METHODOLOGICAL STRUCTURE FOR THE AGGREGATION OF MUNICIPALITIES UNDER UNCERTAINTY CONDITIONS. THE CASE OF MICHOACÁN, MÉXICO

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ABSTRACT.

Through the last years, there has been an increasing interest for accelerating the economical, social and environmental development of cities through associations, organization and creation of synergies. Our investigation pretends to apply administration models for the analysis and treatment of variables, combinatory processes and affinity models, which could find the most similar municipalities of one region. The results obtained by this study pretend to support projects in order to increase the regional development of the Latin-American State of Michoacán, México. Through the model, process and results we look forward to offer a strategic proposal for associations between similar municipalities, by doing this action, we try to fill the gap that is found in the field of analysing the present frames of associations, which are mainly driven by empirical decisions. In order to achieve this task we will use tools for the treatment of fuzzy sets theory, evaluating related elements and finding similarities between municipalities under the Pichat algorithm.

Keywords: Fuzzy logic, Pichat algorithm, creative process, regional development, creative cities.

RESUMEN.

A través de los últimos años, ha habido un creciente interés por acelerar el desarrollo económico, social y ambiental de las ciudades a través de las asociaciones, la organización y la creación de sinergias. Nuestra

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investigación pretende aplicar modelos de gestión para el análisis y tratamiento de las variables, procesos combinatorios y modelos de afinidad, que podrían encontrar los municipios más similares de una región. Los resultados obtenidos por este estudio pretenden apoyar proyectos con el fin de incrementar el desarrollo regional del estado de Michoacán, México. A través del modelo, el proceso y los resultados esperamos poder ofrecer una propuesta estratégica para las asociaciones entre municipios similares; al hacer esta acción, tratamos de llenar el vacío que se encuentra en el campo de análisis de los marcos actuales de las asociaciones, que se debe principalmente por las decisiones empíricas. Para lograr esta tarea vamos a utilizar herramientas para el tratamiento de la teoría de conjuntos difusos, la evaluación de los elementos relacionados y encontrar similitudes entre los municipios bajo el algoritmo Pichat.

Palabras clave: Lógica difusa, algoritmo Pichat, proceso de creación, desarrollo regional, ciudades creativas.

Clasificación JEL: C15, C65, C67.

1. INTRODUCTION.

The investigation about the regional development of the State of Michoacán de Ocampo grows from the profound changes that the emergent economies have suffered in present years. It is in this complex reality, where different factors such as globalisation, open markets, creative economies, and innovation play different roles in the development of cities and regions; therefore the adoption of decisions under uncertainty has gained special relevance. These kinds of studies and research have been increasing since the last century, and have proven efficacy while dealing with complex phenomena.

In relation to the theory of decision under uncertainty, the investigation initializes with the theory of Fuzzy Sets (Zadeh, 1965), with the appearance of the article "Fuzzy sets. Information and Control", made by the professor Lofti Zadeh, instructor at the University of Berkeley. The theory of Fuzzy Sets has been applied in the field of the formal sciences, but in the past 43 years, researchers from all around the world have been publishing many research studies with applications in diverse fields of knowledge.

The intention of this work is to classify and group, with a certain level of significance, different municipalities of the State of Michoacán

de Ocampo, which could by the association, organization and creation of synergies, increase their competitiveness as a whole. The method to classify and group these municipalities will have as a basis the known Pichat Algorithm (Pichat, 1970), and the theory of fuzzy sets. These approximations allow us to create a generalized model adapted to the conditions of expectancy and instability.

2. PRELIMINARIES.

This section tries to engage the reader in the general aspects of this study. In order to do so, we introduce some aspects of the origins of the theories that support our investigation, basic description of the region in which our investigation is oriented, municipalities in which we will focus attention and the methodology that we will follow through our research.

2.1 Origins.

The origins of this study rely on the importance and relevance that emerging economies thus, emergent cities are exhibiting. Moreover the positive impact which studies in Regions and Mega Regions present, in which finding the connections, relations, and similarities that exist between some cities could generate synergies and raise the level of competitiveness of the cities. These efforts in organization and synergy should exert benefits in the economical, social and environmental realm by producing greater effects than the sum of the individual efforts of the cities.

In the publication "The Creative Cities" Florida (2008) the concept of region and mega – region is described as a "new natural economical unit: it is not an artifact of political frontiers, such as the concept of State – Nation or their provinces, but the product of the concentration of innovation centers, production and consumer markets." He also explains the technical considerations of the mega – region, which has to be an area of contiguous light with more than one city or important metropolitan region and produce more than 100,000 million of dollars in terms of LRP (Light Regional Production).

In the article "Cities and Competitiveness" (Begg, 1999) the concept of *competitiveness* and its relationship with the city is analyzed. As the author describes, there are different definitions related to the concept, but what is a fact is that "the capacity of a city to compete is made by the connections between attributes of localization, strengths and weaknesses

of the enterprises that reside in it". This idea leads us to understand the link that unifies the competitiveness of a city and starts the discussion of knowing and finding the differentials that because the diverse capacity of growth, which has been shown, varies among cities.

In this investigation we maintain an approach to these theories, which will lead us to obtain the variables that will be used to formulate the model and sustain our results; we now proceed to present the studied region.

2.2 Studied Region.

32 States integrate the United Mexican States, 31 of them are free and sovereign entities, which have the right of having an own constitution and legislative powers. The last State is the federal District territory under the share dominance of the Mexican Federation and the local government entities.

The State of Michoacán de Ocampo occupies the 3.0% of the National territory with a surface of 58,599 km^2, it has a total population of 4,351,037 habitants from which 2,248928 are women, and 2,102,109 are men. The State presents a distribution of 69% of urban locations and 31% of rural locations. In terms of schooling it is observed that from every 100 people: 10.7 do not have access to education, 61.8 have the primary education, 0.4 have a technical or commercial primary school, 4.8 have finalized the high school, 11.8 have concluded university, and 0.5 is not specified. In the State 92% of the population is considered catholic, less than 3% of the population speaks a native language. In 2010 there were 1,066,061 private homes, from which: 87.7%, have access to potable water, 88.6%, have access to drainage 98.0% counts with electricity. The main economic indicators present that the State provides 2.5 % to the GDP being the activity of commerce the most relevant one, the primary sector provides 11.27% of the State GDP, the secondary activities provide the 19.97% to the State GDP and the third sector of economic activities provide 68.76% to the State GDP.

2.3 Municipalities.

In this study we will take 12 of the whole 113 municipalities that the studied region concentrate, we chose these municipalities due to the level of economical importance and the amount of people that reside in them. Almost 50% of the total population of the State lives in these 12 municipalities; therefore the importance of these localities and the interest in focus our attention on them. It is important to mention that this study

can be expanded and could in further research add more cities to advance in the knowledge of synergies that could be applied in the whole region.

The municipalities chosen to be analyzed in our methodology are: Morelia, Uruapan, Zamora, Lázaro Cárdenas, Zitácuaro, Apatzingán, Hidalgo, La Piedad, Pátzcuaro, Maravatío, Tarímbaro and Zacapu.

Each of the municipalities chosen present different attributes, culture, population, economical drivers, education levels, etc. Those attributes are precisely what we need to analyze in order to obtain the most affine cities, and the possible connections that could raise the competitiveness of them.

2.4 Methodology.

Due to the complexity of the nature that we are trying to analyze, the use of the fuzzy sets theory and the theory of affinities are approaches that in general terms will lead our investigation. The methodology that will be employed in order to obtain the affinity between the municipalities chosen will be:

2.4.1 Acquisition of variables.

In general terms are the proposition of variables that are relevant to each municipality; these variables concentrate economical, social, cultural, political and environmental data which gives a general overview of the city and its main drivers. The variables chosen are presented in section 3 of this study.

2.4.2 Measurement of the municipalities regarding the variables found.

Each municipality due to its inherent characteristics will be evaluated through a linguistic tag between 0 and 1 in which:

1, 0: Excellent performance.
0, 9: Great performance.
0, 8: Really good performance.
0, 7: Good performance.
0, 6: Rather a better tan a poor performance.
0, 5: Nor a good or poor performance.
0, 4: Rather a poor tan a good performance.
0, 3: Poor performance.
0, 2: Really poor performance.
0, 1: Worst performance.
0, 0: Disastrous performance.

2.4.3 Finding distances between municipalities.
In this analysis we will use a whether known concept: Hamming's relative distance. In order to obtain Hamming's relative distance between two sets of fuzzy sets, the general procedure is to subtract the existent levels in each criteria, add those differences in absolute values and divide the sum by the number of criteria chosen, so the final result would be numbers between 0 and 1.

$$\delta(\tilde{A}, \tilde{B}) = \sum_{i=1}^{n} |\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)$$

$$donde\ x_i \in X, \forall i = 1, \dots, n\ y\ 0 \leq d(\tilde{A}, \tilde{B}) \leq n$$

2.4.4 Matrix of Distances.
With the results obtained by the Hamming's relative distance, we now proceed to create a matrix in which the symmetrical and anti-reflexive relationship between the elements is stated.

2.4.5 Matrix of similarities.
In this step we create another matrix known as the similarity relationship, in which we just state the complementarily to the unit of the matrix of differences.

2.4.6 Maximum similarity associations: Pichat Algorithm.
In order to get the maximum similarity associations we will use the Pichat Algorithm (Pichat, 1970). The main products of the Pichat Algorithm are sub-matrixes, which allow us to identify the main groups of entities that reveal the greater similarities. These are the main steps to follow:

a) The starting point comes from the existence or creation of a Boolean relation of similarity.
b) From that relation (matrix) we consider only the part above the main diagonal.
c) From the matrix we only take into account the zeros in each line, multiplying the elements from those columns in which zeros are presented. Then we proceed to make a Boolean addition of the element from the line with the last product.
d) The additions have to follow the next rules: the process excludes the lines without zeros. During the process of addition, whether in the

sum appears an element in two terms and one of those is isolated, the addition is substituted by the element.
Therefore: $a + abc = a\ (because\ a + abc = a(1 + bc) = a \cdot 1 = a)$.

e) Finally we get an addition of elements. For each one it is necessary to obtain the complementary element in relation to the reference of elements. Each of those complementary elements is the maximum sub-matrixes of similarity.

2.4.7 Aggregation and Results.
The final step in our methodology is the process of making groups out of the similar municipalities and obtaining results, these results have to be explained and get into context.

3. PROPOSED VARIABLES.

In this section we state the variables that will be used in our methodology, all of the variables were chosen to create a basis in which they reflected the reality in different aspects of the municipality. As we stated in the methodology they were evaluated from 0 to 1, and it is necessary to mention that the evaluation was supported data collected from the National Database of Statistics and regional plans of development from the municipalities. It is important to mention that these variables are not exhaustive and they have been treated with the same level of importance, we are presently working on further investigation, in which the nature of the variables and the importance of them affect, and apply certain weights in the model.

3.1 Introduced Variables.

3.1.1 Integration of the Population:
The level in which the population of the city is merged. Whether the integration is higher, the better evaluation gets. This index comprehends elements like: Native population, level of immigrants, number of religions, and digital centers of integration.

3.1.2 Infrastructures of the city.
The level in which the infrastructure of the city provides support to the communities. This index comprehends elements like: Number of schools, hospitals, health centers, sport units, airports, highways, post offices, railroads, ports, toll free roads, and telecommunication centers.

3.1.3 Public Services.
The level in which the municipalities offer public services, the major coverage of the services the better level. This index comprehends elements like: percentage of coverage of electricity, water and drainage.

3.1.4 Tourism.
The level in which the city attracts and provides services for tourists. This index comprehends elements like: Touristic centers, tourists attracted crafts, and local festivities.

3.1.5 Recreation.
The level in which the city provides special zones for the people to make sports, recreational activities and creative zones. This index comprehends elements like: Number of stadiums, sport clubs, cultural houses, museums, parks.

3.1.6 Political alternation.
The level in which the Political party is changed from period to period in the last 5 periods. The major changes give a higher index.

3.1.7 Education.
The level in which the community enhances education policies. This index comprehends elements like: percentage of the population with a bachelor's degree, percentage of the population with a postgraduate degree, level of literacy, number of teachers and amount of schools and universities in the location.

3.1.8 Active population.
The level in which the population is inserted in economical activities, as a percentage of the whole working force of the location.

3.1.9 Minimum wage.
Percentage of the population that aspires for more than 2 minimum wages per day of labor.

3.1.10 Marginality.
Level in which the community is catalogued as a marginal zone or not.

3.1.11 Economy of the zone.
Level in which the economical drivers of the city relies on the first, second or third economic units.

3.1.12 Technology.
Level in which the community utilizes and develops technology. This index comprehends elements like: Number of high technology industries, number of patents registered.

3.1.13 Human development index.
The level in which the UNCTAD catalogues the HDI for each municipality.

3.1.14 Security.
The level in which the security is perceived in the locality. This index comprehends elements like: number of offenses presented in the municipality, rate of people with a condemnatory sentence.

3.2 Evaluation Matrix.

In this section we present the evaluation matrix, in which we assigned levels between 0 and 1 to the different municipalities and for the different variables that we stated before. This process is explained in step 2.4.2 of our methodology. The results we obtained are the next ones:

	Integration	Infraestructure	Public Services	Tourism	Recreation	Political Alternance	Education	Active Population
Morelia	0.8	0.9	0.8	1	1	0.8	0.9	1
Uruapan	0.8	0.7	0.6	0.8	0.4	0.3	0.8	0.8
Zamora	0.4	0.4	0.7	0.4	0.1	0.3	0.5	0.8
Lázaro Cárdenas	0.7	0.6	0.4	0.5	0.3	0.3	0.6	0.8
Zitácuaro	0.8	0.4	0.2	0.2	0.1	1	0.6	0.3
Apatzingán	0.4	0.3	0.8	0.3	0.3	0.3	0.2	0.8
Hidalgo	0.4	0.3	0.3	0.4	0.1	0.3	0.3	0.3
La Piedad	0.3	0.3	0.9	0.4	0.1	0.1	0.4	0.8
Pátzcuaro	0.4	0.3	0.3	0.8	0.1	0.3	0.4	0.3
Maravatío	0.3	0.3	0.2	0.3	0.1	0.3	0.2	0.1
Tarímbaro	0.1	0.3	0.8	0.1	0.1	1	0.2	0.3
Zacapu	0.4	0.3	0.8	0.4	0.1	1	0.3	0.3

Source: Authors.

	Minimum Wage	Marginality	Primary Sector	Secondary Sector	Third Sector	Technology	HDI	Security
Morelia	0.8	1	0.1	0.3	1	0.8	1	0.6
Uruapan	0.8	1	0.3	0.3	0.8	0.3	0.7	0.7
Zamora	0.8	0.8	0.8	0.3	0.8	0.1	0.7	0.7
Lázaro Cárdenas	1	0.8	0.3	0.8	0.8	0.9	0.8	0.8
Zitácuaro	0.3	0.1	0.8	0.3	0.3	0.8	0.3	0.8
Apatzingán	0.8	0.3	0.8	0.1	0.8	0.1	0.3	0.7
Hidalgo	0.3	0.1	0.3	1	0.3	0.1	0.3	0.6
La Piedad	0.8	0.8	0.3	0.8	0.8	0.8	0.8	0.6
Pátzcuaro	0.3	0.3	0.3	0.8	0.8	0.3	0.3	0.6
Maravatío	0	0.1	1	0.3	0.3	0.3	0.2	0.8
Tarímbaro	0.3	0.1	0.8	0.3	0.1	0.1	0.3	0.7
Zacapu	0.8	0.8	0.3	0.8	0.8	0.8	0.8	0.7

Source: Authors.

4. PROCEDURE.

In this section we introduce the models and matrixes we obtained following the steps mentioned in the methodology in order to identify the affinities between the municipalities we chose. All of the next are results from working the evaluation matrix.

4.1 Distances matrix.

Applying the Hamming relative distance stated in step 4.2.3 of our methodology, we obtain:

	Morelia	Uruapan	Zamora	Lázaro Cárdenas	Zitácuaro	Apatzingán	Hidalgo	La Piedad	Pátzcuaro	Maravatío	Tarímbaro	Zacapu
Morelia	0.00	0.21	0.36	0.30	0.48	0.44	0.58	0.34	0.48	0.64	0.58	0.34
Uruapan	0.21	0.00	0.17	0.17	0.40	0.26	0.38	0.24	0.28	0.43	0.46	0.29
Zamora	0.36	0.17	0.00	0.21	0.33	0.12	0.29	0.16	0.26	0.30	0.29	0.21
Lázaro Cárdenas	0.30	0.17	0.21	0.00	0.36	0.31	0.34	0.15	0.28	0.44	0.50	0.20
Zitácuaro	0.48	0.40	0.33	0.36	0.00	0.33	0.24	0.41	0.28	0.19	0.18	0.31
Apatzingán	0.44	0.26	0.12	0.31	0.33	0.00	0.26	0.24	0.24	0.24	0.22	0.28
Hidalgo	0.58	0.38	0.29	0.34	0.24	0.26	0.00	0.29	0.10	0.18	0.21	0.28
La Piedad	0.34	0.24	0.16	0.15	0.41	0.24	0.29	0.00	0.24	0.40	0.40	0.11
Pátzcuaro	0.48	0.28	0.26	0.28	0.28	0.24	0.10	0.24	0.00	0.23	0.29	0.24
Maravatío	0.64	0.43	0.39	0.44	0.19	0.24	0.18	0.40	0.23	0.00	0.19	0.39
Tarímbaro	0.58	0.46	0.29	0.50	0.18	0.22	0.21	0.40	0.29	0.19	0.00	0.30
Zacapu	0.34	0.29	0.21	0.20	0.31	0.28	0.28	0.11	0.24	0.39	0.30	0.00

Source: Authors.

4.2 Similarity matrix.

Applying the methodology stated in step 4.2.4 of our methodology, we obtain:

	Morelia	Uruapan	Zamora	Lázaro Cárdenas	Zitácuaro	Apatzingán	Hidalgo	La Piedad	Pátzcuaro	Maravatío	Tarímbaro	Zacapu
Morelia	1.00	0.79	0.64	0.70	0.52	0.56	0.43	0.66	0.53	0.36	0.43	0.66
Uruapan	0.79	1.00	0.83	0.83	0.60	0.74	0.62	0.76	0.72	0.57	0.54	0.71
Zamora	0.64	0.83	1.00	0.79	0.67	0.88	0.71	0.84	0.74	0.70	0.71	0.79
Lázaro Cárdenas	0.70	0.83	0.79	1.00	0.64	0.69	0.66	0.85	0.73	0.56	0.50	0.80
Zitácuaro	0.52	0.60	0.67	0.64	1.00	0.68	0.76	0.59	0.72	0.81	0.82	0.69
Apatzingán	0.56	0.74	0.88	0.69	0.68	1.00	0.74	0.76	0.76	0.76	0.78	0.72
Hidalgo	0.43	0.62	0.71	0.66	0.76	0.74	1.00	0.71	0.90	0.83	0.79	0.73
La Piedad	0.66	0.76	0.84	0.85	0.59	0.76	0.71	1.00	0.76	0.60	0.60	0.89
Pátzcuaro	0.53	0.72	0.74	0.73	0.72	0.76	0.90	0.76	1.00	0.78	0.71	0.76
Maravatío	0.36	0.57	0.61	0.56	0.81	0.76	0.83	0.60	0.78	1.00	0.81	0.61
Tarímbaro	0.43	0.54	0.71	0.50	0.82	0.78	0.79	0.60	0.71	0.81	1.00	0.70
Zacapu	0.66	0.71	0.79	0.80	0.69	0.72	0.73	0.89	0.76	0.61	0.70	1.00

Source: Authors.

4.3 Maximum similarity associations: Pichat's Algorithm.

Continuing with our methodology we now proceed to generate the Algorithm using a significance level of = 0.70, this means we will take as part of the procedure only those elements in the similarity matrix, which

exceed the 0.70. We then obtain the next binary matrix:

	a	b	c	d	e	f	g	h	i	j	k	l
a	1	1	0	0	0	0	0	0	0	0	0	0
b		1	1	1	0	1	0	1	1	0	0	1
c			1	1	0	1	1	1	1	0	1	1
d				1	0	0	0	1	1	0	0	1
e					1	0	1	0	1	1	1	0
f						1	1	1	1	1	1	1
g							1	1	1	1	1	1
h								1	1	0	0	1
i									1	1	1	1
j										1	1	0
k											1	0
l												1

Source: Authors.

We proceed to develop the algorithm and the next equation as we stated in the methodology.

$$S = (a+bcdefghijkl) \cdot (b+egjk) \cdot (c+ej) \cdot (d+efgjk) \cdot (e+fhl) \cdot (h+jk) \cdot (j+l) \cdot (k+l)$$

We obtain the next aggrupation:

$$S' = fgi + ab + egi + cfghi + bcfhi + bcdhi + cfgik + fgijk + egijk$$

As a way to ascertain the results obtained before we now present the sub –matrixes of each association, in which is easy to observe that all the elements inside are above the level of significance of = 0.70.

	f	g	i
f	1	0.74	0.76
g		1	0.90
i			1

	a	b
b	1	0.79
b		1

	e	g	i
e	1	0.76	0.72
g		1	0.90
i			1

	c	f	g	h	i
c	1	0.88	0.71	0.84	0.74
f		1	0.74	0.76	0.76
g			1	0.71	0.90
h				1	0.76
i					1

	b	c	f	h	i
b	1	0.83	0.74	0.76	0.72
c		1	0.88	0.84	0.74
f			1	0.76	0.76
h				1	0.76
i					1

	b	c	d	h	i
b	1	0.83	0.83	0.76	0.72
c		1	0.79	0.84	0.74
d			1	0.85	0.73
h				1	0.76
i					1

	c	f	g	i	k
c	1	0.88	0.71	0.74	0.71
f		1	0.74	0.76	0.78
g			1	0.90	0.79
i				1	0.71
k					1

	f	g	i	j	k
f	1	0.74	0.76	0.76	0.78
g		1	0.90	0.83	0.79
i			1	0.78	0.71
j				1	0.81
k					1

	e	g	i	j	k
e	1	0.76	0.72	0.81	0.82
g		1	0.90	0.83	0.79
i			1	0.78	0.71
j				1	0.81
k					1

Source: Authors.

4.4 Aggregation and results.

Consequently to the results of the Pichat algorithm, the most similar municipalities in the State of Michoacán, México are aggregated as follows:

1) (f, g, i): Apatzingán, Hidalgo, Pátzcuaro.
2) (a, b): Morelia, Uruapan.
3) (e, g, i): Zitácuaro, Hidalgo, Pátzcuaro.
4) (c, f, g, h, i): Zamora, Apatzingán, Hidalgo, La Piedad, Pátzcuaro.
5) (b, c, f, h i): Uruapan, Zamora, Apatzingán La Piedad, Pátzcuaro.
6) (b, c, d, h, i): Uruapan, Zamora, Lázaro Cárdenas La Piedad, Pátzcuaro.
7) (c, f, g, i, k): Zamora, Apatzingán, Hidalgo, Maravatío, Tarímbaro.
8) (f, g, i, j, k): Apatzingán, Hidalgo, Pátzcuaro, Maravatio, Tarímbaro.
9) (e, g, i, j, k): Zitácuaro, Hidalgo, Pátzcuaro, Maravatío, Tarímbaro.

These municipalities have shown high affinity under the variables proposed. We can assure with a high level of statistical certainty that they share common aspects which could be used in order to create synergies between them, although further research is been developing in the creation of different scenarios in which their affinities could be linked and aid the growth of economical, social and environmental sectors, therefore this research pretends to be leverage for further analyses.

5. CONCLUSIONS.

Through the process and methodology stated in this study, we have obtained the most similar municipalities that share common factors, by associating, organizing and creating synergies between these municipalities the State of Michoacán de Ocampo, could increase the probability of success in major plans that associate different relative elements. By knowing the most affine municipalities, the State should be able to target specific resources to promote positive social and economical development to the region. This analysis contributes to the improvement of emergent city's economies and could be replicated in similar regions to associate different municipalities and increase the benefits of programs, plans and projects of the State.

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