

Applied Intelligent Systems of Support for Public-Private Partnership in Foreign Economic Activity

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Abstract

The article deals with the following applied intelligent systems designed to manage national economies: artificial neural networks, expert systems, hybrid intelligence systems, fuzzy systems, genetic algorithm, etc. Besides it specifies the essential components of support for public-private partnership in foreign economic activity. These components, associated with regulatory, institutional, analytical, financial and organizational support, can enhance the national economy, improve economic and social infrastructure and solve pressing economic and social problems. It is advisable to apply morphological analysis and relevant online algorithms to maintain a rational order of their formation and, thus, identify a set of significant stages of the analysis. Practical validation of the method has allowed one to form the following sequence of support for public-private partnership in foreign economic activity: financial; regulatory; organizational; institutional; analytical support.

Keywords

Public-private partnership, foreign economic activity, intelligent systems, support, morphological analysis

1. Introduction

Nowadays, market relations are developing in the conditions of technological advances, innovation processes, information accessibility and Internet penetration into all aspects of the national economy and social existence. This creates new opportunities for governments and businesses and exacerbates economic and social problems.

As is well-known, intelligent systems are information computing systems with the necessary knowledge base, an algorithm of actions, intellectual support (software and instrumentation, algorithmic and mathematical support), as a result of which the system is able to work without the help of a specialist operator responsible for making decisions about an action [1]. They are widely employed in various types of economic activity. For instance, decision support intelligent systems are used in planning and monitoring activities; forecasting and classification of events; processing of natural language texts (quasi-summarization, quasi-annotation) and others [2]. Intelligent manufacturing systems enable timely changes in the manufacturing environment (product upgrades, changes in manufacturing system configurations) under the influence of global competition and consumer tastes [3].

Parsanejad A., Nayeb M. A. highlight the importance of using intelligent systems (namely, a fuzzy assignment model) in industrial private and governmental sectors [4]. To analyze macroeconomic structural issues for intelligent country modelling, Makriyannis E. designed a new intelligent systems model, the Growth and Trade Country Analyser (GTCA) [5].

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Kh. M-S. Murtazova also prioritizes the creation and implementation of artificial intelligence techniques and intelligent technologies to support the decision-making process. The researcher also considers fuzzy intelligent systems of administrative decision-making support as the components of information technologies of business analytics and knowledge management [6].

Given the non-linear and uncertain behavior of current financial programmes, the financial market applies three well-known methods of artificial intelligence, such as artificial neural networks, expert systems and hybrid intelligence systems. There is evidence that confirms that their accuracy is higher than that of traditional statistical methods in solving financial problems [7, 8]. The following types of intelligent systems are used to solve complex problems in the construction industry: Expert Systems, Fuzzy Systems, Genetic Algorithm, Knowledge-Based Systems, Neural Networks, Context Aware Applications, Embedded Systems [9].

In the research by Abu Hassan Shaari Md Nor, Behrooz Gharleghi, NNARX as a dynamic non-linear neural network, artificial neural network (ANN) as a static neural network, GARCH as a non-linear econometric model and ARIMA as a linear econometric model are applied to forecast exchange rate [10].

There are other examples and recommendations on the use of intelligent systems in various areas of economic activity. However, intelligent systems have not become widespread in the management of the national economy. Nevertheless, the potential for their use exists in the implementation of public-private partnership (hereinafter “PPP”) projects in foreign economic activity. The latter is aimed at attracting the necessary investment resources, enhancing innovation activity and developing infrastructure. Below is a detailed analysis of these possibilities.

2. Related Works

In the context of foreign economic activity, public-private partnership is the cooperation between the state and business structures, namely, the actors in the economic activity of Ukraine and the foreign actors in economic activity (including, the actors in the economic activity of Ukraine with foreign states). It is one of the conditions for attracting the necessary investment, enhancing innovation in the economy, developing economic and social infrastructure and solving economic and social problems.

The implementation of PPP projects in foreign economic activity determines the features of their completion, which can be considered as PPP disincentives. According to Bondar N. M., they include a short period of PPP projects implementation, a low level of planning, lack of private partners’ interest in the final results of projects, ineffective legal framework, politicization, inability of local authorities to administer contracts with private partners, PPP projects implementation delays [11, 12]. At the same time, Fedulova L. I. indicates both incompetence and unreadiness of state partners in the face of regional authorities to implement PPP in foreign economic activity [13].

Tarash L. I. and Petrova I. P. have assessed the readiness of the national economy for PPP, taking into account the regulatory framework, institutional structure, functional maturity, investment climate, financial mechanisms and the value of the sub-national adjustment factor. The obtained results confirm only functional readiness (maturity) for PPP in foreign economic activity [14]. Therefore, it is crucial to further develop the regulatory framework, institutional structure, functional maturity, investment climate and current financial mechanisms as the components of PPP support.

As noted by Pavliuk K. V. and Pavliuk S. M., it is essential to provide favourable institutional support for PPP (by establishing corresponding authorities and civil society institutions), develop and improve the regulatory framework of PPP (its regulatory support) in terms of state support and guarantees to private partners [15]. Stepanova O. V. also believes that the prerequisite for successful implementation of PPP projects in various sectors of the economy and social sphere is to create an appropriate institutional and regulatory environment [16].

Maistro S. V. points out the insufficient pace of PPP projects development at the regional and local levels [17]. Their increase is possible with a unified approach to developing a mechanism for effective interaction between PPP participants. Besides, this particular mechanism should be able to ensure the successful implementation of PPP projects [17-18].

These and other problems in the PPP development have drawn increased attention to the issue of PPP support in foreign economic activity. Consequently, the leading economists (Fedulova L. I., Tarash L. I., Petrova I. P., Stepanova O. V., Pavliuk K. V., Pavliuk S. M., Dubok I. P. et al.) have identified the essential components of PPP projects. These include institutional support, regulatory support, analytical support, organizational support, financial support. It is important to analyze each of these components more in a detail [11-18].

The components of PPP support in foreign economic activity are presented in Fig. 1.

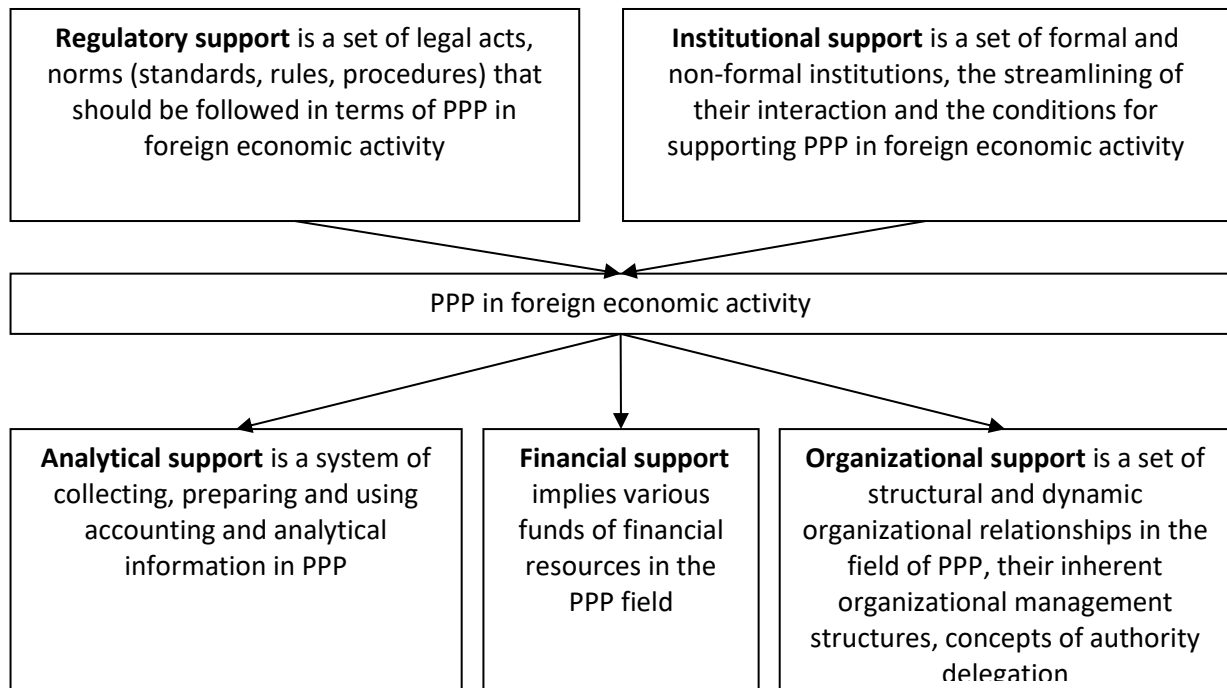


Figure 1: The components of PPP support in foreign economic activity

Thus, regulatory support is a set of legal acts and norms (standards, rules, procedures) that should be followed in terms of PPP project implementation in foreign economic activity. It relies on the legal acts and norms which are reflected in the concept of PPP development through the coordination with the strategy, areas and goals of socio-economic development of regions (within the national economy).

Institutional support is a set of formal and non-formal institutions (structures), which have been established to support PPP in foreign economic activity, streamline their interaction and operational conditions. According to relevant recommendations [15], institutional support for PPP in foreign economic activity involves state and local PPP authorities, civil society institutions (associations, unions, expert and advisory committees).

Organizational support is a set of structural and dynamic organizational relationships in the field of PPP, their inherent organizational management structures, functions, management methods and policies. At the same time, there are no uniform standards and criteria for the organizational structure of PPP project management [15].

Financial support implies various funds of financial resources in the PPP field (formed by financial and non-financial institutions: development banks; investment, venture and other funds for long-term financing of PPP projects; information, consulting, methodological, organizational, expert and other organizations) and their inherent financing mechanisms, which include government guarantees and tax benefits [11, 13].

Analytical support determines information support of analytical systems of PPP project participants in foreign economic activity. It is characterized by systemic coordination of information activities (collecting, preparing and using analytical information in PPP, as well as storing and destroying information), software for their implementation, analytical data and indicators.

Hrytesnko L.L. explains the links between regulatory and institutional support of PPP. Summarizing the main stages of PPP, the researcher adheres to the following sequence: developing the regulatory framework of PPP and adjusting it to current legislation; establishing specialized units for PPP management; analysing existing sources of funding and attracting new ones; creating a comprehensive PPP management system [19].

In this regard, one should use the following procedure for supporting PPP in foreign economic activity: regulatory support (elaborating the regulatory framework of PPP, as well as PPP development concepts); institutional support (establishing specialized units for PPP management); financial support (analysing financial tools, progress on financing projects, existing sources of funding and attracting new ones); organizational support (creating an effective system of PPP management). The described procedure, however, does not provide for analytical support [19].

3. Methods

Morphological analysis has been applied to maintain a rational order of supporting PPP in foreign economic activity. The process consisted of the following stages: identifying and analysing the problem to specify individual components (decomposition); searching for a similar problem and options for its solution; comparing alternative solutions to the problem by studying alternative combinations of certain management decisions; selecting an optimal alternative designed to solve the problem (Fig. 2) [20-22].

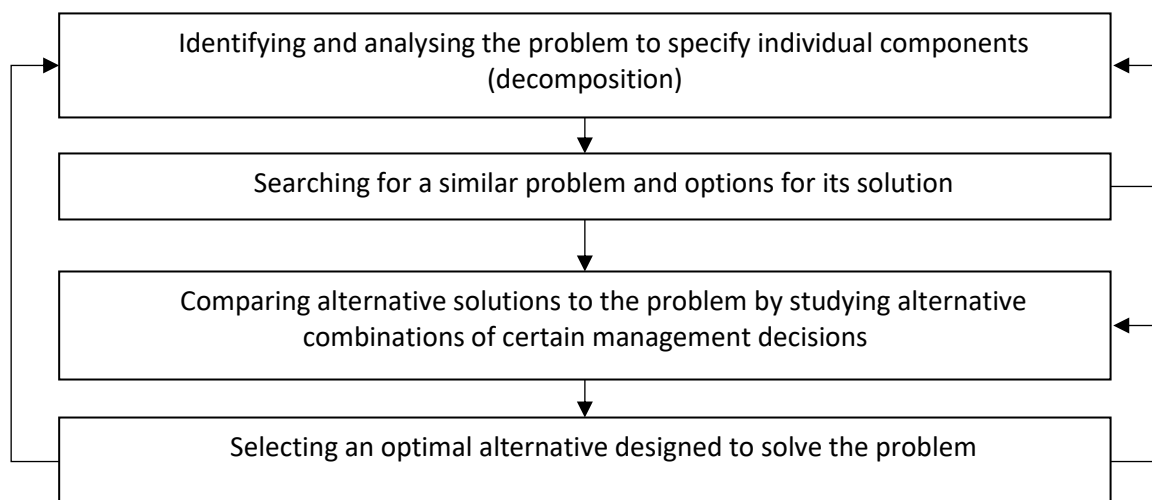


Figure 2: Stages of morphological analysis of components of PPP support in foreign economic activity

The problem decomposition is presented in the form of a morphological table of PPP in foreign economic activity (Table 1). It includes critical parameters of PPP configuration: the goals of PPP in foreign economic activity (F_1), support of PPP in foreign economic activity (F_2) and its components (F_3).

Critical parameters of configuration (F_1 , F_2 , F_3) can also be presented in the form of “a morphological box”. The latter is understood as a conditional matrix that shows possible ways of supporting PPP in foreign economic activity, as well as its components formed under the goals of PPP in foreign economic activity. However, this has been omitted since the morphological box is an alternative to the morphological table.

Given the specified stages of morphological analysis, the method involves the decomposition of the problem (PPP in foreign economic activity) into constituent elements (goals, support and its components) and determines the impact of the selected elements on the overall system. It allows one to deliberately discard unnecessary objects (components) and minimize their number, which characterizes an optimal state of the system [23-30].

Table 1

A morphological table of PPP in foreign economic activity

Critical parameters of PPP configuration		
F ₁	F ₂	F ₃
The goals of PPP in foreign economic activity	Support of PPP in foreign economic activity	The components of support for PPP in foreign economic activity
$a_1^{(1)}$ Improving the regulatory framework	$a_1^{(2)}$ Regulatory support	$a_1^{(3)}$ Legal acts
$a_2^{(1)}$ Enhancing PPP	$a_2^{(2)}$ Institutional support	$a_2^{(3)}$ Legal norms
$a_3^{(1)}$ Providing favourable institutional support for PPP	$a_3^{(2)}$ Financial support	$a_3^{(3)}$ Concepts of PPP development
$a_4^{(1)}$ Ensuring effective cooperation between the actors in PPP	$a_4^{(2)}$ Organizational support	$a_4^{(3)}$ State and local PPP authorities
$a_5^{(1)}$ The equality of PPP partners	$a_5^{(2)}$ Analytical support	$a_5^{(3)}$ Civil society institutions
		$a_6^{(3)}$ Management structures
		$a_7^{(3)}$ Functional methods
		$a_8^{(3)}$ Management policy
		$a_9^{(3)}$ Financial and non-financial institutions
		$a_{10}^{(3)}$ Financing mechanisms
		$a_{11}^{(3)}$ Software tools
		$a_{12}^{(3)}$ Analytical data
		$a_{13}^{(3)}$ Information management

4. Experimental

Therefore, it is essential to choose an optimal configuration of support for PPP in foreign economic activity. Emphasis should be placed on those that meet the criteria of rationality (Table 1). It follows that one should exclude irrational configurations from all the possible ones, using the interoperability matrix (Table 2).

Table 2

The interoperability matrix of PPP configurations in foreign economic activity

	F ₁		F ₂
	The goals of PPP in foreign economic activity		
	$a_1^{(1)}$...	$a_i^{(2)}$
F ₂	$a_1^{(2)}$		
Support of PPP in foreign economic activity		
	$a_j^{(2)}$		
F ₃	$a_1^{(3)}$		
The components of support for PPP in foreign economic activity	...		
	$a_j^{(3)}$		

This matrix makes it possible to take into account the critical configuration parameters (Table 1) in its structure (Table 2) simultaneously, which means using probability values in the range [0; 1], where:

- “1” – the occurrence of one of the alternative configurations leads to that of another;
- “0” – independent occurrence of appropriate alternative parameters of PPP configuration in foreign economic activity.

A negative value of the probability of PPP configuration in foreign economic activity (“-1” indicates the impossibility of simultaneous occurrence of PPP configuration parameters or event cancellation) has not been considered. It was important to further process the data, using the Bayesian approach to simultaneous equations estimation (<https://planetcalc.ru/7683/>).

Thus, negative values of the interoperability matrix of PPP configurations in foreign economic activity, which means a decrease in the probability of simultaneous occurrence of appropriate alternatives to critical configuration parameters, have not been taken into account [23].

It is also essential to calculate the probabilities of alternatives using the Bayesian equations system (with two characterizing parameters with two alternatives each):

$$\begin{cases} P(a_1^{(1)}) = P(a_1^{(1)}|a_1^{(2)}) \times P(a_1^{(2)}) + P(a_1^{(1)}|a_1^{(2)}) \times P(a_1^{(2)}), \\ P(a_2^{(1)}) = P(a_2^{(1)}|a_1^{(2)}) \times P(a_1^{(2)}) + P(a_2^{(1)}|a_1^{(2)}) \times P(a_1^{(2)}), \\ P(a_1^{(2)}) = P(a_1^{(2)}|a_1^{(1)}) \times P(a_1^{(1)}) + P(a_1^{(2)}|a_1^{(1)}) \times P(a_2^{(1)}), \\ P(a_1^{(1)}) + P(a_2^{(1)}) = 1, \\ P(a_1^{(2)}) + P(a_2^{(2)}) = 1, \end{cases} \quad (1)$$

where $P(a_i^{(j)})$ – the probability of occurrence of the i alternative of the j critical parameter;

$P(a_i^{(j)}|a_i^{(j)})$ – the conditional probability of occurrence of the i alternative of the j critical parameter provided that the j parameter has acquired the i value.

The conditional probability is determined using the interoperability matrix and approximated by the fulfilment of such a condition:

$$P(P_{ij}|P_{i-1j-1}) = \begin{cases} 0, a_{ij,i-1,j-1} = -1, \\ P_{ij}, a_{ij,i-1,j-1} = 0, \\ 1, a_{ij,i-1,j-1} = 1, \end{cases} \quad (2)$$

where $a_{ij,i-1,j-1}$ – values in the interoperability matrix for the i alternative of the j critical parameter;

P_{ij} – independent probability estimated by the occurrence of the i alternative of the j critical parameter [23].

5. Results and Discussion

Calculations have been made with the help of an online algorithm of the Bayesian equations system (<https://planetcalc.ru/7683/>). The input data of the modelling (the interoperability matrix of F_1 and F_2) are presented in Table 3.

The result is the probability of support, depending on the goals of PPP in foreign economic activity. They indicate the following procedure for supporting PPP in foreign economic activity:

1. Financial support.
2. Regulatory support.
3. Organizational support.
4. Institutional support.
5. Analytical support.

Table 3The interoperability matrix of F_1 and F_2 critical parameters of PPP in foreign economic activity

		F_1				
		The goals of PPP in foreign economic activity				
		$a_1^{(1)}$	$a_2^{(1)}$	$a_3^{(1)}$	$a_4^{(1)}$	$a_5^{(1)}$
F_2 Support of PPP in foreign economic activity	$a_1^{(2)}$	0.14	0.4	0.1	0.03	0.33
	$a_2^{(2)}$	0.2	0.12	0.1	0.1	0.48
	$a_3^{(2)}$	0.12	0.26	0.39	0.1	0.13
	$a_4^{(2)}$	0.11	0.11	0.06	0.26	0.46
	$a_5^{(2)}$	0.09	0.03	0.05	0.2	0.63

Results of calculated probabilities of using the critical parameter, depending on the critical parameter are presented in Table 4.

Table 4The calculated probabilities of using the F_2 critical parameter, depending on the F_1 critical parameter

F_1	$P(a_i^{(j)} a_i^{(j)})$				
	$a_1^{(2)}$	$a_2^{(2)}$	$a_3^{(2)}$	$a_4^{(2)}$	$a_5^{(2)}$
$a_1^{(1)}$	0.2121	0.303	0.1818	0.1667	0.1364
$a_2^{(1)}$	0.4348	0.1304	0.2826	0.1196	0.0326
$a_3^{(1)}$	0.1429	0.1429	0.5571	0.0857	0.0714
$a_4^{(1)}$	0.0435	0.1449	0.1449	0.3768	0.2899
$a_5^{(1)}$	0.165	0.24	0.065	0.215	0.315
Total	0.9983	0.9612	1.2314	0.9638	0.8453

Similarly, one can determine the order of forming PPP support components in foreign economic activity, using the recommended interoperability matrix of PPP configurations in foreign economic activity (Table 2) and the online algorithm (<https://planetcalc.ru/7683/>). The input data of the modelling are presented in Table 5.

Table 5

The interoperability matrix of the critical parameters and PPP in foreign economic activity

		F_2				
		Support of PPP in foreign economic activity				
		$a_1^{(2)}$	$a_2^{(2)}$	$a_3^{(2)}$	$a_4^{(2)}$	$a_5^{(2)}$
1	2	3	4	5	6	
F_3 The components of support for PPP in foreign economic activity	$a_1^{(3)}$	0.1	0.06	0.05	0.21	0.58
	$a_2^{(3)}$	0.22	0.02	0.12	0.16	0.48
	$a_3^{(3)}$	0.6	0.03	0.06	0.16	0.15
	$a_4^{(3)}$	0.2	0.12	0.16	0.03	0.49
	$a_5^{(3)}$	0.2	0.03	0.15	0.4	0.22
	$a_6^{(3)}$	0.2	0.12	0.3	0.26	0.12
	$a_7^{(3)}$	0.05	0.03	0.03	0.16	0.73

1	2	3	4	5	6	7
	$a_8^{(3)}$	0.06	0.23	0.01	0.21	0.49
	$a_9^{(3)}$	0.1	0.09	0.06	0.12	0.63
	$a_{10}^{(3)}$	0.1	0.12	0.03	0.02	0.73
	$a_{11}^{(3)}$	0.06	0.15	0.4	0.3	0.09
	$a_{12}^{(3)}$	0.1	0.16	0.2	0.2	0.34
	$a_{13}^{(3)}$	0.1	0.01	0.6	0.06	0.23

The results of the modelling are summarized in Table 6.

Table 6

The calculated probabilities of using the F_2 critical parameter, depending on the F_1 critical parameter

F_2	$P(a_i^{(j)} a_i^{(j)})$												
	$a_1^{(3)}$	$a_2^{(3)}$	$a_3^{(3)}$	$a_4^{(3)}$	$a_5^{(3)}$	$a_6^{(3)}$	$a_7^{(3)}$	$a_8^{(3)}$	$a_9^{(3)}$	$a_{10}^{(3)}$	$a_{11}^{(3)}$	$a_{12}^{(3)}$	$a_{13}^{(3)}$
$a_1^{(2)}$	0.23	0.24	0.16	0.13	0.21	0.31	0.16	0.40	0.14	0.38	0.39	0.10	0.28
$a_2^{(2)}$	0.13	0.09	0.18	0.02	0.01	0.13	0.09	0.34	0.55	0.37	0.16	0.38	0.04
$a_3^{(2)}$	0.10	0.03	0.09	0.06	0.06	0.04	0.21	0.17	0.31	0.19	0.21	0.39	0.03
$a_4^{(2)}$	0.23	0.11	0.04	0.34	0.02	0.40	0.28	0.14	0.32	0.48	0.29	0.06	0.03
$a_5^{(2)}$	0.08	0.01	0.15	0.05	0.24	0.22	0.23	0.06	0.55	0.35	0.25	0.06	0.50
Total	0.78	0.48	0.62	0.60	0.54	1.09	0.96	1.11	1.87	1.78	1.31	0.98	0.88

As can be seen from the obtained results, one should pay considerable attention to financial and non-financial institutions, PPP management policy, management structure, PPP financing mechanisms when forming the components of support for PPP in foreign economic activity.

6. Conclusions

The article analyzes applied intelligent systems designed to manage national economies (artificial neural networks, expert systems, hybrid intelligence systems, fuzzy systems, genetic algorithm, knowledge-based systems). It specifies the essential components of support for PPP in foreign economic activity that can enhance the national economy, improve economic and social infrastructure and solve pressing economic and social problems. They are as follows: regulatory support (elaborating the regulatory framework of PPP, as well as PPP development concepts); institutional support (establishing specialized units for PPP management); financial support (analyzing financial tools, progress on financing projects, existing sources of funding and attracting new ones); organizational support (creating an effective system of PPP management).

Both morphological analysis and online algorithm have been applied to determine the sequence of their implementation (as well as of their elements). The process consisted of the following stages: identifying and analyzing the problem to specify individual components (decomposition); searching for a similar problem and options for its solution; comparing alternative solutions to the problem by studying alternative combinations of certain management decisions; selecting an optimal alternative designed to solve the problem. As the result, the procedure for supporting PPP in foreign economic activity should be the following: financial support; regulatory support; organizational support; institutional support; analytical support.

Further research should aim to study how one can use software products to automatize morphological analysis through expert systems.

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