

Cognitive Analysis and Modeling of the Investment Situation in Ukraine

Volodymyr Beglytsia^a, Sergey Tymofeev^a and Aleksandr Gozhyj^a

^a*Petro Mohyla Black Sea National University, Mykolaiv, 54003, Ukraine*

Abstract

The article deals with the issues of cognitive analysis and modeling of the investment situation in Ukraine. With the help of fuzzy cognitive analysis, the main factors influencing the investment situation were identified. Based on these factors, a fuzzy cognitive model of the investment situation was built. To construct a fuzzy cognitive model, Silov's cognitive maps were used. The systemic indicators of the cognitive map were determined, which made it possible to identify the main factors that affect the investment situation. The ranking of factors influencing the development of the situation has been carried out. Based on the analysis of these factors, a probable model of the development of the investment situation was built. The model was built on the basis of a Bayesian network. The performance of the model was verified on benchmark data. The probabilities of three possible variants of the situation development have been determined. The analysis of simulation results is carried out.

Keywords

SInvestment situation, Fuzzy cognitive analysis, Fuzzy cognitive model, Cognitive maps, Systemic indicators, Predictive models, Bayesian network

1. Introduction

Complex socio-economic systems, parameters and laws of behavior which are described, mainly on a qualitative level, are difficult to predict because the change in their parameters can lead to difficult predictable changes in their structure and behavior. Therefore, it should be noted that analyzing and modeling such systems and managing them using traditional approaches based on analytical description or statistical observation of dependencies between inputs or output parameters is often impossible, and we have to resort to subjective models based on information obtained from experts and which is cultivated with the involvement of logical thinking, intuition and heuristics. Traditional methods of system analysis are not suitable for solving problems of analysis and forecasting of the state of such phenomena and systems.

Most methods used to analyze weakly structured systems often do not work effectively and do not find practice in a widespread use, if they are not used systematically with other methods in the context of the task to be solved.

Not only is the use of sign graphs in the simulation of complex systems, which are based on expert information [1]. When expert construction of real models of complex socio-economic

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✉ science@chmnu.edu.ua (V. Beglytsia); stymofeev@gmail.com (S. Tymofeev); alex.gozhyj@gmail.com (A. Gozhyj)

ORCID 0000-0002-8994-4600 (V. Beglytsia); 0000-0002-9223-1468 (S. Tymofeev); 0000-0002-3517-580X (A. Gozhyj)



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systems is practically impossible to build an adequate model and make a forecast of the development of the system. But from this position one can find a solution using fuzzy graphs to analyze the information and use the results of the analysis for further research. One kind of fuzzy graphs is fuzzy cognitive maps. Fuzzy cognitive maps have an advantage over traditional models in the form of sign graphs: using special algorithms, it is possible to "trace" the path of influence of positive and negative connections on one or several elements of the system on a fuzzy cognitive map (given by a fuzzy graph) [1, 2].

Note that cognitive analysis is very specific and this is manifested in the fact that the formal methods of analysis are applied to models that describe the subjective vision of the situation. And that at each stage of the formation of the model, the analyst or expert must make decisions on which the adequacy of the model depends, so the expert is a very important task, and his decisions form the further course of the analysis of the model. Such decisions include the choice of the model itself, the formation of a set of factors and relationships between them, the choice of scales and weight of ties, the choice of methods for calculating impacts. Different methods will yield different results. The set of models and methods proposed in the literature does not in itself guarantee the adequacy of the model. Adequacy is finally cleared up only in the process of real work.

Problem statement. The article explores the use of fuzzy cognitive modeling to study the investment situation in Ukraine and the use of Bayesian networks for making forecasts based on fuzzy cognitive analysis.

2. Materials and Methods

This section discusses the issues of modeling the investment situation in Ukraine. The analysis of the investment situation and the construction of a fuzzy cognitive model of investment processes are presented. The analysis of system indicators of a fuzzy cognitive map is carried out and the main factors influencing the investment situation are determined.

2.1. Analysis of the investment situation in Ukraine

For many years, the European Union has been one example of a fairly successful political and economic system. This applies to both domestic and economic relations. Thus, the European Union has created favorable conditions for doing business. Large, medium and small businesses here have enough opportunities for their operation and development. Such positions, together with political stability and the stability of legislation, have become the basis for ensuring competitive products, attracting high technology and increasing investment potential.

In view of this, it is significant that in recent years Ukraine has taken confident steps towards integration with the European Union. In fact, we can say that internal and external conflicts have led to an increase in the intensity of European integration processes. Pro-European positions among the political elite and society in general have significantly strengthened. At the same time, the politically active share of citizens has already clearly decided on their choice to build a modern democratic state.

One of the main indicators of European integration relations is the investment climate in Ukraine. The development of the investment market depends on many factors, one of the main

being the development of social and legal institutions in the country and the level of favorable conditions for the development of the investment situation.

Investment policy is one of the most important components of Ukraine's economic policy. In today's financial and economic crisis, it gets a special priority. At the disposal of the state are the main means of regulating the production process. Investment policy should help to boost the economy, increase production efficiency, ensure social and economic stability and solve a number of other problems.

The analysis of the investment situation in Ukraine in recent years suggests a reduction of direct investment from foreign investors [3]. The economic situation in Ukraine can be characterized as unstable. The economy of Ukraine is significantly behind the developed countries of the world in terms of the combined productivity of all factors of production and, accordingly, the level of welfare of the population. Most enterprises are technologically backward, energy intensive, with a weak diversification of products and markets. This is due to the fact that Ukraine is in a situation of military conflict and instability of the state investment policy, investment law issues, lack of proper development of the investment market and its instruments, and as a consequence - insufficient level of domestic and foreign investments [4, 5].

The dynamics of investment in Ukraine is presented in Fig. 1 [4].

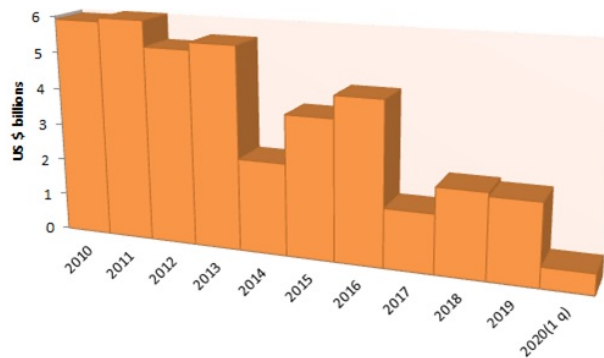


Figure 1: The dynamics of investment in Ukraine

Investments are diverted into already developed areas of economic activity. The main volumes of direct investment revenues were sent to institutions and organizations engaged in financial and insurance activities - 26.1% and industrial enterprises - 27.3% [4].

The key investor countries include the Netherlands - 33.2%, the Russian Federation - 17.3%, Cyprus - 16.6%, Austria - 7.1%, France - 3.9%, the United Kingdom - 3.4%, Poland - 3.2%, Germany - 2.4%, the Virgin Islands (Brit.) - 2.1%, and Switzerland - 1.9% [4].

The following branches of the Ukrainian economy, which are the most attractive for investors, are agriculture, aerospace technologies, transit potential of Ukraine, metallurgical and chemical industries. It also attracts investors with an inexpensive and highly skilled workforce. But a potential investor faces an obstacle already during his first business visit to Ukraine. This obstacle is corruption. This is a major obstacle to investment, according to an annual poll of foreign investors conducted by leading sociological agencies.

On the territory of Ukraine, the investor, besides corruption, is waiting for "surprises" connected with the judicial system, financial instability. But also significantly affect his work various sectoral monopolies and large corporations that belong to businessmen close to the authorities (the so-called oligarchs).

On the basis of the analysis of information sources [3, 4] the rating of "negative" factors, which essentially affect the investment situation in Ukraine, is as follows:

1. Large-scale corruption.
2. Corrupt court system.
3. Non-stable currency and financial system.
4. Monopolization of markets and the influence of oligarchs on power.
5. A conflict with Russia.
6. Problems in the legislative sphere.
7. Corrupt law enforcement structures.
8. Restrictions on the movement of capital and foreign exchange operations.
9. Solid tax administration.
10. Level of labor migration (Given the COVID-19 epidemic).

According to this rating, the actual war with Russia in the East of Ukraine - only in the fifth place in the rating of obstacles to investment. Also a substantial barriers to investment in Ukraine is complex and changing legislation, the actions of law enforcement, restrictions on financial markets, difficult tax administration and labor migration of Ukrainian specialists abroad.

The analysis of the investment situation in Ukraine shows that the main obstacles to investments are corruption, a corrupt judicial system and problems in the legislative sphere. In order to overcome them, it is necessary to systematically consider all factors that affect the investment climate in the state and determine the priority ways to overcome corruption.

2.2. Fuzzy cognitive model of the investment situation

The development of cognitive modeling methods is largely due to the need to study semi-structured systems and situations that include many elements of a different nature, and the relationships between the elements of which are both quantitative and qualitative. Roberts F. [6] proposed a cognitive approach to the study of semi-structured and complex problems due to the limited applicability of exact analytical models of complex systems and the study of their behavior and situations arising from the functioning and development of such systems. With this approach, the construction of models of semi-structured systems or situations is based on the subjective understanding and presentation of the control object about the parameters of the controlled system and the relationship between them.

To understand and analyze the behavior of a complex system, it is necessary to construct a structural diagram of cause-and-effect relationships in the form of a cognitive map.

To analyze the investment situation, the method of fuzzy cognitive analysis is used. The method of fuzzy cognitive analysis is based on building a fuzzy map of cognitive problems,

Table 1
List of concepts

№	Identification concept	Concept Name
1	C1	Corruption
2	C2	Corrupt court system
3	C3	Non-stable currency and financial system
4	C4	Monopolization
5	C5	A conflict with Russia
6	C6	Problem in the legislative sphere
7	C7	Corrupt law enforcement structures
8	C8	Restrictions on the movement of capital and foreign exchange operations
9	C9	Solid tax administration
10	C10	High level of labor migration from Ukraine from Ukraine

calculating system indicators and analyzing modeling results. The modeling method based on fuzzy cognitive maps is described in [7, 8].

A fuzzy map of a cognitive problem displays the relationship between the elements of the system and shows the influence of the elements on each other. The values of the mutual influence of elements (concepts) on a fuzzy cognitive map are given by fuzzy numbers. Modeling of the investment situation in Ukraine was carried out using fuzzy cognitive maps of Silov [8].

To build a cognitive map for modeling an investment situation, a list of concepts was developed based on information about the investment situation (Table 1). Based on these concepts, a fuzzy cognitive map was built, shown in Figure 2. This fuzzy cognitive map shows the causal relationships between the main concepts affecting the investment situation in Ukraine.

Build of a fuzzy cognitive map and calculation of system parameters and modeling was carried out in FCMS environment [9].

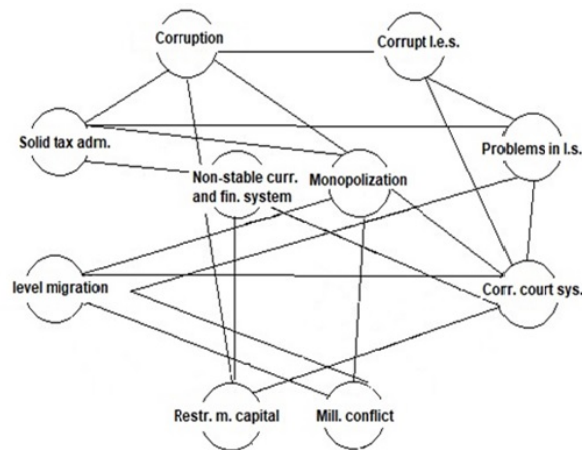


Figure 2: Fuzzy cognitive map for modeling investment situation

Based on the fuzzy cognitive map (Fig. 2), a matrix of concepts (Fig. 3) was created, which describes the causal relationships of the fuzzy cognitive map. Based on the fuzzy cognitive map (Fig. 2), a matrix of concepts (Fig. 3) was created, which describes the causal relationships of the fuzzy cognitive map. The values of bonds are determined based on expert assessments.

	1	2	3	4	5	6	7	8	9	10
1	0	0	.4	.1	0	0	0	.1	0	0
2	0	0	0	-.1	.2	0	0	.6	.6	-.4
3	.4	0	0	-.3	-.1	0	0	0	.4	0
4	.1	-.1	-.3	0	0	.1	0	0	0	.15
5	0	.2	-.1	0	0	.7	0	0	0	0
6	0	0	0	.1	.7	0	.7	0	0	0
7	0	0	0	0	0	.7	0	0	0	0
8	.1	.6	0	0	0	0	0	0	.4	0
9	0	.6	.4	0	0	0	0	.4	0	0
10	0	.4	0	.15	0	0	0	0	0	0

Figure 3: Matrix concepts of fuzzy cognitive map for modeling

On the basis of the concept matrix, system indicators were calculated. System indicators this *outdegree*, *indegree* and *impact on system concepts* [10, 8]. According to the values of the system indicators, the most important concepts in the system and the level of their influence on the system were identified. The results of calculating system indicators are shown in Figure 4.

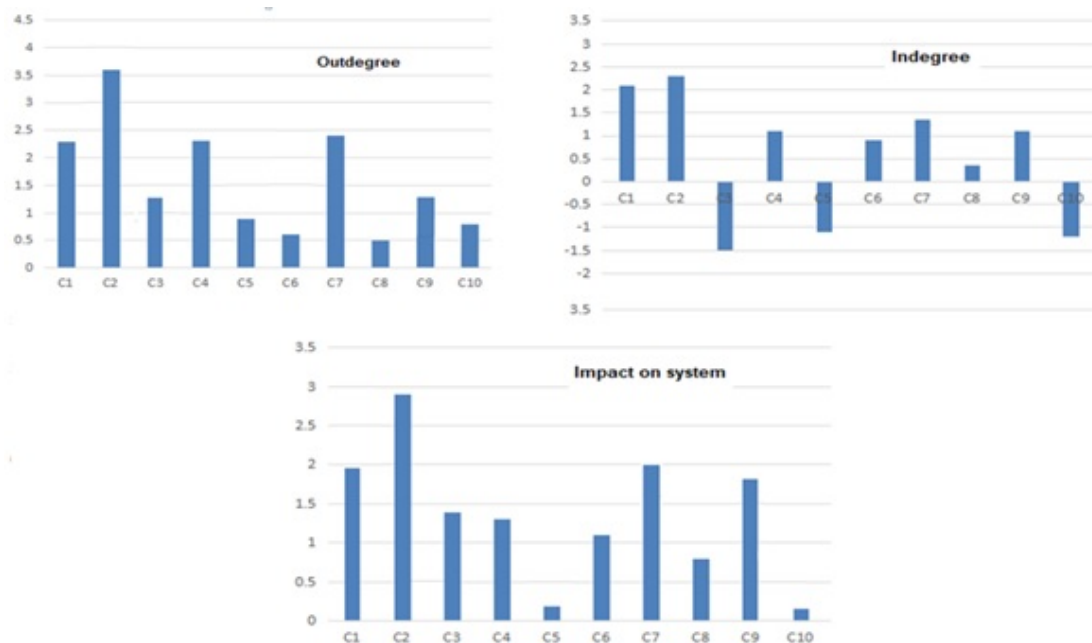


Figure 4: Fuzzy cognitive modeling results

Based on the analysis of the results of fuzzy cognitive modeling (calculation and analysis of system indicators of a fuzzy cognitive map), we can conclude that the most important concepts in the system that affect the investment situation in Ukraine are: C1 (corruption), C2 (corrupt judicial system), C3 (corrupt law enforcement structures). The concepts C5 (conflict with Russia), C9 (tax administration), C10 (labor migration) are more likely a consequence of C1, C2, C3. The concepts C4 (monopolization), C6 (problem in the legislative sphere), C7 (corrupt law enforcement structures), C8 (restrictions on the movement of capital and foreign exchange operations) are causal concepts.

2.3. Investigation of the investment situation of Bayesian networks

For the research and investment situation modeling was used Bayesian network (BN) [2]. Bayesian networks, [11] are widely used for probabilistic modeling and forecasting in information processing systems, statistics represented by time series and time sections, as well as qualitative data represented by expert estimates, linguistic variables and interval values. The main feature of Bayesian networks is that they allow you to establish cause-and-effect relationships between events and determine the probability of a given situation occurring when new information is received about a change in the state of any network node.

Bayesian network can be considered as a model for representing probabilistic dependencies (relations) between the vertices of an acyclic graph. In this case, with respect to the set of variables, the Markov condition is satisfied, each variable of the network does not depend on all other variables, except for the parent predecessors of this variable [12, 13, 14, 15, 16].

To model the investment situation in Ukraine, a model was built in the form of a Bayesian network. The simulation was performed using a Bayesian network.

The main criteria for determining the current level of investment in Ukraine are tax legislation, an unstable monetary situation, restrictions on the movement of capital and foreign exchange transactions, monopolization of markets and influence on the power of oligarchs, labor migration, the presence of a military conflict and a significant level of corruption. The Bayesian network model is shown in Figure 5.

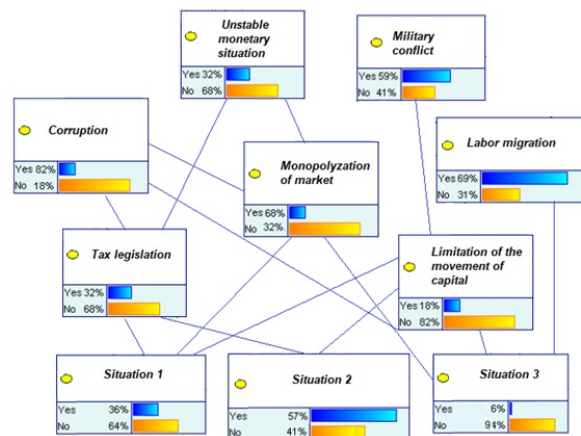


Figure 5: Bayesian network is presented to model the investment situation

Table 2
Bayesian Network Probabilities

№	Outcomes	Probability
1	Corruption	0.82
2	Military conflict with Russia	0.59
3	Unstable monetary situation	0.32
4	Monopolization of market	0.68
5	Labor migration	0.45
6	Tax legislation	0.32
7	Restrictions on the movement of capital	0.18
8	Situation 1	0.36
9	Situation 2	0.57
10	Situation 3	0.06

The built Bayesian network models the investment situation in Ukraine. Bayesian network is built in the environment Genie. The model is based on expert data characterizing the current situation. As a result of the work of this Bayesian network, the probabilities of investment situations in Ukraine are calculated. This Bayesian network considers the probabilities of three situations. Situation 1 - investments are insignificant, Situation 2 - investments grow, the situation is positive, Situation 3 - there are no investments. Table 2 presents the probabilities for estimating the current investment situation. By varying the probabilities in the network, you can model various investment situations. To check the adequacy of the model, modeling was carried out for the indicators of 2017 and 2018. The model is effective. For more accurate modeling, it is necessary to build a large cognitive map. But there is a high probability of error when defining fuzzy links in the model. This may affect the accuracy of the model. The probabilities of possible outcomes are presented in Table 2. The most probable situation 2.

3. Conclusions

The article discusses an approach to the analysis of the investment situation based on fuzzy cognitive analysis and probabilistic modeling based on Bayesian networks. A fuzzy cognitive map was developed to analyze and model the investment situation. With the help of system indicators, the main factors influencing investments in Ukraine were identified. The main factors affecting investment are high levels of corruption, hostilities, monopolization of markets, restrictions on the financial market and high levels of labor migration. Based on the analysis of a fuzzy cognitive map, a Bayesian network was built for probabilistic modeling of the investment situation in Ukraine. Using the Bayesian network, the probabilities of the possible development of the investment situation were calculated.

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