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A MODEL FOR SUPPLIER SELECTION IN MANUFACTURING INDUSTRIES

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ABSTRACT

The success of a company depends on its ability to manage its supply chain. Moreover, the consumer demands and the fierce competition existing in local and international markets have pushed companies to focus on their relationships with their suppliers. The choice of the latter (suppliers) is a major stake in the supply chain and represents a key step, which can strongly impact the global performance of the company.

The goal of this research is to develop a decision support model that allows companies to identify the most appropriate suppliers for their business. This model considers the various decision criteria and then ranks the suppliers according to their output indicator.

For the validation of this proposed model, an experimental study was conducted to rank (03) suppliers available on the market related to the delivery of raw material for the case of a company manufacturing plastic products. The proposed model meets the desired objective and is therefore retained for the selection of the best supplier in a certain/uncertain multi-attribute and multi-actor context.

Key words: *Supply chain, Supplier, Fuzzy logic,* Global performance , *decision support.*

1. INTRODUCTION

The supply chain is a vital component of any company's operations. It includes the various stages of the product creation and its sales. The choice of a supplier is very important for the success of the company. The selection of a supplier mainly depends on the company's various criteria, such as quality, cost, and deadline. Due to the varying requirements of different companies, the need for a consistent set of criteria becomes more critical. In terms of selection grids, many studies have been conducted on this issue. In 1996, DICKSON conducted an evaluation study on 274 Canadian and American companies. It identified 23 selection criteria that were used to evaluate a supplier. A literature review conducted in 1991 by Weber et al, which processed 74 articles published between 1966 and 1990 on the evaluation of suppliers. confirmed the criteria used by DICKSON in its evaluation of suppliers. However, the importance and the coefficient of the selected criteria have changed due to the different economies. Several models in the literature have focused on multi-criteria decision support processes. In this paper, the fuzzy logic method presented by L. Zadeh was used to select the best supplier.

The objective of this study is to develop a fuzzy logic model that allows experts to select the most appropriate supplier from the available ones. The model is then analyzed and formulated according to the decision rules. The results of the study will be shown in an example of a prioritized list of four suppliers.

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2. LITERATURE REVIEW

“With a single evaluation criterion, the choice of suppliers would be obvious. However, considering multiple criteria simultaneously made this task a little more complicated” [1]. The AHP (Analytic Hierarchy Process) method developed in 1980 by Saaty (1980) allows solving complex problems with multicriteria (Ben Jeddou 2015). But the problem arises in the classification of criteria according to the order of priority for each company. Each criterion has its value in the industrial field. That is, it is difficult to classify them according to the order. "The network process (AHP), scoring models, over ranking, goal programming, expert systems, data envelopment analysis (DEA) and analysis (DEA), etc.” [2]. But they also share some common characteristics such as the conflict between criteria and incomparable units (Safaei Gharbi, 2021). Incomparable (Safaei Ghadikolaei et al.,

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2014) On the other hand, PROMETHEE and ELECTRE methods of decision making are widely applied in different fields such as academic literature (Kumar et al., 2017). (Haleh & Hamidi, 2011), an extension of linear programming, goal-based programming (GP) which allows solving multiple-goal problems, but the problem arises to provide appropriate weights (Chen et al., 2011). Decision-making tools are very useful tools in different domains with different factors, especially to determine an appropriate solution it is a difficult task (Chen et al., 2011). Rezaei (2015) used BWM to solve multi-criteria decision-making (MCDM) problems. In [3], "Statistical results show that BWM performs significantly better than AHP's inconsistency ratio and other evaluation criteria: minimum violation, total deviation, and compliance (...). According to BWM, the best (e.g., most important) and worst (e.g., least important) criteria are defined by the decision-maker. Pairwise comparisons are then made between each of these two criteria (best and worst) and the other criteria."

Contrary to binary logic, fuzzy logic was first formulated by mathematician Lotfi Zadeh in the 1960s. It allows for better modeling of intuitive parameters via membership functions, interconnected through fuzzy rules, which is a mathematical object.

The advantage of the adopted method over other MCDM decision making methods adopted in the literature is its ability to model intuitive indicators via membership functions. Moreover, the model developed provides the ability to rank an infinite number of suppliers without the need to make complex comparisons between suppliers. In fact, other MCDM methods require a complete recalculation of the data.

3. METHODOLOGY.

3.1. Fuzzy Logic.

Fuzzy logic is a technique used in artificial intelligence formalized by Lotfi Zadeh, used in fields as varied as robotics, mechanics, traffic management (red lights) and many other areas, this logic is based on the mathematical theory of fuzzy sets, which is an extension of the classic set or the degree of truth of a function takes one of two values (true or false) or (0 or 1) in binary [4].

"The fuzzy logic confers thus a very appreciable flexibility to the reasonings which use it, which makes it possible to take into account the imprecisions and the uncertainties" [5]." One of the interests of fuzzy logic to formalize human reasoning is that the rules are stated in natural language" [6]. In order to understand the use of fuzzy logic to facilitate the choice of the best provider, this section presents the principles of this logic and its inference process

3.2. The fuzzy set and linguistic variable concepts.

Instead of being associated with a set of true or false values, fuzzy logic accepts degrees of membership to a set. A membership function is linked to a variable's value, and the membership factor is calculated by a number between 0 and 1. This concept allows to assign a membership function which goes from 0 to 1 in order to allow gradations in the membership of an element to a class, i.e. to allow an element to belong more or less strongly to this class [7]; The fuzzy subsets are thus useful to represent the imprecision of the inputs or the uncertainty related to the implemented knowledge

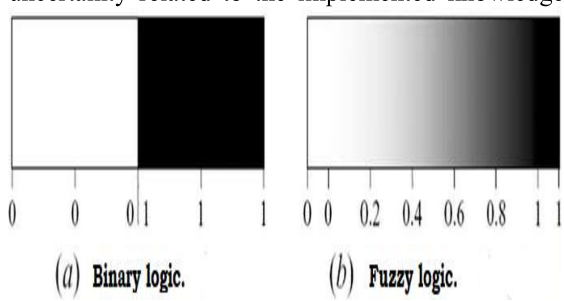

Figure 1. Differentiation between fuzzy logic and Binary logic [7].

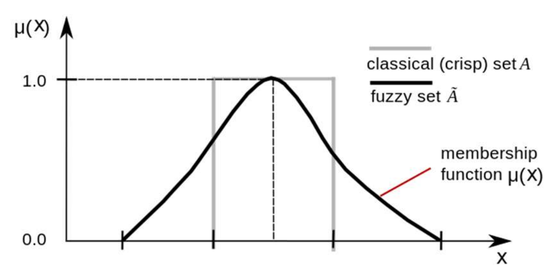

Figure 2. Classic and fuzzy sets.

This figures 1 and 2 illustrates the difference between the functions of membership of the classic logic and the fuzzy logic, In the 1st, the appearance is binary 0 or 1, in mathematical term, a variable " X " is it contains to a set " E " " or not on the other hand in the 2nd the degree of appearance is a numerical value which varies in the interval [0 ;1]. Moreover, this variable can belong to several sets at the same time contrary to the classical logic.

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Figure 2 is a synoptic outline of a fuzzy system that we are going to approach thereafter

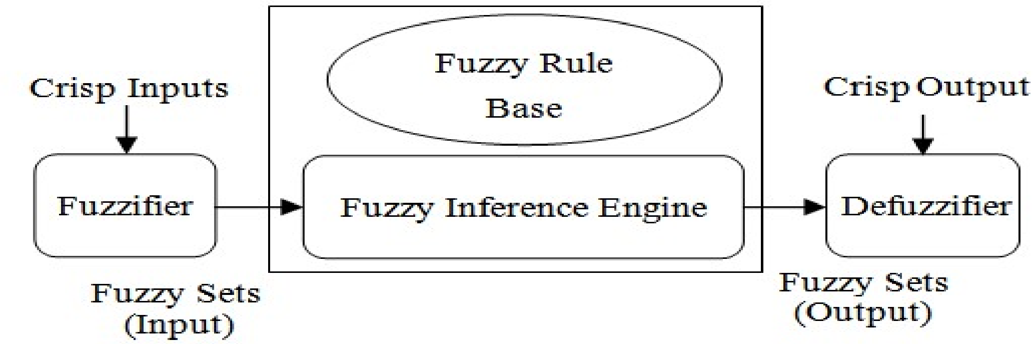

Figure 3. Architecture of a fuzzy logic system.

Step 1 : Fuzzification des valeurs numériques en valeurs floues.

A fuzzy inference system is a system composed of three big bricks: the fuzzification, the inference engine and the defuzzification (Figure 1). The inputs of our fuzzy inference system are the scores that we will assign to each variable of our decision making that must be quantifiable [8].

The first part that will allow to translate a numerical data coming from a sensor into a linguistic variable is called fuzzification. Thanks to a membership function created by the fuzzy system designer. A membership function is a function that allows to define the degree of membership of a numerical data to a linguistic variable [9]. Membership functions can theoretically take any form as in figure 3. However, they are often defined by functions: triangular, rectangular, Gaussian ...

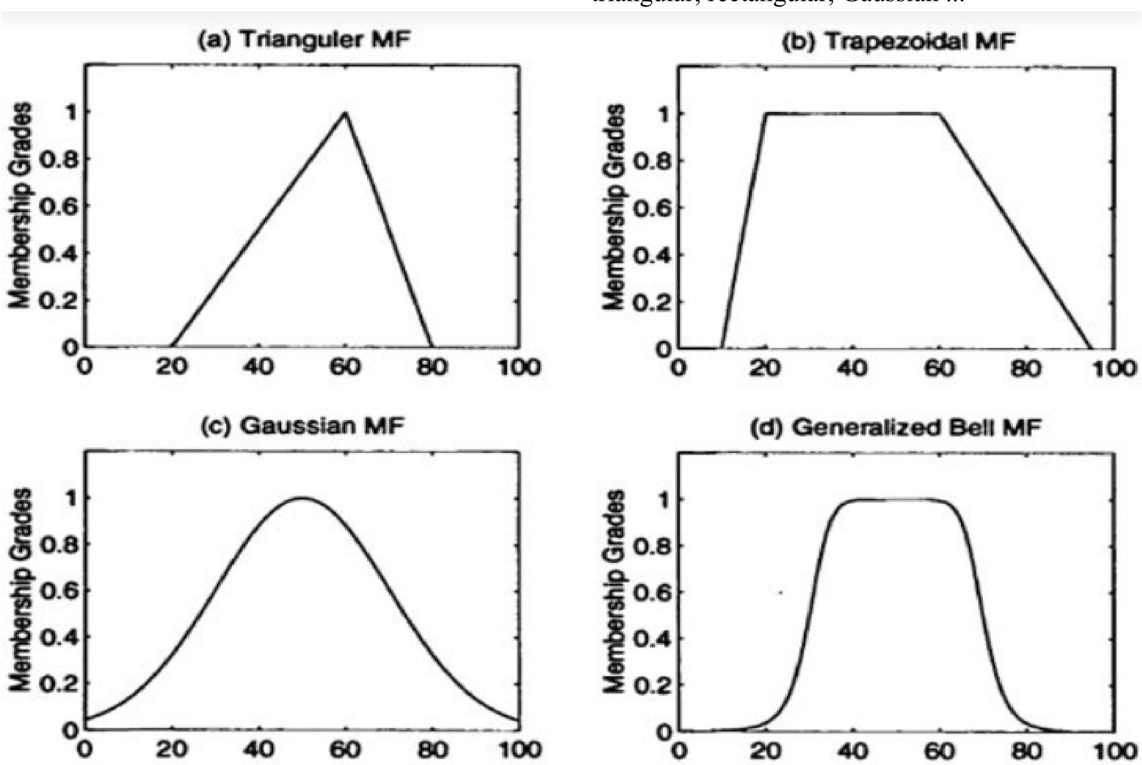

Figure 4. Different types of membership functions [10].

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This first step of fuzzification will translate the numerical data of the sensors into different linguistic variables. Fuzzy logic thus makes it possible to integrate expert systems into automated processes [11]. "This This point is both a strength and a weakness of fuzzy logic" [12].

Step 2: Fuzzy inference.
Now that we have linguistic variables, we can pass them into the inference engine [13]. Here, "each rule of the inference engine is written by the designer of the fuzzy system according to the knowledge he has" [14]. The first thing to do for this second part is to list all the rules that we know and that apply to the system. A rule must be in the form If condition, then conclusion. Then, fuzzy inference is the construction of rules (and results) based on linguistic variables, assigning a truth to each rule, then aggregating the rules to obtain a single (linguistic) result.
The problem with inference rules is to know what the logical operators mean. Indeed, the operators of classical logic (AND, OR) are no longer valid in fuzzy logic [15]. So, we have to redefine them ourselves as in figure 4.

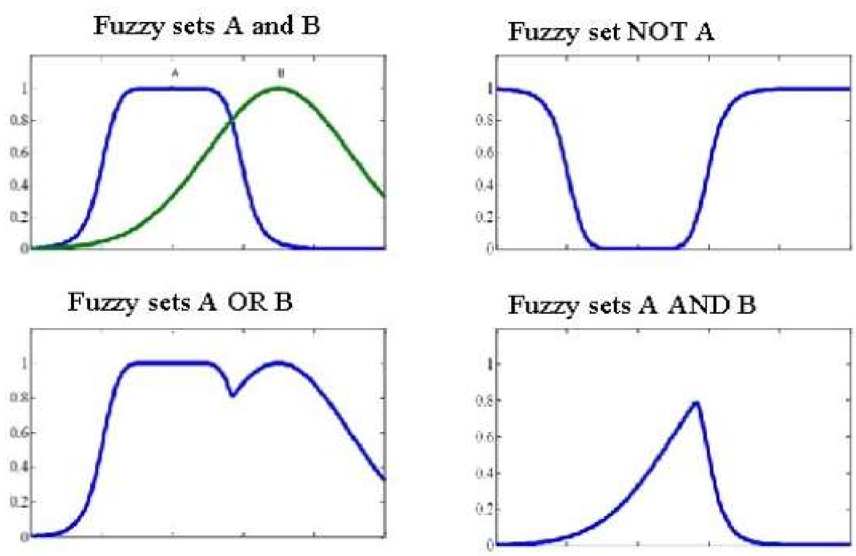


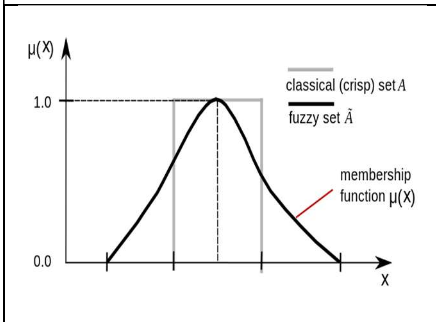
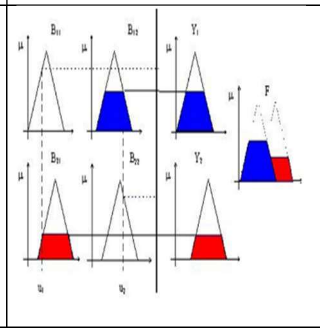
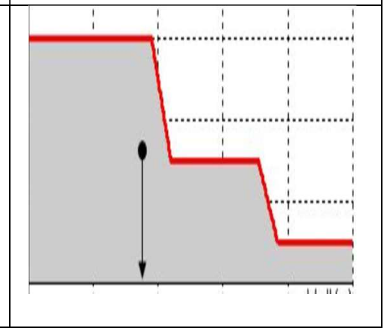
Figure 5. Operations on fuzzy sets [16].

The inference engine is the step in which we will parameterize our "If..., then..." decision rules. Thanks to this engine, we will be able to apply the rules we have set to our fuzzy input variable [8].
Step 3: Defuzzification
"Inference methods provide a resulting membership function μ_X of the output variable **X**" [7]. It is therefore fuzzy information. It is necessary to transform this fuzzy information into a given value that will be applied to the process control interface. This transformation is called defuzzification. The most used defuzzification method is the determination of the center of gravity [7].

3.2. Fuzzy inference system description.

The fuzzy inference system shown in this figure consists of three parts

Tableau 1. Steps of fuzzy logic.

Step 1 : Fuzzyfication	Step2 : Fuzzy inference	Step3 : Deffuzyfication
		

4. CAS OF STUDY.

4.1. Presenting the Indicators.

The appropriate supplier is the one that meets all the criteria established by the client company, in our case the company requires the following criteria

Cost: is the price agreed between the supplier and the company so that it can deliver a product or provide a service in its favor;

Quality: "quality encompasses all the characteristics of a product or service that affects its ability to satisfy expressed or implied needs” [17], then the quality of a product can be defined in terms of these objective characteristics and its ability to perform its functions perfectly.

Delay: the professional supplier must deliver the good or provide the service to the company on the date or within the time specified in the contract. And it is the sum of the time it takes the supplier to deliver an order after it has been placed - and the order delay - the time elapsed before a next order can be placed.

As an output function, there is the Supplier Score which is a number between 0 and 1, reflecting the degree of suitability of the supplier to the company. The closer its value is to 1, the more suitable the supplier is, and the closer it is to 0, the more inappropriate the supplier is.

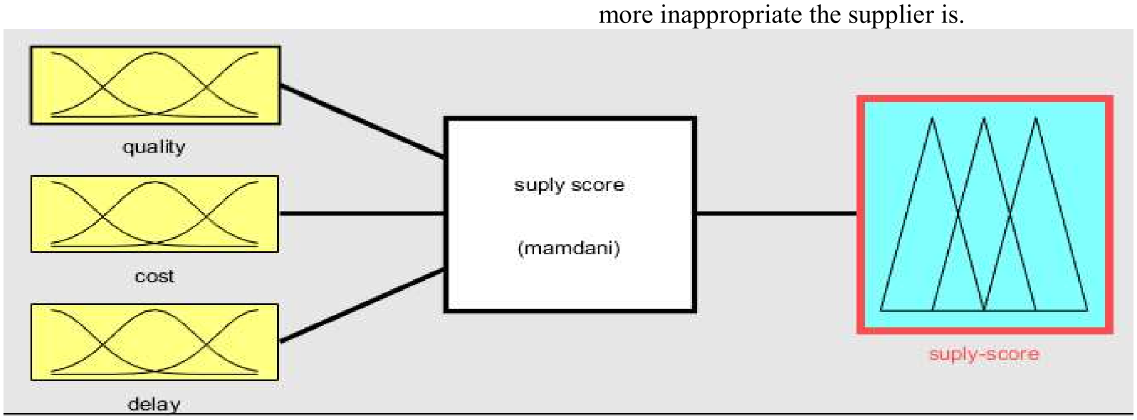


Figure 6. Parameters Presentation.

4.2. Indicator Modeling.

Indicator modeling is characterized by transforming variables into fuzzy variables (also called linguistic variables) by associating veracity laws to them.

The figure below shows the quality membership function μ (quality) to a universe of discourse with subsets < Low, High> using Mamdani as the inference type.

The quality variable is divided into modalities (high and low).

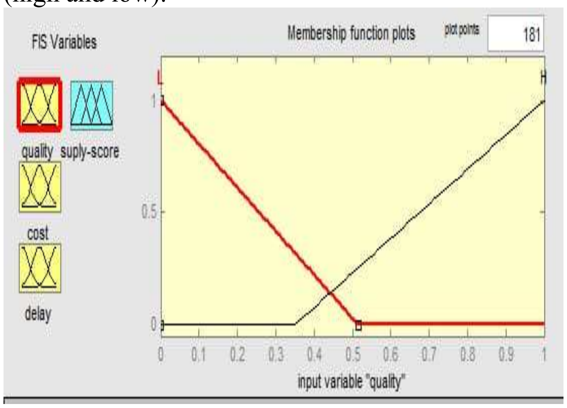


Figure 7. Quality Member Ship Function.

The other indicators are modeled by the same principle by triangular type membership functions using linguistic terms appropriate to each indicator

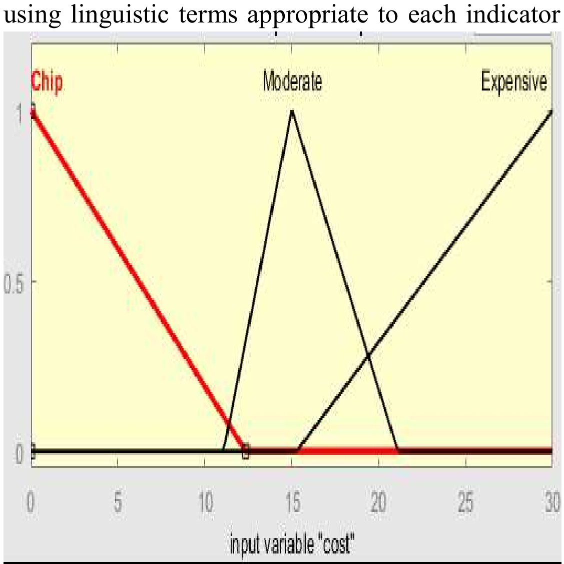


Figure 8. Cost Member Ship Function.

The figure below shows the Delay membership function µ (Delay) to a universe of discourse with subsets < Short, Long>

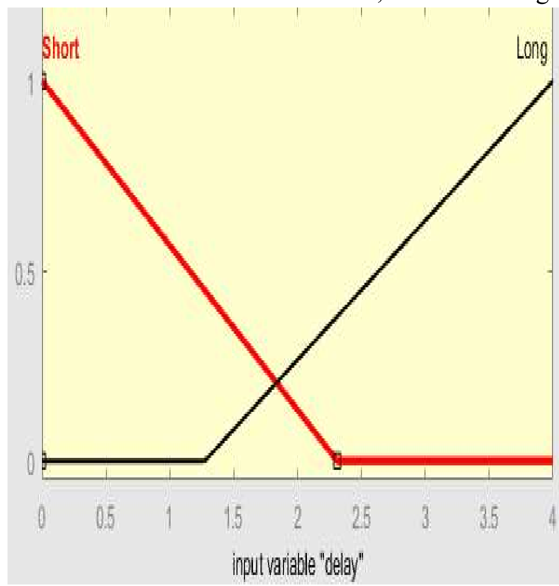


Figure 9. Delay Member Ship Function.

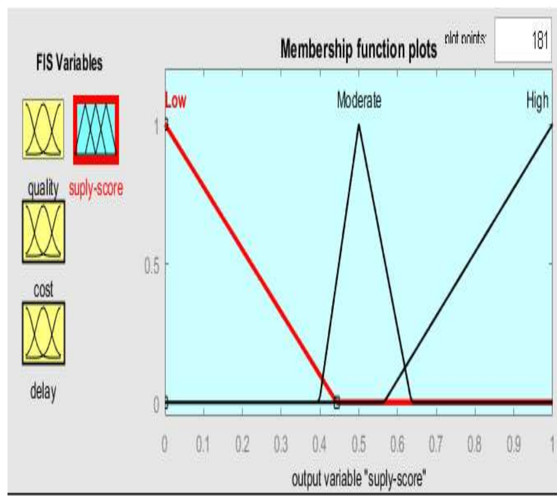


Figure 10. The Output "Supply Score" Member Ship Function.

4.3. Fuzzy Inference.

The part where the experts define the fuzzy rules using the set of input indicators. In our case study we set up 9 fuzzy rules with the <ET> operator illustrated in Table 1

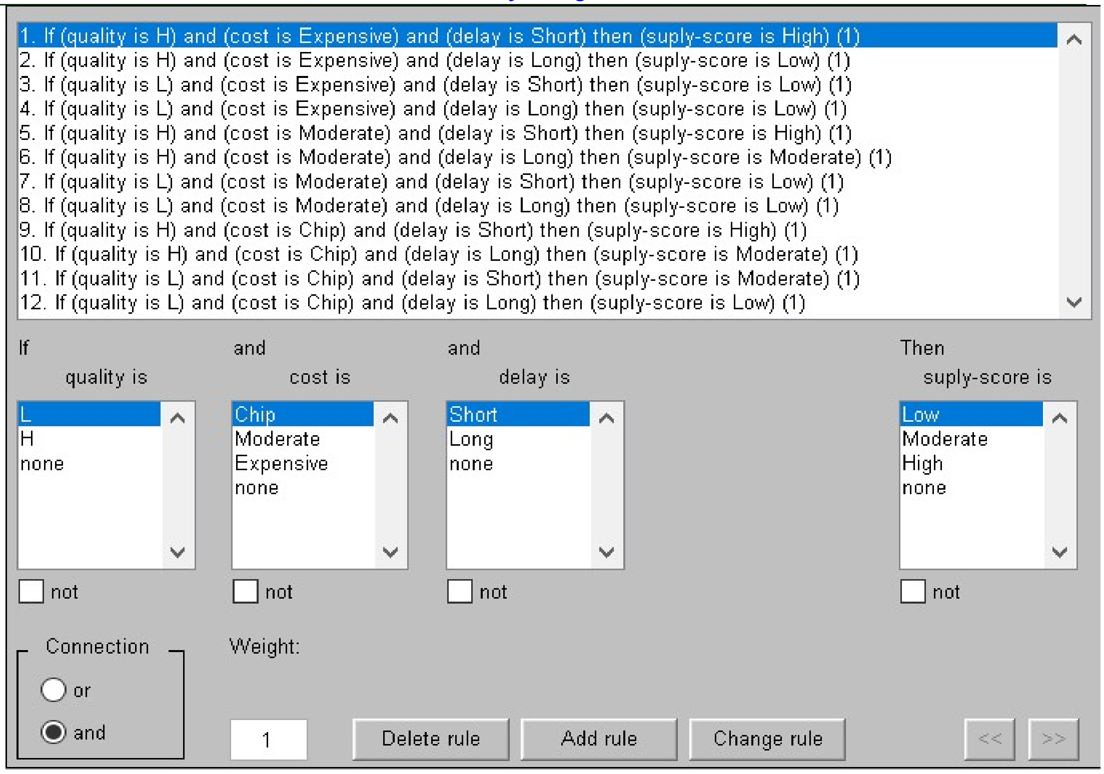


Figure 11. Fuzzy Rules Presentation

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4.4/ Defuzzification

Graphically, the following figure shows the defuzzification step, which consists in transforming the fuzzy set associated with the inputs: Cost, Quality and lead time into a net value by applying the center of gravity method [8].

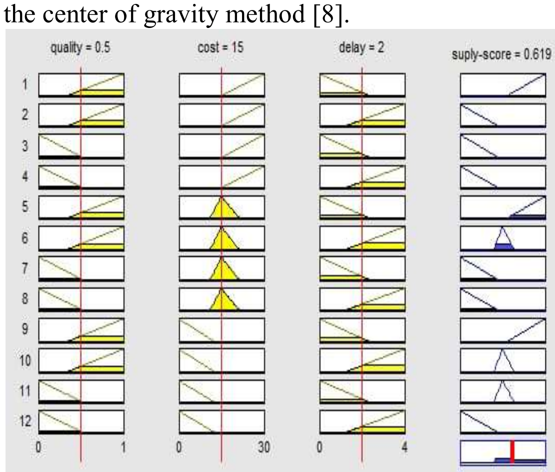

Figure 12. Defuzzification Process.

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4. RESULT AND DISCUSSION

The proposed model consists in elaborating a function having as input variables (Quality; Cost and Delay) and providing as output value the supplier score.

Through a deep analysis of the surfaces below we could deduce the weighting of each input parameter in order to identify the most dominant ones impacting on the supplier score

4.1. Surface Viewer

The simulated surfaces below reflect the dependency relationship between the input indicators and the output indicator. Nevertheless, the weighting of these inputs is not the same, among which there is the one more influential than the others.

To analyze the surfaces, we work with only 2 inputs and we fix the third one on a constant value (abscissa axis) and we visualize the result of the output on the coordinate axis.

Case N°1: (Med, Y, Z)

In this case the quality indicator is set as Medium.

Med: Quality indicator.

Y: Cost indicator.

Z: Delay indicator.

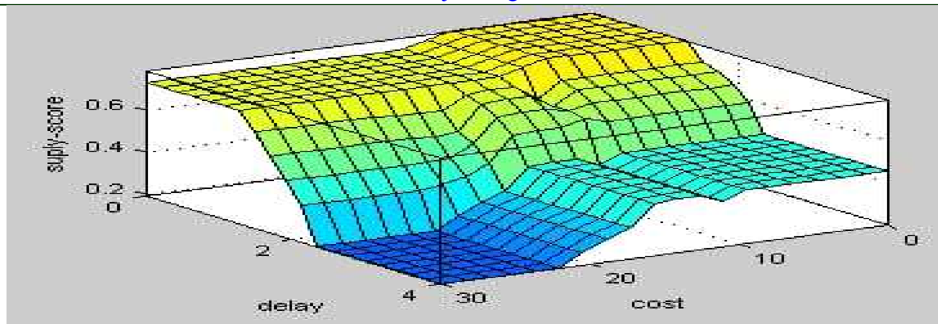

Figure 13. The Cube For Case N°1 Case N°1 : (Med, Y, Z).

By taking the quality criterion as an average value, we can see through an analysis of the graph that the score attributed to the supplier is high when the delivery time is short, reflecting the weight of this criterion. However, this score is small when the delay is long and the cost is expensive. Similarly, we can assign a medium score for a supplier who provides the material in a short time but with a high cost.

This analysis shows the weighting of the criteria is precisely the delay since the supplier must give more importance to this criterion compared to the others to have a high score

Case N°2: (X, Med, Z).

In this case the indicator of the Cost is fixed in moderate.

X: Quality indicator.

Med: Cost indicator.

Z: The Delay Indicator.

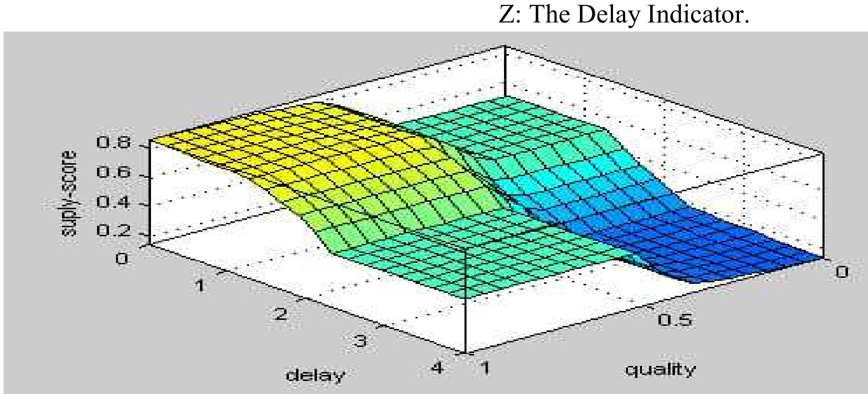

Figure 14. The Cube For Case N°2 : (X, Med, Z).

The displayed surface shows that the supplier's score is small when the quality is Low and Delay is Long. However, the score is to Moderate when the input indicators (Quality, Delay) are respectively (High, Long) or (Low, Short). It is suitable if the quality is good and the delay is short.

The results obtained are not found in binary logic where the supplier score will be null if only one of the input parameters is null, hence the advantage of fuzzy logic

This simulation is a direct projection to the decision rules set up by the experts, hence the usefulness of modifying these rules if necessary by restoring the rules and allocating the appropriate membership functions to each input variable.

The model allows to rank the suppliers according to their scores. Moreover, the surface gives a vision on the weighting of the input parameters to determine the predominant ones. Then to validate the ranking of the suppliers the experts compare the weighting of the parameters with the requirements of the company. If the results obtained are inconsistent with these requirements then the experts are invited to adjust the fuzzy rules or to redefine the membership functions of the variables

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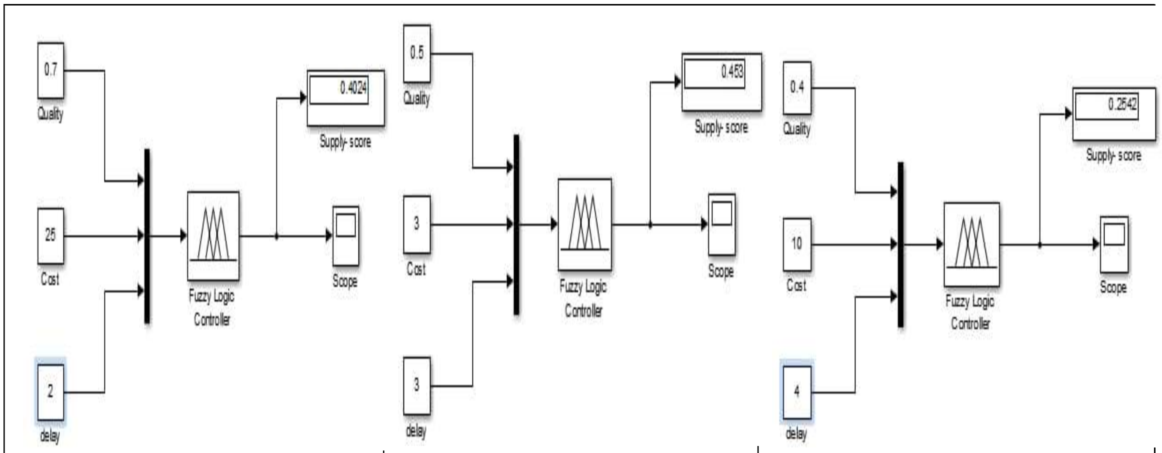
4.2 Simulation of results with "Matlab Simulink

The following figure shows a simulation model of the suppliers' scores by the Matlab Simulink software

Tableau 2. Simulation Results Of Our Fuzzy Logic Inference System.



Supplier N°1	Supplier N°2	Supplier N°3

Based on the scores obtained by this simulation, the rank of each supplier is as follows:

Tableau 3. Ranking suppliers regarding their scores.

N° Supplier	Cost	Quality	Delay	Score
1	10	0.4	10	0.254
2	3	0.5	3	0.453
3	25	0.7	2	0.102

.

The model ends with the establishment of a ranking list as mentioned in the table above.

This list allows to prioritize the probable suppliers available on the market through a score attributed to each supplier which represent the alternative of choice. Thus, the N°2 supplier is the most appropriate followed by the N°1 and N°3 suppliers.

This ranking depends essentially on the weighting of the entry criteria. However, for the same suppliers the ranking can be different. For example, for a company that gives more importance to the quality criterion, then supplier N°3 will be the most appropriate.

The result obtained is associated to each company, since it is the company that defines in advance the weighting of the entry criteria and the one among them that counts the most, this appears in the establishment of the decision rules by the experts of the company based on the vision and the need of the company that give to a criterion more advantage than the others.

5. CONCLUSION

Faced with new demands in term of raw materials or components, the company proceeds to a search of suppliers. For this reason, it Therefore, it draws up specifications that it makes known to its suppliers. It establishes criteria that can vary according to the nature of the purchase: deadlines, quality, cost.

The objective of this research work is to establish a selection model to rank the suppliers. From the criteria previously established by the company, we assign a score to each supplier. The supplier with the best score will be the one selected by the company.

In this article, we show how an artificial intelligence model can be used to automatically identify the most appropriate supplier for a company. This model is unique because it can adapt to the company's requirements and decision criteria [8]. This method will allow the company to develop a unique model that fits their needs.

The objective of this project is to develop a model that can identify the most appropriate supplier for a company based on its fuzzy logic.

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6. LIMITATION.

The advantage proposed in our research will allow the company to establish its own model, which takes into consideration its requirements presented in the decision rules. Nevertheless, the ranking obtained by this method is very sensitive to the variation of the rules, in effects for the suppliers and a variation of a rule this ranking becomes inappropriate. This shows the difficulty of establishing the rules. In the same way, with the introduction of a new criterion the model becomes obsolete and requires re-establishment.

The proposed method allows the experts to concretize the choice rules in the form of a model that uses artificial intelligence.

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