Strategic Planning of Foreign Economic Activity: Applied Intelligent Systems in Public-Private Partnership

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Abstract

The article offers effective strategic planning to determine the prospects and future overall state of implementation of public-private partnership (PPP) projects in foreign economic activity. It consists of some elements of game theory and stages related to a) designing a matrix model of cooperation among PPP actors in foreign economic activity (including basic PPP models and strategies for cooperation among its actors), b) evaluating the probability of implementing the PPP model in foreign economic activity, c) calculating the Hurwicz criterion, the reliability coefficient, d) selecting an optimal way of cooperation among PPP actors in foreign economic activity based on corresponding criteria, e) summarizing game theory outcomes. Its use in conjunction with applied intelligent systems has ensured mutually beneficial cooperation in foreign economic activity on a long-term basis and attracted investments in the most promising infrastructure projects in need of creation, restoration, modernization, reconstruction and development in the amalgamated territorial community (ATC) of Davydiv.

Keywords

Strategic planning, applied intelligent systems, public-private partnership, foreign economic activity, development

1. Introduction

Currently, the development of the world economy and international economic relations lies in the convergence of the economies of different countries, the modernization of production and technology and the promotion of an information society. In turn, these processes accelerate the development of forms of international economic relations and foreign trade and strengthen globalization processes. In these conditions, however, one can observe the escalation of economic and social problems, as well as a notable shift in priorities from the development of economic systems to the solution of these problems.

Since the mechanism of public-private partnership (PPP) has proven its efficiency in various forms of economic activity, one can use it to solve the above-mentioned problems and create a strong foundation for cooperation between the state and business. Significant potential for its development lies in the foreign economic sphere, which requires timely attention to the issues of PPP strategic planning in foreign economic activity and the use of optimal models of cooperation in the form of PPP in foreign economic activity.

As is known, one can increase the efficiency of PPP projects through intelligent systems and technologies, decision-making processes and information management practices. Special emphasis should be placed on applied intelligent systems.

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2. Related Works

Numerous researchers have explored the issue of strategic planning and assessment of public-private partnership (Bondar N. M., Filippova V. D., Budnyk V. A., Mykhailiv H. V., Hryniv L. V., Los O. I., Berrone P., Ricart J. E., Duch A. I., Bernardo V., Salvador J., Piedra Peña J., Rodríguez Planas M., Lernichenko K. V., Spoann V., Fujiwara T., Seng B., Lay C., Yim M., et al.). They identify the main vectors of PPP efficiency and methods for its assessment and justify the principles and peculiarities of PPP assessment in foreign economic activity. It is essential to analyze them more in detail.

As noted by Spoann V., Fujiwara T., Seng B., Lay C., Yim M., a public-private partnership develops performance of the public sector, including reducing costs, improving efficiency and ensuring environmental protection [1]. The expected economic effect of PPP for society lies in the fact that it obtains better social benefits and services while reducing costs. PPP projects are of interest to partners in terms to reduce the cost, improve service quality and make a formal link between public and private sector operations to improve the efficiency of the entire sector. In the article, a quantitative and qualitative assessment of PPP projects was carried out, an opportunity to assess the causal link between actions and outcomes in a real-life situation was proposed, for which a set of key questions was used, a sustainability assessment by a success and efficiency factor method and operational components were evaluated. The study did not estimate costs of private waste operators and public sector agency due to limited information on costs.

Berrone P., Ricart J. E., Duch A. I., Bernardo V., Salvador J., Piedra Peña J., Rodríguez Planas M. believe that «most of the current theoretical approaches and evaluation tools to measure the impact of PPPs are primarily focused on the economic dimensions or economic implications of PPP projects» [2]. Authors recommend a model that accounts not only for PPPs' economic impact or value for money, but also their impact on society (value for people) and the environment (value for the planet), and therefore, their contribution to the achievement of the Sustainable Development Goals (SDGs). The author's model provides quantitative and qualitative assessment. It contains 53 questions to be answered by several respondents and statistical analysis of the obtained results. It should be noted that it is recommended as complementary tool to improve both the quality and impact of current methods of evaluating PPPs, in particular in regard to its relation to the SDGs and sustainable development [2].

As noted by Osei-Kyei R., Chan A. P., Yu Y., Chen C., Ke Y., Tijani B in [3], surveys are one of the most widely used research methods in PPP research because of the sensitive nature of issues related to it. At the same time, in order to study the importance of social responsibility factors, the article by these authors used a survey on a 5-point Likert scale. The authors also disclosed the content of the methods of statistical analysis of the obtained evaluation results: Kendall's coefficient of concordance, mean analysis, and Mann Whitney U test. Authors used The Statistical Package for Social Sciences (SPSS).

In addition to the above-mentioned recommendations [3], it is crucial to characterize some conceptual foundations for creating a system of PPP project assessment [4]. First, one should consider redistribution effects when assessing the social and regional efficiency of PPP projects (budgetary efficiency, social utility). In particular, it is necessary to exclude the following components from the financial income and expenses of PPP projects: taxes, duties, transfers, subsidies, benefits and other forms of redistribution of funds between domestic project actors and the government (in the form of regional authorities).

According to the European Bank for Reconstruction and Development (EBRD) and Economist Intelligent Unit (EIU), a country's ability to create and implement PPP projects can be measured by calculating the readiness index. This index provides a comparison of countries based on six criteria (regulatory and legal framework, institutional structure, operational readiness (functional readiness), investment climate, financial mechanisms, sub-national (regional-municipal) corrective index), using 19 quantitative and qualitative indexes [5]. Thus, these indexes can be used to assess public-private partnership in foreign economic activity.

Liang Y., Jia H. claims that project efficiency is possible in the presence of revenues higher than expenses incurred. At the same time, the benefits of PPP projects for various stakeholders should be taken into account. The researcher analyzes key factors for PPP success: «benefits to private partner»,

«benefits to public partner», «benefits to end user», «what is a better service», «meeting design goals», «meeting planning goals», «the delivery time to end user», etc. [6].

To assess PPP projects Tajani F., Morano P., Di Liddo F., Locurcio M. propose to use economic assessment tools and calculate the net present value (NPV), the internal rate of return (IRR) and the discounted payback period (DPP) [7]. These indexes were used by Sheng M., Sreenivasan A., Sharp B., Wilson D. J., Ranjitkar P. in their work to assess the efficiency of PPP projects in the field of economic viability of a DIPT system for EVs [8]. However, with the aim of improving the level and reliability of assessment processes, they were supplemented with a mathematical apparatus of fuzzy sets. The researchers also applied an additional efficiency index, i.e., the opportunity profit for the private investor.

This corresponds to «Methods of Analyzing Public-Private Partnership Efficiency», approved by Order of the Ministry of Economic Development and Trade of Ukraine No 255 dated February 27, 2012. In particular, Order of the Ministry of Economic Development and Trade of Ukraine No 1735 as of November 29, 2017 stipulates the procedure for calculating economic and financial indexes of public-private partnership implementation (NPV, IRR, PI, DPP for both the project as a whole and interested parties) [9].

Following the above-mentioned Order No 255, Filippova V. D., Budnyk V. A., Mykhailiv H. V., Hryniv L. V. and Los O. I. recommends determining the internal value of PPP projects from the perspectives of the state and the private partner to align the interests of actors in PPP projects [10]. To calculate this index, it is necessary to modify a formula for calculating the NPV of the PPP project. Consequently, a third appendix was introduced, which is the terminal value (TV) of the monetary flows from the implementation of PPP projects beyond the period with expected monetary receipts.

In their turn, V. A. Budnik & K. V. Lernichenko offer a methodical approach to assessing the efficiency and development of urban water transport enterprises (UWTE) [11]. It involves the calculation of assessment of PPP performance indexes (NPV, IRR, PI, DPP, capital value) from the concessionaire's position (UWTEs); that from the concession grantor's position; the agreement of PPP conditions with local government bodies; criterion values of performance indexes; a model of actions of PPP project actors.

Despite significant interest in the issues of assessment and strategic planning of PPP in foreign economic activity, applied intelligent systems (AIS) still have not been widely applied in this process. Most successful PPP projects are aimed at introducing the achievements of artificial intelligence (AI) into the activities of cities and communities. They include e-governance projects, automated driving technologies, intelligent transport systems (telecommunications and information infrastructure, subsystem tolls, transport operating centres, subsystem video surveillance cameras hotspots, emergency call subsystem, weighing subsystem), Intelligent Vehicles [12-17].

When speaking about the use of AIS in implementing PPP projects in foreign economic activity, one can mention the following. Applying the Leximancer software, Tingting Liu, Sherif Mostafa, Sherif Mohamed & Tuan Son Nguyen analyzed and grouped available publications on the issue of identifying innovations in PPP projects on smart city construction [18]. Multi-Attribute Utility Analysis (MAUA) was conducted by P. T. I. Lama & W. Yan to analyze the costs of PPP projects on smart city construction and the results of their implementation [19].

Neurofuzzy decision support system (NFDSS) is described and analyzed by Jin & Xiao-Hua. By combining fuzzy and neural network techniques, a synthesized fuzzy inference system was established and taken as the core component of the NFDSS. The scope of using the recommended system lies in the field of selecting risk management strategies when implementing PPP projects in foreign economic activity [20].

A. Sharafi, H. Iranmanesh, M. S. Amalnick & M. Abdollahzade applied Local Linear Neuro Fuzzy and Multi-Layer Perceptron methods to forecast the stochastic variables in the course of financial assessment of PPP projects. In addition, a fuzzy multi-objective model is proposed to identify the most feasible and satisfactory solution [21].

The mean impact value (MIV) method and the back-propagation (BP) feed-forward neural network improved by the sparrow search algorithm (SSA) are used by S. Wang, J. Fang, L. Liu & H. Wu to predict ticket prices for a public-private partnership (PPP) subway system [22].

Thus, it is important to highlight the significant potential of using AIS to solve management problems in PPP projects, which indicates their expediency in the strategic planning of PPP in foreign economic activity.

3. Methods

Special emphasis should be placed on ideas on the use of game theory elements in assessing PPP in foreign economic activity. Previously, V. M. Yuritsyn employed game theory (a prisoner's dilemma) to model the cooperation between customs agencies and businesses. In particular, the researcher offered an objective model for optimizing such cooperation and systematized its possible scenarios through mathematical models: a matrix model of cooperation between customs agencies and businesses; a bi-matrix model of cooperation between customs agencies and businesses. These models rely on game theory (a prisoner's dilemma), allowing one to determine the state of cooperation between customs agencies and businesses and discover ways of optimizing it. Finally, V. M. Yuritsyn confirmed the possibility of increasing its efficiency through public-private partnership [23].

This article shows how one can use theoretical game-based modelling and apply some elements of the playing with nature" game, described at [24], to assess PPP in foreign economic activity. According to the rules of the game, its players do not oppose each other as one acts consciously and the other makes moves randomly without a clearly defined strategy [25].

At the same time, it was decided to use the game during decision-making regarding PPP in foreign economic activity. According to the commonly accepted PPP classification, the following are presented as the elements of a matrix model of cooperation among PPP actors in foreign economic activity:

A_1 – cooperation between the state and business structures – the actors in the economic activity of Ukraine and the foreign actors in economic activity;

A_2 – cooperation between the state and business structures – the actors in the economic activity of Ukraine with foreign states);

A_3 – cooperation between the state and business structures – the actors in the economic activity of Ukraine.

It is possible to implement basic models of PPP in foreign economic activity in each of the cooperation options (A1-A3 elements of matrix models):

S_1 – management agreement;

S_2 – leasing;

S_3 – concession;

S_4 – agreements on the creation or reconstruction of objects;

S_5 – sale of assets.

They are also included in the matrix of cooperation among PPP actors in foreign economic activity (see Table 1). The net present value (NPV) has been selected as the resulting index designed to assess PPP in foreign economic activity following "Methods of Analyzing Public-Private Partnership Efficiency", approved by Order of the Ministry of Economic Development and Trade of Ukraine No 255 as of February 27, 2012.

Table 1

Matrix of Cooperation among PPP Actors in Foreign Economic Activity

Elements	S_1	S_2	S_3	S_4	S_5
A_1	NVP_{11}	NVP_{21}	NVP_{31}	NVP_{41}	NVP_{51}
A_2	NVP_{12}	NVP_{22}	NVP_{32}	NVP_{42}	NVP_{52}
A_3	NVP_{13}	NVP_{23}	NVP_{33}	NVP_{43}	NVP_{53}

After calculating the values of the matrix's indexes, the following is in order.

The procedure below can be used to assess PPP models in foreign economic activity depending on the nature of cooperation among PPP actors (A1-A3 elements of matrix models) [24]:

1. Assessing the probability of implementing the PPP model in foreign economic activity;

2. Calculating the Hurwicz criterion, the reliability coefficient. The Hurwicz criterion can be estimated by an expert in the range [0;1], where 0 corresponds to extreme pessimism [26].

The reliability coefficient (K_r) can be calculated with the following formula:

$$K_r = \sum_{i=1}^{n} P_i \times K_{is}, \quad (1)$$

where P_i – the probability that the source contains 100% reliable information;
K_{is}– the reliability weight of the information source;
n – the number of information sources.

For sources containing 100% reliable information, the reliability weight is equal to 1; 50% reliable information – 0.5; unreliable (0%) information – 0. The reliability weight of information sources can be determined based on objective data on the responsibility for the truthfulness of the object (actor) that led to the appearance of this information or by an expert [27, 28].

3. Selecting optimal cooperation among PPP actors in foreign economic activity following the Bayesian information criterion (BIC), the Laplace criterion (LC), the Wald's maximum criterion (WMC), the Hurwicz criterion (HC), the Hodges-Lehmann estimator (HLE) and the Savage's minimax regret criterion (SMRC). Below they are analyzed more in detail:

$$W_i = \sum_{i=1}^{5} a_{ij} \times P_j, \quad (2)$$

The maximum value of the Bayesian information criterion (BIC) is considered as optimal.

The Laplace criterion (LC) means calculating the average value of the elements of each row using the following formula:

$$W_i = \frac{1}{5} \sum_{i=1}^{5} a_{ij}, \quad (3)$$

The maximum value of the Laplace criterion (LC) is considered as optimal.

To calculate the Wald's maximum criterion (WMC), one should calculate the minimum element in each row using the formula below:

$$W_i = \min_{1>j<5} a_{ij}, \quad (4)$$

To select an optimal strategy, it is advisable to calculate the maximum value under the given criterion.

The Hurwicz criterion (HC). For each row, one calculates the value of the criterion using the following formula:

$$W_i = C \times \min_{1>j<5} a_{ij} + (1 - C) \max_{1>j<5} a_{ij}, \quad (5)$$

where C – a coefficient of pessimism.

According to this criterion, one also considers the maximum value as optimal.

The Hodges-Lehmann estimator (HLE) allows a calculation for each row under the formula below:

$$W_i = U \times a_{ij} + (1 - U) \min_{1>j<5} a_{ij}, \quad (6)$$

where U – the reliability coefficient.

The optimal value of the Hodges-Lehmann estimator (HLE) also corresponds to the maximum of the obtained values.

The Savage's minimax regret criterion (SMRC) involves calculating the risk matrix. It is recommended to fill in the matrix in columns (SMRC). In each column, one should calculate the maximum element, subtract all other elements of the column from it and record the results in the appropriate places according to the following formula:

$$r_i = \max_j a_{ij} - a_{ij}, \quad (7)$$

According to W_i, the maximum value should be chosen for each row of the risk matrix. The minimum value of the risk matrix (W_i) should be considered as optimal in this case.

It is crucial to apply different criteria when using game theory in linear programming problems. This allows one to make a justified decision on the strategy of cooperation among PPP actors in foreign economic activity. Providing that the results of using these criteria are consistent, the choice of strategy is indeed obvious. Otherwise, one should obtain additional information about the environment, rely on the criterion more suitable for this situation, or use additional assessment criteria [29, 30].

4. Summarizing the results of game theory, selecting the strategy of cooperation among PPP actors in foreign economic activity and making managerial decisions.

It is possible to simplify most stages of the recommended sequence by using appropriate online algorithms and software products. During its practical validation, the authors of this article relied on

automated calculations performed with Microsoft Excel. A ready software solution for solving game theory problems in strategic planning of PPP in foreign economic activity still has not been found.

Stages of recommended order to assess the prospects of cooperation among PPP actors in foreign economic activity summarized on figure 1.

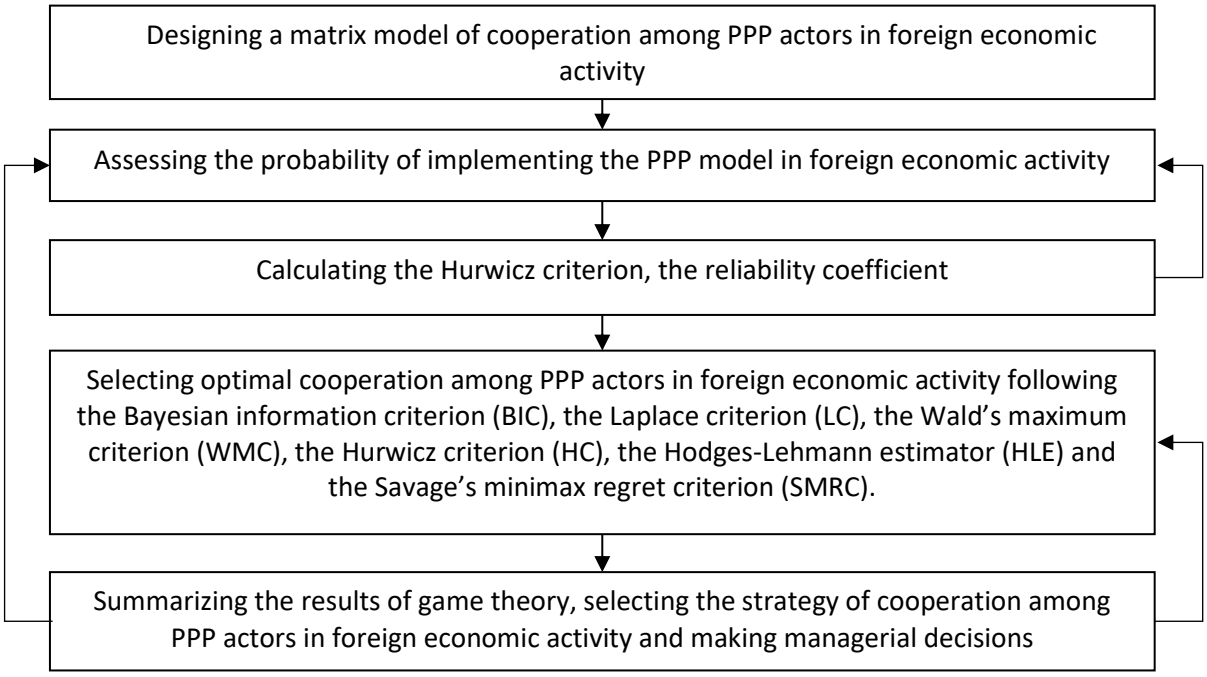

Figure 1: Stages of recommended order to assess the prospects of cooperation among PPP actors in foreign economic activity

4. Results and Discussion

This article follows the recommended order to assess the prospects of cooperation among PPP actors in foreign economic activity as part of implementation of the public-private partnership project on "Capital Repair of Roads on Heroiv UPA St. (from Secondary School of Levels 1-2 to the church) in Horodyslavychi village of Lviv District in Lviv Oblast" involving Davydiv Village Council of Lviv District in Lviv Oblast and Onur Construction International LLC under the agreement No T-18/21 as of November 30, 2021.

It was decided to organize an expert group from the amalgamated territorial community (ATC) of Davydiv and Onur Construction International LLC to create a matrix of cooperation among PPP actors in foreign economic activity and assess information reliability. This group included employees of economic and legal departments of ATC Davydiv and those of Onur Construction International LLC.

Consequently, the following matrix has been designed (see Table 2), U =0.8, C =0.6.

Table 2

Matrix of cooperation among PPP actors in foreign economic activity as part of the PPP project on "Capital Repair of Roads on Heroiv UPA St. (from Secondary School of Levels 1-2 to the church) in Horodyslavychi village of Lviv District in Lviv Oblast"

Elements	S_1	S_2	S_3	S_4	S_5
A_1	255300	17200	62780	18920	7920
A_2	272080	21650	58630	23650	7250
A_3	189600	8340	49260	24520	14300
P	0.3	0.3	0.1	0.12	0.18

One can choose an optimal strategy of cooperation among PPP actors in foreign economic activity by calculating the above-mentioned criteria (see Table 3).

Table 3

Results of calculations by the criteria

Elements	Criteria					
	BIC	LC	WMC	HC	HLE	SMRC
A_1	91724	72424	7920	106872	74963	247380
A_2	**98125**	**76652**	7250	**113182**	**79950**	264830
A_3	69824	57204	**8340**	80844	57528	**181260**

Note: an optimal value of W_i is marked in bold

To calculate the SMRC criterion, it was necessary to create a risk matrix for the PPP project on "Capital Repair of Roads on Heroiv UPA St. (from Secondary School of Levels 1-2 to the church) in Horodyslavychi village of Lviv District in Lviv Oblast" (see Table 4).

Table 4

Risk matrix for the PPP project on "Capital Repair of Roads on Heroiv UPA St. (from Secondary School of Levels 1-2 to the church) in Horodyslavychi village of Lviv District in Lviv Oblast"

Elements	S_1	S_2	S_3	S_4	W_i
r_1	0	238100	192520	236380	247380
r_2	0	250430	213450	248430	264830
r_3	0	181260	140340	165080	175300

Given the obtained results, an optimal strategy for the project in question is A2. It involves cooperation between the state and business structures – the actors in the economic activity of Ukraine with foreign states.

5. Conclusions

The article explores applied intelligent systems and analyzes the ways of using them in the implementation of PPP projects in foreign economic activity. To make justified decisions concerning PPP in foreign economic activity, it was decided to use some elements of game theory (the «playing with nature» game) and follow a relevant procedure of economic assessment based on automated calculations with Microsoft Excel. Importantly, this procedure can be improved using online algorithms. It involves the following stages:

1. Designing a matrix model of cooperation among PPP actors in foreign economic activity (including basic PPP models and strategies for cooperation among its actors), whose resulting index is the NPV of PPP projects;
2. Evaluating the probability of implementing the PPP model in foreign economic activity;
3. Calculating the Hurwicz criterion, the reliability coefficient;
4. Selecting optimal cooperation among PPP actors in foreign economic activity under the Bayesian information criterion (BIC), the Laplace criterion (LC), the Wald's maximum criterion (WMC), the Hurwicz criterion (HC), the Hodges-Lehmann estimator (HLE) and the Savage's minimax regret criterion (SMRC);
5. Summarizing game theory outcomes, choosing a strategy of cooperation among PPP actors in foreign economic activity, making managerial decisions.

Using the offered strategic planning of PPP in foreign economic activity, one can determine prospects and future overall state of implementation of PPP projects in foreign economic activity by choosing those that ensure mutually beneficial cooperation in foreign economic activity on a long-term basis and attract investments in the most promising infrastructure projects in need of creation,

restoration, modernization, reconstruction and development. It has been validated in Davydiv ATC as part of implementation of the PPP on «Capital Repair of Roads on Heroiv UPA St. (from Secondary School of Levels 1-2 to the church) in Horodyslavychi village of Lviv District in Lviv Oblast».

In further research on the problem, PPP strategies in foreign economic activity for real situations in different regions of Ukraine should be analyzed.

The recommended method should be used to strategize PPPs in foreign economic activity regarding reconstruction projects of infrastructural facilities in the post-war period in Ukraine, with the aim of increasing their effectiveness and quickly solving socio-economic problems. At the same time, potential sources of financing PPP projects in foreign economic activity in the post-war period should be taken into account, which should be used to rebuild critical infrastructure and maximize the benefits of all interested parties.

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