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### COGNITIVE MODELLING IN PROCESS MANAGEMENT OF PUBLIC-PRIVATE PARTNERSHIPS INTENSIFYING IN UKRAINE

*The article presents the author's view on the cognitive modelling processes application to enhance the management of public-private partnerships (PPPs) in the regions of Ukraine. The authors have formed a factors system for public and private partners, that have a positive or negative effect on the PPPs activation (target concept "Investments"). It was proposed to use cognitive maps to investigate causal relationships among factors. It was developed the cognitive model concepts influence set of the target concept "Investments" and it was made its static analysis (it was identified concepts that carry the greatest dissonance of the system).*

Keywords: public-private partnership, cognitive modelling, symbolic directed graph, consonance, dissonance, economic reforms.

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**Problem statement.** Economic reforms in Ukraine have more rapid pace since 2014. Directions and areas of reforms are wide. This fact can be seen in government program documents, such as Sustainable Development Strategy of Ukraine – 2020 [1], Plan of legislative support of the reforms [2], The Cabinet of Ministers Program activities [3] and others. The priority of economic development incentives is presented in all this documents. In particular, public-private partnerships are considered as an effective mechanism for accelerating of economic growth in the regions of the country. Under the current economic conditions the country lacks its own funds to finance socially important projects and services in the whole state and regions. It forced these projects to involve businesses, so urgent the problem of interaction between the state and the private partner is. The situation in the sphere of interaction between the state and business is characterized, on the one hand, by the recognition of government officials, business sector and the academic community of high relevance to stimulate intersectional cooperation, the emergence of successful management models and the positive results of the PPPs, strengthening of institutional preconditions for efficient management of such an interaction, on the other hand, there is no consistency in addressing emerging issues, not clearly defined imperatives and vector control of these changes in the context of stimulating the socio-economic development. One of the most promising and most convenient options for such cooperation is the public-private partnerships (PPPs). Despite the recognition of this form of cooperation as one of the major tools for improving national competitiveness, implementation of PPPs in Ukrainian practice is extremely slow. The problem in management process of both partners interaction is referred to poorly structured systems. The modelling of such systems and their management using of traditional approaches based on analytical description or statistical observation are difficult processes. To assess the effects of economy management system of PPPs influences it is necessary to encourage the use of partnerships at regional and national levels, and cognitive modelling can be an effective tool. Application of this tool allows

identifying and analyzing the main causal relationships in system components interaction between public and private sectors that are integrated into the regional socio-economic system identifying areas of control actions that are aimed at stimulating the activation of interaction.

**Analysis of recent researches and publications.** Cognitive modelling problem was examined by a lot of famous scientists, such as R. Axelrod [4], A. Bakurova [5], E. Bykovskaya [6], I. Dolzhanskiy [7], B. Kosko [8], O. Kolodiziev [9], D. Lagerev [10], V. Maksimov [11,12], N. Paklin [13], W. Sylov [14], V. Shemayev [15,16]. The following aspects of cognitive modelling are not worked out; in particular, methods for structuring situations that build cognitive maps are based on the work of the experts, explain the methods and results of adjustment models for situation analysis. The fundamental theoretical and practical aspects of partnership between the state and the private sector (PPPs) are considered in the works such scientists as O. Golovinov [17], M. Gerrard [18], I. Zapatrina [19], L. Fedulova [20], P. Shylepnytskyi [21]. But scientists did not pay enough attention to studying the factors that contribute to the stimulation of PPPs.

**The aim of the article** is to determine the factors that contribute to the stimulation of PPPs suggestion using cognitive modelling.

**Results of the research.** The principal difference of PPPs is the subjects who participate in the project. In the study [22] it was used the subjective approach and defined the essence of public and private partners. To determine the factors that contribute to the stimulation of PPPs suggest using cognitive modelling (Figure 1).

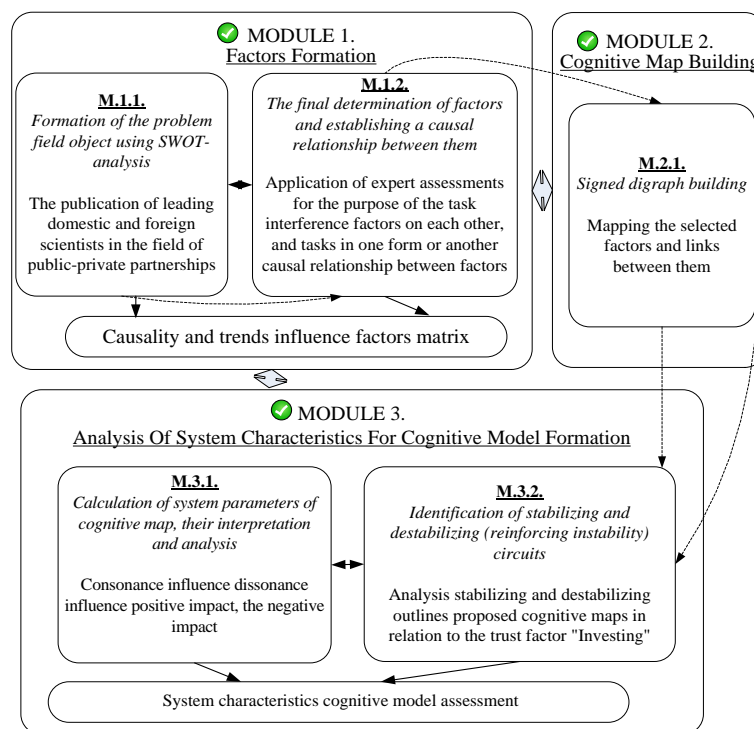


Figure 1 – The general scheme of theoretical and methodological approach to study the factors that contribute to the stimulation of PPPs (prepared by the authors)

Positive aspects of the chosen research methods are shown in Table 1.

Table 1 – Positive aspects of cognitive modelling processes to PPPs stimulation (generalized by [8,14])

Positive aspects	Characteristic	Implementation details in PPPs system
Multiaspects and interconnectedness of phenomena and processes consideration	Introduction of cognitive maps in the form of graphs allows to predict an indirect link among impacts and reflects the causal relationships among them	The need to consider many factors and targets with complex hierarchical structure of the relationship, and often conflicting needs to take account of all the relationships among them
The visual image of the subject area that is simulated	Represents only basic (small amount) factors and relationships. Displays only the main laws and regularities. Constructability, visibility and relative ease the interpretation on the basis of causality (relations) among concepts	Illustration of causal relationships among factors of internal and external environment of PPPs allows to further consider subjective opinion makers decision
Efficiency in terms of incomplete information	Unlike simulation modelling approaches that focus on quantitative objective assessments, traditional methods of decision theory, based on the methods of selecting the best alternative from a set of clearly defined alternatives and scenario analysis techniques, cognitive maps are used in conditions of uncertainty and inability decision, management decisions are only based on quantitative assessments because some details of the situation (mentioned factors, the degree of influence among them) are not quantitative and qualitative	The development of PPPs is characterized by the inability to describe the unambiguous analytical or statistical observation dependencies between input and output parameters of the system. Often we have to resort to subjective models based on expert information processes involving logic of "common sense", intuition and heuristics
Increase quality of management solutions	The integration scenario and competency approach provide a view of all important aspects of the research object or problem situation with its presence and anticipate all scenarios	Lack of information about the dynamic processes of PPPs offset system formation of causal relationships between factors of influence allows to develop different kinds of scenarios
Displaying strait relations between factors	Is implemented through the basic system performance, which is determined by mutual consonance, dissonance, positive and negative effects of concepts on each other	Constructability, visibility and relative ease of interpretation on the basis of causality (relations) among concepts

Cognitive model of causal relationships among factors that contribute to the promotion of PPPs is presented as a formal dependence [6]:

$$K_{PPP}(E, F), \quad (1)$$

where  $E (E_1, E_2)$  is a directed graph (a cognitive map), which vertices correspond to elements of the set  $E_1$  (factors):

$$E_1 = \{e_1^i | e_1^j \in E_1\}, i = \overline{1, n}, j = \overline{1, m} \quad (2)$$

$$E_2 = \{e_2^i | e_2^j \in E_2\}, i = \overline{1, n}, j = \overline{1, m}, \quad (3)$$

The impact can be positive, negative or non-existent. Functional transformation curves:

$$F = F(E_1, E_2), \quad (4)$$

Building of the cognitive model is based on a cognitive map which is designed for visual presentation of basic laws and patterns as a sign-oriented graph in following [16]:

1) peaks in cognitive maps meet basic factors influencing the PPPs activation;  
 2) curves determine causal relationships among factors describing the propagation effects of particular factors on the other ones. There are two types of causation in the cognitive model: positive and negative. If relationship among the factors is positive it is shown as "+" sign on the map, if there is a negative correlation, it is shown as "-" sign on the map.

**MODULE 1:** the system factors were formed and distinguished into two general groups by views of scientists who have studied PPPs [17-21] (Table 2). Formation of the problem field object using SWOT-analysis is presented in the study [23].

Table 2 – System factors that contribute to the promotion of PPPs (prepared by the authors)

Symbol	Group	Factor	Explanation
E <sub>1</sub>	Public Partner	Legislation quality	Positive or negative changes in the law regarding the scope of implementation of PPPs
E <sub>2</sub>		The share of government spending on infrastructure operation	Spending on public sector infrastructure operation in the PPPs implementation
E <sub>3</sub>		The economic security of the region	Measures and the ability of the economy to maintain the implementation of national and state interests
E <sub>4</sub>		The quality of public services	Services, which are provided at public partner in the implementation of PPPs
E <sub>5</sub>		Labour market	Increase or decrease of the number of jobs depending on the PPPs development in the region
E <sub>6</sub>		Infrastructure and institutional environment	The development of infrastructure in the region and its institutional environment
E <sub>7</sub>		PPPs risks	Increase or decrease of various types of risks that arise during the implementation of PPPs programs and projects
E <sub>8</sub>		Bureaucracy and corruption	Bureaucratic barriers between public and private partners in the PPPs implementation
E <sub>9</sub>	Private Partner	Innovations	Involvement of modern highly efficient, resource-saving programs and new technologies in the PPPs projects implementation
E <sub>10</sub>		Competitiveness	The ability to implement large scale PPPs projects
E <sub>11</sub>		The relative cost of services for consumers	Cost of services (works, products) and costs under PPPs
E <sub>12</sub>		The economic security of private business	Ensuring the security of private sector in the PPPs implementation
E <sub>13</sub>		Business risk	Increase or decrease of various types of risks that arise during the PPPs programs and projects implementation
E <sub>14</sub>		Investments	The volume of attracted funds of private partner in the PPPs mechanisms implementation

**MODULE 2:** definition of relationship of causality and direction of influence among selected factors are shown in the matrix (Table 3).

The relative trust factor "Investments" is presented in the form of cognitive maps (Figure 2), which is a sign graph. Sign graph includes the most important direct links. This graph is used for the qualitative evaluation of the impact of certain factors on the stability of the system (test vector). Peak of cognitive maps corresponds to the factors that determine the situation and oriented edges that are the causal relationships among them. The positive cycle is a positive feedback circuit, weight gain factor in the cycle leads to the further growth. The negative cycle prevents deviation from its original state, but instability is possible in the form of significant fluctuations in the cycle. It includes the most important links.

Table 3 – Causality and directions of factors matrix on the public-private partnerships revitalization

(prepared by the authors)

Group Factor	Public partner factors							Private partner factors						
	E <sub>1</sub>	E <sub>2</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>9</sub>	E <sub>10</sub>	E <sub>11</sub>	E <sub>12</sub>	E <sub>13</sub>	E <sub>14</sub>
Public partner factors														
Legislation Quality (E <sub>1</sub> )		-1	+1	+1	+1	+1	-1	-1	+1	+1	-1	+1	-1	+1
The share of government spending on infrastructure operation (E <sub>2</sub> )	0		+1	+1	0	+1	+1	0	+1	+1	-1	+1	-1	0
The economic security of the region (E <sub>3</sub> )	0	0		+1	0	+1	-1	-1	+1	+1	-1	+1	-1	+1
The quality of public services (E <sub>4</sub> )	0	0	0		0	0	-1	0	0	+1	-1	+1	-1	0
Labour market (E <sub>5</sub> )	0	0	0	0		0	0	0	-1	0	+1	0	+1	0
Infrastructure and institutional environment (E <sub>6</sub> )	0	0	+1	0	+1		-1	0	+1	+1	-1	+1	-1	+1
PPPs Risks (E <sub>7</sub> )	0	0	0	0	0	0		0	-1	-1	+1	-1	+1	-1
Bureaucracy and corruption (E <sub>8</sub> )	-1	0	0	0	0	0	+1		-1	-1	0	-1	0	-1
Private partner factors														
Innovations (E <sub>9</sub> )	0	0	0	+1	0	0	0	0		+1	-1	+1	-1	+1
Competitiveness (E <sub>10</sub> )	0	0	0	0	0	0	0	0	+1		0	+1	-1	+1
The relative cost of services for consumers (E <sub>11</sub> )	0	0	0	0	0	0	0	0	0	0		-1	+1	-1
The economic security of private business (E <sub>12</sub> )	0	0	0	0	0	0	-1	0	0	0	0		-1	+1
Business risk (E <sub>13</sub> )	0	0	0	0	0	0	0	+1	0	-1	0	0		-1
Investments (E <sub>14</sub> )	0	-1	0	+1	0	0	-1	0	+1	+1	0	0	0	

Note: "+" – Positive connections; "-" – Negative connections; 0 – Lack of connections

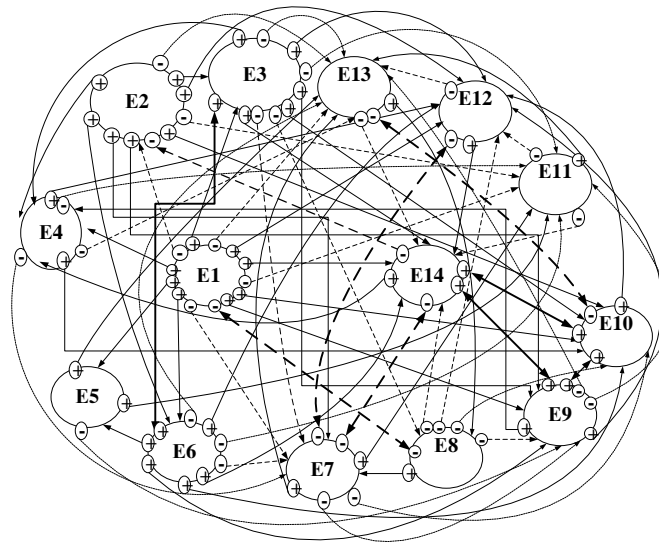


Figure 2 – The sign graph of cognitive maps for causal relationships among factors influencing incentives for public-private partnerships (prepared by the authors)

It was identified the factors that affect the interaction stimulate public and private partners for PPPs. It was based on the installation of causal relationships among the set of factors using cognitive modeling:

1) factor "Innovation" ( $E_9$ ). An innovative way of development is a strategic factor that allows consolidating efforts through science, government and business to achieve improvement in engineering and technology, economic performance, social life, new quality of economic growth. Effective innovation is largely determined by forming support innovative initiatives that create attractive conditions for private investors, which is achieved through activation of interaction among public and private partners;

2) factor "Competitiveness" ( $E_{10}$ ) is an important factor affecting the development of the national economy and the economy as a whole. Implementation of competitive state projects on terms of partnership, on the one hand, is more attractive to private investors due to minimizing the risks of their implementation, and on the other hand, part business makes them more competitive thanks to the synergistic effect of joint efforts;

3) factors "PPPs Risks" ( $E_7$ ) and "Business Risk" ( $E_{13}$ ). Reduction of various types of risks that arise in the PPPs projects and programs implementation (both public partner and the private ones) has a positive impact on volume of attracted funds and increased PPPs;

4) factor "Infrastructure and institutional environment" ( $E_6$ ) is the basic tool that provides high-quality economic development. Infrastructure and institutional environment strengthen economic security of the country and facilitate the formation of an effective system of interaction among public and private partners;

5) factor "Quality of legislation" ( $E_1$ ) is characterized by the ability to reflect the objective laws of social relations, encourage positive trends in their changes. In the economic sphere the law is the main regulator of business, which aim is not only to protect it but also to promote development in various forms and manifestations, including public-private partnerships. PPPs develop actively in politically stable countries with effective legislative institutions that protect the rights of investors;

6) factor "Bureaucracy and corruption" ( $E_8$ ) is a factor that slows down the dynamic development of the economy. Improper performance of administrative procedures has a negative impact on the relations of public and private partners and leads to obstacles in business. Therefore, reduction of bureaucratic obstacles in the implementation of PPPs leads to reduction of risks to business and enhances PPPs;

7) factors "Economic security of the region" ( $E_3$ ) and "Economic security of private business" ( $E_{12}$ ). Socio-economic security of the country and its regions determines the stability of their development and holding back the threat of various political and economic risks that affect the social, innovation, investment and business climate. All of them influence the activation of partnership;

8) factor "Relative cost of services for consumers" ( $E_{11}$ ). World experience shows that the correlation between quality services and funds spent on it in the case of partnership usage is the best.

Another way of static analysis of cognitive model search is finding stabilizing and destabilizing (reinforcing instability) circuits. The greater number of simultaneous effects (in different ways) exists among the concepts, the stronger mutual influence is.

**MODULE 3:** there are the most important direct links among factors (those connections that are clear in the representation of experts) on the cognitive map (see Figure 2). But it also requires information on implicit (indirect) mutual influence factors for a full analysis of the causal effects of the set of factors on the activation process of PPPs. It was considered only the outlines, in which the target concept of cognitive model "Investments" is presented (Table 4).

Analysis of stabilizing and destabilizing outlines on cognitive maps showed that: all selected factors can be used as a target; it was allocated 34 cycles, amplified deviation and stabilized 31 cycles; it is possible to determine the direction of the impact of various factors influencing the activation process for PPPs on the basis of a signed digraph and causality matrix building.

*Table 4 – The analysis of the sign count (compiled by the authors)*

Positive feedback (stabilizing contours)	
$E_{14} - E_4 - E_{12} - E_{14}$	$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_{14}$
$E_{14} - E_4 - E_{10} - E_{14}$	$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_{12} - E_{14}$
$E_{14} - E_4 - E_{10} - E_{12} - E_{14}$	$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_{14}$	$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{12} - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_{12} - E_{14}$	$E_{14} - E_9 - E_{12} - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_4 - E_{12} - E_{14}$	$E_{14} - E_9 - E_{10} - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_{14}$	$E_{14} - E_9 - E_{10} - E_9 - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_{12} - E_{14}$	$E_{14} - E_9 - E_{10} - E_{12} - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{14}$	$E_{14} - E_{10} - E_{14}$
$E_{14} - E_4 - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{12} - E_{14}$	$E_{14} - E_{10} - E_{12} - E_{14}$
$E_{14} - E_9 - E_{14}$	$E_{14} - E_{10} - E_9 - E_{14}$
$E_{14} - E_9 - E_4 - E_{12} - E_{14}$	$E_{14} - E_{10} - E_9 - E_{12} - E_{14}$
$E_{14} - E_9 - E_4 - E_{10} - E_{14}$	$E_{14} - E_{10} - E_9 - E_4 - E_{12} - E_{14}$
$E_{14} - E_9 - E_4 - E_{10} - E_{12} - E_{14}$	$E_{14} - E_{10} - E_9 - E_4 - E_{10} - E_{14}$
$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_{14}$	$E_{14} - E_{10} - E_9 - E_4 - E_{10} - E_{12} - E_{14}$
$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_{12} - E_{14}$	$E_{14} - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{14}$
$E_{14} - E_9 - E_4 - E_{10} - E_9 - E_4 - E_{12} - E_{14}$	$E_{14} - E_{10} - E_9 - E_4 - E_{10} - E_9 - E_{12} - E_{14}$
Negative feedback (destabilizing contours)	
$E_{14} - E_7 - E_{14}$	$E_{14} - E_7 - E_{12} - E_7 - E_9 - E_{11} - E_{14}$
$E_{14} - E_7 - E_9 - E_{13} - E_{14}$	$E_{14} - E_7 - E_{12} - E_7 - E_9 - E_{13} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{14}$	$E_{14} - E_7 - E_{12} - E_7 - E_{10} - E_{13} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_{14}$	$E_{14} - E_2 - E_{11} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_{13} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_{12} - E_7 - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_{12} - E_7 - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_9 - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$
$E_{14} - E_7 - E_9 - E_{11} - E_{12} - E_7 - E_{10} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{14}$
$E_{14} - E_7 - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_9 - E_{11} - E_{14}$
$E_{14} - E_7 - E_{12} - E_7 - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_9 - E_{13} - E_{14}$
$E_{14} - E_7 - E_{12} - E_7 - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{11} - E_{12} - E_7 - E_{10} - E_{13} - E_{14}$
$E_{14} - E_7 - E_{12} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{13} - E_{14}$
$E_{14} - E_7 - E_{12} - E_7 - E_9 - E_{11} - E_{12} - E_{13} - E_{14}$	$E_{14} - E_2 - E_{13} - E_{10} - E_{13} - E_{14}$

It was determined the directions of development of the cognitive model (as detailed disclosure of meaningful indicators of the interaction between public and private sectors, identified functional relationships and causal relationships among factors of the system), which determines the possibility of setting up as a key element of the mechanism management decisions in the context of PPPs enhance the light of available empirical research base. It is possible to choose a suitable strategy for raising the activation of PPPs in Ukrainian regions based on the analysis of the relations of consonance, negative and positive impact. The developed model of specific numerical values will take into account the peculiarities of the system of PPPs and preferred directions of its development through ranking the degree of impact on the system as a whole.

**The practical significance of the results of the study.** It was determined that the proposed in the modelling tools control of the interaction between public and private sectors, which includes an assessment of regional economy effects of management actions, can be used by leaders of public organizations to improve the validity of the choice of strategies, formulation of objectives for sectorial cooperation and methods of achieving them.

**Conclusions.** Cognitive technology of analysis and modelling allows solving complex and uncertain

situations quickly, comprehensively and systematically, describing and justifying on a qualitative level to offer solutions to problems in a given situation, taking into account various factors (concepts) of environment. It is possible to choose a suitable strategy for raising the activation of PPPs in Ukrainian regions based on these factors. Filling the specific content of the model will take into account the peculiarities of the system of PPPs and preferred directions of its development through ranking the degree of impact on the system as a whole. One of the areas for the further research can be a transition to sign directed graph in cognitive model for dynamic analysis of possible scenarios in time.

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**Когнітивне моделювання при управлінні процесами активізації публічно-приватного партнерства в Україні**

#### Розділ 4 Проблеми управління інноваційним розвитком

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У статті викладено авторський погляд на застосування когнітивного моделювання при управлінні процесами активізації публічно–приватного партнерства (ППП) в регіонах України. Авторами проаналізовано фактори позитивного та негативного впливу на активізацію PPP з боку публічного та приватного партнерів, які чинять позитивний чи негативний вплив на активізацію PPP (цільовий концепт «Інвестиції»). З метою дослідження причинно-наслідкових зв'язки між факторами запропоновано використання когнітивних карт. Розроблено когнітивну модель впливу множини концептів на цільовий концепт «Інвестиції» та здійснено її статичний аналіз (виявлено концепти, які здійснюють найбільший дисонанс системи).

Ключові слова: публічно–приватне партнерство, когнітивне моделювання, знаковий орграф, консонанс, дисонанс, економічні реформи.

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#### Когнитивное моделирование при управлении процессами активизации публично–частного партнерства в Украине

В статье изложен авторский взгляд на применение когнитивного моделирования при управлении процессами активизации государственно–частного партнерства (ППП) в регионах Украины. Авторами проанализированы факторы положительного и отрицательного влияния на активизацию PPP со стороны публичного и частного партнеров, оказывающих положительное или отрицательное влияние на активизацию PPP (целевой концепт «Инвестиции»). С целью исследования причинно–следственных связей между факторами предложено использование когнитивных карт. Разработана когнитивная модель влияния множества концептов на целевой концепт «Инвестиции» и осуществлен статический анализ (выявлены концепты, которые осуществляют наибольшее диссонанс системы).

Ключевые слова: государственно–частное партнерство, когнитивное моделирование, знаковый орграф, консонанс, диссонанс, экономические реформы.

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