Fuzzy Cognitive Map as a Decision Support System for Political Decisions:The case of "Great Albania"

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Abstract—— Fuzzy Cognitive Maps (FCMs) is an Artificial Neural Networks technique that incorporates ideas from Fuzzy Logic, to create a Decision Support System. Using this strucrure we develop a qualitative model of the relationships that exist in the field of political decisions in the case of "Great Albania". The model that is constructed is examined statically using graph theory techniques to identify the direct vicious or virtuous cycles of the decision process. Additionally graph 's density and the conceptual centrality of model's concepts are calculated. The dynamical behavior of the model is studied through computer simulations and conclusions are drawn for decisions to be taken. The role of Greece in the case of "Great Albania" is examined and possible ways are identified that make FCM an important and useful tool for the decision makers. Conclusions are drawn for the use of FCM as a decision support system for political decisions in general.

Index Terms—Decision Making, Decision Support Systems, Artificial Neural Networks, Fuzzy Logic, Graph Theory

I. INTRODUCTION

Decision Support Systems are defined as "interactive computer-based systems, which help decision makers utilize data and models to solve unstructured problems" [1]. Unstructured problems are defined as "fuzzy, complex problems for which there is no cut-and-dried solutions" [2]. In International Relations theory, negotiations and crisis management [3] are consider unstructured or semistructured areas where Decision Support Systems can assist by providing new potentials to the decision making process.

Such a decision support system, the Cognitive Map (CM) was first introduced by Axelrod in late 1970's [4]. Cognitive Maps create qualitative models that were extensively used for political Analysis and Decision Making in International Relations [4], [5].

Crisis situations are considered highly fuzzy and the contribution of Fuzzy Logic [6] is able to give CMs increased representing capabilities. Fuzzy Cognitive Maps

(FCMs) were introduced by Kosko [7], [8] incorporating ideas for Fuzzy Logic.

FCMs models are created as collections of concepts and the various causal relationships that exist between these concepts. The nodes represent concepts and the directed arcs between the nodes represent the causal relationships between the nodes/concepts. The degree of the causal relation between two nodes is also represented by a weight that accompanies the arc that connects the two nodes. The weights are signed, determining the positive or negative causal relation between the two concepts-nodes. An example of FCM is given in figure 1, showing the causal relationships of South African apartheid politics [8].
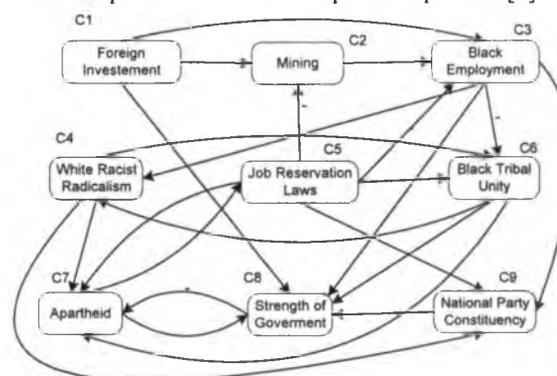

Figure 1. South African apartheid politics FCM [8]

Certainty Neuron Fuzzy Cognitive Maps (CNFCMs) were introduced in 1997 [9], giving additional fuzzification to the FCM structure. CNFCMs allow the activation of each concept's activation to be a number from the whole interval $[-1,1]$ (or, as in our case, in the interval $[0,1]$) allowing the representation of both the sign of the activation and its degree, while on the contrary, FCM allows each concept to have a binary value (-1 or 1), representing a negative or a positive activation and not the degree of the activation.

Furthermore in CNFCM, the aggregation of the influences that each concept receives from other concepts is handled by function f_M () that was used in MYCIN Expert System [10], [11] for certainty factors' handling. The dynamical behavior and the characteristics of this function are studied in [12]. The artificial neurons that use this function as their threshold function are defined as Certainty Neurons [13]. Using such neurons, the updating function of CNFCMs, as a dynamical evolving system, is the following:

$$A_i^{t+1} = f_M \left(A_i^t, S_i^t \right) - d_i \, A_i^t$$

where, A_i^{t+1} is the activation level of concept C_i at time step t+1, $S_i^t = \sum_j w_{ji} A_j^t$ is the sum of the weighted influences that concept receives at time step t from all other concepts, d_i is a decay factor and

$$f_M(A_i', S_i') = \begin{cases} A_i' + S_i'(1 - A_i') = A_i' + S_i' - S_i' A_i' & \text{if } A_i' \geq 0, \, S_i' \geq 0 \\ A_i' + S_i'(1 + A_i') = A_i' + S_i' + S_i' A_i' & \text{if } A_i' < 0, \, S_i' < 0 \quad |A_i'|,|S_i'| \leq 1 \\ (A_i' + S_i') / \left(1 - \min\left(|A_i'|,|S_i'|\right)\right) & \text{otherwise} \end{cases}$$

is the function that was used for the aggregation of certainty factors in MYCIN expert system.

II. THE CASE OF "GREAT ALBANIA"

The idea of "Great Albania", that is the dream of the creation of a greater Albanian state by expanding the borders of the current Albanian state to neighbor countries that have or is assumed to contain Albanian nationality citizens, is not new. Albanian Nationalism and Irredentism generated that dream of unifying all Albanian in Balkans and together with the demand for better political and economic standing of Albanians in Kosovo and FYROM, they were among the main reasons that led to the break out of war in these regions. The wars in these areas lead to additional Albanian Nationalism, causing Albanians to have direct intentions to areas in Montenegro and Greece. Various maps exist that define the borders of "Great Albania" and they are exhibited on the Internet[1]. In these maps, a part of Greece call "Chameria", is considered as an area of "Great Albania".

The Albanian Government does not officially accept any responsibility for the dream of "Great Albania". It insists that, as Albanian Minister of Foreign Affairs Pascal Miljo said in March 2001 "The idea for Great Albania is only a fiction created by Anti-Albanian circles that have always wanted to justify their activities". But Albanian insurgents continue their acts in Kosovo and FYROM. The open military actions in these areas affect the general stability of the Balkan area and could lead to a domino phenomenon, drawing into war, Greece, Turkey and Bulgaria [14], [15].

All countries in the area are concerned with the course of events. Albania, Yugoslavia, FYROM, Greece, Bulgaria, Turkey and of course NATO are involved in the situation and they are the main players in the "Great Albania's" chessboard.

III. CONSTRUCTION OF FCM MODEL

For the construction of the FCM model for "Great Albania", the Questionnaire method was used [16], [17]. This method involves interviews and answering

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[1] http://www.chegevara.cg.yu/ArhivaINFO/velika_albanija_e.asp, http://www.rotgruen.de/backgrou.htm

questionnaires by a domain expert or a group of domain experts. Since the model is created by the personal opinions and points of view of the expert(s) on the specific topic, the reliability of the model is heavily depended on the level of expertise of the domain expert(s).

The domain expert that was used for the construction of "Great Albania's" FCM is a faculty member of the Department of International & European, Economic & Political Studies of the University of Macedonia, Thessaloniki, Greece. During the interviews, the concepts that should be included in the model were defined and the causal relationships exist between these concepts were identified, accompanied by the degree of interaction of each causal relationship. The list of the concepts that were identified as playing important role in the case of "Great Albania" and appear in the FCM model, are the following:

1. Albanian Government's official position on the dream of "Great Albania"
2. The dream of "Great Albania"
3. Albanian Nationalism – Irredentism
4. Fight for Independent Kosovo
5. War in Kosovo
6. Demands for Better Political and Economic Standing of Albanians in other countries
7. War in FYROM
8. FYROM's Reaction
9. Yugoslavia's-Montenegro's Reaction
10. Greek Reaction
11. Bulgarian Reaction
12. Turkey's Reaction
13. NATO's Reaction

Statements from the domain expert that were taken into account during the construction of the FCM model are the following:

1. A reason for the break out of war in Kosovo and FYROM was the demand for better political and economic standing of Albanians in these regions.
2. Albanian nationalism, irredentism and also the dream of "Great Albania" was another reason of the outbreak of these wars.
3. War in Kosovo and the fight for independent Kosovo was supportive to the breaking of war in FYROM.
4. War in FYROM, war in Kosovo and the fight for independent Kosovo strengthen the dream of "Great Albania", which in its turn assisted these wars.
5. The main reactions for the war in Kosovo come from Yugoslavia and NATO.
6. NATO, in the after Milosevic era, is supporting Yugoslavia in the Kosovo war.
7. War in FYROM caused not only the reactions of FYROM and NATO but also these of the neighbor countries, Greece and Bulgaria.
8. There is no clear view of the Bulgaria's position on the "Great Albania" issue.
9. Turkey is considered supportive to the dream of "Great Albania"

10. Greece asks for NATO reactions to end the wars.

After the interviews and taking into account the above statements, the FCM model of figure 2 was created. The weights of the arcs are given in Appendix A. This model will be examined both statically and dynamically.
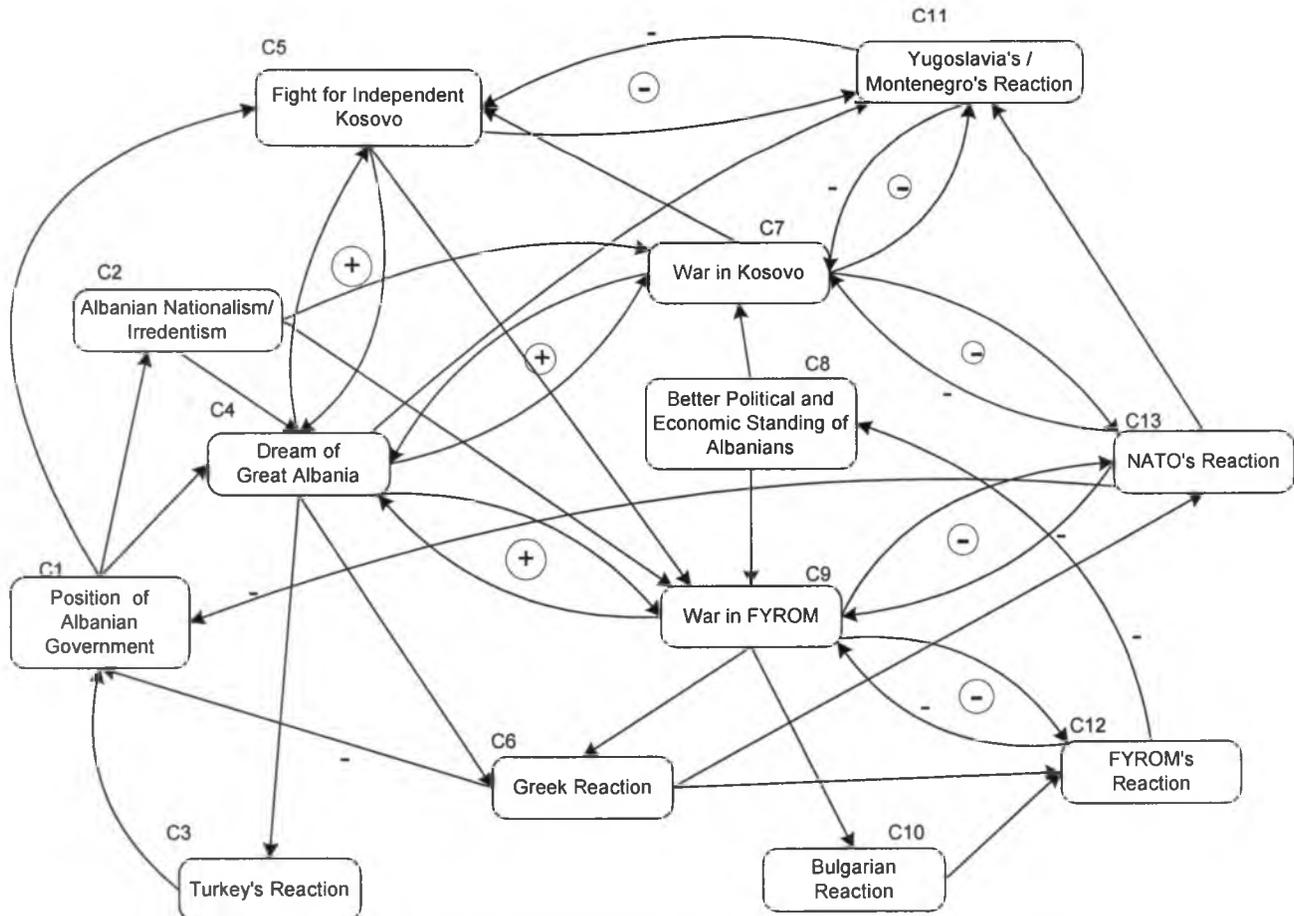

Figure 2. FCM Model of "Great Albania" (arcs having no sign are consider positive)

VI. STATIC ANALYSIS OF FCM MODEL

In the static analysis of the FCM, the graph of the model is examined using graph theory techniques. The characteristics of the graph that are examined are the following: a) The direct vicious or virtuous cycles that exist in the graph, b) the graph density and c) node's importance (or cognitive/conceptual centrality).

Direct vicious cycle [18] is a cycle created between two concepts of the graph, that directly interact with each other in a positive way. The two arcs that connect the two nodes should either be both positive or both negative. Such cycles are also called deviation-amplifying cycles [19] or augmented cycles [17]. Such a cycle is that between the concepts "Fight for Independent Kosovo" and "Dream of Great Albania". This vicious cycle says that the fight for independent Kosovo will strengthen the dream of "Great Albania" which in turn will strengthen the fight of independent Kosovo and so on. The cycle leads to a continuous strengthen of both concepts and only a third concept is able to stop this continuous increase. In the graph of figure 2, there are three such cycles, shown with a circled minus.

1. Fight for independent Kosovo ⇔ Dream of "Great Albania"
2. War in Kosovo ⇔ Dream of "Great Albania"
3. War in FYROM ⇔ Dream of "Great Albania"

Direct virtuous cycle [18] is a cycle created between two concepts of the graph that directly interact with each other in a negative. The two arcs that connect the two nodes should have different signs (one should be positive and the other should be negative). Such cycles are also called deviation counteracting cycles [19] or inhibiting cycles [17]. Such a cycle is that between the concepts "Fight for Independent Kosovo" and "Yugoslavia/Montenegro Reaction". This virtuous cycle says that the fight for independent Kosovo will face Yugoslavia's Reaction that will act against the fight for independent Kosovo. The cycle leads to a continuous negative interaction between the two concepts, each concept attempting to be imposed to the

other. In the graph of the FCM model, there are five such cycles shown with a circled positive sign.

1. Fight for independent Kosovo ⇔Yugoslavia's/Montenegro's Reaction
2. War in Kosovo ⇔ Yugoslavia's/Montenegro's Reaction
3. War in Kosovo ⇔ NATO's Reaction
4. War in FYROM ⇔ FYROM's Reaction
5. War in FYROM ⇔ NATO's Reaction

Direct vicious and virtuous cycles play important role to the out come of the situation represented in the FCM model. In case we isolate the two concepts, certain criteria have been found, depending on the weights and signs of the arcs between the two concepts, that determine the dynamical behavior of the two concepts' system [20].

Another way to examine statically the model's graph is by calculating its density [5]. The density d is defined as

$$d = \frac{m}{n(n-1)}$$

where m is the number of arcs in the model and n is the number of concepts of the model (product n(n-1) is equal to the maximum number of arcs that a graph of n nodes can have). Density gives an indication of the complexity of the model. High density indicates increased complexity in the model and respectively to the problem that the model represents. Typical values of density are in the interval [0.05, 0.3]. The density of the graph in figure 2 is 39/(13x12) = 0.25 which is high, and gives an indication of the complexity of the problem that it represents.

Graph Theory provides also the notion of node's importance [4] that assists the static analysis of FCM models. Node's importance (or cognitive/conceptual centrality as it is called by others [21], [22]) gives an indication of the importance that the node/concept have for the model, by measuring the degree to which the node is central to the graph. The importance of a node i is evaluated as

$$imp(i) = in(i) + out(i)$$

where $in(i)$ is the number of incoming arcs of node i and $out(i)$ is the number of outcoming arcs of node i. According to this definition, the importance of the nodes of the FCM model for "Great Albania" is the following:

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
6	4	2	11	7	5	9	3	11	3	6	5	7

As it is expected the concept C4: "Dream of Great Albania" is found the most central to the model. Concepts C9: "War in FYROM" is equally central, with C7: "War in Kosovo" and C13: "NATO's Reaction" to follow.

V. DYNAMICAL BEHAVIOR OF CNFCM MODEL

The model of the case of "Great Albania" was simulated using the CNFCM technique that was mentioned in section

1. After inserting to the simulation program the 13 concepts of the model and the causal relationships that exist among these concepts, the system's concepts was free to interact and the system to evolve dynamically. The dynamical behavior of the model is shown in figure 3 where we can see that reaches equilibrium at a fixed point. The activation of each concept at this equilibrium point is given in the following table.

TABLE I

Concept	Activation level at Equilibrium
Albanian Government's official position on the dream of "Great Albania"	0
Albanian Nationalism – Irredentism	0
Turkey's Reaction	0.581
The dream of "Great Albania"	0.744
Fight for Independent Kosovo	0.607
Greek Reaction	0.755
War in Kosovo	0
Demands for better political and economic standing of Albanians in other countries	0
War in FYROM	0.176
Bulgarian Reaction	0.330
Yugoslavia's-Montenegro's Reaction	0.330
FYROM's Reaction	0.776
NATO's Reaction	0.741

The equilibrium point is interpreted in the following way: The reactions of NATO, FYROM and Greece is high (activation ~0,750, with 1.0 to be the maximum) and the reaction of Yugoslavia is medium (0.330). The war in Kosovo is ended, together with the support of Albanian government to the dream of "Great Albania", the increasing Albanian Nationalism and Albanian demands (activation 0). The dream of "Great Albania" is still high (0.744) and so is the fight for independent Kosovo (0.607). The war in FYROM has not ended but it is limited (0.176). Turkey's reaction is still positive to the dream of "Great Albania".

The justification of this equilibrium point can be given by studying the transition phase of the system, as it is shown in figure 3. The equilibrium point can be justified in the following way: The wars in Kosovo and FYROM caused significant reactions from NATO, Yugoslavia, Greece that led to the diminish of the support of Albanian government to the dream of "Great Albania", to the end of the increase of the Albanian nationalism and more significantly, to the end of war in Kosovo. In the mean time, the dream of "Great Albania" and the idea of independent Kosovo became stronger. These two factors acted supportively to the war in FYROM. The war in FYROM was close to its end, as it is shown in point A of figure 3, but these two factor acting together, did not let that happen. The reactions of FYROM, NATO, Greece and Bulgaria managed to limit, but not to end the war in FYROM. The vicious cycle between "Fight for independent Kosovo" and "Dream of Great Albania" did not let the war in FYROM to be ended.
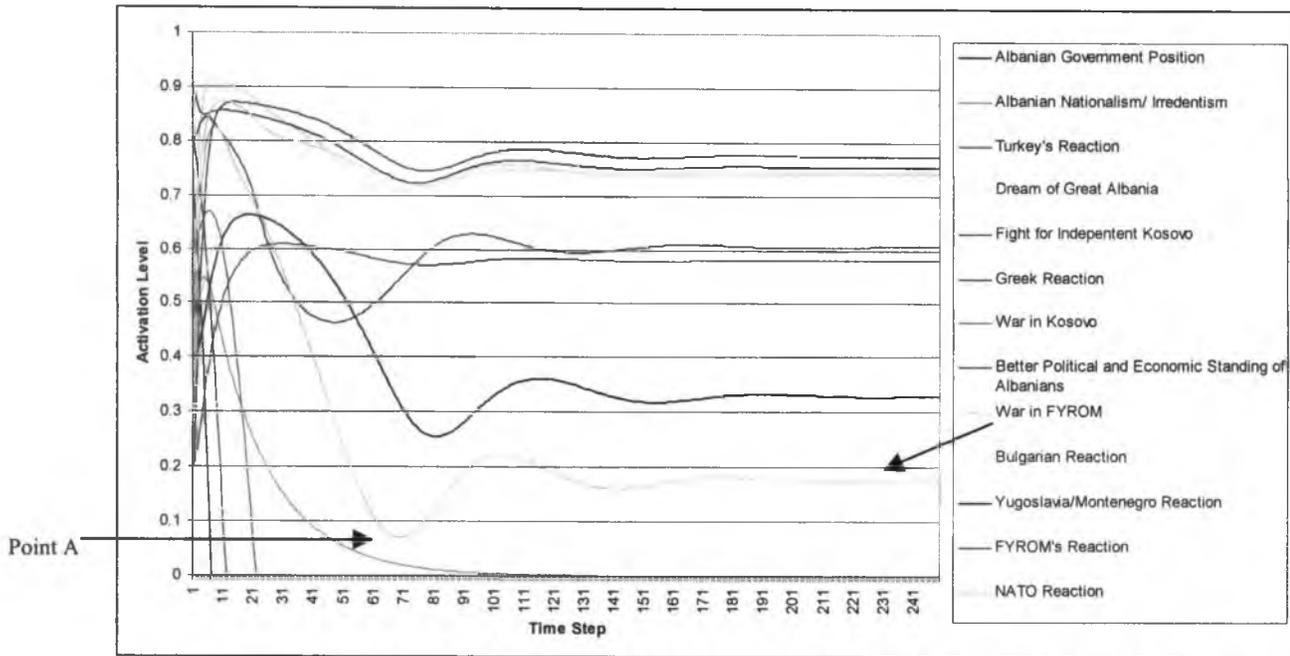
Figure 3. Simulation of CNFCM Model of "Great Albania". Transition phase to equilibrium

It is important to the authors to show the contribution of Greece to averting the war in FYROM. This can be done e.g. by removing the support of Greece to FYROM, that is removing from the model the arc connecting concepts C6: "Greek reaction" with concept C12: "FYROM's reaction". Running the simulations once again with the above scenario, the system reached another equilibrium point. The transition to this equilibrium point is shown in figure 4, while the equilibrium point is given in the following table.

TABLE II

Concept	Activation level at Equilibrium
Albanian Government's official position on the dream of "Great Albania"	0
Albanian Nationalism – Irredentism	0
Turkey's Reaction	0.583
The dream of "Great Albania"	0.753
Fight for Independent Kosovo	0.541
Greek Reaction	0.777
War in Kosovo	0
Demands for Better Political and Economic Standing of Albanians in other countries	0
War in FYROM	0.276
Bulgarian Reaction	0.430
Yugoslavia's-Montenegro's Reaction	0.435
FYROM's Reaction	0.663
NATO's Reaction	0.760

In this scenario, we see that the transition phase has the same format with that of figure 3 but the equilibrium point is different. Now the concept "War in FYROM" is more activated (0.276) than that of the first scenario (0.176).

Bulgarian reaction gets bigger (0.430) but finally FYROM's reaction is in this scenario less (0.663, while 0.776 in the first case) due to the denial of Greek direct support. It can be concluded that Greece by directly supporting FYROM, helped the limitation of the war in FYROM.

Greece also supports indirectly FYROM by its influence to NATO. Using the model, the contribution of Greece to the limitation of the war in FYROM can be checked. In this scenario, the arc that connects concept C6: "Greek reaction" with concept C13: "NATO's reaction" is also removed from the model. The transition phase is given in figure 5. The equilibrium point is given in table III.

TABLE III

Concept	Activation level at Equilibrium
Albanian Government's official position on the dream of "Great Albania"	0
Albanian Nationalism – Irredentism	0
Turkey's Reaction	0.586
The dream of "Great Albania"	0.763
Fight for Independent Kosovo	0.468
Greek Reaction	0.798
War in Kosovo	0
Demands for Better Political and Economic Standing of Albanians in other countries	0
War in FYROM	0.398
Bulgarian Reaction	0.527
Yugoslavia's-Montenegro's Reaction	0.527
FYROM's Reaction	0.726
NATO's Reaction	0.481

As it is shown in the above table, the war is FYROM now is becoming more intense. Although the reaction of Bulgaria to the war in FYROM was increased, NATO's reaction is now less strong and this hinders the limitation of the war. It is concluded that the impact of Greece to averting the war in FYROM, through its influence to NATO is important for the outcome of the war in FYROM. The war in FYROM is also studied in [23], using the CNFCM method.
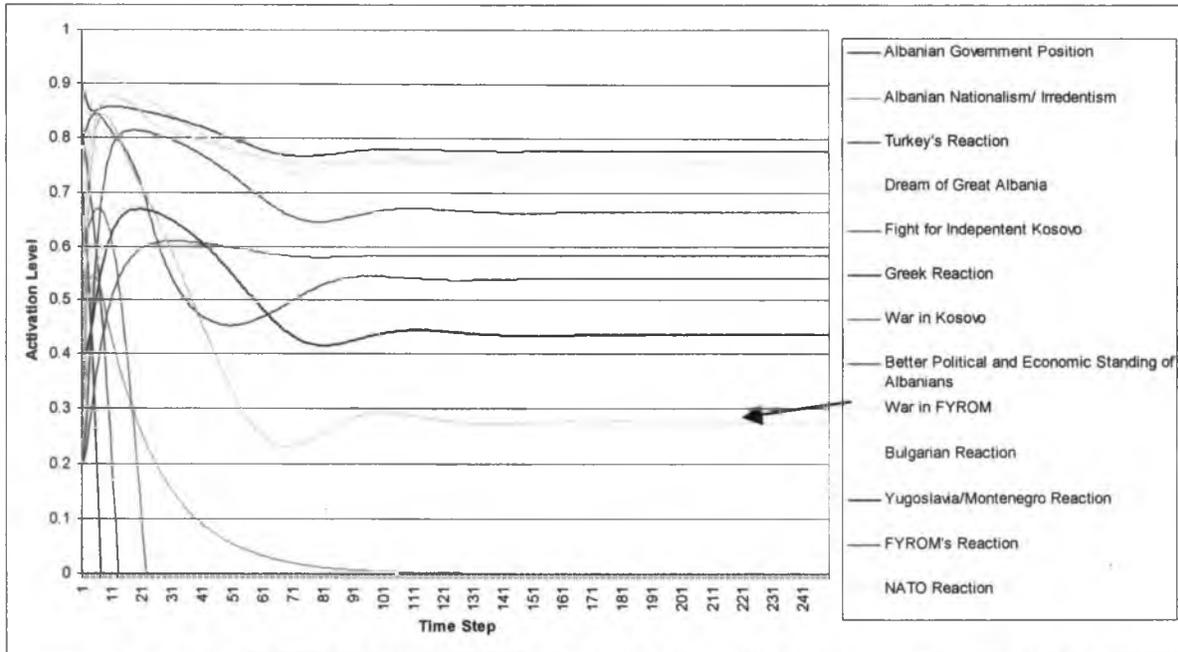

Figure 4. Transition phase of CNFCM Model of "Great Albania". No direct Greek Support to FYROM
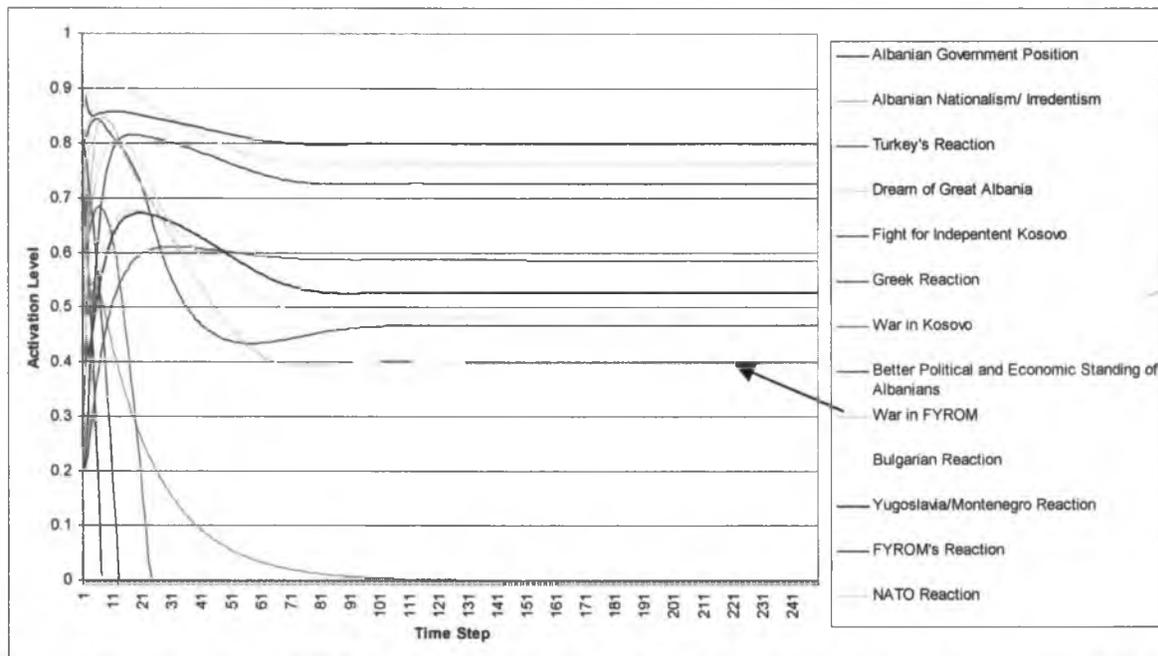

Figure 5. Transition phase of CNFCM Model of "Great Albania". No direct or indirect Greek Support to FYROM

VI. SUMMARY - CONCLUSIONS

An FCM model was created for the case of "Great Albania" based on the opinions of a domain expert. The model was first examined statically, identifying the direct vicious and virtuous cycles that exist in model's graph. The density of model's graph was calculated and found high, indicating the complexity of the case. The conceptual centralities of the concepts that exist in the model were also calculated and

the most central, and consequently the most important concepts of the model were found.

The model was then simulated in a computer and it was predicted that
a) War in Kosovo is ending.
b) War in FYROM will be limited but not ended.
c) The dream of "Great Albania" will stay alive.
d) The fight and the idea of independent Kosovo will stay also alive.
e) The dream of "Great Albania" and independent Kosovo and the war in FYROM create vicious cycles that should be studied.
f) Most importantly, the contribution of Greece was important for the limitation of the war in FYROM, both by supporting FYROM and also by influencing NATO.

The CNFCM system was identified as an important and useful Decision Support System, since it is capable to provide support to decision makers, by making predictions on various scenarios that are imposed to the model that CNFCM creates. Conclusions on these scenarios are not drawn only from the final equilibrium that the system reaches, but also by studying the transition phase of the DSS system to equilibrium. The decision maker can test his decisions, by applying them to the CNFCM system and see the consequences to the other concepts of the model. The application of these decisions in real life depends on weather the predicted consequences are the desired. CNFCM technique was found suitable as a Decision Support System for political decisions/

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Appendix A - Weight matrix of "Great Albania's" FCM model

Concepts / Weights	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1: Albanian Government Position	0	0	0.3	0	0	-0.5	0	0	0	0	0	0	-0.4
C2: Albanian Nationalism/ Irredentism	0.6	0	0	0	0	0	0	0	0	0	0	0	0
C3: Turkey's Reaction	0	0	0	0.4	0	0	0	0	0	0	0	0	0
C4: Dream of "Great Albania"	0.5	0.9	0	0	0.8	0	0.6	0	0.8	0	0	0	0
C5: Fight for Independent Kosovo	0.8	0	0	0.8	0	0	0.9	0	0	0	-0.8	0	0
C6: Greek Reaction	0	0	0	0.7	0	0	0	0	0.8	0	0	0	0
C7: War in Kosovo	0	0.8	0	0.6	0	0	0	0.6	0	0	-0.9	0	-0.5
C8: Better Political and Economic Standing of Albanians	0	0	0	0	0	0	0	0	0	0	0	-0.5	0
C9: War in FYROM	0	0.9	0	0.8	0.6	0	0	0.8	0	0	0	-0.7	-0.5
C10: Bulgarian Reaction	0	0	0	0	0	0	0	0	0.6	0	0	0	0
C11: Yugoslavia/Montenegro Reaction	0	0	0	0.6	0.9	0	0.6	0	0	0	0	0	0.6
C12: FYROM's Reaction	0	0	0	0	0	0.6	0	0	0.9	0.4	0	0	0
C13: NATO's Reaction	0	0	0	0	0	0.7	0.8	0	0.5	0	0	0	0