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INNOVATIVE DIGITAL TECHNOLOGIES IN PUBLIC-PRIVATE PARTNERSHIP PRACTICES: SWOT ANALYSIS

ABSTRACT

The article is devoted to the study of the role of innovative digital technologies in public-private partnership (PPP) practices and the assessment of their impact on the efficiency, transparency, and sustainability of PPP project implementation in conditions of increased uncertainty, war, and post-war challenges. The study's relevance stems from the rise in fiscal constraints, the need for accelerated infrastructure reconstruction, and the need to bolster investor and public confidence in PPP mechanisms.

The purpose of the study is to comprehensively substantiate the potential of innovative digital technologies within the public-private partnership system and to determine their impact on the quality of management, reducing transaction costs, and minimizing risks at all stages of the PPP project life cycle. The study summarizes modern approaches to the use of digital platforms, big data analytics, artificial intelligence, BIM technologies, the Internet of Things, cloud solutions, and blockchain in PPP preparation, contracting, implementation, and monitoring.

The main results were obtained through a SWOT analysis, which allowed us to systematize the strengths of digitalization in PPP, including increased transparency of procedures, improved control over the fulfillment of obligations, greater investment attractiveness, and improved quality of public services. At the same time, key weaknesses and threats included cybersecurity issues, legal uncertainty, a lack of digital competencies, high initial costs, and risks of technological dependence.

It was concluded that innovative digital technologies have not only a technical but also an institutional impact on public-private partnership, forming a new logic of interaction between the public and private sectors. Their effective implementation can be an important tool for accelerating post-war reconstruction, mobilizing investments, and strengthening the state's economic security, provided that the regulatory, institutional, and security environment is developed in a coordinated manner.

Keywords: public-private partnership, digitalization, digital technologies, digital platforms, SWOT analysis, infrastructure projects, risk management, economic security, transparency

JEL Classification: H54, H41, O33

INTRODUCTION

Public-private partnerships (PPP) remain one of the key instruments for attracting private capital and management competencies for infrastructure development and the provision of socially significant services. In the context of growing fiscal constraints, increased uncertainty, and heightened requirements for transparency and accountability in public finances, the effectiveness of PPP implementation increasingly depends on the ability of the state and businesses to apply modern, innovative digital technologies. Digital platforms, big data analytics, artificial intelligence, BIM technologies, the Internet of Things, and blockchain are considered not only as technical solutions, but also as institutional tools for transforming the entire PPP life cycle - from project identification and preparation to contracting, monitoring, and performance evaluation.

The relevance of the study stems from the fact that traditional approaches to PPP management are often accompanied by high transaction costs, information asymmetry between partners, risks of opportunistic behavior, and the state's limited ability to effectively monitor the implementation of obligations. In war and post-war periods, these problems are exacerbated by resource shortages, the need for rapid infrastructure reconstruction, and increased investor demands for transparency and predictability of the rules of the game. Ukraine has taken significant steps in this direction by adopting a new version of the Law "On Public-Private Partnership" (On Public-Private Partnership, 2025) in 2025, which introduces mandatory full digitalization of PPP procedures, from project announcement to contract conclusion. At the same time, digitalization creates new opportunities to increase trust, reduce risks, and accelerate managerial decision-making, but also challenges related to cybersecurity, legal regulation, and inequality of access to digital tools.

Despite growing scientific interest in PPP, the systemic role of innovative digital technologies in these practices remains insufficiently generalized. Most studies focus on individual sectoral or project solutions, without developing a comprehensive understanding of their impact on institutional efficiency, economic security, and the sustainability of partnerships. In this context, there is a need for a comprehensive analysis of the potential and limitations of digital technologies in PPP, which allows not only to identify their advantages, but also to assess the risks and conditions for successful implementation. That is why this article aims to substantiate the role of innovative digital technologies in public-private partnership practices and analyze their impact on the efficiency, transparency, and sustainability of PPP using the SWOT analysis tool.

LITERATURE REVIEW

Many modern scholars devote their work to examining issues in PPP implementation and the introduction of modern digital technologies into this process. Thus, the article by Batjargal & Zhang (2021) summarizes the key problems in implementing public-private partnerships, particularly institutional, legal, organizational, and risk-related issues, which reduce the effectiveness and sustainability of PPP projects. The authors demonstrate that most challenges stem from insufficient prior planning for risk management. At the same time, the work leaves unresolved the role of innovative digital technologies in increasing transparency, improving risk management effectiveness, and enhancing PPP monitoring. Sarmento & Renneboog (2021) examine the phenomenon of frequent PPP contract renegotiations, arguing that they are caused by incompleteness of long-term contracts, political cycles, opportunistic behavior of the parties, and weak institutional learning, which leads to a redistribution of benefits in favor of private partners. At the same time, the authors hardly consider how innovative digital technologies can reduce contractual incompleteness, limit opportunism, and reduce the need for PPP revisions. Verweij & van Meerkerk (2021) show, based on empirical data from transport infrastructure projects in the Netherlands, that DBFM PPP contracts are more cost-effective than conventional contracts. At the same time, the authors do not analyze what role innovative digital technologies can play in further improving the cost and time efficiency of PPPs. Memari, Ogunmakinde & Skulmoski (2025) systematize factors and strategies for improving supply chain efficiency in PPP infrastructure projects, with a focus on risk management, stakeholder coordination, sustainability, and the use of digital technologies (AI, data analytics, BIM, IoT) to improve transparency and control. At the same time, the work does not reveal the holistic institutional role of innovative digital technologies in PPP practices (as integrated digital platforms for public management, contracting, and monitoring at the public policy level). Bak et al. (2025) systematically review the ethical aspects of public-private partnerships in digital health, highlighting key issues of data protection, determination of public benefit, and good governance and trust in digital PPPs. At the same time, the work largely overlooks innovative digital technologies as tools for practical PPP management, thereby limiting the transfer of ethical recommendations to broader PPP practices beyond the healthcare sector. In the article by Kopanska et al. (2024), based on an econometric analysis of PPP tenders in Poland (2009–2020), the key motives of private partners are identified: flexible contracts with a more balanced distribution of risks, shorter project duration, stability and financial capacity of the public partner, as well as support in the form of project subsidies, while organizational support from the public side can restrain business interest. At the same time, the work practically does not show how innovative digital technologies (digital platforms for PPP preparation and support, data analytics to reduce transaction costs, digital risk management, and contract management tools) can influence private partners' motivation and increase the attractiveness of PPPs. In the article by Prasad et al. (2024), the effectiveness of PPP models in Indian transport infrastructure was analyzed using a highway project as an example, comparing BOT-Toll, BOT-Annuity, and HAM in terms of financial indicators (IRR, NPV), and proposed an improved PPP framework for timely and cost-effective project implementation. However, the study did not consider how innovative digital and AI technologies can improve the effectiveness of financial analysis, uncertainty management, and PPP performance.

Thus, the results of the analyzed studies indicate that modern scientific approaches to public-private partnerships focus mainly on the institutional, financial, contractual, and managerial aspects of PPP implementation, as well as on assessing their effectiveness in terms of cost, timing, and risk allocation. Some works address the use of digital tools in industry or

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project solutions, but they are fragmentary and do not provide a holistic view of the systemic role of innovative digital technologies in PPP practices. At the same time, the scientific literature does not sufficiently highlight the potential of digital platforms, data analytics, artificial intelligence, and smart contracts as tools to increase transparency, reduce transaction costs, minimize opportunistic behavior, and strengthen monitoring of PPP performance across all stages of their life cycle. This establishes the existence of a scientific gap and justifies the feasibility of further research aimed at developing a comprehensive approach to implementing innovative digital technologies in public-private partnership practices, which guides this article.

AIMS AND OBJECTIVES

The purpose of this article is to comprehensively substantiate the role of innovative digital technologies in public-private partnership practices and assess their impact on the efficiency, transparency, and sustainability of PPP projects in conditions of increased uncertainty, war, and post-war challenges.

To achieve this goal, the article provides a solution to the following main tasks:

1. To summarize modern approaches to the use of innovative digital technologies in the public-private partnership system.
2. To identify key problems of traditional PPP practices that can be mitigated or solved through digitalization.
3. To assess the strengths, weaknesses, opportunities, and threats of the implementation of digital technologies in PPP using SWOT analysis.

The implementation of these tasks allows you to form a holistic vision of the opportunities and limitations of PPP digitalization and create an analytical basis for improving state policy in the field of public-private partnership.

METHODS

The methodological basis of the study is a set of general scientific and specialized methods of cognition that allow for a comprehensive analysis of the role of innovative digital technologies in public-private partnership practices and for assessing their impact on the effectiveness and sustainability of PPP.

In the course of the study, the methods of analysis and synthesis were used to generalize theoretical approaches to the essence of public-private partnership and to systematize scientific views on the application of digital technologies in the field of PPP. A comparative analysis was used to examine traditional and digitalized PPP practices and identify differences in project management, risk allocation, and performance control.

To identify the key advantages and limitations of the implementation of innovative digital technologies in PPP, a SWOT analysis was used, which allowed for a structured assessment of the internal strengths and weaknesses of PPP digitalization, as well as external opportunities and threats that are formed under the influence of the institutional, technological, and security environment. This method was used as an analytical tool for integrating the results of the theoretical review and practical examples.

The study also used the generalization method to form conclusions about the systemic role of digital technologies at different stages of the PPP project life cycle - from preparation and contracting to monitoring and evaluation of effectiveness. The logic modeling method was used to substantiate the relationship between PPP digitalization, reduced transaction costs, increased transparency, and strengthened state economic security.

The study's information base comprised scientific publications in professional international journals, analytical reports, materials from international organizations, regulatory and legal acts, and expert publications that regulate and highlight the development of public-private partnerships and digital transformation. The use of these methods ensured the validity of the results and enabled achieving the study's goal.

RESULTS

Modern information and digital technologies are increasingly being implemented at all stages of public-private partnership implementation - from planning and project preparation to agreement conclusion and subsequent monitoring (Table 1).

In this context, the use of databases and analytical tools for decision-making is becoming widespread in the PPP implementation system.

Table 1. Stages and directions of using innovative digital technologies in PPP. *(Source: compiled by the authors based on Huubse (2025), Kumar (2025), Memari et al. (2025), PeoplePlanetProfit GmbH & Co. KG (n.d.), Prasad et al. (2024), and Service Works Global (2025))*

Information and digital technology	Stages and directions of use in PPP
PPP databases and analytical platforms	Preparation and planning of PPP projects; formation of project registers; market analysis; risk assessment, value for money; support for management decision-making
Big Data and data analytics	Forecasting demand for infrastructure facilities; financial modeling; project effectiveness assessment; traffic and load analysis
Artificial Intelligence (AI)	Demand assessment; optimization of facility operation; forecasting of technical failures; risk management at the implementation and operation stage
Building Information Modeling (BIM)	Design and construction of PPP facilities; coordination of participants; facility life cycle management; optimization of operating costs
Digital twins (Digital Twins)	Monitoring the technical condition of facilities; operation management; wear and tear forecasting; infrastructure modernization
Internet of Things (IoT) and smart sensors	Operational phase of PPP; real-time infrastructure monitoring; quality of service control; automatic KPI measurement
Cloud technologies (Cloud solutions)	Stakeholder coordination; document collaboration; project management; PPP e-offices; increased transparency
Blockchain and smart contracts	Control of financial flows; ensuring transparency of transactions; automation of payments; monitoring of fulfillment of contractual obligations
Electronic monitoring and reporting systems	Ongoing monitoring of project implementation; performance assessment; accountability of the private partner
GIS systems (geoinformation technologies)	Spatial planning of PPP projects; location selection; territorial development analysis
Mobile and digital feedback platforms	Public engagement; service quality assessment; increasing trust in PPP

Digitalization allows for the accumulation of significant amounts of data on PPP projects, which are used to make informed decisions based on evidence. In Ukraine, it is planned that a single PPP platform will contain information on all current and planned projects, tender history, standard documents, and related materials (DLF attorneys-at-law, 2025). This will actually create an open PPP registry, useful both for government agencies for planning and for investors for market analysis. Based on this data, it is possible to build forecast models, assess value for money, and project risks. Modern software complexes can perform financial modeling of PPP projects, sensitivity analysis, and calculate budget obligations. In addition, governments are beginning to use artificial intelligence (AI) and Big Data to assess infrastructure demand or model traffic in transport projects, thereby improving the quality of PPP preparation. According to research, AI algorithms and data analysis can improve operational management of facilities – for example, optimizing maintenance schedules or predicting roadway congestion. In the US, technological innovations in PPP are already showing their impact: the implementation of AI and IoT (Internet of Things) at facilities enables real-time monitoring of operations, accident prevention, and cost savings (Kumar, 2025). Thus, data and analytics are becoming the "new oil" for PPP, enabling both partners to make more informed decisions throughout the project lifecycle.

One direction of digitalization of the PPP system is the use of Building Information Modeling (BIM) technology, which involves creating detailed 3D digital models of infrastructure facilities and is now being actively implemented in PPP projects around the world. The United Kingdom was one of the first countries to make BIM mandatory for all new public construction contracts, including PPP contracts, starting in 2016. BIM allows all participants (designers, engineers, contractors, operating companies) to work with a single information model of the facility, where all data is accumulated - from drawings to repair schedules. This simplifies coordination and reduces the risk of errors. For PPP with a long-term operational phase, BIM is a real game changer, as it allows you to optimize operations: for example, a digital model of a hospital or road provides quick access to technical data and maintenance history, and enables modeling modernization scenarios (Service Works Global, 2025). It is estimated that BIM use can reduce project implementation costs by up to 20% through more accurate planning and the avoidance of rework (Kumar, 2025). Digital twins, a technology that has evolved from BIM, enable real-time monitoring of an object's condition using sensors and comparison with a digital model. In PPP, this opens up opportunities for proactive management: for example, a concession road operator can use a digital twin to detect

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abnormal pavement wear and repair it before serious damage occurs. Thus, BIM and digital twins improve the quality and efficiency of the private partner's performance, benefiting both the state and businesses.

Promising digital technologies in the PTT system are the Internet of Things (IoT) and smart sensors. Many modern PTT projects, especially in the field of "smart cities" and energy, integrate IoT solutions for data collection and automatic system control. Smart meters, motion sensors, cameras, etc., are installed within the framework of street lighting projects, traffic management, energy efficiency in buildings, and water supply networks. For example, in a typical street lighting concession project, the private partner installs LED lamps with sensors that adjust brightness based on time of day and the presence of people, thereby reducing electricity consumption; at the same time, the system collects data on faulty lamps and automatically notifies service crews. In transport PTT (motorways, toll roads), traffic sensors enable online monitoring of vehicle flows and the detection of congestion or incidents, which is important for ensuring the agreed level of service. The vast amount of data from IoT devices can be analyzed by artificial intelligence to optimize infrastructure performance. From the perspective of PPP contracts, the emergence of IoT enables the introduction of automatically measured key performance indicators (KPIs) – for example, the percentage of time the lighting is operational or the average speed of traffic on the road. This facilitates monitoring of contract performance and the calculation of accessibility payments where such a model is used (Kumar, 2025). In Ukraine, the concept of a "smart city" is only gaining momentum, but in the post-war reconstruction of cities, the integration of IoT through PPPs can become one of the innovations that will simultaneously improve the quality of services and attract technology companies to the reconstruction.

To coordinate the work of numerous stakeholders in PPP projects, cloud solutions are increasingly used, providing real-time access to documents, schedules, and reports. Cloud project management platforms allow the state partner, investors, contractors, and consultants to work in a single information space, exchanging up-to-date information. This is especially relevant during wartime, when physical meetings are difficult; online collaboration ensures the continuity of work. For example, electronic "project offices" where the parties jointly maintain a calendar of events and financial plans, and discuss changes, significantly increase the efficiency and transparency of interaction. Due to the automation of routine processes (document versioning, task tracking), team productivity increases by 15% (Kumar, 2025). In addition, cloud computing enables connecting more complex analytical tools and models without investing in their own infrastructure, which is a plus for public partners with limited IT resources. Within the framework of PPPs, this can also be organized as a service from the private partner - for example, the creation and maintenance of a joint electronic project portal is included in its obligations. In general, the transition to "digital offices" of PPP projects using cloud services contributes to better coordination and accountability of the parties.

The latest distributed ledger technologies are gradually being used in the PPP sector, primarily to ensure transparency and security of critical transactions and data. Blockchain enables an immutable log of all actions and transactions within the project, which is especially important for distributing financial flows, controlling the targeted use of funds, and monitoring the fulfillment of contractual obligations. For example, payments for the availability of an object or penalties for violating KPIs can be recorded in a smart contract that automatically initiates transactions when specific conditions are met. The advantages of blockchain are decentralization (no single point of failure or influence), protection against data tampering, and high system reliability (PeoplePlanetProfit GmbH & Co. KG., n.d.). In theory, this significantly complicates the possibility of any manipulation by unscrupulous participants or third-party attackers. Researchers note the great potential of blockchain for modernizing public procurement and partnerships – in particular, the technology can increase public trust in PPPs by providing open, real-time access to key contract data (Huubse, 2025). In Ukraine, given the course for digital transformation and participation in the global PPP Transparency initiative, blockchain is also considered as one of the tools for strengthening public control and combating corruption in infrastructure projects. However, implementing this technology requires resolving a number of issues – from regulatory recognition of smart contracts to ensuring compatibility with existing electronic document management systems.

The listed technologies do not exhaust the entire range of innovations that can be applied in PPP. In different countries, electronic monitoring and reporting systems, mobile applications for collecting feedback from service users, GIS systems for project spatial planning, etc., are also used. The general trend is that digital technologies penetrate all phases of PPPs - from preparation and financing (for example, crowdfunding platforms or online auctions for placing PPP project bonds) to the operation of facilities (for example, smart maintenance systems for predicting breakdowns). Each of these innovations is designed to make the partnership between the state and business more "smart", flexible, and reliable. It is important to note that the implementation of IT solutions in PPP is not an end in itself, but a tool for achieving strategic goals: increasing project efficiency, reducing costs, accelerating infrastructure development, and ultimately strengthening economic security, because modern digital infrastructure directly correlates with the growth of GDP and the country's investment attractiveness (AlYahya, 2025).

To systematically assess the impact of digital technologies on public-private partnerships, we will consider their strengths, weaknesses, opportunities, and threats (SWOT). Such an analysis will help summarize both the positive effects of implementing innovative digital technologies in PPP and the potential problems that require attention from the state and private partners.

Strengths

Increased transparency and trust.

Digital platforms make the process of selecting private partners and implementing projects more open to oversight. Mandatory electronic tendering eliminates opaque backroom decisions and reduces the human factor in evaluating proposals. This significantly strengthens investor and public trust in PPP processes. For example, Ukrainian law stipulates that all stages of PPP are conducted online via Prozorro, making it impossible to conceal information or corruption during the tender (Stepanenko, 2025). As a result, private investors are more willing to enter the market when they see clear and fair rules of the game. According to experts, transparency and clear performance metrics are critically important for the success of PPP - they form an "atmosphere of trust" between partners and an understanding of mutual benefit.

Efficiency and speed of project implementation. Process automation significantly reduces bureaucratic delays and time costs. What previously required weeks of paper-based approvals can now be completed in a matter of days through online systems (e.g., proposal submissions and consideration, appeals of results, etc.). Simplified electronic procedures introduced by the new law for "small" PPP projects in Ukraine allow them to be implemented without a full-fledged feasibility study – a fairly short concept that is quickly agreed upon via an electronic office. Digital communications (video conferences, shared cloud workspaces) allow for prompt resolution of issues between the state and the investor, even under remote working conditions or military restrictions. In general, the implementation of ICT reduces the partnership's transaction costs – it saves employees' time and reduces costs for printing documents, logistics, and business trips. This allows resources to be concentrated directly on construction/service delivery, accelerating the return on projects.

Improved control and quality of services.

Thanks to digital tools, the public partner receives more effective mechanisms for monitoring contract performance. Online systems can monitor, in real time, key performance indicators (KPIs) for the facility or the quality of services provided by the private partner. For example, a concession road control center equipped with IoT sensors immediately sees violations (potholes, traffic jams, accidents) and can require a response in accordance with the terms of the contract. If a digital twin or BIM model of the facility is implemented, regulatory authorities will have complete information about the asset's condition and the work performed. This reduces the asymmetry of information between the state and the private operator, making it difficult for the private operator to hide shortcomings. In addition, smart contracts can guarantee the fulfillment of obligations; for example, payments for accessibility can be embedded in a smart contract and automatically suspended if KPIs are not met. All this improves the quality of infrastructure and services for citizens, which is the ultimate goal of PPP.

Mobilization of a wider range of investors.

Digitalization opens up opportunities for international and non-state actors to participate in PPPs, who previously might not have had access to information or doubted the transparency of procedures. Online portals with English-language interfaces allow foreign companies to easily familiarize themselves with projects and submit an application. The lack of the need for physical presence at all stages (an electronic signature is enough) attracts both a large diaspora and international financial organizations. Moreover, innovative forms of Internet financing (such as crowdfunding and platforms for issuing "infrastructure" bonds to the public) can ensure the inflow of funds from individuals and institutional investors. Thus, the digital transformation of PPPs increases the country's investment attractiveness, which is especially important for post-war recovery, when financing needs are huge. According to estimates by the Ministry of Economy of Ukraine, the updated digital model of PPPs can unlock up to USD 1 billion. investments in priority sectors in the coming years (Stepanenko, 2025).

Innovation and capacity building.

Involving IT solutions in public-private projects contributes to improving overall digital literacy and fostering an innovation culture in public administration. Public institutions are forced to master new technologies, improve data skills, and ensure cybersecurity, which leads to institutional development. Private partners, in turn, receive incentives to implement the latest

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technical solutions to increase the efficiency and profitability of projects (after all, many contracts provide for payment by results, so innovation = more profit). Mutual exchange of experience between the IT sector, construction companies, and officials within the PPP framework creates a synergy of knowledge. In a global context, this means preparing the state for the digital economy of the future. Therefore, the digitalization of PPPs is not only about the partnerships themselves, but also about transforming the public sector towards greater technologicality and openness.

Weaknesses

High initial costs and complexity of implementation.

The transition to electronic systems requires significant investments - both financial and time. The development and maintenance of a secure national PPP platform, staff training, and the digitization of a large volume of documents - all of this burdens the budgets and human resources of state bodies. Many authorities may lack sufficient IT expertise to define technical requirements or effectively manage development contractors. Technical difficulties also inevitably arise: integrating various information systems (for example, connecting the PPP platform to the existing public procurement system or registers), bug fixing, scaling servers as load increases, etc. At the initial stage, such problems can even lead to a temporary slowdown in processes (for example, if an electronic auction failed due to a system failure, the bidding deadlines need to be postponed). Also, complex digital tools like BIM or blockchain require highly qualified personnel for their operation and data analysis, which may be in short supply among both public and private partners. Therefore, without proper training and resources, digitalization can reveal internal weaknesses in institutional capacity, resulting in less-than-expected effects.

The need to restructure processes and resist change.

The implementation of ICT inevitably requires reengineering business processes in government agencies and companies. Old procedures, instructions, and even legal norms may no longer align with new digital realities. For example, the transition to electronic document management requires legal recognition of electronic documents and signatures, which is recognized in Ukraine but remains a problem in some countries. It happens that company officials and employees show passive resistance to change - unwillingness to learn new things, prejudices about the reliability of technology ("paper is more reliable, because it is physically visible"), fear of losing influence or work (less manual work = less need for numerical apparatus). Such a human factor can slow down digital initiatives or lead to a formal approach (when the system is implemented, but everything continues to be duplicated on paper "just in case"). It is difficult to break this culture - political will and leadership from above are needed, along with motivation and training for performers. In addition, digital solutions often standardize approaches, reducing the space for individual maneuvering, which may not be to middle managers' liking. In private companies, there may also be a reluctance to invest in additional IT systems for a specific project if they do not see a direct benefit or fear that this is a requirement "imposed" by the state.

Cybersecurity and data protection issues.

The digitization of information about PPP projects makes it a target for cyberattacks, both financially motivated (ransomware) and politically motivated (sabotage, espionage) (Potter, 2017). PPP projects are often related to critical infrastructure (energy, transport, medicine) or contain confidential information (trade secrets, personal data, financial calculations). A system breach can lead to the theft of important data, its distortion or deletion, resulting in financial losses and undermining trust. A cyberattack can also disrupt infrastructure operations if the control system (SCADA, etc.) is integrated with online services - in 2017, the Petya virus paralyzed the work of state structures in Ukraine, and within the PPP, such a risk is also real. The weak link is that the partnership involves two parties – the public and the private – so cyber risks are doubled, as attacks can also be launched through the less secure network of a private operator to gain access to government data. Coordination of cyber security efforts between partners may not be clear enough: who is responsible for what in the event of an incident, is there sufficient insurance coverage for cyber risks, etc. Finally, the protection of users' personal data collected during the project (for example, patient data in a hospital operating under a PPP) imposes additional requirements on systems (under GDPR and similar regulations). If these aspects are not thought out at the start, digitalization can become a vulnerability that, in itself, poses a threat to national security, especially in the context of cyber warfare.

Dependence on technology and risk of failures.

Full digitalization of procedures means that failures in equipment or software can halt key processes. For example, if the central PPP portal is unavailable due to a technical failure or DDoS attack, all announcements or tenders for this period are "frozen." Or if the electronic document management system fails, the parties may miss critical deadlines in executing the contract. Therefore, the reliability of the infrastructure (backup servers, disaster recovery, and constant technical

support) comes to the fore. This entails additional costs and requires highly qualified personnel. In countries with unstable Internet or power supply (as during wartime), full reliance on electronic means can be a weak point; manual backup plans are necessary, which partially offset the benefits of automation. Another aspect is the rapid obsolescence of technology: the IT sphere is evolving rapidly, and a system implemented 5 years ago can become obsolete and potentially insecure without updates. Therefore, the state must plan for continuous upgrades, which is difficult to budget for and organize (tenders for new IT solutions can take a long time, while new needs arise during this period). Thus, the technological component itself can become an "Achilles' heel" if its reliability and relevance are not ensured.

Legal and regulatory constraints.

Not all countries have yet adapted their legislation to the digital reality. In Ukraine, for example, although the law on PPP now contains regulations on electronic procedures, there may be gaps in the by-laws regarding the details of the system, the procedure for storing electronic data, and the resolution of IT-related disputes (for example, what to do if the tender application did not load due to a technical failure - should the participant be considered to have submitted it on time?). The legal force of digital evidence can also be problematic: for example, will a court accept a blockchain record as evidence of improper performance of a contract without a paper act? Also, data protection and cybersecurity regulations may conflict with practical solutions (is it possible to store project data in the cloud abroad - no, from a security point of view, but yes, from an accessibility point of view). Therefore, the regulatory field must keep up with technology; otherwise, digitalization will be hampered by legal conflicts. If this does not happen, private partners may bear additional risks (legal uncertainty = risk = more expensive offers or refusal to participate). It is important for Ukraine to continue harmonizing its regulatory framework with EU law in the field of e-government to ensure the new digital PPP system operates smoothly.

Opportunities

Accelerating post-war reconstruction and economic growth.

Digitalization of PPPs opens up the possibility of implementing large-scale infrastructure restoration projects that Ukraine and other post-conflict countries need most effectively. Rapid and transparent project preparation means that donor and private investor funds will be utilized without delay and for their intended purpose, which is critical for rebuilding cities, roads, and energy networks. In addition, digital technologies themselves can become the subject of PPPs: the state can, through partnerships, deploy broadband Internet, 5G mobile communications, and data centers necessary for a modern economy. Experience shows that the development of digital infrastructure leads to GDP growth - according to the ITU, a +10% increase in Internet penetration adds 2.8% to GDP growth in developing countries (AlYahya, 2025). That is, through digital PPPs, Ukraine can not only rebuild, but also make an economic leap, building "smart" cities and modernizing the economy on new technological foundations.

Attracting international support and best practices.

The presence of a modern digital ecosystem for PPPs increases the country's chances of receiving assistance from international organizations and partners. For example, the EBRD and the World Bank actively finance projects to develop e-government and transparent governance – the Ukrainian PPP platform can apply for grants or technical assistance, as was the case in Kazakhstan, where the Eurasian Development Bank provided a grant to create a PPP portal. In addition to financial support, international partners bring expertise: thanks to joint digital projects, the best global standards in infrastructure management, cybersecurity, and project management can be implemented in Ukraine. This will also contribute to integration with the EU – a joint digital platform will facilitate the participation of European companies in our projects and ours in theirs, creating a single PPP market. Also, world-class technology companies can consider the war and post-war period as a testing ground for innovation: for example, pilot implementations of blockchain or AI for reconstruction, which can then be scaled globally. PPPs can become a convenient framework for their participation (risk-sharing with the state, guarantees). This is a chance for Ukraine to become a "showcase" of digital reconstruction, attracting global attention and additional investments.

Development of the local IT sector and digital skills.

The mass digitalization of government processes, particularly in the field of PPP, creates demand for IT companies' and startups' services. Development of software modules, mobile applications, data analytics, and cybersecurity - all these are niches where Ukrainian technology businesses can prove themselves and receive contracts. Therefore, PPPs in digital format stimulate the development of the local IT industry, create jobs for highly qualified specialists, and indirectly contribute to economic security (reducing brain drain and increasing the export of IT services). In addition, officials and

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managers who interact with modern systems increase their digital competencies, which they subsequently transfer to other areas of public administration. In the long term, the population also benefits through services like "Diya", citizens become accustomed to digital interaction with the state, demand transparency and accountability, which improves the country's overall climate. Thus, digital PPPs have a multiplier effect on education and technology.

Improving risk management and contract flexibility.

The use of modern IT enables better risk analysis and risk distribution in projects. For example, based on large data sets on weather, traffic, and demographics, it is possible to more accurately predict demand for the facility's services and, therefore, adjust the terms of the contract (payment schedule, attendance thresholds, etc.). This may lead to the emergence of more adaptive PPP contracts that provide mechanisms for dynamic adjustment to changing circumstances (which is especially relevant in unstable wartime). Digital models (BIM, twins) allow you to play out "what-if" scenarios – for example, what will happen to the financial model if there are new quarantine restrictions or population migration; and to build in appropriate conditions in advance. Thus, the SWOT analysis of the project becomes deeper thanks to IT: the project's strengths and weaknesses are visible even at the feasibility study stage through computer modeling. This increases the chances of successful implementation because the parties are better prepared. Accordingly, the state's economic security is strengthened, as fewer resources will be wasted on failed or risky projects – digital tools will help filter them out at an early stage.

Social sustainability and citizen engagement.

Digital platforms create opportunities for greater public involvement in monitoring and cooperation in PPP projects. Open data portals can be implemented, where citizens can see the progress of construction or the project's financial costs in real time, and can report problems (for example, through a mobile application, residents can signal a non-working streetlight serviced by a private partner). This creates a shared responsibility and partnership not only between the state and business, but also with communities, i.e., PPP + People. In wartime, when state resources are limited, a tripartite alliance (government-business-population) supported by digital tools can significantly help identify priority needs, ensure quality reconstruction, and maintain order. Involving citizens contributes to the legitimacy of PPPs - people better understand the goals of projects, see the benefits, and are less opposed to them. This ultimately contributes to the stability of long-term project implementation, a component of economic security (fewer social conflicts over construction, tariffs, etc.).

Threats

Cyber threats and hybrid warfare.

In war and post-war periods, the risks of targeted attacks on digital infrastructure by hostile states or groups are particularly high. The PPP platform, as part of state services, can be a target for cyberattacks aimed at disrupting economic activity. Russian hackers have repeatedly attacked Ukrainian state websites; one can expect attempts to disrupt electronic bidding, steal investor data, or falsify competition results in order to sow chaos and distrust. Politically motivated attacks can also target private partners - for example, hacking the control system of a power plant built within the PPP framework can threaten real destruction. Therefore, the threat of cyber sabotage is quite material. If the state cannot guarantee cybersecurity, investors will be wary of entering into such projects, given the risk of losses and reputational damage. In addition to cyberattacks, information attacks are also possible in hybrid warfare - the spread of fakes about the alleged opacity of the electronic system, discrediting the very idea of PPP through the media. This can undermine citizens' trust and political support for such projects, even if everything works technically. Therefore, along with technological protection measures, counter-propaganda, and public trust are needed to repel these threats.

Inequality of access and the "digital divide."

It cannot be ruled out that the transition to digital formats will complicate access to participation in PPP for certain categories of potential partners, especially small businesses or businesses from regions with worse Internet infrastructure. If everything is announced online and interaction is purely through electronic cabinets, companies without adequate IT capacity (no qualified employees, unable to set up an electronic signature, slow internet) may be at a disadvantage. This can narrow competition, leaving only large players, which is contrary to the goal of expanding participation. Similarly, communities or local governments in remote areas may not have access to high-speed internet to fully use the national PPP system, leaving them out of the process and resulting in underinvestment in the infrastructure of these regions. The language barrier can also be a problem: international platforms are mostly English-speaking, which makes it difficult for

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local businesses to participate, while national systems may be incomprehensible to foreigners without translation. Therefore, there is a threat that digitalization will create a new gap between "digitally rich" and "digitally poor" companies/regions. It is necessary to be proactive in training, supporting, and ensuring Internet coverage to prevent this threat from materializing.

Change in regulatory and political course.

Digital transformation in the field of PPP largely depends on the consistency of state policy. If, due to a change of government or other circumstances, the priority of digitalization is reduced, reforms may stall. For example, the next government may decide to return some of the processes "to the ground" under the pretext of protecting national security or due to lobbying by those who benefit from old schemes. Or it may not allocate enough funds to support and update the system, and it will gradually degrade. Political turbulence is also dangerous because investors need stability in the rules: if there is a risk that electronic contracts or procedures will later be declared invalid or their terms changed retroactively, the private sector will charge a premium for that risk or bypass the market altogether. Therefore, the threat is any inconsistency or populist steps that could undermine the institutional basis of digital PPP. To minimize this threat, it is important to enshrine basic principles (digital transparency, competition) in laws and international obligations, making them more difficult to change in a timely manner.

Rapid technological development and the risk of lagging behind.

Paradoxically, the rapid progress of IT can pose a threat: the system currently being implemented may be considered obsolete in a few years if fundamentally new technologies emerge (for example, quantum computing, Web3, etc.). If the state and business are not ready to continually invest in upgrades, the PPP's digital infrastructure may lag behind market needs. And this will lead to the opposite effect - bureaucracy will grow again, because the system will have to be bypassed; cybersecurity will decrease; users will be dissatisfied. It is especially risky to invest in technologies for which standards have not yet been established - perhaps in 5 years it will turn out that the chosen platform is a dead end, and you will have to switch to another, spending twice as much. The private sector has its own motive: it does not want to invest in something that will not pay off during the contract, so it may hold innovations "in reserve" for implementation. So, there is a threat of technological uncertainty. It can be mitigated by modular systems (so components can be gradually updated) and by monitoring international trends and participating in standardization, so the country does not end up on the sidelines in an isolated "zoo" of incompatible solutions.

Ethical and legal issues of data use.

The large-scale application of digital technologies raises issues of privacy, ethics, and human rights. For example, if PPPs collect large-scale data on citizens' movements (speed cameras) or their health (medical partnerships), there is a risk of misuse or leakage of this data. The question may arise: who owns the data collected by a private partner at a public facility? Can he commercialize it? Is it a public good? If the state starts sharing data with private operators, won't that violate citizens' rights? Such challenges can lead to public discontent or lawsuits that slow the implementation of technologies. For example, the EU has very high data protection requirements (GDPR), and partnerships that fail to comply with them may be fined. Also ethical is the issue of transparency of AI algorithms that can make decisions in projects (for example, AI selects applications - you need to be sure that it is impartial and does not discriminate). If these aspects are not taken into account, digitalization may face public protests or regulatory blocking.

Summarizing the SWOT analysis, it can be argued that the digitalization of the PPP system has an overwhelmingly positive impact on the state's economic security in difficult war and post-war times. The strengths and opportunities provided by modern technologies - transparency, efficiency, investment attraction, innovative development - directly contribute to economic stability, rapid recovery, and growth. At the same time, there are significant risks and challenges that require proactive management: investments in cybersecurity and backup systems, personnel training, improving legislation, and combating the "digital divide." A SWOT analysis shows that the success of the digital transformation of the PPP depends on the state and businesses' ability to leverage existing opportunities while minimizing internal weaknesses and external threats. In the context of Ukraine, this means completing the creation of a single electronic PPP platform, ensuring its compliance with best global practices (EU standards), and building reliable protection and backup mechanisms.

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DISCUSSION

The results obtained indicate that innovative digital technologies have the potential to significantly transform public-private partnership practices, affecting not only individual operational processes, but also the institutional quality of PPPs in general. The SWOT analysis showed that digitalization can reduce information asymmetry between public and private partners, reduce transaction costs, and increase transparency and accountability at all stages of the PPP project life cycle. This confirms the conclusions of previous studies, which emphasize the importance of effective risk management, control, and institutional trust for the successful implementation of PPPs.

Comparing the results of this study with existing scientific literature allows us to conclude that most previous work focuses primarily on the financial, contractual, or organizational aspects of PPPs, treating digital technologies only fragmentarily as supporting tools within individual projects or industries. In contrast, the article's results justify considering innovative digital technologies as a systemic factor that shapes a new logic of PPP management, alters the mechanisms of interaction between the parties, and affects the distribution of responsibilities and risks. Thus, the study complements the scientific discussion by expanding the focus from the project level to public policy and the institutional environment.

At the same time, the results obtained are consistent with critical reservations presented in previous studies regarding the risks of PPP digitalization. In particular, cyber threats, legal uncertainty, a lack of digital competencies, and high initial costs can offset the expected benefits of implementing digital solutions. This indicates that the positive effects of digital technologies are not automatic and depend largely on the quality of institutional design, the coherence of regulation, and the state's ability to ensure cybersecurity and long-term support for digital platforms.

At the same time, the study's results emphasize the specific relevance of digitalizing PPPs for countries in war or post-war periods. In this regard, a contribution has been made to the development of the scientific discussion, as it has been shown that innovative digital technologies can serve as a tool to accelerate reconstruction, mobilize investments, and strengthen economic security, provided that technological, legal, and security risks are managed simultaneously.

The limitations of this study include its predominantly conceptual and analytical nature. The use of SWOT analysis provides a general view of the strengths and weaknesses of digitalization in PPPs, but does not allow a quantitative assessment of the scale of the impact of individual technologies on the financial or socio-economic outcomes of specific projects. In addition, the analysis is based on secondary sources and examples from different countries, which may limit the direct transfer of individual conclusions to the national context without accounting for the specifics of the institutional environment. Also, detailed empirical assessments of the effectiveness of individual digital tools, in particular based on microdata or case studies, remained outside the scope of the study. Despite the aforementioned limitations, the study's results provide an analytical basis for further scientific work aimed at empirically testing the proposed conclusions and developing practical recommendations for integrating innovative digital technologies into the public-private partnership system.

CONCLUSIONS

The article substantiates those innovative digital technologies are becoming a key factor in transforming public-private partnership practices, affecting the efficiency of management, the transparency of procedures, and the sustainability of PPP projects. The study showed that the digitalization of PPP goes beyond purely technical solutions and acquires institutional significance, forming new approaches to the interaction of public and private partners throughout the entire life cycle of projects.

Generalizing the results of the SWOT analysis showed that the strengths and opportunities of digital technologies, particularly increased transparency, reduced transaction costs, improved control over contract implementation, and expanded access to investment resources, outweigh the existing weaknesses and threats. At the same time, the effectiveness of the digital transformation of PPPs significantly depends on the quality of the institutional environment, the level of digital competencies, the coherence of regulatory and legal frameworks, and the state's ability to ensure an appropriate level of cybersecurity.

It is especially emphasized that, in the context of war and post-war periods, innovative digital technologies can play a strategic role in accelerating infrastructure reconstruction, increasing investor confidence, and strengthening the state's economic security. At the same time, the digitalization of PPP is not a universal solution and requires a comprehensive approach that combines technological innovations with institutional reforms, risk management, and active stakeholder participation. Promising areas for further research include the empirical assessment of the impact of individual digital tools on the financial, social, and infrastructure outcomes of PPP projects, as well as the development of practical models for

integrating digital technologies into national systems of public-private partnerships, taking into account industry- and institutional-specific factors.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ІННОВАЦІЙНО-ЦИФРОВІ ТЕХНОЛОГІЇ В ПРАКТИКАХ ПУБЛІЧНО-ПРИВАТНОГО ПАРТНЕРСТВА: SWOT-АНАЛІЗ

Статтю присвячено дослідженню ролі інноваційно-цифрових технологій у практиках публічно-приватного партнерства (ППП) та оцінюванню їхнього впливу на ефективність, прозорість і стійкість реалізації ППП-проєктів в умовах підвищеної невизначеності, воєнних і повоєнних викликів. Актуальність дослідження зумовлена зростанням фіскальних обмежень, потребою прискореної відбудови інфраструктури та необхідністю підвищення довіри інвесторів і суспільства до механізмів ППП.

Метою дослідження є комплексне обґрунтування потенціалу інноваційно-цифрових технологій у системі публічно-приватного партнерства та визначення їхнього впливу на якість управління, зниження транзакційних витрат і мінімізацію ризиків на всіх етапах життєвого циклу ППП-проєктів. У межах дослідження узагальнено сучасні підходи до застосування цифрових платформ, аналітики великих даних, штучного інтелекту, BIM-технологій, інтернету речей, хмарних рішень і блокчейну в процесах підготовки, контрактування, реалізації та моніторингу ППП.

Основні результати отримано на основі SWOT-аналізу, який дозволив систематизувати сильні сторони цифровізації ППП, зокрема підвищення прозорості процедур, покращення контролю виконання зобов'язань, зростання інвестиційної привабливості та підвищення якості публічних послуг. Водночас ідентифіковано ключові слабкі місця та загрози, пов'язані з кібербезпекою, правовою невизначеністю, дефіцитом цифрових компетенцій, високими початковими витратами та ризиками технологічної залежності.

Зроблено висновок, що інноваційно-цифрові технології мають не лише технічний, а й інституційний характер впливу на публічно-приватне партнерство, формуючи нову логіку взаємодії публічного та приватного секторів. Їх ефективне впровадження здатне стати важливим інструментом прискорення післявоєнної відбудови, мобілізації інвестицій і зміцнення економічної безпеки держави за умови узгодженого розвитку нормативного, інституційного та безпекового середовища.

Ключові слова: публічно-приватне партнерство, цифровізація, інноваційні технології, цифрові платформи, SWOT-аналіз, економічна безпека, інфраструктурні проєкти, управління ризиками, прозорість

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