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MATRIX OF COMBINED FINANCING ADAPTABILITY OF INFRASTRUCTURE PROJECTS TO VUCA ENVIRONMENT

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МАТРИЦЯ АДАПТОВАНOSTІ КОМБІНОВАНОГО ФІНАНСУВАННЯ ІНФРАСТРУКТУРНИХ ПРОЄКТІВ ДО СЕРЕДОВИЩА VUCA

In the post-war reconstruction of Ukraine, infrastructure projects will play a key role. An infrastructure project can be defined as a large-scale long-term investment initiative aimed at creating or modernizing infrastructure assets that provide basic services, generate systemic socio-economic effects, and require combined financial risk-adapted implementation mechanisms.

The post-war reconstruction of Ukraine will take place in conditions of high volatility, uncertainty, complexity, and ambiguity (VUCA). Volatility creates sudden short-term fluctuations in the dynamics of income and expenses, while uncertainty "erodes" the long-term predictability of cash flows. Complexity leads to an increase in indirect financial costs due to management and coordination problems, and ambiguity limits confidence in the correctness of investment decisions made. Therefore, the dimensions of the VUCA environment are triggers of financial risks of infrastructure projects.

The financing model for an infrastructure project must be adapted to modern conditions. Project finance is a financing method based on cash flows generated by the project itself. Blended finance combines public (state) funds with private funds to achieve socially beneficial goals. Sustainable finance is an investment concept that takes into account environmental, social and governance (ESG) criteria, ensuring long-term sustainability. It can be said that these are three different but interrelated concepts that describe different aspects of financing, from the mechanism (project) to the mission (sustainable) and the combination of sources (blended).

The purpose of the article is to propose a conceptual framework that combines three approaches — (1) project-based, (2) blended, and (3) sustainable financing of infrastructure projects in the context of their integrated application to increase adaptability to the impacts (risk triggers) of the VUCA environment.

The proposed analytical and conceptual matrix allows for a systematic argumentation and visualization of the feasibility of combined financing of infrastructure projects in the context of post-war modernization of the economy (according to four risk triggers in a turbulent economic environment). This is the scientific novelty of this study. The practical significance of the proposed matrix is that a structured justification of the "project-blended-sustainable financing" model will contribute to the successful attraction of investment funds for the implementation of infrastructure projects for the post-war reconstruction of Ukraine. Further research on this topic should be conducted in the context of impact investing.

В умовах післявоєнної відбудови України інфраструктурні проекти відіграватимуть ключову роль. Інфраструктурний проєкт можна визначити як великомасштабну довгострокову інвестиційну ініціативу, спрямовану на створення або модернізацію інфраструктурних активів, що забезпечують надання базових послуг, формують системні соціально-економічні ефекти та потребують комбінованих фінансових ризик-адаптованих механізмів реалізації.

Післявоєнна відбудова України відбуватиметься в умовах високої мінливості, невизначеності, складності та неоднозначності (VUCA). Мінливість створює раптові короткострокові коливання в динаміці доходів та витрат, тоді як невизначеність "розмиває" довгострокову прогнозованість грошових потоків. Складність призводить до зростання непрямих фінансових витрат через управлінські та координаційні проблеми, а неоднозначність обмежує впевненість у правильності інвестиційних рішень, що приймаються. Отже, виміри VUCA-середовища є тригерами фінансових ризиків інфраструктурних проєктів.

Модель фінансування інфраструктурного проєкту має бути пристосованою до сучасних умов. Проєктне фінансування — це спосіб фінансування на основі грошових потоків, отримуваних від самого проєкту. Змішане фінансування поєднує публічні (державні) кошти з приватними для досягнення суспільно корисних цілей. Стале фінансування — це концепція інвестицій, яка враховує екологічні, соціальні та управлінські (ESG) критерії, забезпечуючи довгострокову стійкість. Можна сказати, що це три різні, але взаємопов'язані концепції, що описують різні аспекти фінансування, від механізму (проєктне) до місії (стале) та поєднання джерел (змішане).

Мета статті — запропонувати концептуальну рамку, яка комбінує три підходи — (1) проєктне, (2) змішане та (3) стале фінансування інфраструктурних проєктів у контексті їх інтегрованого застосування для підвищення адаптованості до впливів (тригерів ризиків) VUCA-середовища.

Пропонована аналітико-концептуальна матриця дозволяє систематизовано аргументувати та візуалізувати доцільність комбінованого фінансування інфраструктурних проєктів в умовах післявоєнної модернізації економіки (за чотирма тригерами ризиків у турбулентному економічному середовищі). У цьому і полягає наукова новизна даного дослідження. Практична значимість пропонованої матриці полягає у тому, що структуроване обґрунтування моделі "проєктне-змішане-стале фінансування" сприятиме успішному залученню інвестиційних коштів на реалізацію інфраструктурних проєктів післявоєнної відбудови України. Подальші дослідження за цією темою доцільно провести в контексті імпакт-інвестування.

Key words: variability, uncertainty, complexity, ambiguity, project finance, blended finance, sustainable finance.

Ключові слова: мінливість, невизначеність, складність, неоднозначність, проєктне фінансування, змішане фінансування, стале фінансування.

GENERAL STATEMENT OF THE PROBLEM AND ITS CONNECTION WITH IMPORTANT SCIENTIFIC AND PRACTICAL TASKS

In a general sense, infrastructure encompasses the set of basic physical, organizational and institutional

structures and facilities necessary for the functioning of the economy and society. Infrastructure includes transport networks, energy systems, water supply and wastewater facilities, telecommunications, and other structures that significantly affect the quality of life, productivity and long-

Table 1. Impact of VUCA environment on risks and financial results of infrastructure projects

<i>Characteristics of VUCA</i>	<i>Key impacts on project risks</i>	<i>Key influences on the financial aspects of infrastructure projects</i>
Variability	The high frequency and amplitude of changes in macroeconomic indicators (inflation, exchange rates, interest rates, energy prices), and the cost of construction resources increase the risks of exceeding the project budget and reducing profits.	Increasing capital and operating costs; worsening net present value (NPV); decreasing internal rate of return (IRR); instability of debt coverage ratios; increasing cost of financing due to increased risk premiums.
Uncertainty	Limited predictability leads to possible errors in cash flow forecasting, increasing risks of demand for the product or service of an infrastructure project.	Decreased reliability of cash flow forecasts; expansion of the range of possible NPV and IRR values; increase in the amounts of guarantees, preferential financing, and state support provided.
Complexity	The interdependence of a large number of system elements, numerous interconnections between subsystems, and multi-level structures increase coordination, contractual, transactional, and management risks.	Increased transaction and structuring costs; extended project preparation phase; reduced financial efficiency; potential dilution of equity returns through complex risk-sharing mechanisms.
Ambiguity	The lack of clear benchmarks, incomplete information on long-term demand and technological development trajectories increases strategic risks. Ambiguity complicates data interpretation and hinders decision-making.	Using conservative financial assumptions, postponing investment decisions, increasing the discount rate.

Source: compiled by the authors.

term economic growth [1]. In modern conditions, digital infrastructure, in particular, large-scale data centers, AI villages, digital hubs, etc., is becoming a strategic framework for innovative development [2]. Studies [3] and [4] demonstrate the positive impact of the development of transport and digital infrastructure on the effectiveness of "green" innovations and sustainable economic growth.

This article is devoted to the general scientific problem of defining and substantiating the concept of financing infrastructure projects that would best meet modern requirements and conditions. In Ukraine, the relevance of research in this area is particularly high, as the post-war modernization of the economy will require the implementation of a large number of infrastructure projects.

ANALYSIS OF RESEARCH AND PUBLICATIONS

Project finance is the process of financing a specific economic unit that is created specifically for a project, where the return on investment is ensured by the flow of funds generated by the project itself [5]. The work [6] analyzes the possibilities of applying different models of project finance in Ukraine, emphasizing the need to adapt international practices to the national institutional environment.

Blended finance is increasingly seen as a key mechanism for financing infrastructure projects in conditions characterized by high risk and significant development needs. This approach is defined as the

strategic use of concessional public or philanthropic capital to mobilize additional commercial private investment in projects [7; 8]. The defining feature of blended finance is not the amount of government support, but its catalytic role in improving the risk-return ratio of projects that would otherwise not be attractive to private investors.

Sustainable finance is defined as finance that supports economic growth while reducing negative environmental impacts and taking into account social and governance aspects [9].

Decision-making in the field of investment and lending for infrastructure projects is influenced by external financial and economic conditions. The acronym VUCA (volatile, uncertain, complex, ambiguous) is a characteristic of the state of the modern world. Volatility (V) in the general sense here means rapid and unexpected changes with an unclear duration of such fluctuations; uncertainty (U) — the unknown of what will happen in the future; complexity (C) — the interaction of too many interconnected parts at different levels; ambiguity (A) — the presence of many different perspectives and points of view, confusion of cause-and-effect relationships [10].

To date, no peer-reviewed academic articles have been identified that simultaneously integrate project, blended and sustainable finance on the one hand, and use VUCA as an explicit analytical or conceptual framework on the other. Therefore, it can be said that this research niche is currently largely unfilled.

FORMULATION OF THE ARTICLE'S GOALS (TASK STATEMENT)

The purpose of the article is to propose a conceptual framework that combines three approaches — (1) project, (2) blended and (3) sustainable financing of infrastructure projects in the context of their integrated application to increase adaptability to the impacts (risk triggers) of the VUCA environment.

This goal determines the following research objectives:

- to characterize the impact of the VUCA environment on the risks and financial results of infrastructure projects;
- to develop a conceptual matrix of drivers of project adaptation from combined financing to the risk triggers of the VUCA environment;
- to determine the role of each element of the matrix and emphasize its synergistic effect.

THE PAPER MAIN BODY

In the course of this study, the following methods were used: systematization and classification of information, abstraction and grouping (in particular, to describe the modern environment of risk triggers — VUCA, in the context of the topic of the article), structural-functional method, scientific abstraction, induction and deduction,

graphical (the last of the listed methods is for visual presentation of results).

Table 1 shows the impact of VUCA environment triggers on the risks and financial results of infrastructure projects.

The information presented in Table 1 indicates the following. The general meaning of each of the VUCA dimensions, which is presented in the section "Analysis of Research and Publications", in the context of finance is transformed into the corresponding impacts on the risks and financial results of infrastructure projects. Therefore, the VUCA dimensions (variability, uncertainty, complexity and ambiguity) are, among other things, triggers of financial risks of infrastructure projects. The question is how the studied financing concepts (project, blended and sustainable) and their combination adapt projects to VUCA conditions. The above definitions of the three financing concepts allow to make the following generalization. Project financing is a method of financing based on cash flows received from the project itself. Mixed financing combines public (state) funds with private ones to achieve socially beneficial goals. Sustainable financing is an investment concept that takes into account environmental, social and governance (ESG) criteria, ensuring long-term sustainability. It can be said that these are three different but interrelated concepts, which, among other things, can

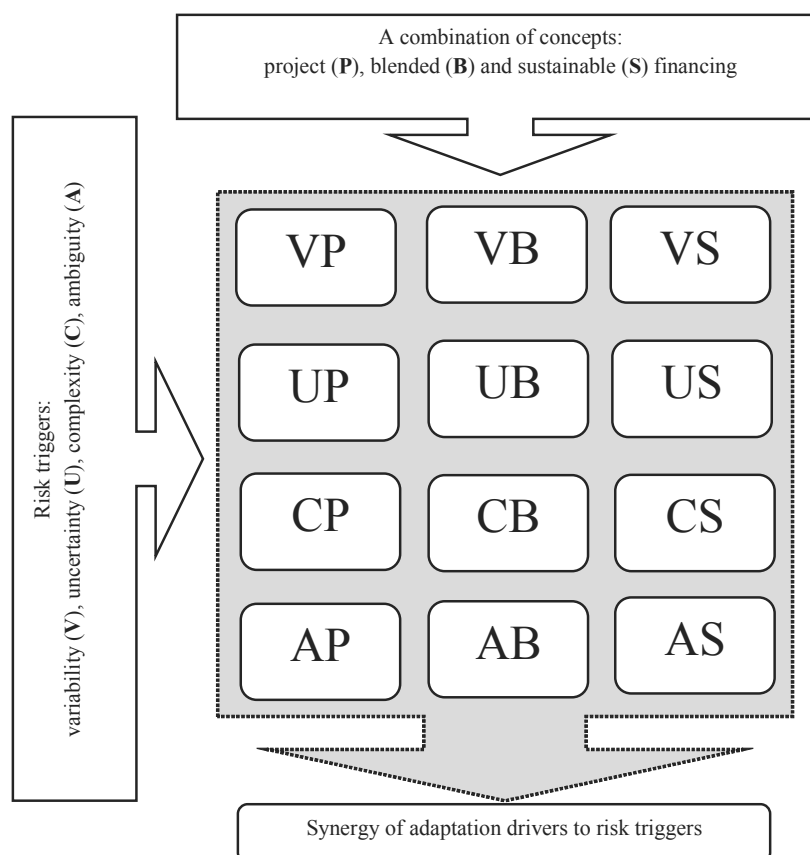


Fig. 1. Matrix of drivers of combined finance for adaptation to risk triggers of the VUCA environment

Note: VP, VB, VS — shock absorbers (adaptation drivers to) variability from the elements "project finance", "blended financing" and "sustainable financing" respectively; UP, UB, US — shock absorbers of uncertainty from the elements "project finance", "blended financing" and "sustainable financing" respectively; CP, CB, CS — shock absorbers of complexity from the elements "project finance", "blended financing" and "sustainable financing" respectively; AP, AB, AS — shock absorbers of ambiguity from the elements "project finance", "blended financing" and "sustainable financing" respectively (the content of each of the drivers is disclosed in the text of the article).

Source: formed by the authors.

be recognized as dimensions of the space of proactive adaptation to the risk environment of financing in the coordinates of (X) mechanism (project), (Y) mission (sustainable) and (Z) array of sources (mixed).

Combined financing integrates project, blended and sustainable financing into a unified concept that creates a positive synergistic effect.

The matrix of key drivers of combined ("project-blended-sustainable" — PBS) financing of an infrastructure project, which serve as factors of preventive adaptation to risk triggers (variability, uncertainty, complexity, ambiguity — VUCA) is shown in Fig. 1.

The matrix of synergistic action of key shock absorbers of combined financing (means of resistance to the effects of risk triggers in the VUCA environment) includes the following elements (Fig. 1):

VP (key means of adaptation to variability from the side of the "project financing" factor) — the use of an EPC contract (Engineering, Procurement, Construction) with the contractor's responsibility for a fixed price and terms, placing a particular risk on the stakeholder who has the greatest influence on it;

VB (key means of adaptation to variability from the side of the "mixed financing" factor) — absorption of variability through state guarantees or first-loss instruments;

VS (key means of adaptation to variability from the side of the "sustainable financing" factor) — natural for this concept, investors' focus on the long full life cycle of the "project-asset" and long-term value, rather than on short-term financial fluctuations, independent external assurance/audit, constant monitoring and measurement;

UP (key means of adapting to uncertainty from the "project finance" factor) — the use of non-recourse or limited-recourse financing, long-term purchase and sale agreements (offtake), hedging instruments and reserve accounts to ensure debt repayment from project revenues;

UB (key means of adapting to uncertainty from the "blended finance" factor) — reducing uncertainty by signaling public commitment and political support: participation of the state or international financial institutions (IFIs);

US (key means of adapting to uncertainty from the "sustainable finance" factor) — scenario analysis, alignment of investments with long-term ESG priorities and public policy goals (climate transition, social development) and relevant preferences;

CP (key means of adapting to complexity from the "project finance" factor) — creation of SPV, application of a clear hierarchy of cash flows (cash-flow waterfall), standardized documentation and separation of project risks from the balance sheets of sponsors;

CB (key means of adapting to complexity from the "mixed finance" factor) — active management of complexity by coordinating heterogeneous participants (public sector, MFIs, private investors) and harmonizing different expectations of risk and return within a single financial structure;

CS (key means of adapting to complexity from the "sustainable finance" factor) — systematic application of best practices of hierarchical structuring of work (WBS), for example [11], development of strategic roadmaps;

AP (key means of adapting to ambiguity from the "project finance" factor) — giving preference to proven technologies and mature business models, structuring of deals;

AB (key means of adapting to ambiguity from the "mixed financing" factor) — absorption of ambiguity through public or concessional capital;

AS (key means of adapting to ambiguity from the "sustainable financing" factor) — clear standards, such as [12; 13], disclosure and public reporting, stakeholder engagement and active feedback.

The above description of the matrix contains precisely the key means of adaptation to risk triggers from each of its elements. Moreover, the means of adaptation are presented in such a way that each of them is given in only one element (this emphasizes a certain specificity of each element). Thus, this description is clearly focused. At the same time, it should be noted that with a less focused (broader) description of the matrix elements, certain means of adaptation to risk triggers would be repeated in several elements. For example, the adaptation means "... at the expense of public or preferential capital" would take place not only in element AB, but also, say, in element VB.

Summarizing the above, we can say that combined (PBS) financing provides an investment infrastructure project with adaptability to risks in a four-dimensional VUCA environment. It should be noted that as a result of the integrated application of three concepts ("project-blended-sustainable" financing), the adaptability of an investment infrastructure project to the challenges of the risk environment increases with a synergistic effect.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH IN THIS AREA

An infrastructure project can be defined as a large-scale long-term investment initiative aimed at creating or modernizing infrastructure assets that provide basic services, generate systemic socio-economic effects, and require combined financial risk-adapted implementation mechanisms.

The post-war reconstruction of Ukraine will take place in conditions of high volatility, uncertainty, complexity, and ambiguity (VUCA). Volatility creates sudden short-term fluctuations in the dynamics of revenues and expenses, while uncertainty "erodes" the long-term predictability of cash flows. Complexity leads to an increase in indirect financial costs due to management and coordination problems, and ambiguity limits confidence in the correctness of investment decisions made. Therefore, the dimensions of the VUCA environment are triggers of financial risks of infrastructure projects.

The key result of this work is the creation of a matrix of drivers of combined ("project-mixed-sustainable") financing of an infrastructure project, which are factors of adaptation to risk triggers (variability, uncertainty, complexity, ambiguity — VUCA).

The proposed analytical and conceptual matrix allows for a systematic argumentation of the feasibility of using combined financing of infrastructure projects in the conditions of post-war modernization of the economy (according to four risk triggers in a turbulent economic

environment). This is the scientific novelty of this study. The practical significance of the proposed matrix lies in the fact that a structured justification of the "project-mixed-sustainable financing" model will contribute to the successful attraction of investment funds for the implementation of infrastructure projects for the post-war reconstruction of Ukraine.

Further research on this topic should be conducted in the context of the impact-investment mechanism.

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