to build modern infrastructure in almost all sectors. However, the current practice of PPP project implementation has demonstrated that the real set of tools is very limited. As evidenced by the data of the World Bank reports, it is mainly equity and credit financing. Other methods and sources of funding have not been widely developed. Public sources are dominated by the loans of international organizations (Table 5).

Table 5. Composition and structure of private-sector infrastructure financing (according to the World Bank data).

Indicators	2017		2018		2019	
	bn. \$	% Total	bn. \$	% Total	bn. \$	% Total
Total number of projects, units	29		198		159	
Volume of financing including	4.4	100	45.7	100	50.1	100
Public sources including:	0.3	7.0	8	17.0	6.5	13.0
International debt	0.08	2	6.4	14.1	5.5	11
Public capital	0.1	3	0.2	0.5	0.25	0.5
Grants and subsidies	0.08	2	1.1	2.4	0.75	1.5
Private sources including:	2.4	55.0	29	64.0	31.2	62.0
Equity capital	1.06	24	10.5	23.1	15.9	31.5
Commercial loans	1.36	31	18.5	40.9	15.3	30.5
DEFI * support	1.7	38.0	8.7	19.0	12.4	25.0

* Supported by the Development and Export Financing Institute. Source: Compiled on the basis of the World Bank reports of 2013–2017; 2018; 2019 (World Bank 2019b).

However, the set of methods and instruments that can be used during the implementation of PPP projects can be more diverse, which is considered below.

Meanwhile, the composition of possible sources of funding and the tools for their formation will also vary depending on the stage of implementation of the PPP project.

- At the pre-investment stage of PPP project development, the project funds are dominated by the project initiator's own funds:
 - own savings and profits, which can be supplemented in a small amount by budgetary funds (extrabudgetary funds) for the development of project doc-

- umentation, means of grants, competitions, finances of business angels if the initiator is a private party;
- budgetary funds (extrabudgetary funds) provided for the implementation of this project if the initiator is a public party.
2. At the investment stage of the PPP project, the choice of sources of financing is somewhat expanded. At this stage, the following sources can be used:
 - the project participants' own funds: savings and profits, funds and reserves created if the initiator is a private party;
 - budgetary funds (extrabudgetary funds) assigned for the project, including guarantees, if the initiator is a public party;
 - resources mobilized in the financial market: grants, competitions, funds of commercial investors on the terms of co-financing, funds from the issuance and sale of shares, other securities; funds raised in project financing;
 - borrowed sources: budgetary loans, loans from banks and other financial institutions, loans of international institutions, bond loans, leasing, project financing.
 3. During the project's operation, the choice of sources of funding becomes the widest possible and may include:
 - the project participants' own funds: equity, savings and profits, depreciation, development funds, and other target funds and reserves (private party); budgetary funds or extrabudgetary funds provided for the project (public party);
 - sources raised in the financial market: grants, competitions, funds of commercial investors on the terms of co-financing, attracted to the project, funds from the issuance of additional shares, other securities; funds coming within the framework of project financing;
 - funds received through redistribution: insurance reimbursements, resources generated on equity (share) basis;
 - borrowed sources: budgetary and tax investment loans, guarantees, loans of banks and other financial institutions, syndicated loans, loans of international institutions, bond loans, factoring, guarantees.
 4. At the final (liquidation) phase of the project, the choice of sources of funding is again significantly reduced. They are:
 - the project participants' own funds: equity, savings and profits, depreciation, development funds, and other trust funds and reserves (private party);
 - funds obtained through re-release and mobilized in the financial market: insurance reimbursements, limited budgetary and extrabudgetary resources involved in the project on a targeted basis; funds from the sale of securities; funds received from the sale of surplus, unused, outdated fixed assets;
 - borrowed resources: bank loans are limited, possible receipt of funds within the framework of project financing.

Thus, at the pre-investment and investment stage, the main task is to attract large investors and creditors. During its implementation, the project no longer requires financial resources on this scale, and the project can be financed by internal sources, as well as borrowing to offset current and other expenses.

We should note, however, that funding problems and lack of investment are often viewed as significant barriers, hindering the development of PPP.

The authors believe that in order to overcome these problems, it is advisable to consider the possibility of using digital instruments in the PPP mechanism.

3.2. Digital Instruments for PPP Project Investments

The digital transformation of the economy leads to its penetration into the investment process and the financing mechanism of investment projects, causing the emergence of digital investment instruments.

Over the past few years, the concept of digital investment has been significantly transformed. If initially, digital investments meant investments in digital technologies and the IT industry, now digital investments are understood as digital solutions and digital technologies for organizing the investment process as such.

As a rule, digital investments are based on the tokenization mechanism, that is, the creation of a digital analog of an asset (token) with the goal of buying and selling it (turnover) at the digital (financial) market. Each market asset can be presented as a token, a digital financial asset. Events of token generation, TGE (Token Generating Event), or their initial placement, ITO (Initial Token Offering), in order to attract investments, can be carried out by legal entities and individual entrepreneurs. To account for transactions with digital tokens, blockchain technology is used, which ensures the safety and security of transactions with digital assets. Blockchain technology, opening up new complex opportunities for the economic system, attracts much attention and launches many projects in various industries (Chan et al. 2020).

Blockchain is a promising catalyst for achieving global sustainable development goals and can be applied in many sectors of the economy in the future (Giungato et al. 2017).

Currently, the following three main forms of attracting investment through tokenization and blockchain technologies have become widespread: ICO, IEO, and STO, which are considered as business financing tools (Howell et al. 2018).

1. ICO (Initial Coin Offering)

ICO is a form of crowdfunding (financing projects by raising money from Internet users) using cryptocurrencies. The attraction of investments is carried out in the form of selling a fixed number of new units of cryptocurrencies or tokens to investors (Bank of Russia 2017). The initiators of the ICO can be organizations, individual entrepreneurs, and individuals who organize an event to raise funds. ICO investors obtain tokens for investing in cryptocurrencies or traditional currencies (Hacker and Thomale 2018).

The benefit for investors lies in the potential profit they can get if the project is successfully implemented, or when the cryptocurrency or project in which they were invested will enter the open market, and the exchange rate market value of their cryptocurrencies and tokens will increase significantly. The ICO investment boom, which was observed in 2017–2018, was quickly replaced by a sharp outflow of capital and a drop in interest in digital investments due to the fact that a significant part of startups and crypto projects turned out to be fraudulent, due to the underdevelopment of the legislative framework regarding the initiators of ICOs.

The investor's risk is that the project may not be able to be implemented cost-effectively if there is no system of protection of the rights and interests of investors and pre-audit of projects in this market.

2. STO (Security Token Offering)

STO is a system of investment of blockchain projects in the form of the issuance of digital assets in full compliance with the requirements of the securities legislation (Lai 2018). STO tokens, as an economic instrument, represent real assets expressed by stocks and bonds. As a form of digital investment, STO is used in those jurisdictions where the circulation of digital financial assets is, in fact, equated to investments in securities. Investors in STO are exclusively professional (accredited) investment institutions of the financial market. To mitigate the risks of financial tax fraud and prevent money laundering, STO transactions require mandatory KYC/AML identification of counterparties (principles of counterparty/client awareness). In order to ensure investor trust, all issues of STO tokens undergo state registration, STO organizers must provide reliable information about the finances and activities of the issuing company of digital assets and comply with securities laws. Financial requirements are provided for STO issuers and investors (Taylor Vinters Via LLC 2018).

The higher security of STOs compared to ICOs attracts investors. On the other hand, the strict requirements and additional costs for the implementation of the STO project, the

issue, and the registration of tokens make this form of digital investment inaccessible to many market participants.

3. IEO (Initial Exchange Offering).

The IEO or initial exchange offering is an innovative form of investment attraction in which the token offer is made through a digital investment platform or crypto-exchange (Amsden and Schweizer 2018).

Unlike ICO, where crypto-issuers directly appeal to investors, IEO issuers attract an institutional trade organizer to place tokens. Placing tokens and attracting investments through a trade organizer (crypto-exchange, investment platform) has certain features and advantages, both for initiators of the placement and for investors, which include: improving the quality of projects, protecting the interests of investors; protecting the interests of issuers who initiate projects. Implementation of IEO projects involves payment for the services of a trade organizer; compared to token securitization (STO), the initial exchange offering (IEO) does not require participants to comply with securities legislation and opens up a digital investment market for medium and small businesses, individual entrepreneurs and even individuals.

According to the authors, the IEO form of digital investment provides the necessary balance between the level of protection and openness (accessibility) of the digital investment market for participants and is more effective from the point of view of attracting additional financing.

Table 6 provides a comparative characteristic of the three types of digital investments reviewed.

Table 6. Comparative characteristics of ICO, STO, and IEO.

Indicator.	ICO	STO	IEO
Project initiator	Anyone	Organizations: public joint-stock companies; State: executive authorities; or in accordance with the local legislation	Organizations, individual entrepreneurs, individuals; or in accordance with the rules of the trade organizer (exchange platform, digital investment platform)
Investor	Anyone	Skilled investor or in accordance with the local legislation	Client of the trade organizer (exchange platform, digital investment platform)
Location	Special website or stock exchange platform	Exchange platform (crypto-exchange), digital investment platform	Exchange platform (crypto-exchange), digital investment platform
Listing, listing fee	-	Yes	Yes
Investment mechanism	Smart contract	Smart contract	Smart contract, through the crypto-exchange account
Investment project regulator	N/a	The country’s specialized public authority	Trade organizer (exchange platform, digital investment platform)
Requirements for an investment project	-	In accordance with the local legislation	In accordance with the rules of the trade organizer
Investor identity verification procedure	N/a or being conducted through third-party services	KYC/AML, in accordance with the local legislation	KYC/AML, in accordance with the rules of the trade organizer

Source: developed and compiled by the authors.

The laws passed in different countries provide for the possibility of issuing, accounting, and circulating equity securities, the rights to which are certified by digital financial assets. In fact, this opens up an opportunity for businesses and the state to widely use digital investment instruments created on the basis of distributed ledger technologies (TPP,

blockchain) and providing for the issuance of tokens. The absolute advantage of such investments is their availability for large companies, small businesses, and individual entrepreneurs alike.

Our analysis of digital investment tools suggests that they have a number of advantages for financing public-private partnership projects. On the one hand, crowdfunding as a form of digital investment having a mainly social (non-business) nature, involves the accumulation of money (voluntary donations) from a large number of people who are interested in the implementation of a socially useful project. Crowdfunding and Crowdlending have a more pronounced business focus, which allows one to implement cost-effective business projects through these digital investment tools.

The digital investment market unites (combines, maintains, anticipates) social investment and business investment. In our opinion, this best meets the needs of the public-private partnership for the implementation of projects, as PPP projects simultaneously combine social interests and business goals.

Crowdfunding is a new financial tool that has become widespread and popular around the world as an alternative to financing entrepreneurship (Wonglimpiyarat 2018). It is a form of project financing through the attraction of small amounts of money from a large number of Internet users (Ante and Fiedler 2019).

Crowdlending is a mutual lending service, implemented with the help of intermediaries: investment platforms.

Crowdfunding is a financial instrument that has a commercial focus and requires larger investments, used most often in lending to small businesses (Adhami et al. 2018).

These tools have not yet been widely applied in the PPP mechanism, although the experience of using them in other areas was established to be positive.

Investors of the crowdfunding segment may be interested in social projects, including projects that meet the goals of sustainable development, renewable energy, climate projects. They can be placed on crowdfunding platforms (websites) and receive funding from people and organizations focused on socially responsible investments. PPP projects that are commercially focused can receive funding in the crowdfunding and crowdlending segment. The benefits for PPP participants are presented in Table 7.

Table 7. Advantages (benefits) of digital investment tools for (participants, implementation) of public-private partnership projects.

State (Public Party)	Business (Private Party)	Investors	Society
<ul style="list-style-type: none"> - Implementing more projects; - Developing the digital economy; - Attracting foreign investment. 	<ul style="list-style-type: none"> - Attracting additional investment (for project implementation); - Attracting investments for small and medium-sized businesses (an alternative to bank credit and IPO, which is only available to large businesses). 	<ul style="list-style-type: none"> - Participating in socially responsible investment projects; - Reducing the risks of digital investment (by participating in projects involving the state as the public party). 	<ul style="list-style-type: none"> - Public control for increasing transparency in the implementation of PPP projects; - Reorienting investment flows into socially responsible projects.

Source: Compiled by the authors.

We believe that an emergence of a new class (group) of digital tools, coins, which are produced to attract investment to finance public-private partnership infrastructure projects, is possible. Such coins could be placed on the largest crypto-exchanges. Funding for such projects can be provided by a smart contract, which will increase control over the expenditure of funds (transparency) and the reliability of the PPP project implementation. Investors working on crypto-exchanges get the opportunity to invest their money (funds)

into reliable PPP projects. The emergence of reliable and transparent PPP projects as investment facilities on crypto-exchanges will increase the sustainability of the entire digital investment sector.

Thus, the authors believe that digital investment instruments based on the tokenization mechanism already widespread in the private investment market (ICO, IEO, and STO) can be used to finance PPP infrastructure projects. The issuance of tokens to finance PPP projects means that such tokens have collateral: an infrastructure project, verified by the public party. Infrastructure projects have economic and social benefits, so are most in line with the nature of collective financing. The issuance of PPP tokens will allow one to attract additional investments in PPP infrastructure projects, which will serve to develop PPP practice and increase infrastructure investment. The digital investment market will receive a confirmed, that is, state-verified, investment asset, ensuring the growth of the market's stability, and investors will receive a proven tool that provides economic and social effects and benefits.

As a result, these digital instruments can be used in full or with restrictions in the financing of investment projects on PPP terms.

4. Discussion (Digital Transformation of Interactions between PPP Participants)

Investment tools considered, including digital ones, along with undeniable advantages, have drawbacks, which have been noted above. In this regard, the question of the development and application of tools allowing to combine and strengthen the positive aspects of existing tools and minimize the negative ones arises. This new tool could be digital platforms (DP) that are already in use in world practice.

Despite different approaches to the concept of the digital platform, it is often interpreted as a digital form of interaction between suppliers and consumers in order to minimize transaction costs when looking for partners, goods, services, payment organization, contracting, enforcement of agreements, evaluation of the reputation of industry participants, etc. (Belleflamme et al. 2015).

Digital platforms are created to organize an information environment in which mutually beneficial interaction of different categories of participants in socioeconomic activities is carried out (Broekhuizen et al. 2019); they accelerate the exchange of valuables between two or more groups of users, consumers, and manufacturers (Moazed and Johnson 2019). This interaction takes place through modern information and communication technologies and services that are part of the platform. However, the very concept of a digital platform goes beyond technology alone. It is fundamentally important here to determine the goals and needs of the parties involved, to ensure the implementation of a set of organizational and technical measures to meet these needs in the digital platform environment. The developed digital platforms can be an important factor in global economic competitiveness. Digital platforms can become a significant strategic resource in the sphere of public administration (Li and Mann 2018).

Based on the functionality, different types of digital platforms can be distinguished: operational, innovative, investment, social, integrated, aggregated, etc. (Mesropian 2018).

At first glance, it may seem that investment platforms will become the basis for the introduction of platform solutions in PPP mechanisms. Their main participants are investors and representatives of investment projects.

Investment platforms have the potential to attract investment in PPP projects and therefore can be useful at some stages of projects, primarily the investment one.

The results of the study led the authors to conclude that the following can be identified as sources of funding for PPP projects using digital investment platforms: crowdfunding, crowdlending, crowdinvesting (Table 8).

Table 8. Digital sources of funding for the PPP projects based on the implementation stage.

Digital Sources of Funding for PPP Projects	Stage of Project Implementation			
	Pre-Investment	Investment	Operation	Completion
Crowdfunding	+	+	–	+
Crowdlending	–	+	+	–
Crowdfunding	–	+	+	–

«+»—all are used; «–»—none are used. Source: Developed and compiled by the authors.

However, investment platforms are not the only type of digital platforms to be used in PPP projects. Many and different stakeholders arise and interact at different stages of a PPP project. The interests of the stakeholders of the PPP project go far beyond investment only (Glukhikh et al. 2021). Therefore, it is necessary to consider other possible types of platforms that will correspond to these diverse interests at different stages of a PPP project.

The authors analyzed the platform solutions used to organize PPP and PPP project realization, on the basis of which the following table with their types (Table 9) is proposed.

Table 9. Digital PPP platforms.

Types of Digital Platforms for PPP	Main Purpose/PPP Project Stage	Examples
Investment platforms	Investment attraction/Investment and operation stage	Kickstarter https://www.kickstarter.com/ (accessed on 11 March 2021) MMC’s PPP Platform https://www.mcc.gov (accessed on 11 March 2021)
Platform services	Choice of models and PPP maintenance/Pre-investment, investment, operation	PPP Advisor https://pppadvisor.ru/o-proekte/ (accessed on 11 March 2021) China PPP Center http://www.cpppc.org (accessed on 11 March 2021)
Information analysis and search	Search for information, project analytics, presentation of results/All stages	Rosinfra https://rosinfra.ru/ (accessed on 11 March 2021) China PPP Center http://www.cpppc.org (accessed on 11 March 2021)
Interactive digital platforms	Comprehensive facilitation of PPP business processes/All stages	None to date

Source: developed and compiled by the authors.

Table 9 does not contain all the digital tools used by PPP project teams in their activities. For example, it does not include other information technology services and software solutions that are used in project management, systems engineering, or business planning. We proceed from the assumption that they are not specific to PPPs (although they can be used in PPP projects), therefore, consideration of such systems was not among the goals of our paper.

The study showed that the platforms available on the market do not fully cover both the stages of the PPP life cycle and the amount of functionality required for the implementation of the PPP project.

The authors believe that specialized digital PPP platforms that provide interactions between a wide range of PPP stakeholders (from initiators and government authorities to performers and consumers of the project results) can act as an integrated tool to address a large part of the above problems (Glukhikh et al. 2021). The feasibility of creating such

digital platforms is especially important when implementing large PPP projects when the needs of many stakeholders collide directly or indirectly, and there are no tools ensuring their effective interaction.

Thus, the development of digital platforms, and especially the creation of specialized platforms for the interactions of PPP participants, seems to us to be another direction for the digitalization of PPP mechanisms.

5. Conclusions

This study allowed the authors to draw a number of conclusions.

The PPP mechanism aims to address important infrastructure and social development objectives by involving the private investor. The PPP mechanism allows using a fairly wide range of tools for implementing PPP projects, including digital instruments.

In the process of implementing PPP projects, the determining factors are the choice of tools for organizing and financing projects. It was revealed that the use of traditional methods and tools has certain limitations. Considering this, the authors examined the possibilities of using digital instruments for the implementation of PPP projects.

Modern digital investments are based on the tokenization mechanism, that is, the creation of a digital analog of an asset (token) with the goal of its turnover in the digital market. The most well-known forms of attracting investment through tokenization and blockchain technologies are ICO, IEO, and STO, which can be used by the private side of the project as a financing tool.

According to the authors, digital platforms and, in particular, integrated interaction platforms can become a new tool reducing the shortcomings of existing traditional and digital tools.

The authors believe that the use of platform solutions and different types of platforms in the implementation of PPP projects will help in solving the problem of organizing the interaction of project participants and in satisfying the interests of a significant number of stakeholders, that is, those interested in their realization.

Thus, the study allows one to identify two relevant, according to the authors, directions of PPP digitalization. First, it is the active use of digital financial instruments for attracting additional investment in PPP projects; secondly, it is the creation of a digital environment for the interaction of PPP participants as well as other stakeholders of PPP projects. This environment can be facilitated through the creation of specialized digital PPP platforms. This will not only reduce the transaction costs of PPP but will also allow, through consideration of the interests of a wide range of stakeholders, to ensure the sustainability and dynamics of the development of local and global infrastructure projects.

The results of the study will be primarily in demand by the entrepreneurial sector, which focuses on the use of digital economy tools in its activities. In addition, the recommendations of the authors of the article can be taken into account during the development of public-private partnership support, when forming a mechanism for financing public-private projects by national and foreign investors in the digital investment markets. All this, in our opinion, will contribute to the development of digital transformation of public-private partnership tools.

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