Technology and Innovation in Organizations Using Fuzzy Systems

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Abstract **– The economic importance of SMEs in the world is transcendental, since the union of their local profits generates global benefits; however, managers do not know how to visualize their problems to implement automated processes. There are solutions on the market, but they are expensive and with unnecessary modules that are not useful for SME leaders. Systems based on fuzzy models provide technology that allows, through Fuzzy Cognitive Maps (FCMs synthesizing problems and show solution strategies; In this case, the problems became Items in an FCM to simulate the entry and exit of causes and effects in the company, converted into proposals for automated processes.**

Keywords **– SMEs, Fuzzy Cognitive Maps, fuzzy models.**

1. Introduction

In the productive world, companies are classified taking into account different aspects; due to the magnitude of their size, they are classified as large, medium, and small.

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This classification is made by each country according to the parameters defined by their governments, the main indicator, commonly, is the number of employees; For example, for small companies in Tanzania they are 20, Vietnam 300, several economies consider them with 10 employees, as is the case in Nicaragua and Ghana [10].

In Mexico, [8] classifies as shown in graph the figure 1.

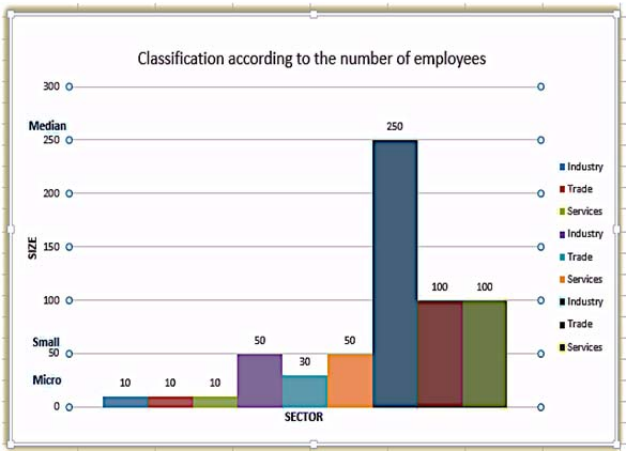

Figure 1. Classification of companies in Mexico [8].

99% of SMEs contribute 61% of formal employment and 25% of the production of goods and services, according to data published by [4].

In other parts of the world, they are also important; in Spain, they encompass more than 95% of companies and generate more than 90% of employment, but they have been the most affected by the effects produced by the COVID-19 pandemic [14].

The International Labor Organization stipulates that in 99 countries from which data has been collected, 70 percent of total employment is generated by micro-enterprises [9]; in addition, in some countries, SMEs are important generators of employment throughout the world, positively impacting the well being of the poorest households, Vial and Hanoteau, 2015, mentioned in [1].

The accelerated advance of technology has converged to the transformation of production processes, administration, and management of manufacturing and service companies, specifically large ones; although this has not happened in SMEs, because according to [24], there are 80% of SMEs in the world that have not been digitized and although Covid has channeled companies to digitization, it has not yet been achieved mostly; this generates a problem of inequality linked to the existing productivity gaps between large companies and SMEs [4].

To the International Labor Organization, "ILO" microenterprises arise from an entrepreneurial project formed by the entrepreneur who is also the administrator, whose education in most cases is low. Companies that sell products in small quantities and that do not require large investments to function; instead, skilled and talented individuals have access to the formal financing needed to open a larger business [2].

The lack of automated processes in SMEs leads to common disorganization in their production, administrative, and management processes. In this aspect, microenterprises, due to their characteristics, do not take into account the implementation of technology, which results in a short development and little life of the companies within of the industry [11].

On the contrary, for large companies, where they have historically had an advantage over their smaller competitors vague they can afford to do a lot of things in-house, then doing business in-house makes them serve their customers better [19].

The main problem of this inequality that generates more economic resources in large companies than in small ones is the incorporation of technology in companies.

Small and medium-sized companies need to apply technology that improves their business, but they do not know what type of software or hardware they need to do it. Considering that they generate a large part of the economic benefits, this could be detrimental to the economy of their countries [25].

To help companies in the incorporation of their automated processes, there are technological resources that help large organizations and that could remedy these deficiencies of digital resources in small and medium-sized ones; they are called Enterprise Resource Planning Systems "ERP".

ERPs are systems that produce information as a result of the interaction between data, people, procedures, and resources [13] and, that are efficient in the acquisition, elaboration, and communication of information.

There are ERPs for managing logistics, inventories, production, accounting, marketing, or customer relations; all with the idea of offering companies what they need in that specific area quickly and efficiently [17].

ERPs are information systems dedicated to specific areas and would be very useful to companies; however, they need tools that lead to a transformation towards solutions that include complex tasks. The challenge for companies is that with the implementation of technology, they can be competitive and, at the same time, manage all the technical aspects they require [16].

The problem with commercially available ERPs is that they are complexly large and contain various modules that, depending on the line of business, can be used all or only some; but in general, the price of ERPs is high, which represents a problem for the acquisition of this by SMEs, since they generally range between 35 to 50 thousand dollars.

However, as has already been mentioned, the managers of small and medium-sized companies do not know what type of software their company needs, and considering that ERPs have components that they would not be interested in having; buying an ERP for your business would generate a waste of investment.

ERP systems can also be created with certain characteristics according to the needs of companies; however, the problem is that the managers of SMEs do not know how to solve the problems they have and even less the type of technology they must acquire, they even do not perceive the problem or the area of their company where it is generated.

To know the problems that a company has, as well as to propose solutions, a method is required that allows concretely visualizing the information, showing the benefits that certain actions can give according to their importance.

Fuzzy model-based systems can be applied to different social aspects and are very effective for presenting summary information; they efficiently solve many problems from different approaches, which supports decision making, time series forecasting, system control, pattern classification, and more [23].

This research used decision support to give a vision of the problems summarized in a fuzzy cognitive map (FCM), which shows the decisions that the person who runs the company must make, giving each decision a weight according to its importance.

An FCM integrates with different sources of knowledge, where the concepts are related to each other, providing new knowledge [15].

The FCM is a system that is suitable for decision making, whose usefulness, given in the modeling of decision making for different areas, for example: for recognition patterns, in risk analysis and crisis

management, as a support tool for decision-making decisions, to model an underwater virtual world of dolphins, fish, and sharks, for socio-economic development planning, and to support the decision-making process for photovoltaic solar energy sector development, numerical and linguistic forecasting, among others [18].

To confirm that they can be applied to the management of any type of manufacturing company, the study was carried out on 2 companies that manufacture different products, analyzing their problems and generating improvement strategies; this was implemented in a system based on Fuzzy-type models implemented with cognitive maps.

The first company is called Gamma, a medium-sized company dedicated to the production of metal furniture with cutting-edge engineering; This manufacturer has had an upward growth of 30 years and throughout its history, it has established itself as a company that produces high-quality products.

Protexjd is a small company dedicated to manufacturing uniforms for commercial companies and has one year of experience in the field.

The study was carried out using a fuzzy simulator that is trained with items that represent the problems of the companies concerning the implementation of the technology, as well as items with proposed solutions; this method details the benefits of using the different types of the technology proposed by the model.

The results obtained from the fuzzy type simulators of the two companies were compared to determine if the methodology works for different types of companies or even for different types of problems where cause strategies are required to obtain certain effects.

2. Background

SMEs should know the type of technology they need to run their business effectively and generate improvement strategies; this generates conflict because the leaders of these companies usually do not know why, how and for what, the use of these technologies.

SMEs do not have a reliable innovation culture or lack policies that support this technological implementation, that is, these companies know that the technology exists, but they do not know which one is suitable for each area of their company. The characteristics of the study companies were as follows:

The company "Gamma" makes various items in the category of metal shelves, designed in various sizes and appropriate to the needs of warehouses, businesses or companies.

The company is medium-sized and currently has 60 people in its human resources. Their areas of work are the following: warehouse, sales, production, finance, and human resources. Its manufacturing process is displayed in figure 2.

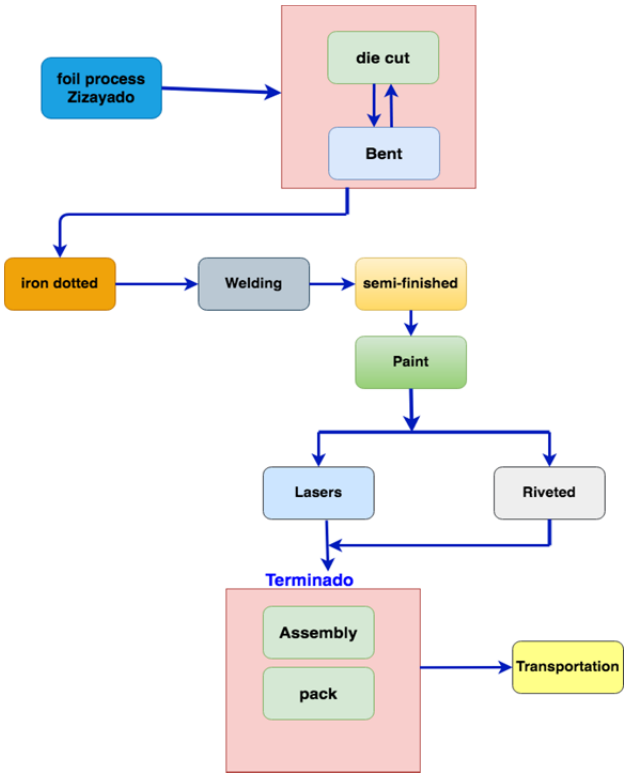

Figure 2. Gamma Company, manufacturing process

The second company under analysis is dedicated to the manufacture of uniforms and is called "Protexjd", this company currently has 15 people in its human resources and manages the following areas: warehouse, production, finance, and human resources. The company's manufacturing is based on the process in Figure 3.

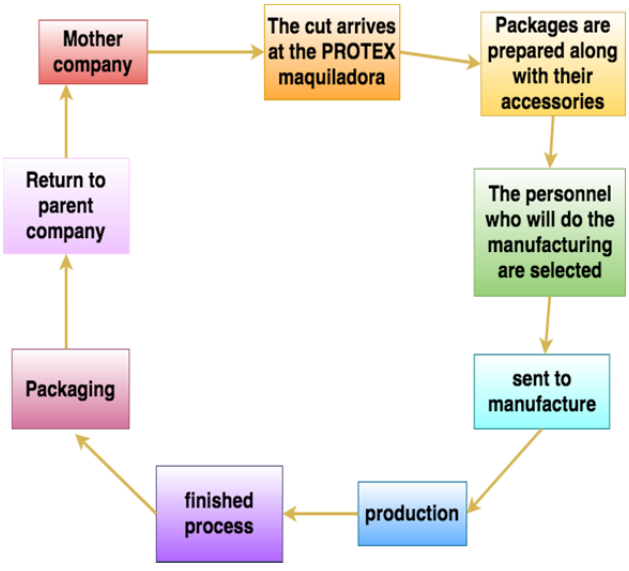

Figure 3. The manufacturing process of the Protexjd Company

The model used for the analysis and determination of improvement strategies in terms of technology implementation was supported by Zadeh's theory based on Fuzzy models [21], whose fuzzy sets have components that may belong to them to varying degrees, of belonging, which helps the model to conceptualize itself as the real world does.

Concepts such as low income or high inflation, or high or low error, are examples in which artificial quantification makes them restrictive; in a fuzzy set the opposite happens, it assigns to its elements several degrees of membership.

The so-called "membership function" quantifies different degrees of membership. Membership level is measured by the degree of membership of an element in a set. The degree of membership is satisfied when the level of membership is closer to 1 since the variance is between 0 and 1 and due to its smoothness and concise notation, the Gaussian membership function is more popular to solve problems based on fuzzy models [22].

The "fuzzy theory" uses sets that do not have a specific limit, since they have elements that belong to it (grade 1) and/or that do not belong to it (grade 0) [5].

To implement the theory of fuzzy models in the research, FCM fuzzy cognitive maps were used, which offer a transparent representation of relationships between objects; their rules do not have representativeness and exhaustiveness, which makes them suitable for the description of typical relationships of chained rules and closed loops. The FCM nodes are represented in a knowledge matrix to which weights are assigned; an FCM with its corresponding matrix is the one shown in figure 4.

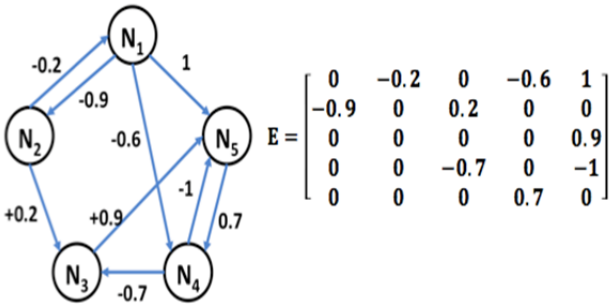

Figure 4. FCM and table of knowledge

The foundation of the FCM model was the tuple (C, W, A, f) given by [7]; its elements are the following:

C = set of concepts.
W: weight matrix with its intensity signs
A: function that calculates the degree of activation of the concepts.
f: transfer function.

3. Materials and Methods

For the analysis and obtaining the strategies, the following steps were carried out:

a. The problems of the companies were determined.
b. From the common words, the nodes that would serve as input and output items in the FCM of each company were obtained.
c. From the FCM, the knowledge matrix was established, based on the values that each expert applied to the node transitions, depending on the importance that each action represented for each company.
d. The behavior of each company with input hypotheses and output behaviors were simulated in a system, obtaining the strategies at the moment in which the output values of the knowledge matrix no longer showed changes.

The application of the methodology is broken down below:

a. Business Problems

In the Gamma Company, the problems were the following:

1. Work orders do not have a correct check-in and checkout sequence, leading to delivery issues.
2. There is no production delivery time because there is no control of the manufacturing process of each order.
3. The delivery of materials is not related to those that must be used in the work orders, which causes the necessary material does not match the material used.
4. There is no stock in the inventories, derived from the lack of efficient control in them.
5. The training of the personnel is not uniform, which causes delays in the work due to the absence of some workers.
6. Lack of planning for the acquisition of machinery speeds up some processes but causes a bottleneck in others, which increases the cost of the manufacturing process.
7. They do not have a perception of the economic benefits that the company is granting that gives them a vision of what they have or what they lose.
8. It does not have an organization chart that allows following a line of orders or planning of activities.

The problems of the Protexjd Company were the following:

1. There is no inventory of the garments, nor of the inputs, nor the outputs of material; In addition, there is no system that indicates the problem for which some garments were not sent, this

generates debts from the Protexjd Company to the main company, in addition, not knowing where the missing pieces or products are.
2. The maquiladoras are not given production specifications, they are only explained and are allowed to see the sample garment and trust that it will be saved in their memory, which leads to manufacturing errors that have to be corrected and that generates waste of material and more production time.
3. There are many similar products, but the manufacture of the product is not constant, so, since the characteristics of the skills of each manufacturer are not stored, the work is distributed to them without taking them into account, which does not allow them to do a better job and much quicker.
4. Production monitoring is not carried out to know where the garments are, who has delivered them, and/or how many each worker has; this causes losses of material, money, and even products.
5. Each product must have a series of specifications, but there is no stored file for each model, which means that when it is remade, it has to be analyzed again through the garment already made or what they remember about the design.
6. Staff training is not uniform, leading to work backlogs.
7. There is no monitoring of the flow of perceptions.

As can be seen, most of the problems are concentrated in the administration and production processes, which became the items in the FCM.

b. Fuzzy Cognitive Map

The input and output variables are set in an FCM.

The input variables become the cause of the problem and the output variables will be the effect of the solution; all are visualized as nodes on a cognitive map.

The FCM of each company is observed in figures 5 and 6.

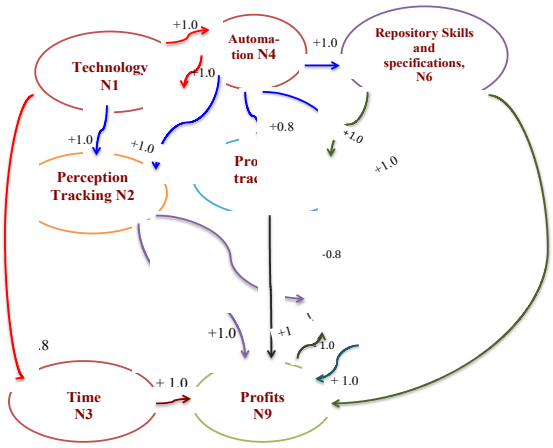

Figure 6. Protexjd Company FCM

c. Knowledge matrix

To analyze a set of fuzzy elements, it is done in a fuzzy matrix, which is made up of elements that are related to the attributes of the object of study and their relationships are classified according to their degree of belonging [26].

The knowledge matrices were made with the established variables. Tables 1 and 2 show those corresponding to each company.

The values of the vertices that connect the nodes of the FCM, are given in a range of [-1.0, +1.0], which represents the degree of influence of one node over another, which is established by experts in the manufacturing area and its degree depends on the importance of applying one strategy or another.

Table 1. Gamma Knowledge Matrix

	Nd1	Nd2	Nd3	Nd4	Nd5	Nd6	Nd7	Nd8	Nd9
Nd1	0.0	1.0	-0.8	1.0	0.0	0.0	0.0	0.0	0.0
Nd2	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	1.0
Nd3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Nd4	1.0	1.0	0.0	0.0	1.0	1.0	0.0	0.8	0.0
Nd5	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	0.0	0.0
Nd6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Nd7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Nd8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Nd9	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0

Table 2. Protexjd knowledge matrix

	Nd1	Nd2	Nd3	Nd4	Nd5	Nd6	Nd7	Nd8	Nd9
Nd1	0.0	0.9	-0.8	1.0	0.0	0.0	0.0	0.0	0.0
Nd2	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	1.0
Nd3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Nd4	1.0	1.0	0.0	0.0	0.9	0.9	0.0	0.8	0.0
Nd5	0.0	0.0	0.0	0.0	0.0	0.0	-0.8	0.0	0.0
Nd6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.0
Nd7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Nd8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
Nd9	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0

d. Simulation with a fuzzy system

The network training was performed with a fuzzy system, a computer application that followed the rules mentioned in [6].

Fuzzy simulators were tested with various hypotheses; of which one is shown for each company as described below:

Gamma Company

The FCM is systems that draw the spatial distribution of data inputs, and then process them with pre-established rules to produce suitable outputs to solve a problem, these systems are known within the category of Fuzzy Inference "FIS" [12]; The fuzzy rules of these systems are:

"IF-THEN"; these connect between antecedent and consequent concepts, which move and are located in the sets depending on their fuzzy operators applied with the membership functions [3].

Several sets of fuzzy rules were established in the Gamma Company, one of them was:

If there is technology (Nd1 = 1.0), then there is automation (Nd4 = 1.0)

If there is automation (Nd4 = 1.0) then there is planning in work orders (Nd6 = 0.8)

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The input hypothesis is that of table 3.

Table 3. Gamma hypothesis

Nd1	Nd2	Nd3	Nd4	Nd5	Nd6	Nd7	Nd8	Nd9
1.0	0.0	0.0	1.0	0.0	0.8	0.0	0.9	1.0

The simulator showed the following strategies derived from the planted hypothesis.

If technology is increased, then:

- Economic monitoring is increased
- Time is decreased,
- Automation is on the rise
- Material inventory is increased
- Order planning is increased
- Losses decrease.
- Production monitoring is increased, and
- Profits are increased

Protexjd Company

The article advanced fuzzy systems design and applications, says that FCMs are knowledge represented in simulators based on fuzzy rules IF-THEN [20]:

For the company Protexjd, a set of rules was as follows:

If there is technology (Nd1 = 1.0), then there is automation (Nd4 = 1.0)

If there is automation (Nd4 = 1.0) then there is insight tracking (Nd2 = 1.0)

If there is the tracking of perceptions (Nd2 = 1.0) then there are fewer losses (Nd7=-1.0),

If there are fewer losses (Nd7=-1.0), then there are more profits (Nd9=1.0).

The input hypothesis is that in table 4.

Table 4. Protexjd hypothesis

Nd1	Nd2	Nd3	Nd4	Nd5	Nd6	Nd7	Nd8	Nd9
1.0	1.0	0.0	1.0	0.0	0.0	-1.0	0.0	1.0

After training the simulator, the proposed strategies are:

If technology is increased then:

- Follow-up perceptions are increased
- Time is decreased,
- Automation is on the rise
- Inventory management is increased
- The repository of skills and specifications is increased.
- Losses decrease.
- Production monitoring is increased
- Profits are increased

4. Results and Discussion

The simulator takes the given hypothesis as input and multiplies it by the knowledge matrix, generating a new one-dimensional array. The evolution of the new values of each node are activated according to the following process:

If the result is negative, then the value of the vector will be 0; if it is positive, then the output value is 1; and if it is 0, the output does not change.

The process is done iteratively until the stability of the last vector is obtained, which, according to the rules, becomes strategies for the company that reports the benefits of the technology.

The final result of the fuzzy model of the Gamma Company is shown in figure 7 (matrix) and figure 8 (simulation).

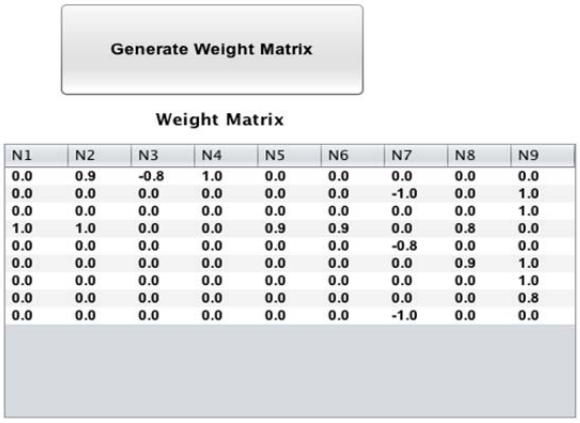

Figure 7. Weight matrix of the Gamma Company

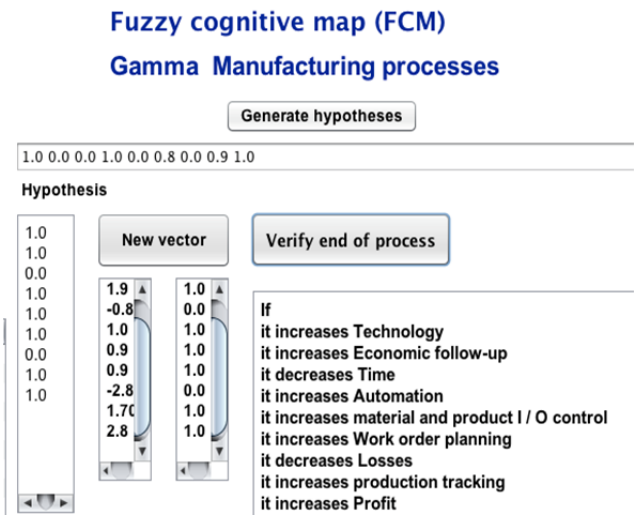

Figure 8. Fuzzy model results for company Gamma

The final result of the fuzzy model of the Protexjd Company is shown in figure 9 (matrix) and figure 10 (simulation).

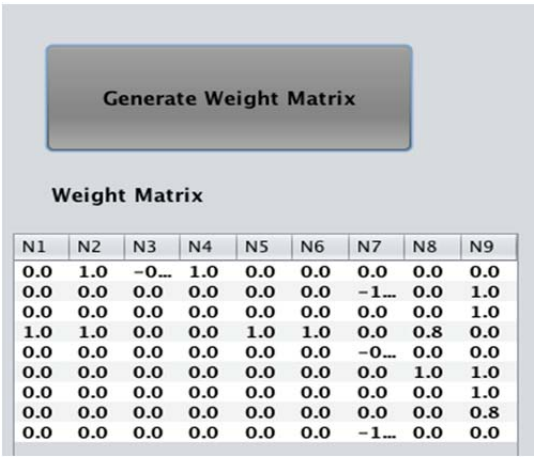

Figure 9. Weight matrix of the Protexjd Company

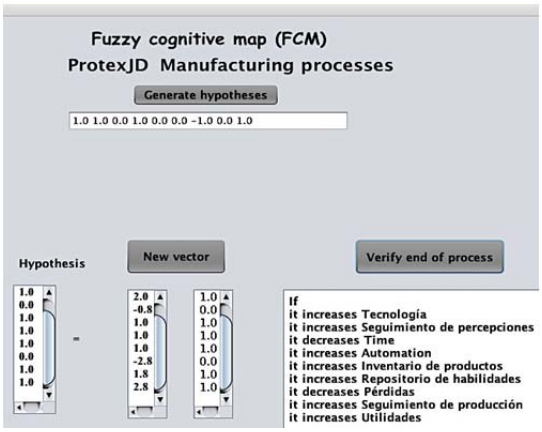

Figure 10. Results of the fuzzy model for the company Protexjd

The training was carried out with hypotheses in which technology and automation were the foundation of the simulation; therefore, the results generated in these training sessions can be read as follows:

If technology increases, then elements that can become positive strategies for the company increase, and elements with negative effects decrease.

The result of the simulation of the fuzzy system showed that, if technology is introduced in the hypotheses, the simulation shows that it is necessary to carry out software engineering to automate the industrial processes of the companies.

The results in the simulators of each company were similar in terms of their problems and therefore in their results. What was observed in the implementation of Fuzzy systems is that FCMs can work on any type of problem.

Taking into account the problems of each company, they could be solved in the following way:

1. With the implementation of technology, processes could be automated, such as work orders, carrying out a sequence of correct inputs and outputs, in such a way that the work process in which the product being manufactured is found at any time; solving the problem of product deliveries to customers at the wrong time (for the Gamma Company).
2. Both companies agreed on the lack of control of inventories, the automation of the process would record what is owed and what has been used in the manufacture of the product, avoiding small losses of material, which in the long term is reflected in the decrease of utilities.
3. Personal data should be stored for both companies, including their skills; the generation of Databases could be the solution to store them, in addition to the designs and specifications of the products made and any other type of useful information.
4. With the monitoring of manufacturing processes, production times are measured, which would be effective for planning activities, and reducing production and delivery times.
5. In addition to the above, both companies need to automate economic monitoring, showing the profits or losses generated by their processes.

The computer simulator based on an FCM is ideal so that, from a matrix built based on problems and solutions, it shows a series of strategies with cause and effect of actions.

5. Conclusions

In the economy of the countries, SMEs are a factor that influences the generation of national employment; but the technology does not affect their processes, because, for those who direct them, it is difficult for them to know the implementation area.

In many SMEs, the people who are in charge of coordination do not believe in the functionality of

technology, so they do not implement it in their businesses.

Models based on fuzzy technology provide elements of cause and effect that help formulate improvement strategies for companies. Fuzzy models synthesize information to show you the benefits or consequences of process automation.

Fuzzy models are used to analyze and synthesize any type of information or apply them to the study of any company and the objective results will be the same.

In this study, it was observed that with the implementation of technology, the benefit was significant, since the implementation of systems for monitoring work orders, perceptions, or production could be suggested; In addition to automated inventories and repositories of elements that are essential for the company's manufacturing, all this results in reducing losses and increasing company profits, actions that are the purpose of any business organization.

The FCM-based methodology is an excellent tool to carry out a process that breaks down problems and converts them into solution items, which become weights of a knowledge matrix to be trained in a computer simulator and ensure that the results become strategies for the productive and administrative improvement of companies.

It must be taken into account that the simulator emits results visualized as improvement strategies, only if the input nodes include technology and therefore automation, otherwise, the results are not visualized as benefits, rather, they are seen as problems, since a decrease is seen in them.

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