Causal modeling of the higher education determinants regarding the labour market absorption of graduates: a Fuzzy Cognitive Maps approach

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Abstract—The paper aims at developing a framework methodology based on Fuzzy Cognitive Maps (FCM) for causal modeling of the higher education determinants regarding the labor market absorption of the Romanian universities graduates, shorthand notation here as HEtoJob problem. As the FCM is a cognition intelligent tool useful to model and analyze complex dynamical systems in those situations where other methods do not cover them, the results of the conducted research reveal the propagation of causality within the relationship between the concepts of such complex socio-economic system including higher education and labor market. Furthermore, the Fuzzy Cognitive Map methodology highlights the higher education determinants and their order of importance able to help policy makers to know on which priority should intervene by appropriate educational policies. Finally, the scenario simulations allow higher education decision-makers to analyze and understand relational structures as a facile visual tool in order to fit higher education policies to a better labor market absorption of graduates. Through network analysis of the FCM we determined that the concept "higher education-job match", denoted here as HE-job match, exerts the greatest force in the model and hence impacts the dynamism and complexity of the system. Moreover, such an approach proposed in this paper can underpin substantiate higher education policies built on the principle of bottom up, based on the perception of the participants in the higher education process and ensure their implementation with a high degree of trust from them.

Keywords— higher education – job match, Fuzzy Cognitive Map (FCM), subjective perceptions..

I INTRODUCTION

Present approach of applying FCM for higher education determinants regarding the labor market absorption of graduates consists of distinctive parts: Higher Education to Job (HEtoJob); Description of Fuzzy Cognitive Maps (FCM); Concept selection and causal relations; Creating cognitive maps using stakeholders interviews; Coding the cognitive maps into adjacency matrices, Formalization of the FCM; FCM analysis, FCM computing scenarios, and Results FCM computing scenarios.

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As an emerged powerful research methodology for knowledge representation and a simulation mechanism, the FCM is applicable to numerous research and application fields. So, in his survey work Papageorgiou [1] tried to review the most recent applications and trends on fuzzy cognitive maps (FCMs) at the last ten years (Fig. 1).

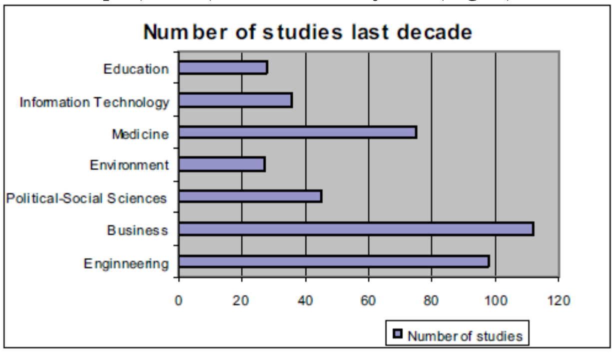

Fig. 1 Number of FCM studies during the last decade, per category [1]

Furthermore, some types of typical problems solved by FCMs are modeling, analysis, knowledge representation, reasoning, stakeholders' analysis, prediction, interpreting, classification, monitoring, decision support, decision making, inference, planning, management, learning [1].

During the last decade, the FCMs gradually emerged as a technique for policies modeling and supporting the decision-making process in view of representation of a given situation in order to ascertain the introduction of any necessary changes. Thus, the FCMs emerged as a technique for modeling of different policies especially when consulting of the policies' beneficiaries could help overcome of an imminent crisis of confidence in these policies.

Carvalho (2010) in his recent study [2], discussed the possible use of FCM as tools to model and simulate complex social, economic and political systems, while clarifying some problems that have been recurrent in published FCM papers.

There is an extensive literature on using FCMs in modelling the dynamics of the system considering the opinions and perceptions of a system`s beneficiaries in different fields [3] as well as in education in order to simulate the dynamics of the analyzed system, understand the complexity of the system and identify the key factors influencing the dynamics of the system.

From Lin Chun-Mei who used inference mechanism of FCM for adaptive control framework [4] to Cole and Persichitte [5] who use fuzzy cognitive maps as a tool for creating metaknowledge and exploring hidden implications of a learner`s understanding, the last of them emphasize that the most obvious use of FCMs in educational organization settings is as a tool enabling students to monitor their own performance.

Bulut and Kayakutlu [6] analyse the contribution of universities to the regional development by using FCM technique. They identifyed seventeen criteria to construct FCM and formulated some suggestions
to improve university contribution in regional development.

Vasantha Kandasamy and Promodth [7] use Fuzzy Cognitive Maps to study the dropouts in primary education. They obtain the hidden pattern of the cause for the dropouts in primary education which could not be found out using any other method.

Hossain and Brooks [8] use FCMs to model an educational software adoption across UK secondary schools. The model provides insight into the context of educational software adoption in schools, which can be used to guide both educational decision-makers in where to focus their efforts and software developers in terms of more focused and appropriate software development efforts.

A. Higher Education to Job

The higher education reform agenda in EU Member States focus on curricula that deliver relevant, up-to date knowledge and skills, knowledge which is useable in the labour market.

Having regard to the conclusions of the European Council[1], the Council opinion on Romania's convergence programme for 2012-2016 highlights that the mismatches between skills and labour market demand are characteristic of a large proportion of tertiary education programmes. The high unemployment rate among tertiary graduates and the rate of over-qualification make a further alignment of tertiary education with the labour market a high priority.

The problem of labor market mismatches with higher education qualifications represents both a social and economic problem for society as a whole. The most recent debates within the Romanian Congress on Education held in Bucharest, June 14-15, 2013, emphasized the need to develop sustainable policies for matching the supply of higher education graduates with workforce demand.

Also, within this congress were disseminated the results derived from the research conducted by National Center of Studies and Forecasts Regarding Supply and Demand in Higher Education, on the assessment and forecast potential demand for higher education graduates work in the occupational structure in 2020. The study on consistency of demand and supply of workforce with higher education degree highlights that the mismatch index exceeds the average value (0.045) since 2008 [9].

According to Ristea *et al.* [10], the systemic analysis of the determinants of the socio-professional insertion process reveals the fact that the national higher education requires the elaboration of certain strategies on the level of the macroeconomic decisions which facilitate and sustain the cooperation in practice of all actors involved in the transition of young graduates from school to the workplace.

Thus, decision makers have more and more to face the increased complexity of the interrelations inside the dynamic higher education system' components (concepts) of the problem encountered, i.e. higher education to job (HEtoJob).

It is not less true, as stated Mateou, Andreou and Zombanakis in their research paper [11], that requiring numerical data may be hard to trace or unpredictable, so that formulating a mathematical model may be difficult, costly, and even impossible. This means that efforts to communicate an understanding of the system and propose policies will have to rely on natural language arguments in the absence of formal models.

In order to identify the factors that influence higher education graduates to attend the job opportunities available on the labor market and become permanent employees in a short time after graduation, policy-makers must consider the particular perceptions of different categories of higher education process stakeholders.

Our approach is based on examining the perceptions of different stakeholders groups using the Fuzzy Cognitive Map method. This method is well known of being capable to model participative processes, to design knowledge maps, and create scenarios in modeling soft knowledge domains like social policies, for different situations such as: decision making, prediction, complexity explanation of dynamic systems, strategic planning, and policy impact [12], [13].

Our research includes examining the perceptions of different stakeholders about higher education to job problem (HEtoJob) and facilitates the development of policy modeling based on the multi-step FCM analysis presented in detail in [14].

B. Description of Fuzzy Cognitive Maps

Fuzzy Cognitive Maps (FCMs) are causal models with graphical representation given by signed/weighted causal digraph with feedback consisting of concepts and cause-effect relationships between them. Concepts are represented by nodes and causal relationships are represented by arcs pointed from the cause concepts to the effect concepts.

Designing a fuzzy cognitive map is a process that relies on the experts and/or stakeholders experience and knowledge of the system under consideration as inputs extracted through different manual or automated interactive procedures of knowledge acquisition.

Cognitive maps are qualitative models of a complex system which integrate experience and knowledge concerning the determinant factors of the modeled system and the causal relationships between them.

Axelrod's cognitive maps [15] were binary while FCMs of Kosko [16] integrated the cognitive maps by applying fuzzy causal functions to the connections, with real numbers inside the interval $[-1, 1]$.

FCM consists of the following components:
a) Nodes: to represent concepts C_i, $i = 1 \ldots N$, where N is the total number of concepts. Each concept/node is characterized by a value, $A_i \in [0, 1]$, $i = 1 \ldots N$.
b) Edges/arcs: to represent causal links among the concepts.

[1] COM(2013) 373 final.

c) Weights Wij: to represent how much one node influence another, that is the strength of the causal link between two concepts Ci and Cj .
d) Activation events at different moment t. The stimulated events bring changes to certain concepts, edges, or even the overall of FCM.

II. MODELING METHODOLOGY

FCMs allow scientists to construct virtual complex worlds in which the interdependent concepts of a scenario can be captured and their interactions or causal relationships modeled. FCMs, by providing a fuzzy graph structure for systematic causal propagation and ease in processing fuzzy knowledge, are applicable in soft-knowledge domains such as the social, political and economical sciences.

FCM Modeling methodology for higher education to job problem consists of:

a. Selection of concepts and causal relations;
b. Coding the cognitive maps into adjacency matrices;
c. Formalization of FCM;
d. Simulating scenarios.

A. Concept selection and causal relations

Generally, the cognitive maps can be obtained in different ways: from questionnaires, by extraction from written texts, by drawing them from data that shows causal relationships or through interviews with people who draw them directly.

We are interested in developing a tool to assist a bottom–up policy which to address a better degree of correlation between higher education offer and labour market demand, for a better absorption of the graduates. The education ministry's officials and other decision –makers in higher education system have come to believe more in the usefulness of participatory processes as they have come to use these results as recommendations in order to support the process of developing the higher education policy.

In this respect, a participatory policy starts from the institutionalized dialog with those stakeholders who can offer a comprehensive knowledge base in the field, such as the triangle: graduates – employers – universities.

In order to create fuzzy cognitive maps for „HEtoJob" we organized interview sessions with the three homogeneous groups to collect their beliefs and perceptions of the problem, including both traditional knowledge, and expert knowledge.

Each concept of FCM indicates a characteristic or key factor of the system such as events, actions, and states.

First of all, participants have identified the critical factors of higher education policy which in their beliefs are affecting the graduates' employment and drew nodes to symbolize concepts. Then, they detect relations between the concepts found. Interviewees are asked to explain the relationships between the concepts drawing the lines between concepts and assigning arrows to the lines for indicating their directions. For example, if the interviewee thinks that *adequate competences* increases *higher education – job match*, then he would draw a line with the arrow pointing from adequate competences concept to higher education – job match concept. Next, the interviewees are asked to label the lines with positive or negative signs. For example, if the interviewee thinks that *adequate competences* cause substantially increase of *higher education – job match*, he will sign the connection by „+". Finally, each group generates a cognitive map.

B. Creating cognitive maps using stakeholders interviews

Knowledge representation in these cognitive maps has an acquisition process. We illustrate here an interview guideline for creating the cognitive maps for HEtoJob (table 1), which may guide on how to obtain the views of different stakeholders inside each group, their different and similar perceptions about the complexity and dynamics of higher education system in relation with HEtoJob problem. The interview guidelines can be used to conduct the interviews and to obtain comparable maps between the groups. In these interview sessions with homogeneous groups, the participants are assisted by a facilitator who can explain and debate the difficulties of the process of designing a cognitive map and create a common understanding of the problem. The facilitator has to be familiar with the basic concepts of modeling process or at least with the interview topic and techniques, facilitating the process of drawing the cognitive maps. It is important that the participants to receive clear explanations about the process ahead, and also information about what kind of products they can expect to receive, like the digitalized and cleaned version of their map, FCMs, simulations, and final reports of different scenarios.

Table 1 Interview guideline for creating the FCM for HEtoJob

Interview steps/ Research questions	**Interview questions**			**How to conduct the interview**
	HIGHER EDUCATION GRADUATES	**UNIVERSITIES**	**EMPLOYERS**	
1 To establish the policy theme: higher education – job match.	Do you have the experience of the first job after higher education graduation?	To what extent your graduates find a job after graduation?	Do you have the experience of recruiting university graduates as first employer?	Ask the interviewees to emphasize the importance of higher education – job match issue
2 To establish the most important concept.	Which is the most important factor influencing higher education-job match?	What do you think is essential within the educational process of your graduates for employment?	Which is the most important feature you request from recently graduates in order to hire them?	The interviewees are asked to write the most important concept in the middle of a large drawing paper
3 To find what is perceived as important factors/concepts inside the theme chosen above.	What other factors/concepts do you appreciate that affect higher education-job match?			The interviewees are asked to list on the paper all concepts identified
4 To find what significant changes have occurred concerning the dynamics of policy theme.	Do you consider that significant changes have occurred in the last years in the employers requirements have from graduates?	Do you consider that significant changes have occurred in the last years regarding the competence pattern employers require from higher education graduates?	Do you consider that significant changes have occurred in the performance of higher education graduates searching a job?	The interviewees are asked to identify the changes occurred in the system related with the HEJobMatch
5 To draw the connections between the identified concepts.	How do these changes influence the chance to find a job?	How do these changes influence the occupancy rate of the available jobs?	How do these changes influence the occupancy rate of the available jobs?	The interviewee is asked to draw lines between identified concepts in order to represent the relationships that link each of them.
	Does this concept [X] affect any other concepts? Which are, in your opinion, the causes of these changes occurred? Name them as concepts. Are there any concepts that affect the concept [X]?			
6 To indicate the sense of directions of the connections from causal concepts to affected concepts.	The interviewee is asked to point the arrows on drawing lines to indicate the sense of direction from the causal concepts directed to the affected concepts, as they were identified by previous questions.			
7 To establish the positive or negative influence between concepts.	How do these concepts affect each other (positively, negatively, feed-back mechanisms)? For this purpose, label the lines with positive or negative signs. The interviewee is asked to assign a "+" to the positive connections and a "-" to the negative ones.			
8 To determine the strengths of the connections.	„How strength is this positive /negative effect on X (large, medium, small)?" The interviewee is asked to weigh the influences between concepts.			
9 Last step, the facilitator should review the map with the interviewee. During the interview, new concepts should be added as they appear, if they do not belong to an already mentioned concept.				

Source: processed by the authors

The saturation analysis inside each group is run to examine the accumulation curves of the total number of variables versus number of interviews and the number of new variables added per interview. Average accumulation curves can be made by using Monte Carlo techniques. For example, Fig. 2 shows that approximately 30 interviews stabilize the maximum number of different concepts that can be taken into consideration inside each group.

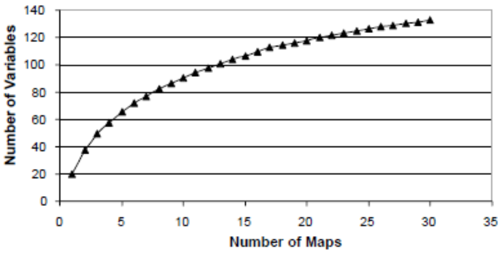

Fig. 2 The accumulation curve of the total number of concepts versus number of maps/interviews [9]

After our extended interviews the identified concepts playing an important role in higher education to job problem that should appear in the FCM, are the following:

C_1 - *higher education-job match*: the matching between delivered university qualifications to the graduates with the type of job occupation vacancies, as job seekers;

C_2 - *required field of study*: the design and implementation of programmes relevant to social and labour market needs;

C_3 - *over-qualification of graduates*: being skilled or educated beyond what is necessary for a job;

C_4 – *employment*: university graduates able to find permanent positions in their chosen field, in a short time after graduation;

C_5 - *number of students enrolled*;

C_6 - *adequate competence*: the right learning outcomes and competences which should help students build a wider base on which they can build their future professional competences;

C_7 - *appropriate internship*: internship is to give the student experience working in his chosen field of university study;

C_8 - high university reputation: reputation for top quality higher education.

C. Coding the cognitive maps into adjacency matrices

The interviewees are also individually asked to assign to each arc a linguistic weight, such as “strong”, “weak”, or “lack” “low”, “medium”, “high” and so on. Thus, the causal relationships between concepts are described by linguistic weights for measuring the strength of the relationship between concepts, and the intensities of the effect related to a cause.

Then, the linguistic weights are transformed into fuzzy values, which are used for coding the cognitive maps into adjacency matrices.

In this respect, the questions use different degrees of comparison to guide interviewees in assigning the corresponding linguistic weights, like in table 2.

Table 2 Question degrees and linguistic weights [1]

	Linguistic weights					
	Question degrees					
Fuzzy weights	**How many?**	**How often?**	**How level?**	**How much?**	**How big?**	**How strong?**
1.00	all	always	highest	most	biggest	strongest
0.80	much more	very often	very high	very much	very big	very strong
0.70	more	often	high	more	big	strong
0.60	moderate	usually	medium	much	medium	moderately strong
0.50	some	some times	low	little	small	weak
0.40	fewer	a few times	very low	less	very small	very weak
0.20	a few	rare	lowest	least	smallest	weakest
0.00	none	none	none	none	none	lack

Finally, defuzzification method [16] is used for the transformation of the linguistic weight to a numerical value within the range [−1, 1].

After the interviews, the cognitive maps are transformed into matrices in the form $(W_{ij})_{ij}$ [16], named adjacency matrix (Fig. 3). The adjacency matrix codify a value between −1 and 1 when a connection exists between two concepts, that means: positive values representing positive causal relationship, negative values representing negative causal relationship, and the 0 value meaning no relationship.

	HE-job match	Field of study	Over-qualification of	Employment	Students enrolled	Adequate competences	Appropriate internship	High university reputation
HE-job match	0	0	0	1	0,2	0	0	0,4
Field of study	1	0	0	0,7	0	0	0	0
Over-qualification	-0,8	0	0	-0,4	0	0	0	0
Employment	0	0	0	0	0,6	0	0	0
Students enrolled	0,20	0	0	0	0	0	0	0
Adequate competences	1	0	0	0,5	0	0	0	0
Appropriate internship	0,4	0	0	0,7	0	0	0	0
High university reputation	0	0	0	0,4	0,2	0	0	0

Fig. 3 Adjacency matrix

D. Formalization of Fuzzy Cognitive Map

All the three group FCMs are augmented using matrix addition to create a social cognitive map, so called „team map” [16], to arrive at a more comprehensive causal model or to reduce the complexity of large maps to a more focused one.

To receive information on the dynamic behaviour of a FCM we have to calculate the influence one factor has on others over a number of iterations, so called the feedbacks between the concepts.

The computation of the C_j node's output is given by formula:

$$C_j(k+1) = f\left(C_j(k) + \sum_{\substack{i=1 \\ i \neq j}}^{n} C_i(k) W_{ij}\right) \quad (1)$$

where k is the iteration counter; and W_{ij} is the weight of the arc connecting concept C_i to concept C_j. The transformation function *f* which includes
recurring relationship between C(t+1) and C(t) is used to confine the weighted sum to a certain range, which is usually set to [0, 1].

$$O_i(k+1) = \frac{1}{1+e^{-C(k)}} \quad (2)$$

At each step, the value of a concept is influenced by the values of concepts connected to it as in equation (1), until the system converge to a point and no other changes take place.

So, after a number of iterations a FCM can simulate its evolution over time and predict its future behavior. Other else the FCM implodes, that is all factor values converge to zero, or explodes, that is all factor values increase /decrease continuously, or FCM has a cyclic stabilization.

E. FCM analysis

Fig. 4 is the graphical representation of CM for HEtoJob for 15 total numbers of connections corresponding to 8 nodes:

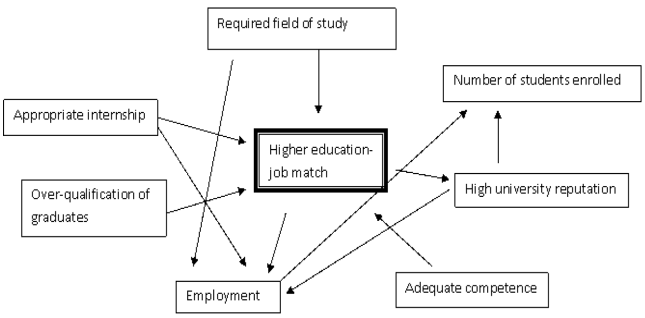

Fig. 4 CM for HEtoJob

Our paper revealed that Fuzzy Cognitive Map method can be used in the particular problem of higher education to job facilitating the understanding of both structural and dynamical system properties.

For the structural analysis we use comparative statistical techniques based on comparing the structural indices values (Fig. 5) (density index, in degree, out degree, transmitter, centrality, hierarchy index, and complexity index) among the groups of stakeholders interviewed.

Concepts	Outdegree	Indegree	Centrality
HE-job match	1.60	3.40	5.00
Required field of study	1.70	0.00	1.70
Over-qualification	1.20	0.00	1.20
Employment	0.60	3.70	4.30
Students enrolled	0.20	1.00	1.20
Adequate competences	1.50	0.00	1.50
Appropriate internship	1.10	0.00	1.10
High university reputation	0.60	0.40	1.00

Fig. 5 Structural indices values

The importance of a node 'i' is evaluated as:

Imp (i)=in(i)+out(i) (3)

where in(i) is the number of incoming arcs of node 'i' and out(i) is the number of out-coming arcs of node 'i'. It gives an indication of the importance that the node/concept has for the model, by measuring the degree to which the node is central to the graph. According to this definition, it is found that the most central/important concept in our model is the concept C_1 „HE-job match" followed by concept C_4 „Employment".

Another way to statically examine the FCM's graph is by calculating its density, as an indication of the complexity of the model. The density „d" is defined as d=m/n(n-1), where m is the number of arcs in the model and n is the number of concepts of the model. The density here is 15/(8×7) = 0.234375 that is a typical value of density included in the interval [0.05, 0.3] [11].

For the dynamical analysis we use computational simulations. A vector of initial state of variables is multiplied by the adjacency matrix of cognitive map and the results are transformed to the (0, 1) interval using a logistic function [13]. These steps are repeated through iterations while the matrix values become stabile. After that it is possible to run „what-if" scenarios, setting certain variables to a desired value and then compare the scenarios outputs with the outputs of the baseline scenario. Positive deviations indicate a positive change compared to a baseline, while a negative deviations indicate a negative trend.

F. FCM computing scenarios

Through policy option simulations, it was possible to determine which policies and combination of policies would encourage the HEtoJob the most.

The use of FCM modeling to simulate different HEtoJob polices scenarios offers a convenient way to experiment with policy alternatives.

We simulated our experiments of FCM using the software FCMapper (http://www.fcmappers.net) and obtained the results presented in table 3.

Table 3 Scenarios results

Concepts	Scene 2	Scene 3	No Changes Scene 1	Results Scene 2	Results Scene 3
HE-job match			0.72	0.87	0.919
Required field of study		1.50	0.50	0.50	1.50
Over-qualification			0.50	0.50	0.50
Employment			0.845	0.913	0.945
Students enrolled			0.682	0.698	0.704
Adequate competences	1.50	1.00	0.50	1.50	1.00
Appropriate internship			0.50	0.50	0.50
High university reputation			0.571	0.586	0.590

The outcomes of the simulation conducted us into exploring the complexity of the problem, as well as in the evaluation of the system behavior and its equilibrium states. In the two scenarios analysis, our FCM indicates the direction in which the system will move, given certain changes in the driving variables.

Given an initial state of the system, represented by a set of arbitrary values of its concepts, the FCM evolved over time until it reached a state of equilibrium. Starting from this steady state we made two scenarios. Fine modifications of two factors in the equilibrium state, taken one by one conducted to different behavior of the system.

So, two scenarios were imagined in our model: first, we increased „adequate competences" from 1 value to 1.5, and second we have increased „required field of study" factor to value 1.5. Comparing both simulated scenarios with the steady state, we have reached the conclusion listed in the previous table.

G. Results of FCM computing scenarios

Graphical maps covering common knowledge about ensuring that higher education offers responds to labour market needs have been of limited use due to the dynamic nature of the concepts. The FCM technique captures greater degrees of dynamism and complexity than static models, allowing relevant concepts to be manipulated and for a much more realistic picture of HEtoJob problem. The result of the degree and closeness centrality computation in our FCM is displayed in fig. 5. Through network analysis of the FCM we determined that *HE–Job match* exerts the greatest force in the model and hence impacts the dynamism and complexity of the HEtoJob problem.

The FCM built to model the complex social system of HEtoJob problem reasonably represented reality for the sample scenarios created.

III. CONCLUSION

Considering the FCM's potential to be used in the policy modeling, this paper explores how FCM can be applied to HEtoJob policy.

In order to create a participatory policy in Romanian higher education system, the first step is to exploration the complexity of system, followed by the evaluation of the behavior of the system until it reaches the equilibrium state, and finally determination of critical factors affecting the policy.

Even the FCMs can be used initially to evaluate behavior of the system and his equilibrium states, for further predictions of the system behavior over time, other simulation methods may be used.

The proposed FCM methodology provides feedback to stakeholders and trust in the policy designed.

The obtained results could be further used to advance the research related to semantic analysis, and visualization for a comprehensive new governance model able to support the complexity of policies and their implementation, as well as the innovative applications of FCMs to the simulation of higher education policy process.

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