Scenario Modelling of University International Activities Based on Fuzzy Cognitive Maps

Anastasia Krivtsun and Daria Kushchiy
Department of Information Technologies and Management, Platov South-Russian State Polytechnic University (NPI), Prosveshchenie Str. 132, 346428 Novocherkassk, Russia
anastasia.srstu@gmail.com, dkushchiy@rambler.ru

Keywords: International Activities, Fuzzy Cognitive Maps, Scenarios, System Analysis, Cognitive Modelling.

Abstract: In this article the concept of managing the effectiveness of international activities of universities based on fuzzy cognitive maps is discussed. The focus on the international relations currently plays an important role in almost all universities, as well as in the general context of higher education policy. However, there is a significant difficulty in analyzing the international activities of a university and making management decisions in this area due to the multifaceted nature of the processes occurring in international activities and their interconnectedness, due to the complexity of studying individual phenomena, and the lack of sufficient quantitative information about the dynamics of processes. In this article for analyzing the international activities of universities, as a weakly structured system, used cognitive analysis. A cognitive model for managing the international activities of universities has been developed. To build this model, we took into account the quality criteria for formalizing experts' ideas about the international activities of universities, as well as statistical data from universities. Using the developed cognitive model for managing the effectiveness of international activities of universities, it is possible to forecast the self-development of the situation; it is possible to forecast the situation with fixed control; it is possible to implement control that ensures the implementation of the required or desired scenario. Several Scenarios for managing the international activities of a university based on the developed cognitive model using the FCMapper tool are considered.

1 INTRODUCTION

The focus on the international relations currently plays an important role in almost all universities, as well as in the general context of higher education policy. However, there is a significant difficulty in analyzing the international activities of a university and making management decisions in this area due to the multifaceted nature of the processes occurring in international activities and their interconnectedness, due to the complexity of studying individual phenomena, and the lack of sufficient quantitative information about the dynamics of processes. Due to these features, the system of international activities of a university can be classified as weakly structured structures.

Several works devoted to study of internationalization and problems of development of international activities of universities [1, 2], consider issues of information support for managing international activities [3, 4] and decision-making systems in managing academic mobility using expert systems technologies, knowledge engineering and processing semi-structured information, as well as reasoning based on precedents [5]. A comprehensive study of the international activities of universities has been done [6]; indicators and indicators used to assess international activities in German universities are considered [7]; modeling of international activities was carried out and the degree of influence of internationalization on the strategic development of universities was determined [8].

Issues of integrated management of international activities are not sufficiently developed. A large number of factors that must be taken into account when assessing the effectiveness and forecasting the international activities of a university requires the use of intelligent methods of information processing and its presentation.

In this article, cognitive modelling is used to analyze and study the international activities of a university.

Cognitive (scenario) modelling is a tool that allows you to make flexible long-term plans and think through how an organization should respond to future events

There are different approaches to developing scenarios:

- Descriptive approach.
- Morphological analysis.
- Mathematical, simulation modelling.

The first approach involves a verbal description of events and the development of the situation.

The second approach is to compile a table in which morphological chains are selected that make it possible to clarify the qualitative characteristics of the system corresponding to various scenarios for the development of the situation.

The concept of the third approach based on a situation model under conditions of risk and uncertainty, the dynamics of output parameters are studied based on changes in input parameters, connections and structural characteristics of the system [9].

One of the most effective approaches is to construct scenarios based on cognitive modelling. It combines the features of all approaches, namely, it contains a comprehensive description of the situation inherent in qualitative methods, as well as clarity, the ability to conduct simulation analysis and forecasting, inherent in formalized methods.

Cognitive modelling in scenario planning processes thus allows one to take into account subjective and objective factors both under conditions of certainty and under conditions of risk and uncertainty. The methodology proposed below for modelling scenarios for the development of the international activities of the university situation ensures the implementation of a systems approach and system analysis and thereby ensures the integrity of the approach to modelling, the connection of theoretical principles with practical problems in economics and management.

Cognitive modeling contributes to a better understanding of the problem situations, identifying contradictions and qualitative analysis of the system. Target modeling consists in forming and clarifying the hypothesis about functioning of the object under study, considered as a complex system, which consists of separate, but still interconnected elements and subsystems. Based on the above, we can conclude that the construction cognitive maps and models for analyzing the international activities of a university as a weakly structured system is the optimal solution.

2 COGNITIVE MAPS AS A TOOL FOR SCENARIO MODELLING

A cognitive map (CM) belongs to a family of models for representing expert knowledge in the form of a structure of cause-and-effect influences of factors characterizing the object of research, its external environment (for example, economic, state, etc.) and the interests of active subjects of the situation [10].

The influence of a factor on a factor is established using linguistic variables that indicate the nature and strength of the influence (for example, consumer demand can be “weak”, “moderate”, “exciting” and the like). The construction of the CM is carried out taking into account the substantive interpretability of the connections between factors entered into the CM, that is, to build a cognitive model using the CM, the verbal states of the factors are mapped to numerical ones from the interval [0, 1] (or [–1, 1]), and the verbal representations of influences are to numbers from the interval [–1, 1].

In modern research [11, 12, 13], to describe changes in a factor, a dynamic equation is written, the structure of which reflects the direct influence on this factor of other factors, as well as factors of the “external environment” (sometimes cognitive models use functional graphs in which the “power of influence” of one factor on the other is a known function). The set of such equations for all QC factors represents a cognitive model of the situation under study.

At the initial stage of constructing a CM, it is essential to identify important factors that influence and determine the situation under study. In works [14, 15], devoted to the use of models based on cognitive maps for the study of weakly structured structures, it is noted that four approaches are used to construct maps:

1) Identification of factors and connections through content analysis of documents;
2) Identification of factors and relationships based on conceptual frameworks (usually PEST analysis and/or SWOT analysis);
3) Identification of factors and connections through analysis of expert views;
4) Identification of factors and relationships through the analysis of quantitative data, for example, regression analysis of time series of parameters.

A distinctive feature of the development of scenarios based on s is the possibility of representing, along with objective factors, subjective opinions of experts regarding a particular situation, as well as combining them to create an integral fuzzy cognitive map.

2.1 Fuzzy Cognitive Maps

Fuzzy cognitive maps (FCM) are a way of representing real dynamic systems in a form that corresponds to human perception of such processes [16]. This is the main reason for their widespread use in various spheres of life.

FCM represents a system as a combination of concepts and the various relationships that exist between the concepts. The FCM consists of nodes (N_1, N_2, …, N_n), which represent the important elements of the system being mapped, and directed arcs (e_{ij}), which represent the cause-and-effect relationships between two nodes (N_i, N_j).

Directed arcs are assigned fuzzy values in the interval [-1, +1], which show the "strength of influence" between factors. A positive value indicates a positive cause-and-effect relationship between two factors, a negative value indicates a negative cause-and-effect relationship between two factors, and a zero value corresponds to the absence of connections between the factors under consideration [17].

The adjacency matrix provides insight into the cognitive map. Based on it, you can calculate the measure of concept centrality, as well as obtain information about direct and indirect cause-and-effect relationships in the map.

FCM, first proposed by Bartolomew Kosko in 1986, best reflect uncertainty, the dynamics of the states of concepts and connections between them.

FCM is an extension and improvement of the cognitive map with the additional ability to model complex chains of cause-and-effect relationships through weighted cause-and-effect relationships [18].

The FCM model describes the behavior of the system, and each concept represents a factor characteristic of the system.

Modelling using fuzzy cognitive maps is a combination of fuzzy logic and cognitive modelling. This is a way to imagine a system under conditions of uncertainty and complexity, when formal logic does not work.

Although fuzzy cognitive maps are computationally similar to an artificial neural network, there are differences between the two models. Fuzzy cognitive maps can be purely expert in nature (although they can also be trained) and correspond to a "white box" model, while an artificial neural network is fundamentally oriented towards learning (a "black box" model).

2.2 Modelling Tool Based on Fuzzy Cognitive Map

Fuzzy cognitive map modelling can be done using the Excel spreadsheet-based tool FCMapper.

This program allows to calculate all significant indices (incoming, outgoing, overall centrality, density), the number of concepts, connections between them, determine the type of factors (sender, recipient, regular), calculate their number, thereby giving a general characteristic of the network. It is possible to conduct a simulation analysis of the behavior of a specific system and to see its development trends. FCMapper creates a file that, using special network analysis programs, e.g.Pajek, allows to visualize a fuzzy cognitive map [19].

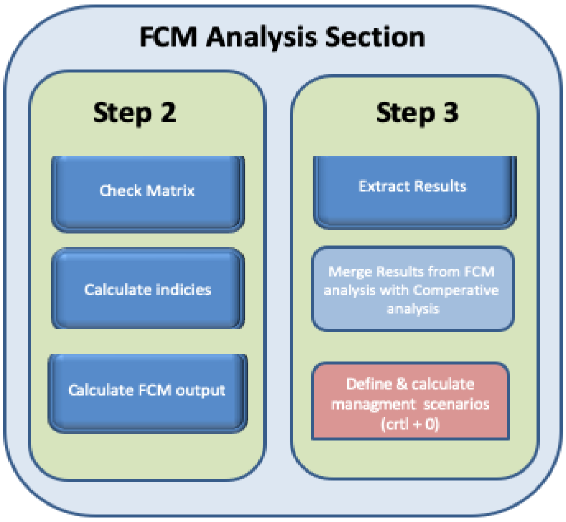

Figure 1: FCMapper interface.

2.3 Basic Scenario Modelling Algorithm Based on Fuzzy Cognitive Maps

Figure 2 shows an FCM-based scenario modelling diagram that includes six main steps. Let's take a closer look at them.

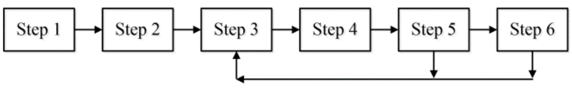

Figure 2: FCM-based scenario simulations.

Step 1. Preparing the scenario. Determining the purpose, timing and boundaries of scenarios.

Step 2. Data collection. Determining the relevant concepts of the cognitive map through studying the literature, interviewing experts; combining cognitive models of various experts; transformation of the combined model into a fuzzy cognitive map, on the basis of which scenarios will be developed.

Step 3. Scenario Modelling. Simplification of cause-and-effect relationships, determination of their weights, selection of a transformation function for assessing the state of concepts.

Step 4. Develop scenarios. Calculation of parameters of a fuzzy cognitive model for various vectors reflecting possible combinations of initial states of concepts.

Step 5.Selection and refinement of scenarios. The scenarios obtained in the fourth step are further evaluated and refined.

Step 6. Strategic decisions. The developed scenarios are used to make strategic decisions.

If the input of additional knowledge from experts or the results of further analysis lead to a new understanding of the situation, then the fuzzy cognitive models built in the third step can be adjusted and recalculated in the fourth step to identify a possible future. Thus, FCM-based scenario modelling becomes a dynamic process.

3 ASSESSMENT OF INTERNATIONAL ACTIVITIES OF THE UNIVERSITY BASED ON FUZZY COGNITIVE MAPS

Let us consider the international activities of the university, paying special attention to external environmental factors at the macro and micro levels, as well as how changes in their condition affect the dynamics of the enterprise's profit.

Factors determined at the meso level make it possible to assess the international activities of each individual university, and factors determined at the macro level make it possible to assess the impact of the country's social and economic activities on the international activities of the university in question.

By the concept of "major factors" we will consider those that characterize the effectiveness of the international activities of a university, and by "minor factors" we will consider those on the variation of which changes in the main factors depend.

3.1 Collection and Processing of Experimental Data

During the research, several experts in the field of international education were interviewed (director of the Institute of International Education of South Russian State Polytechnical University, E.V. Kirievsky; head of the sector of the Institute of International Education of South Russian State Polytechnical University, Tokmakov G.E.; head of the department of international activities of Kazan National Research Aviation University, Gilmetdinova A.M.; deputy head of the department of international activities of Kazan National Research Aviation University, Snegurenko A.P.; head of the international relations department of Volgograd State Technical University, Boyko G.V.).

The survey was conducted using a developed application that allows the expert to establish the significance of the influence of factors on the international activites of a university (major, secondary or insignificant factor), to establish the degree of interaction between factors (definition of the matrix $A = ||a_{kl}||_{M \times M}$,where elements a_{kl} [-1, 1] reflect direct impact *l-th* factor to *k-th* factor, as well as ensure the fulfillment of formalization reliability criteria for models based on cognitive maps and the conditions for their use for protection against risks (criterion of cognitive clarity of a mathematical model, criterion of adequacy of translation templates, criterion of completeness of influences of factors, criterion of proportionality factors according to the generality of concepts).

To confirm or refute the identified cause-and-effect relationships, as well as determine the degree of interaction between factors using regression analysis, statistical data from four universities located in the Rostov region were analyzed: South Russian State Polytechnic University, Rostov State Economic University and Southern Federal University. Statistical data was taken from 2008 to 2015.

Using the estimated knowledge of experts and the analysis of quantitative data, the degree of influence of one factor on another was determined on a scale from -1 to 1. As a result of the expert and regression analysis, 9 factors were identified as major, 18 as secondary, and 3 factors (V6, V7 and V8) are determined to be insignificant for the cognitive model of international activity of university.

The cognitive map of international activity of university is given in Table 1. The name of factors is given below:

- V1 – Foreign trade turnover;
- V2 – Average dollar to ruble exchange rate;
- V3 – Gross regional product;
- V4 – Gross regional product per capita;
- V5 – Number of people employed in education;
- V6 – Number of unemployed;
- V7 – Population of the region;
- V8 – Population of the region by age (from 15 to 24 years);
- V9 – Average cost of studying at universities in the region;
- V10 – Average per capita living expenses in the region;
- V11 – Number of foreign students from CIS countries;
- V12 – Number of foreign students from non-CIS countries;
- V13 – Number of bilateral and multilateral agreements with foreign organizations;
- V14 – The number of international associations and communities in which the educational organization is a member or participates;
- V15 – Number of joint international projects financed by grants (Erasmus+, Horizon, etc.);
- V16 – Position in the international ranking (QS, THE, or others);
- V17 – Amount of funding for international activities at the university (internationalization programs);
- V18 – Number of courses taught in English;
- V19 – Number of educational programs implemented in English;
- V20 – Number of programs leading to a double degree, implemented in partnership with foreign universities;
- V21 – Number of professors, teachers and researchers who have received a master's degree, PhD, etc. in foreign educational and scientific organizations;
- V22 – Number of professors, teachers and researchers working in an educational organization abroad for at least 1 month (outgoing academic mobility);
- V23 – Number of foreign leading professors, teachers and researchers working in an educational organization for at least 1 month (incoming academic mobility);
- V24 – Number of foreign graduate students from CIS countries;
- V25 – Number of foreign graduate students from non-CIS countries;
- V26 – Number of educational programs developed and implemented in partnership with leading foreign universities;
- V27 – Number of articles prepared jointly with foreign organizations;
- V28 – Number of students who received a double diploma in an educational program implemented in partnership with leading foreign universities;
- V29 – Number of foreign students who received scholarship support for studying during a semester in an educational organization (incoming student mobility);
- V30 – Number of students who received scholarship support for studying for a semester at an educational organization abroad (outgoing student mobility).

After the cognitive map has been built, it is possible to simulate the situation. First of all, the final, long-term, stable state of the system is revealed while maintaining the current state of the concepts and connections between them. To do this, the vector of the initial state of concepts, consisting

Table 1: Cognitive map of the university's international activities.

International activity	V1	V2	V3	V4	V5	V9	…	V25	V26	V27	V28	V29	V30
V1	0,00	0,30	0,30	0,30	0,40	0,60	…	0,10	0,10	0,10	0,20	0,20	0,00
V2	-0,40	0,00	-0,30	-0,20	0,30	0,30	…	0,10	0,30	0,20	0,10	0,40	-0,40
V3	0,40	-0,40	0,00	0,70	-0,30	-0,40	…	0,30	0,30	0,40	0,40	0,50	0,40
V4	0,40	-0,40	0,30	0,00	-0,30	-0,40	…	0,20	0,30	0,30	0,30	0,30	0,40
V5	-0,30	0,20	-0,20	-0,20	0,00	0,40	…	-0,30	-0,30	-0,30	-0,30	-0,20	-0,30
V9	-0,30	0,10	-0,20	-0,20	0,60	0,00	…	-0,40	-0,30	-0,40	-0,40	-0,40	-0,30
…	…	…	…	…	…	…	…	…	…	…	…	…	…
V25	0,30	-0,10	0,20	0,20	0,30	0,20	…	0,00	0,80	0,80	0,60	0,50	0,30
V26	0,20	-0,10	0,20	0,20	0,30	0,10	…	0,80	0,00	0,80	0,60	0,60	0,20
V27	0,10	-0,10	0,20	0,20	0,30	0,20	…	0,80	0,80	0,00	0,70	0,50	0,10
V28	0,20	-0,10	0,20	0,20	0,20	0,20	…	0,60	0,60	0,70	0,00	0,30	0,20
V29	0,20	-0,10	0,20	0,20	0,30	0,20	…	0,50	0,60	0,50	0,30	0,00	0,20
V30	0,00	0,30	0,30	0,30	0,40	0,60		0,10	0,10	0,10	0,20	0,20	0,00

of ones, is multiplied by the adjacency matrix. The resulting result is converted using logistic function of the form (1) into a vector of values in the interval [0;1]:

$$C_j(x) = 1/(1 + exp(-c*x)), \quad (1)$$

where $C_j(x)$ - degree of concept activation N_j in the moment of time x;

This positive transformation allows us to better understand and imagine the level of activation of concepts and compare the final states of concepts. This procedure continues until a stable, unchanging state of concepts is achieved. This usually requires less than 30 steps. Theoretically, the system may not come to a fixed state, but to a cycle or a chaotic attractor [20].

3.2 Scenario Modelling

As a result of calculating the first scenario, corresponding to a stable state of the system, fairly close numerical characteristics were obtained.

Table 2: Results of three scenarios.

Results – no change (scenario 1)	Results – scenario 2	Results – Scenario 3
0,99887	1,00	0,9990309
0,0273243	0,5	0,02472257
0,9991667	0,9990398	0,99924687
0,9996941	0,9996638	0,99972348
0,9999797	0,9999824	0,5
0,9997978	0,9998245	0,99975292
0,9999184	0,9999386	0,99994246
0,999910	0,999939	0,99993981
0,999455	0,999589	0,99961538
0,999399	0,999568	0,99957601
0,999955	0,999969	0,999970
0,999836	0,999876	0,999890
0,999634	0,999711	0,999714
0,999799	0,999841	0,999843
0,999853	0,999904	0,999901
0,999879	0,999921	0,999919
0,999900	0,999925	0,999922
0,999890	0,999913	0,999910
0,999950	0,999961	0,999957
0,999890	0,999913	0,999914
0,999900	0,999925	0,999922
0,999989	0,999989	0,999990
0,999985	0,999987	0,999987
0,999963	0,999966	0,999968
0,999877	0,999882	0,999894
0,999818	0,999849	0,999835
0,998873	0,998638	0,999031

Table 2 is an example of the calculation of three scenarios for the cognitive map presented in Table 1. In the second scenario, the value of concept V2 (as the most different in value) is assumed to decrease by 2 times compared to the current state.

In the third scenario, it is assumed that the values of concepts V5, V25, V26 (as those most influencing the state of the system) will be reduced by 2 times compared to the current state.

The analysis of three scenarios allows us to conclude that when making strategic decisions, the main attention must be paid to adjusting the value of the V2 indicator, as well as preventing a decrease in indicators V5, V25, V26.

It is worth noting that reducing the value of V2 is a higher priority than maintaining the values of V5, V25, V26.

4 CONCLUSIONS

This paper describes an aproach for assessing the international activities of a university using fuzzy cognitive maps. As a result of the study, a cognitive model for managing the effectiveness of international activities of universities was built. To build this model, we took into account the quality criteria for formalizing experts' views on the international activities of universities, as well as statistical data. The main purpose of the model is to help the expert to develop the right decision. This model displays and organizes information about international activities of university, taken in account a large number of influencing factors, on different levels. The cognitive model not only allows to systematize and "clarify" the expert's knowledge, but also helps to identify the most advantageous points applications of control actions of the subject of management.

It is important here to foresee what the consequences will be have certain management strategies. To develop such forecasts, a scenario modelling is used within the framework of cognitive analysis. After the cognitive map was built, several scenarios simulated the situation using the FCMapper tool. Three scenarios for the development of the university's international activities were reviewed and analyzed based on a fuzzy contive map.

Future work is connected with development of the decision support system based on the developed congintive map, which will allow experts to set up the most important factors and to simulate the different scenarios.

REFERENCES

[1] T. Schubert, E. Baier, and C. Rammer, "A behavioural approach. Journal of International Business Studies," vol. 49(1), pp. 70-95, January 2018, doi: 10.1057/s41267-017-0101-0.

[2] H. de Wit and P. G. Altbach, "Internationalization in higher education: global trends and recommendations for its future," Policy Reviews in Higher Education, vol. 5(1), pp. 28-46, September 2020, doi: 10.1080/23322969.2020.1820898.

[3] A. Kolomiets, D. Grinchenkov, and K. Vodenko, "PEST- and SWOT-analysis of university internationalization factors," Journal of Physics: Conference Series, vol. 1415, p. 012003, October 2019, doi: 10.1088/1742-6596/1415/1/012003.

[4] G. Sivertsen, "Patterns of internationalization and criteria for research assessment in the social sciences and humanities," Scientometrics, vol. 107, pp. 357-368, May 2016, doi: 10.1007/s11192-016-1845-1.

[5] P. B. Keenan and P. Jankowski, "Spatial Decision Support Systems: Three decades on," Decision Support Systems, vol. 116, pp. 64-76, January 2019, doi: 10.1016/j.dss.2018.10.010.

[6] P. Morone, P. M. Falcone, and A. Lopolito, "How to promote a new and sustainable food consumption model: A fuzzy cognitive map study," Journal of Cleaner Production, vol. 208, pp. 563-574, Jan. 2019, [Online]. Available: https://doi.org/10.1016/j.jclepro.2018.10.075.

[7] E. Bakhtavar, M. Valipour, S. Yousefi, R. Sadiq, and K. Hewage, "Fuzzy cognitive maps in systems risk analysis: a comprehensive review," Complex & Intelligent Systems, vol. 10.1007/s40747-02000228-2, Nov. 2020, [Online]. Available: https://doi.org/10.1007/s40747-020-00228-2.

[8] G. Felix, G. Nápoles, R. Falcon, W. Froelich, K. Vanhoof, and R. Bello, "A review on methods and software for fuzzy cognitive maps," Artificial Intelligence Review, vol. 52, no. 3, pp. 1707-1737, Aug. 2017, [Online]. Available: https://doi.org/10.1007/s10462-017-9575-1.

[9] P. Szwed, "Classification and feature transformation with Fuzzy Cognitive Maps," Applied Soft Computing, vol. 105, p. 107271, Jul. 2021, [Online]. Available: https://doi.org/10.1016/j.asoc.2021.107271.

[10] István Harmati, M. F. Hatwágner, and L. T. Kóczy, "Global stability of fuzzy cognitive maps," Neural Computing and Applications, vol. 35, no. 10, pp. 7283-7295, Dec. 2021, [Online]. Available: https://doi.org/10.1007/s00521-021-06742-9.

[11] G. Sivertsen, "Patterns of internationalization and criteria for research assessment in the social sciences and humanities," Scientometrics, vol. 107, no. 2, pp. 357-368, Feb. 2016, [Online]. Available: https://doi.org/10.1007/s11192-016-1845-1.

[12] Jose A. Fernandez Leon and Gerardo G. Acosta. J. A. Fernández-León and G. Acosta, "Uncovering the Secrets of the Concept of Place in Cognitive Maps Aided by Artificial Intelligence," Cognitive Computation, Oct. 2022, [Online]. Available: https://doi.org/10.1007/s12559-022-10064-w.

[13] N. D. Pankratova, G. Gorelova, and Vladimir Pankratov, "Study of the Plot Suitability for Underground Construction: Cognitive Modelling," Advances in intelligent systems and computing, pp. 246-264, Jul. 2020, [Online]. Available: https://doi.org/10.1007/978-3-030-54215-3_16.

[14] P. Yang, "China in the global field of international student mobility: an analysis of economic, human and symbolic capitals," A Journal of Comparative and International Education, pp. 1-19, May 2020, [Online]. Available: https://doi.org/10.1080/03057925.2020.1764334.

[15] T. Schubert, E. Baier, and C. Rammer, "Firm capabilities, technological dynamism and the internationalisation of innovation: A behavioural approach," Journal of International Business Studies, vol. 49, no. 1, pp. 70-95, Sep. 2017, [Online]. Available: https://doi.org/10.1057/s41267-017-0101-0.

[16] S. Soliman, J. Anchor, and D. Taylor, "The international strategies of universities: deliberate or emergent?," Studies in Higher Education, vol. 44, no. 8, pp. 1-12, Mar. 2018, [Online]. Available: https://doi.org/10.1080/03075079.2018.1445985.

[17] J. Aguilar, "Multilayer Cognitive Maps in the Resolution of Problems using the FCM Designer Tool," Applied Artificial Intelligence, vol. 30, no. 7, pp. 720-743, Aug. 2016, [Online]. Available: https://doi.org/10.1080/08839514.2016.1214422.

[18] Holman Bolívar Barón, Rubén González Crespo, Jordán Pascual Espada, and Óscar Sanjuán Martínez, "Assessment of learning in environments interactive through fuzzy cognitive maps," Soft Computing, vol. 19, no. 4, pp. 1037-1050, May 2014, [Online]. Available: https://doi.org/10.1007/s00500-014-1313-x.

[19] Z. Kahvandi, E. Saghatforoush, A. ZareRavasan, and C. Preece, "Integrated Project Delivery Implementation Challenges in the Construction Industry," Civil Engineering Journal, vol. 5, no. 8, pp. 1672-1683, Aug. 2019, [Online]. Available: https://doi.org/10.28991/cej-2019-03091362.

[20] T. Mansouri, A. ZareRavasan, and A. Ashrafi, "A Learning Fuzzy Cognitive Map (LFCM) Approach to Predict Student Performance," Journal of Information Technology Education: Research, vol. 20, pp. 221-243, 2021, [Online]. Available: https://doi.org/10.28945/4760.