Analysing the Impact of Universities on Regional Development: A Case Study Using Fuzzy Cognitive Maps

K.Bulut and G. Kayakutlu

Abstract—The impact of innovation in industrial development is continuously increasing. Universities have the major roles in innovation. The positive influence of high education in regional development is required and recognized by the authorities. Researchers continue to investigate the subject using a variety of methods. This paper analyses the contribution of universities to the regional development by using the Fuzzy Cognitive Mapping (FCM) technique. FCM is used in modelling the critical factors and the relations between them. In this paper several factors are detected from literature. A model is designed on the detected criteria on which interviews with experts of economy are conducted. As a result seventeen criteria are used to construct FCM. Most important factors are detected and accordingly some suggestions are presented to improve University contribution in regional development.

Index terms: **Fuzzy Cognitive Maps, Regional Development, Universities.**

I. Introduction

Universities are public institutions with important social roles. They are assigned the mission to educate and render expertise. The university graduates design and shape the society. Hence, the influence of education and research run in a University is not limited to the technological capabilities or development of human skills in the region they serve. Therefore, a University established in a city influences the technological development, social development, economical development and cultural development of the city and its vicinity [7]. Moreover, a university is an important resource of information and continuous education which would support the sustainability in business and social services for the region.

Universities can be seen as multifaceted economic actors that are embedded in regions, and not only produce codified knowledge and human capital, but also participate actively as important institutional actors in building and sustaining local networks and flows of knowledge, and in linking them with global ones [2] .Universities are anchor tenants in their regions, which helps stabilize regional economies over the long term, especially in smaller regional economies.

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Politicians are embracing strategies that tie universities to regional economic development through the impacts of academic research on technological advances used by companies, the recruitment of graduates into the regional labour force, and the active role of universities in setting the regional economic development agenda [20].

In literature, there are numerous researches that provide evidence for universities to become driving forces in the regional development [7]. That is why a literature survey was run to define the influential factors. More than forty factors are picked. After interviewing the experts of economy the research is realized on seventeen of them. Fuzzy Cognitive Map (FCM) is useful in modelling complex systems [17]. This research aims to rank and relate the factors that make a University influential in regional development.

Our paper is organised in four sections. The next section presents the selected criteria followed by the clarification of Fuzzy Cognitive Mapping method. Section 4 focuses on the application. The final chapter gives information about the study findings and concludes this paper.

II. University Driven Development

We select the criteria from the literature about the effects of the universities on regional development. Table I presents the description of all the concepts and the source of these concepts.

TABLE I
Criteria of the FCM Model and the Descriptions

Concept	Description	Literature
C1:	The number of university-owned research centres.	Vught F.v., (2006)
C2:	Quality and size of research canter.	Vught F.v., (2006)
C3:	Number of researchers that university has.	Vught F.v., (2006)
C4:	The amount of the region's workforce.	Vught F.v., (2006)
C5:	Skills level of regional labour force.	Drucker J.&Goldsteın H.,(2007)
C6:	The inclusion level of regional work force on research and projects.	Expert Opinion

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Concept	Description	Literature
C7:	Being open to change and the attitude of the people of the region response.	Expert Opinion
C8:	Teaching and research potential of the region to be addressed as an issue.	Expert Opinion
C9:	University-industry cooperation level.	Vught F.v., (2006)
C10:	Number of projects which are developed by the university.	Expert Opinion
C11:	Applicability level of the developed projects.	Expert Opinion
C12:	The budget volume.	Calıskan S., (2010)
C13:	Number of graduates from the university.	Vught F.v., (2006)
C14:	The quality of the professor employed in university.	Expert Opinion
C15:	The amount of the university's support for projects.	Expert Opinion
C16:	The number and quality of the social activities organized by the university.	Expert Opinion
C17:	Graduate student's desire to work in the region.	Expert Opinion

III. Fuzzy Cognitive Maps (FCM)

Cognitive Mapping technique was first used for modelling decision-making processes related to social and political systems by Axelord [1].Cognitive Maps are based on traditional logic system. Traditional binary logic requires that a statement must be either true *or* false [9] .But in fuzzy logic there are intermediate values and also Fuzzy cognitive mapping is based on fuzzy logic.

FCM is a powerful tool for modelling and controlling complex systems with high dimension and a variety of variables and factors. FCM is a soft system methodology that consists of a number of variable concepts and connections which illustrate the cause and effect relations between the concepts [14].FCM consists of concepts, that illustrate different aspects in the behaviour of the system and these concepts interact with each other showing the dynamics of the system. The human experience and knowledge of the operation of the system is used to develop Fuzzy Cognitive Map (FCM), as a result of the method by which it is constructed, i.e., using human experts that know the operation of system and its behaviour in different circumstances. An FCM illustrates the system by a graph showing the cause and effect along concepts, and it is a simple way to describe the system's behaviour in a symbolic manner, exploiting the accumulated knowledge of the complex system [16].

Fuzzy Cognitive Maps consist of concept nodes and weighted arcs, which are graphically illustrated as a signed weighted graph with feedback. Signed weighed arcs, connecting the concept nodes, represent the causal relationship that exists among concepts. In general, concepts of a FCM, represent key-factors and characteristics of the modelled complex system and stand for events, goals, inputs, outputs, states, variables and trends of the complex system been modelled. This graphic display shows clearly which concepts influences with other concepts and what this degree of influence is [16].

Existing knowledge on the behaviour of the system is stored in the structure of nodes and interconnections of the map. Relationships between concepts have three possible types;

a) Either Express positive causality between two concepts ($W_{ij} > 0$);

b) Negative causality ($W_{ij} < 0$);

c) No relationship ($W_{ij} = 0$).

The value of W_{ij} indicates how strongly concept C_i influences concept C_j. The sign of W_{ij} indicates whether the relationship between concepts C_i and C_j is direct or inverse.

A new formulation for calculating the values of concepts at each time step, of a Fuzzy Cognitive Map, is proposed:

$$A_i^t = f\left(\sum_{\substack{j=1 \\ j\neq i}}^{n} A_j^{t-1} W_{ji} + A_i^{t-1}\right) \quad (1)$$

Two kinds of threshold functions are used in the Fuzzy Cognitive Map framework, the unipolar sigmoid function, where $\lambda>0$ determines the steepness of the continuous function:

$$f(x) = \frac{1}{1+e^{-\lambda x}} \qquad (2)$$

When nature of concepts can be negative, their values belong to the interval [-1, 1], the following function is used [21]:

$$f(x) = \tanh(x) \qquad (3)$$

These variables are defined by their out degree [od (v_j)] and in degree [id (v_j)].Out degree is the row sum of absolute values of a variables in the adjacency matrix and shows the cumulative strengths of connections (a_{ij}) exiting the variable [21].

$$od(v_j) = \sum_{k=1}^{N} w_{jk} \qquad (4)$$

Indegree is the column sum of absolute values of a variable and shows the cumulative strength of variables entering the unit [21].

$$id(v_j) = \sum_{k=1}^{N} w_{kj} \qquad (5)$$

The immediate domain of a variable is the summation of its indegree (inarrows) and outdegree (outarrows) also called centrality.

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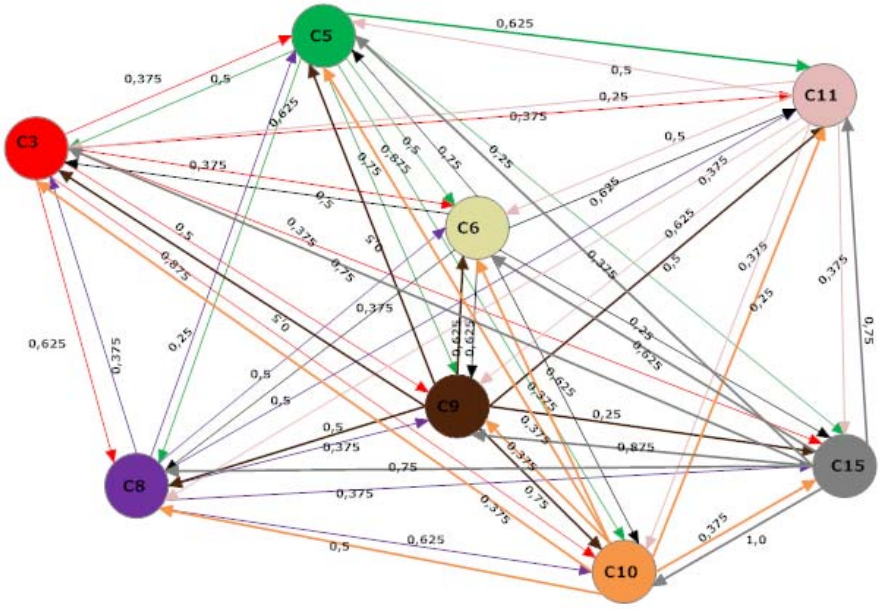

Fig. 1.Fuzzy Cognitive Map Designed

The contribution of a variable in a cognitive map can be depicted by calculating its centrality (c) to finde whether it is a transmitter, receiver or ordinary variable. The centrality (c) of a variable is also called its total degree [td(vi)][21]:

$$c_i = td(v_i) = od(v_i) + id(v_i) \quad (6)$$

FCMs have these specific advantageous characteristics:

- FCMs capture more information in the relationships between concepts.
- FCMs are dynamic.
- FCMs express hidden relationships.
- FCMs are combinable.
- FCMs are tuneable [9].

In literature FCMs are used in different areas. Peláez and Bowles [5] provide a new strategy for predicting failure effects in a complex system by using FCM. Kardaras and Mentzas [15] propose a FCM to model and analyse the business performance. Tseng et al.[19]developed a two-step fuzzy cognitive mapping method in their study. Chen et al. [4] work on academic papers to apply text mining, and then formed a fuzzy cognitive map. Dimitris [6] extends the existing fuzzy cognitive map (FCM) for medical decision making process.

IV. Case Study

In this section, we use the expert-based methods for developing FCM. These methods usually consist of three steps [12]:

1. Identification of important concepts;
2. Identification of causal relationships among the concepts;
3. Estimation of the strength of the causal relationships.

In order to describe the relationship between a university and the region in which the University is located, it is necessary to apply indicators. Furthermore, the intensity of the relation is measured through this indicator. In the first step, the concepts affecting the university's contribution to regional development are determined. In determining concepts, a literature survey is run and validated through interviews with the experts.

Each relationship between these consepts is expressed by a real number I= [-1, 1] [12] interval. The value of 0 denotes no relationship and is implicitly assigned at the end of the second step. Higher absolute values represent stronger relationships, whereas the sign defines the type: *promoting* (positive numbers) or *inhibiting* (negative numbers). [18]

In second step; causal relationships among these concepts are identified through interviews. We ran the survey with four experts. They describe each relationship by means of linguistic terms, e.g. *weak, medium, strong* and *very strong.* Then *we* map the linguistic terms to numerical values, e.g. *weak* to 0.25, *medium* to 0.5, *strong* to 0.75, and *very strong* to 1.0. Assuming no additional information on the credibility of individual experts or assuming that all experts are equally credible, the simplest method for combining the maps is to calculate average of each relationship weight across all experts [18].Therefore, for *k* experts, the connection matrix of the final FCM is established by the following expression [13]:

$$E = \frac{1}{k}(E_1 + E_2 + ... + E_k) \quad (7)$$

This basic formula can be easily modified to accommodate credibility of different experts by assigned a weight w_i that quantifies credibility of the *i* th expert. These weights take value from [0, 1] range and their sum

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is usually normalized, that is. The final, combined model is calculated using the following weighted average [18]:

$$E = \frac{1}{\sum_{i=1}^{k} w_i}(w_1E_1 + w_2E_2 + ... + w_kE_k) \quad (8)$$

For combining the maps, we calculate the average of each relationship weight across all experts who have the same credibility. We use formula (8). After calculations importance measure of the concepts can be seen in Table II.

TABLE II
Rank of The Concepts

Concept	Centrality
C1	12,25
C2	12,5
C3	13,75
C4	12,88
C5	14,38
C6:	14
C7	10,25
C8	14,25
C9	16,13
C10	15,63
C11	14,25
C12	7,5
C13	9,5
C14	11,75
C15	14,38
C16	7,75
C17	11,63

From Table II, the most important concept is found as C9 (*University-Industry Cooperation level)* and the second one is C10 (*Number of projects which are developed by the university).*

The sequence of concepts in importance shows us the most important factors for designing the model. These concepts are C3(*number of researchers* that university has.), C5(*skills level of regional labour force)*, C6 *(the inclusion level of regional work force on research and projects)*, C8 (Teaching and research potential of the region to be addressed as an issue), C9 *(university-industry cooperation level)*, C10(*number of projects which are developed by the university)*, C11*(applicability level of the developed projects)*, and C15 *(the amount of the university's support for projects)*. Fuzzy Cognitive Map is drawn from these important concepts and it can be seen in Fig.1.

It is shown in the map that university-business cooperation is the most important factor causing effects on the others.

V. CONCLUSION

This study is realized to evaluate the importance and relations of criteria influencing the University contributions in regional development of its vicinity.

The case study is run in Kirikkale and it is found that collaboration with the business world, inclusion of the regional workforce in research projects, teaching proportions are important factors for Kirikkale region.

Kirikkale University should focus on the cooperation with the regional business in order to have some positive influence. This is a region where the University can contribute a lot as long as they can collaborate with the regional business centres.

The University- Business collaboration will be the centre of focus for further studies. Policy designs are to be handled both sided: from the industry and from the University. This research will be continued to work on scenarios for regional development with the collaborative effort.

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