APPLICATION OF FUZZY COGNITIVE MAPS ON POLICY ANALYSIS: DETERMINING THE POLICY OF SUPPORTING THE ACADEMIC SPIN OFFS

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ABSTRACT

Fuzzy Cognitive Map (FCM) is a type of artificial neural network. It can be viewed as a weighted directed graph in which vertices represent concepts and edges represent causal links between them. An FCM can be used as an intelligent decision support system (DSS) tool. It works by representing important issues in a given situation and their causal relationships. The evolution of a dynamic system with time can be simulated and the behavior of the systems can be predicted and explained using an FCM. In this case FCM is used to ditermine the policy to support the academic spin off. Simulation brings forth some conclusions and the best policy can be chosen.

Keywords: Fuzzy Cognitive Maps, Policy Analysis, Academic spin off.
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1. INTRODUCTION

Soft computing is an emerging method that combines several advanced theories and methodologies such as Fuzzy logic, Neural networks, and Genetic algorithm. Soft computing provides a hybrid concept of computing technology to answer the real world problem. In soft computing, some theories are combined and become a new theory, such as Neuro fuzzy, fuzzy neural network, neural genetic algorithm, and many other hybrid methodologies.

The soft computing techniques have been successfully applied in signal processing, image recognition, forecasting, expert system, and knowledge-based system. There are diverse approaches of soft computing that have been applied to some conventional theories such as operation research. Fuzzy regression analysis, fuzzy linear programming, and genetic algorithm are frequently used to optimize some problems in industrial engineering which usually uses operational research.

Fuzzy cognitive maps (FCM) belong to the soft computing approach and stem from the implementation of Fuzzy logic to represent knowledge and behavior of a system using a network of interconnected nodes (Stylios, 2000). The FCM can structure virtual worlds that change with time. A FCM links causal events, actors, values, goals, and trends in a fuzzy feedback dynamical system. FCM can be used to model and represent the behavior of a simple and a complex system.

Considering the FCM's capacity, it is interesting to explore how FCM can be applied in the field of policy analysis. The policy analysis is a systematic and comprehensive approach that helps the decision makers to produce a better decision. One of important steps in the policy analysis approach is designing a model of the real world. By modeling the real world, policy instrument can be experimented, and the future can be predicted. In this particular step, FCM can be used to enhance the policies' quality.

The application of FCM in the policy analysis is not many. Very few scholars realize FCM's potential to be used in the policy analysis. Jean-Luc de Kok (2000) from the University of Twente is among the few people who applied FCM in the policy analysis. In his research, he used FCM to predict urbanization. This research tries to apply FCM in the policy analysis to help policy maker to decide the best policy in supporting the spin offs.

2. CONSTRUCTING THE FCM

The FCM is the fuzzy graph with feedback, consisting of nodes and weighted interconnections. FCM is an n matrix, where *Fij* indicates the relationship between i and j. Fij can have value [-1, 1]. There are three possible types of relation:

- *Fij>0* indicates a positive causality between i and j. That means increasing in the value of i will leads to an increase in the value of j.
- *Fij<0* indicates inverse causality between i and j. That means increasing in the value of i will leads to a decrease if the value of j.
- *Fij=0* indicates no relationship between i and j.

The calculation of this relationship is based on the simple differential Hebbian learning law presented by Dickerson and Kosko (1994). Based on their theory, the weights of edges leaving a node are modified when the node has nonzero state change. The change is

$$e_{ij}(t+1) = e_{ij}(t) + c_t\left[\Delta C_i(x_i)\Delta C_j(x_j) - e_{ij}(t)\right]$$

$$c_t(t) = 0.1\left[1 - \frac{t}{1.1N}\right]$$

where e_{ij} denotes the weight of the edge between the i and j-*th* concepts, $\Delta C_i(x_i)$ is the change in the i-*th* concept's activation value, and t is the generational time step.

3. CASE STUDY

This research uses FCM to analyze the policy recommended to Policy maker which influence the policy to support academic spin offs. There are three dimensions of support that should be covered: knowledge, tangible and intangible and network to foster the growth of the spin offs.

FCM model is developed to picture the relation and causality among the factors which influence the spin offs' performance. The aim of policy is simulated by increasing and decreasing the levels of the factors that are related to the three dimensions of support. Besides, the policy is verified by introducing some factor scenarios such as economic situation and technological development. The aim is to test how robust the policy will be in the future.

3.1 Graphical Representation of FCM

Figure below describes the graphical representation of the factors in FCM.

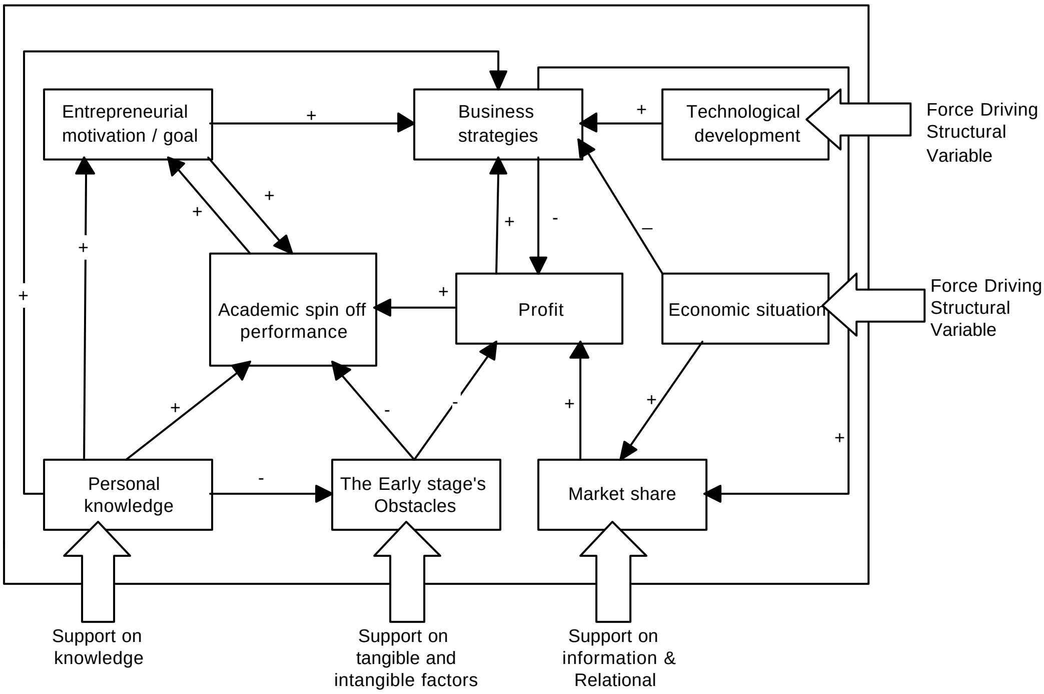

Figure 1. The Fuzzy Cognitive Maps Model

3.2 Selection of Factors

This subsection explains the factors used in the model.

Table 1. Factor Used in the Model

Factor	Description
Entrepreneurial motivation	Enable entrepreneurs to keep up in business.
Entrepreneurial knowledge	All knowledge to manage businesses, including marketing knowledge, sales skill, leadership, etc.
New technology based firm performance	Parameter of firms' successful performance measured through some aspects such as turn over, profit, job-growth.
Business strategies	Strategy applied by entrepreneurs to increase profit.
Obstacle	Firms' barriers and needs in the early stage; obstacles in the model refer to financial and location problem.
Profit	Parameter of firms' performance; sales minus costs.
Market share	Percentage of firms' share in market; the bigger the share, the bigger the profit is.
Economic situation	Situation that is plausible to support or inhibit the firms' performance; for instance, the fall of economic situation causes the decrease of demand, and in turn affects the firms' performance.
Technology development	Technological factor influences customers' preference or product development; for instance, a discovery of new radical technology changes product specification and demand.

3.3 Selection of Relation

The second step in the preparation of the fuzzy cognitive map is to set the causal relationships among the factors.

Causes of Spin Offs' Performance

The main factor that influences spin offs' performance is profit. The relation is high; the bigger the profit, the better the performance is. The entrepreneurs' personal knowledge and obstacles also largely affect the spin offs' performance. Motivation has been proven to have a low correlation with the firms' performance. On the contrary, the firms' performance can influence the entrepreneurs' motivation and goal.

Causes of Profit

The model projects that the market share, business strategy, and obstacles influence the profit. The increasing market share will increase the profit. Better business strategy will likely to give a positive influence on the profit.

3.4 Level of factor

Assuming that the situation of entrepreneurship is steady, the fuzzy cognitive map assigns the level on 50 (out of 100) to represent the levels of all factors. This results in a steady situation in which no factor's level triggers a variation in the level of any other factor. Assigning levels on 50 to all factors does not mean that the levels of all factors, in absolute units, are the same. In fact, every factor has its own level and is measured in units that may not be applicable to other factors

3.5 Simulation

The simulation was first conducted by inputting the external factors in the model. Economic situation and technology development are two external factors that are capable of influencing the firms' performance and the policy's performance. The result shows that a new technology development, when responded by an appropriate strategy, will increase the firms' performance. On the contrary, economic trend does not directly influence the firms' performance, shown by non-linearity of the increase of economic trend with the firms' performance. The simulation was also conducted by experimenting some policy variables:

Knowledge

The support is aimed to increase entrepreneurial knowledge. Thus, the simulation of support on knowledge was done by increasing the level of entrepreneur's knowledge.

Tangible and intangible support

Support on tangible and intangible will minimize the entrepreneurs' problem. The simulation was conducted by decreasing the level of the problems.

Network

Through alliance and merger with other firms, the spin offs firm can increase their market share and in turn give a positive impact on the performance. The simulation was conducted by increasing the level of market share. The simulation was done by applying the three policies in different scenarios. The result reveals that support on knowledge is the most effective and the most influential one on the firms' performance. Below knowledge is tangible and intangible support, also positively influencing the firms' performance. Network that is assumed to increase market share has been proven to give less impact.

The simulation also combined two policies, for instance support on knowledge and support on network. The result shows that support on knowledge is likely to give a positive impact on the firms' performance as entrepreneurs' knowledge has a direct causality with firms' performance. The complete result of the simulation can be seen in the attachment.

3.6 The Result

The result of the simulation brings forth some conclusions. The knowledge support seems to be the best policy because it gives the biggest impact on the performance. Although increasing the performance can also be achieved by combining two alternatives, as shown by the result, the result of combining two alternatives is no better than the knowledge support.

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Appendix: Simulation result

Table 2. Change on the Economics' Level

	20	40	60	80
Knowledge	50	50	50	50
Motivation	49	52	48	51
Performance	48	54	46	52
Problem	50	50	50	50
Profit	49	58	42	51
Strategies	78	77	23	22
Market share	20	40	60	80
Economic	20	40	60	80
Technology	50	50	50	50

Table 3. Change on the Technology's Level

	20	40	60	80
Knowledge	50	50	50	50
Motivation	43	45	55	57
Performance	38	41	59	62
Problem	50	50	50	50
Profit	32	35	65	68
Strategies	13	20	80	87
Market share	50	50	50	50
Economic	50	50	50	50
Technology	20	40	60	58

Table 4. Economic Normal (50)

	Knowledge 75	Problem 25	Market share 75
Knowledge	75	50	50
Motivation	78	63	51
Performance	80	70	50
Problem	0	0	50
Profit	66	64	48
Strategies	82	78	46
Market share	50	50	50
Economic	50	50	50
Technology	50	50	50

Table 5. Economic Down (25)

	Knowledge 75	Problem 25	Market share 75
Knowledge	75	50	50
Motivation	76	60	51
Performance	77	60	51
Problem	0	0	50
Profit	54	52	52
Strategies	83	80	79
Market share	25	25	25
Economic	25	25	25
Technology	50	50	50

Table 6. Economic Boost (75)

	Knowledge 75	Problem 25	Market share 75
Knowledge	75	50	51
Motivation	75	60	51
Performance	76	66	50
Problem	0	0	0
Profit	51	49	49
Strategies	27	23	22
Market share	75	75	75
Economic	75	75	75
Technology	50	50	50

Table 7. Technology enhancement (75)

	Knowledge 75	Problem 25	Market share 75
Knowledge	75	50	50
Motivation	78	63	57
Performance	81	71	62
Problem	0	0	50
Profit	70	68	68
Strategies	90	87	86
Market share	50	50	50
Economic	50	50	50
Technology	75	75	75

Table 8. Economic down (25)

	Knowledge (75) Problem (25)	Knowledge (75) M.share (75)	Problem (25) M. Share (75)	Combination of three
Knowledge	75	75	50	75
Motivation	76	76	60	76
Performance	77	77	66	77
Problem	0	0	0	0
Profit	54	54	52	54
Strategies	83	83	86	84
Market share	25	25	25	25
Economic	25	25	25	25
Technology	50	50	50	50

Table 9. Economic Normal (50)

	Knowledge (75) Problem (25)	Knowledge (75) M.share (75)	Problem (25) M. Share (75)	Combination of three
Knowledge	75	78	50	75
Motivation	78	78	3	78
Performance	80	80	70	80
Problem	0	0	0	0
Profit	66	66	64	66
Strategies	82	82	78	82
Market share	50	50	50	50
Economic	50	50	50	50
Technology	50	50	50	50

Table 10. Economic Boost (75)

	Knowledge (75) Problem (25)	Knowledge (75) M.share (75)	Problem (25) M. Share (75)	Combination of three
Knowledge	75	75	50	75
Motivation	75	75	60	75
Performance	76	76	60	76
Problem	0	0	0	0
Profit	51	51	49	51
Strategies	27	27	23	27
Market share	75	75	75	75
Economic	75	75	75	75
Technology	50	50	50	50

Table 11. Technology Enhancement (75)

	Knowledge (75) Problem (25)	Knowledge (75) M.share (75)	Problem (25) M. Share (75)	Combination of three
Knowledge	75	75	50	75
Motivation	78	78	63	78
Performance	81	81	71	81
Problem	0	0	0	0
Profit	70	70	68	70
Strategies	90	90	87	90
Market share	50	50	50	50
Economic	50	50	50	50
Technology	75	75	75	75