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THE APPLICATION OF FUZZY LOGIC FOR THE SELECTION OF SUPPLIERS FOR THE PURCHASE OF WIND TURBINES IN MOROCCO

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ABSTRACT

To solve the problem related to the uncertainty and the ambiguity and the imprecision of the decision makers, this paper proposes the application of the multicriteria approach of fuzzy logic, to select the best supplier for the purchase of wind turbines for a company in Morocco. In this study, first we discuss the importance and the state of the art of selecting the best supplier and we present the fuzzy logic approach and its steps. We then go on to do the fuzzification for the three entry criteria and the exit variable retained in our study: Cost, Reliability, Proximity of the operating and maintenance teams, supplier. In addition, we build fuzzy rules and then we do defuzzification: We have simulations that tell us in which case we can choose the best supplier for the purchase of wind turbines in Morocco. After we proceed to expose the advantages of the approach used which is the fuzzy logic for this study and we present its limits. Finally we mention our scientific contribution, and some perspectives that we intend to make.

Keywords: *Fuzzy Logic, Supplier Selection, Cost, Proximity Of The Operating and Maintenance Teams, Reliability.*

1. INTRODUCTION

Morocco has recently focused on renewable energies, especially wind energy, as an alternative to fossil fuels, for a carbon-free future, to protect the planet from the dangers of pollution. Since 2009, the Kingdom has adopted, under the High Royal Guidelines, a strategy which targets short, medium and long-term objectives concerning renewable energies, with a percentage set at 52% by 2030 [1].

According to [2], For example here is a 200 MW Biranzarane wind PARK project:

The energy characteristics of the project:

- ✓ Installed power: 200 MW
- ✓ Annual producible: 750 GWh/year
- ✓ Location: 70 km north of the city of Dakhla
- ✓ Site area: approximately 2000 ha

Project cost:

- ✓ 3200 million dirhams

Job creation

- ✓ Number of jobs (operation phase): 60 jobs
- ✓ Number of jobs (construction phase): 200 jobs
- ✓ Planned commissioning date: 2024

Since these renewable energy projects, in particular wind turbines, have a good impact such as the creation of new jobs for young Moroccans or the reduction of pollution; the selection of the best suppliers remains important and essential for the choice of the right wind turbines.

The choice of the best suppliers is the aim priority for decision makers and purchasing managers within a company, in order to have the acquisition of the right products and raw materials with a reasonable price, in a precise time according to Naqvi and Amin [3]. The success of companies at the global level is essentially based on the fact of selecting the best supplier since it is strategic if we refere to Razaei et al.[4] . then allowing time is a key condition for the success of optimal supplier selection [5]. The operation to be done for the good

and best choice of a supplier guides the decision makers to have thereafter either: single, or dual or multi or mix sourcing [6] .

A lot of research has been done for the selection of the best supplier: Kazemi et al. [7] used a mathematical programming model for a multi-objective supplier selection and order allocation problem with fuzzy objectives. Gupta [8] used in fuzzy environment, a weighted possibilistic programming approach for sustainable supplier selection and order allocation. Supplier selection combined with order allocation under disruption risk were the goal of search of Hamdi et al. [9]. Ghorabaee et al. [8] utilized a new multi-criteria model based on interval type-2 fuzzy sets and EDAS method for supplier evaluation and order allocation with environmental considerations. Hajikhani et al.[11] applied a fuzzy multi-objective multi-product supplier selection and order allocation problem in supply chain under coverage and price considerations for an urban agricultural case study. Gören [12] did a search for decision framework for sustainable supplier selection and order allocation with lost sales. Arabsheybani et al.[13] used An integrated fuzzy MOORA method and FMEA technique for sustainable supplier selection considering quantity discounts and supplier's risk. Ahmadi and Amin [14] conducted a search for the selection of the best supplier with An integrated chance-constrained stochastic model for a mobile phone closed-loop supply chain network. Supplier selection is the purpose of the research of Alegoz and Yapicioglu [15] with order allocation decisions under quantity discount and fast service options. Sustainable supplier selection combined with order allocation was the goal of the piece of work of Almasi et al.[16] under risk and inflation condition. Hasan et al. [17] did resilient supplier selection in logistics 4.0 with heterogeneous information.

This picture shows some wind turbine:

Figure 1: Some wind turbine[18]

There was also a significant amount of research that was carried out for the selection of suppliers for the purchase of wind turbines:

Nguyen et al. [19] utilized Spherical Fuzzy Multicriteria Decision-Making Model for Wind Turbine Supplier Selection in a Renewable Energy Project. Adhikary et al.[20] used the Multi-Criteria optimization technique Turbine Supplier Selection For Small Hydro Project. The integrated fuzzy analytic network process (FANP) and the mixed integer goal programming (MIGP) model were utilized by Samut [21] for single wind turbine suppliers in the wind power plant projects. Yang and Li [22] had as their goal in their research, the selection of equipment suppliers for the Wind Power Generation engineering, procurement and construction (EPC) Project. Dinmohammadi and Shafiee [23] studied a determination of the Most Suitable Technology Transfer Strategy for Wind Turbines Using an Integrated AHP-TOPSIS Decision Model.

From the above how can fuzzy logic be applied to make a better choice of a supplier for the purchase of wind turbines?

At the scientific level we will contribute to science by proposing a multi-criteria scientific approach which is the fuzzy logic for the selection of the best suppliers for the purchase of wind turbines in Morocco. A meticulous application of the steps of the scientific approach which is fuzzy logic will create added value at the heart of the renewable energy sector in Morocco.

2. METHODOLOGY

The remainder of this paper is organized as follows:

We presented the theory of fuzzy logic and some authors who used it in their work.

Then in the "case study" section we applied the different steps of the fuzzy logic approach as follows:

- ✓ We have specified the three input variables and the output variable which are the criteria selected by the company's decision-makers who are: Cost, Reliability, Proximity of Operation and Maintenance Teams, supplier
- ✓ We proceed to the fuzzification: We model the input and output variables by the membership functions after having determined the linguistic values of each criterion
- ✓ We determine the different fuzzy rules related to our study for decision-making
- ✓ We apply the Defuzzification phase: The fuzzy values of the different criteria are converted into a net value.

Then we carefully interpret the results obtained, we reveal the different advantages of our research, then we expose the limits of the study, we move on to explain our contribution at the scientific level. Finally we explain the difference between the study we conducted and the study conducted by an author researcher for the selection of suppliers.

The figure below shows the procedure applied in our research:

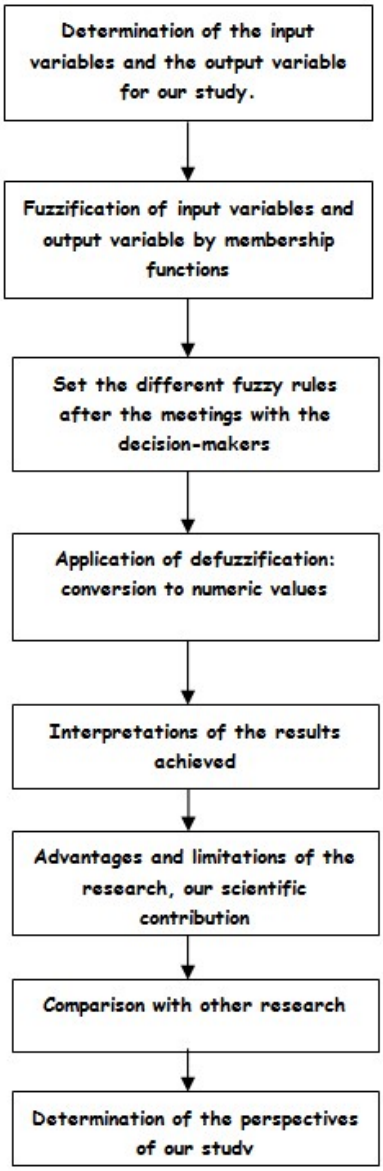

Figure 2: The procedure applied in our research

3. RESULTS

3.1 Fuzzy Logic

It was Zadeh[24] who introduced the theory of fuzzy sets in order to overcome the problem of human thought which mainly based on Vagueness, impreciseness and uncertainty.

The figure below shows the structure of a Fuzzy Logic system :

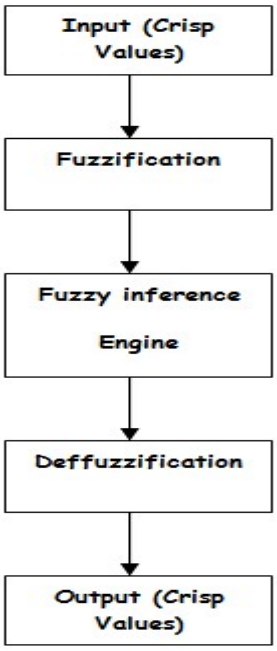

Figure 3: The structure of a Fuzzy Logic system [25][8]

According to Bouzoubaa et al. [26], here is the meaning of the different components of the fuzzy logic system:

- ✓ Knowledge base : Data et Rule Base: this is where we define the the
- ✓ fuzzy sets and the fuzzy rules
- ✓ Fuzzifier : Definition of membership functions of all variables and Conversion to linguistic variables.
- ✓ Inference unit : it is clearly the binding between the linguistic input parameters and the linguistic output variables on a basis of fuzzy rules
- ✓ Defuzzifier : Conversion to crisp values

Many authors have used fuzzy logic in their research: Guran et al.[27] used fuzzy-logic combined with the AHP approach as an Additive An Additive FAHP Based Sentence Score Function for Text Summarization. For improving text summarization, Azhari and Kumar[28] applied fuzzy-logic combined with neural networks. Gupta [6] discussed in his research piece different applications of fuzzy logic that are difficult to solve

with traditional linear techniques. Yilmaz et al.[29] used friendly fuzzy-based system for the selection of electro discharge machining process parameters. Lin and Lin [30] utilized grey-fuzzy logic for the optimization of the manufacturing process.

3.2 Fuzzification

Before starting the first stage of the fuzzy logic, and after having had a meeting with the managers of the company in Morocco for the purchase of the wind turbines. we finally specified three main criteria that we will use for the rest of our study:

Many researchers have used reliability as a criterion in their work for the selection of wind turbines [31] , we mention some of them: Herbert et al. [32] conducted a study on Performance, reliability and failure analysis of wind farm in a developing Country. Wilkinson [33] did a study about measuring wind turbine reliability.

The cost is an important factor for the choice of suppliers sell the wind turbines. knowing that the cost of the wind turbine does not only include its selling cost, but also the cost of its installation.

The intervention of the maintenance team must be made as soon as possible to avoid further breakdowns, afterwards; time plays a very important role in repairing the wind turbine.

3.2.1 Fuzzification for Reliability:

The table below shows the range for Reliability:

Table 1: The range for Reliability

Fuzzy	Variable	Range
1	Negligible	0-60
2	Medium	40-80
3	Important	70-100

The figure below shows the membership function was used for input:

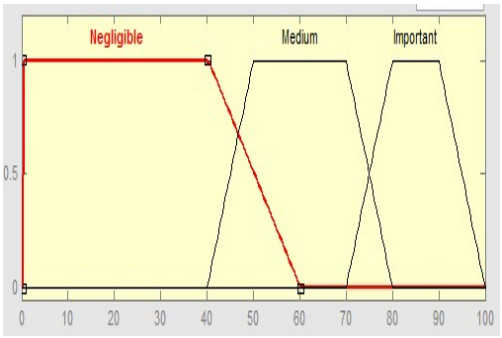

Figure 4: Membership function of Reliability

3.2.2 Fuzzification for Proximity of Operation and Maintenance Teams:

The table below shows the range for Proximity of Operation and Maintenance Teams:

Tableau 2: The range for Proximity of Operation and Maintenance Teams:

Fuzzy	Variable	Range
1	Good	0-60
2	Average	40-80
3	Bad	70-100

The figure below shows the membership function was used for input:

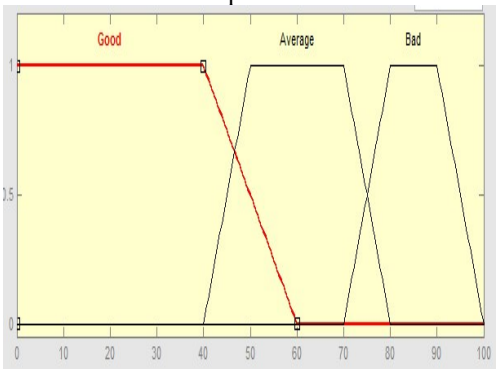

Figure 5: Membership function of Proximity

3.2.3 Fuzzification for Cost:

The table below shows the range for Cost:

Table 3: The range for Cost

Fuzzy	Variable	Range
1	Less	0-40
2	Medium	30-70
3	High	60-100

The figure below shows the membership function was used for input:

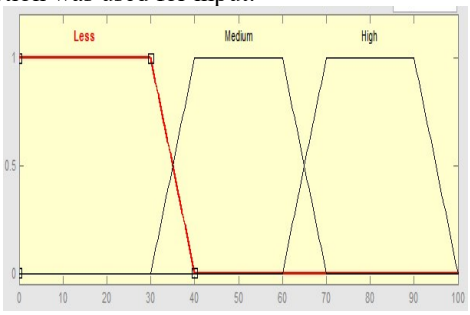

Figure 6: Membership function of Cost

3.2.4 Fuzzification for Supplier:

The table below shows the range for Supplier:

Table 4: the range for Supplier

Fuzzy	Variable	Range
1	Not accepted	0-60
2	Under consider	30-80
3	Accepted	70-100

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The figure below shows the membership function was used for input:

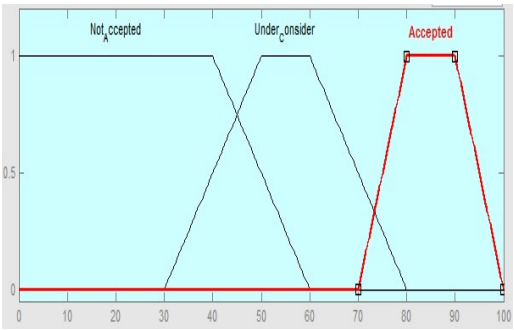

Figure 7: Membership function of Supplier

3.3 Fuzzy Rules

3.3.1 Fuzzy rule construction when cost is less :

We construct Fuzzy Rule when cost is less. Rel : The abbreviation of Reliability and Pro: The abbreviation of Proximity of Operation and Maintenance Teams.

The table below shows Fuzzy rule construction when cost is less:

Table 5: Fuzzy rule construction when cost is less

Rel / Pro	Negligible	Medium	Important
Bad	Not Accepted	Not Accepted	Under Consider
Average	Not Accepted	Not Accepted	Accepted
Good	Not Accepted	Under-Consider	Accepted

3.3.2 Fuzzy rule construction when cost is Medium:

The table below shows Fuzzy rule construction when cost is Medium:

Table 6: Fuzzy rule construction when cost is Medium

Rel / Pro	Negligible	Medium	Important
Bad	Not Accepted	Not Accepted	Not Accepted
Average	Not Accepted	Not Accepted	Under-Consider
Good	Not Accepted	Under-Consider	Accepted

3.3.2 Fuzzy rule construction when cost is High:

The table below shows Fuzzy rule construction when cost is High:

Table 7: Fuzzy rule construction when cost is High

Rel / Pro	Negligible	Medium	Important
Bad	Not Accepted	Not Accepted	Under-Consider
Average	Not Accepted	Not Accepted	Under-Consider
Good	Not Accepted	Not Accepted	Under-Consider

We get 27 rules as shown by the Matlab software:

1. If (Reliability is Negligible) and (Proximity is Bad) and (Cost is Less) then (Supplier is Not_Accepted) (1)
2. If (Reliability is Negligible) and (Proximity is Average) and (Cost is Less) then (Supplier is Not_Accepted) (1)
3. If (Reliability is Negligible) and (Proximity is Good) and (Cost is Less) then (Supplier is Not_Accepted) (1)
4. If (Reliability is Medium) and (Proximity is Bad) and (Cost is Less) then (Supplier is Not_Accepted) (1)
5. If (Reliability is Medium) and (Proximity is Average) and (Cost is Less) then (Supplier is Not_Accepted) (1)
6. If (Reliability is Medium) and (Proximity is Good) and (Cost is Less) then (Supplier is Under_Consider) (1)
7. If (Reliability is Important) and (Proximity is Bad) and (Cost is Less) then (Supplier is Under_Consider) (1)
8. If (Reliability is Important) and (Proximity is Average) and (Cost is Less) then (Supplier is Accepted) (1)
9. If (Reliability is Important) and (Proximity is Good) and (Cost is Less) then (Supplier is Accepted) (1)
10. If (Reliability is Negligible) and (Proximity is Bad) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
11. If (Reliability is Negligible) and (Proximity is Average) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
12. If (Reliability is Negligible) and (Proximity is Good) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
13. If (Reliability is Medium) and (Proximity is Bad) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
14. If (Reliability is Medium) and (Proximity is Average) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
15. If (Reliability is Medium) and (Proximity is Good) and (Cost is Medium) then (Supplier is Under_Consider) (1)
16. If (Reliability is Important) and (Proximity is Bad) and (Cost is Medium) then (Supplier is Not_Accepted) (1)
17. If (Reliability is Important) and (Proximity is Average) and (Cost is Medium) then (Supplier is Under_Consider) (1)
18. If (Reliability is Important) and (Proximity is Good) and (Cost is Medium) then (Supplier is Accepted) (1)
19. If (Reliability is Negligible) and (Proximity is Bad) and (Cost is High) then (Supplier is Not_Accepted) (1)
20. If (Reliability is Negligible) and (Proximity is Average) and (Cost is High) then (Supplier is Not_Accepted) (1)
21. If (Reliability is Negligible) and (Proximity is Good) and (Cost is High) then (Supplier is Not_Accepted) (1)
22. If (Reliability is Medium) and (Proximity is Bad) and (Cost is High) then (Supplier is Not_Accepted) (1)
23. If (Reliability is Medium) and (Proximity is Average) and (Cost is High) then (Supplier is Not_Accepted) (1)
24. If (Reliability is Medium) and (Proximity is Good) and (Cost is High) then (Supplier is Not_Accepted) (1)
25. If (Reliability is Important) and (Proximity is Bad) and (Cost is High) then (Supplier is Under_Consider) (1)
26. If (Reliability is Important) and (Proximity is Average) and (Cost is High) then (Supplier is Under_Consider) (1)
27. If (Reliability is Important) and (Proximity is Good) and (Cost is High) then (Supplier is Under_Consider) (1)

Figure 8: 27 rules

3.4 Defuzzification

We will carry out the defuzzification and we will proceed to the generation of the graphs, their study and interpretation, in order to select the best supplier who will be accepted for the purchase of the wind turbine while taking into consideration the correlation between the three criteria chosen for

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our study which are: Reliability, Proximity of Operation and Maintenance Teams, Cost, supplier.

4. DISCUSSION

We will begin the study and interpretation of the graphs, after defuzzification, while taking into account the selection of accepted supplier according to the three criteria chosen in this piece of research which are: the criterion: " Reliability ", the criterion: "Cost " and finally the criterion: " Proximity of Operation and Maintenance Teams "

Here is what we will treat as an important case for the rest of this study:

Case 1: One indicator is fixed and two indicators are changed.

Case 2: Two indicators are fixed and one indicator is changed.

4.1 One Indicator Is Fixed And Two Are Changed

4.1.1 Example1:

- ✓ One indicator is fixed: cost: Medium
- ✓ Two are changed: Reliability, Proximity of Operation and Maintenance Teams

We will perform the analysis of how our system reacts if we give an average value to the cost indicator: Medium.

We will precisely make an interpretation of the Output "supplier" indicator according to the variation of the two input indicators which are Reliability, Proximity of Operation and Maintenance Teams.

The figure below shows the Surface viewers 3D of example N°1:

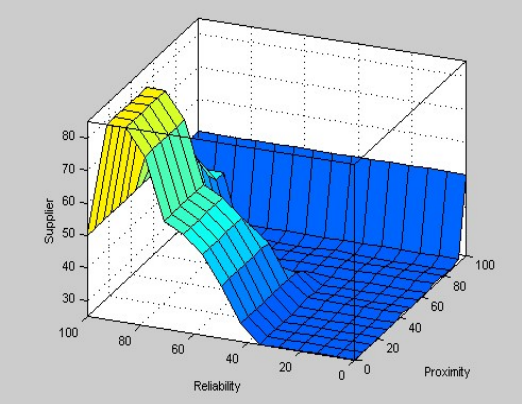

Figure 9: Surface viewers 3D of example N°1.

The figure below shows also the Surface viewers 2D of example N°1:

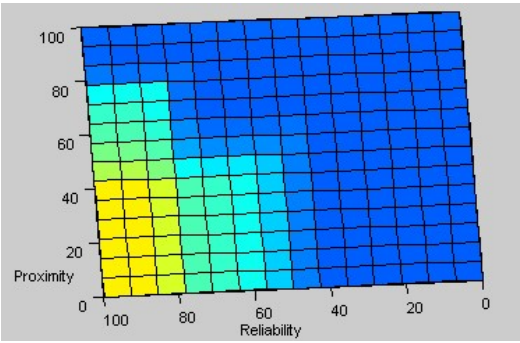

Figure 10: Surface viewers of example N°1.

Discuss curve of the example N°1:

The curve above shows that we can see the three results of the supplier: The first result which supplier is Not accepted:

- ✓ is where Reliability is Negligible of whether the Proximity of Operation and Maintenance Teams is bad or average or good
- ✓ Or the Proximity of Operation and Maintenance Teams is bad or average and Reliability is Medium
- ✓ There is also the case where the Proximity of Operation and Maintenance Teams is bad and Reliability is Important

The second situation is the case where the "supplier" criterion is under-consider. This situation is characterized by the fact that the "Reliability" criterion is Medium regardless of "the Proximity of Operation and Maintenance Teams" criterion whether it is bad, average.

The last situation represents the case where the supplier criterion is accepted. This case occurs when we have a " Reliability " criterion is Important and the Proximity of Operation and Maintenance Teams criterion is Good.

As we can see from the figure below, Rules View for" Reliability " and "the Proximity of Operation and Maintenance Teams" when cost is fixed at 60.

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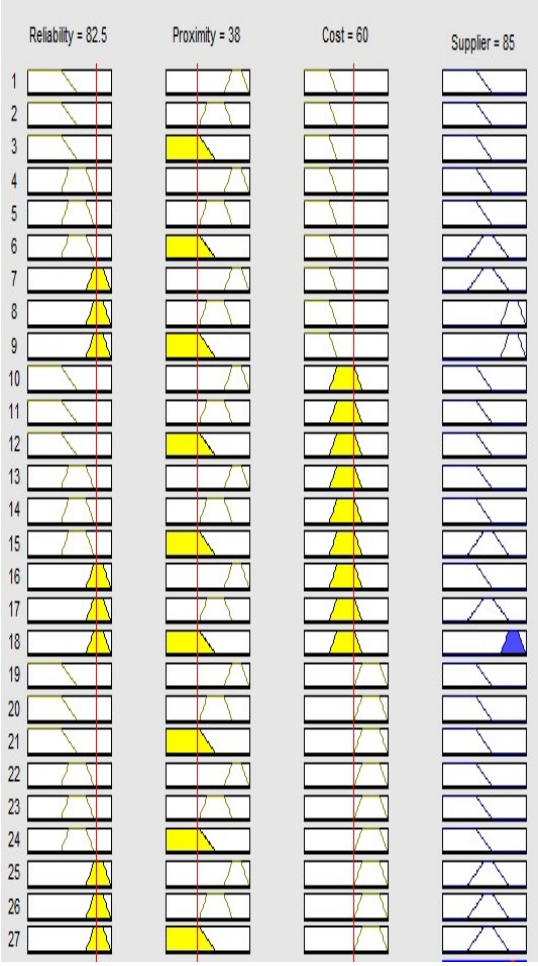

Figure 11: Rules View for" Reliability " and "the Proximity of Operation and Maintenance Teams" when cost is fixed at 60

As we can see from the figure below, and following the defuzzification when the Reliability is important and fixed at 82,5 ,and the Proximity of Operation and Maintenance Teams is fixed at 38, that gives us an accepted Supplier with a net numerical value of 85. The change of the two parameters have an impact on the selection of the supplier.

4.1.2 Example2:

We will perform the analysis of how our system reacts if we give an average value to the Proximity of Operation and Maintenance Teams indicator.

We will precisely make an interpretation of the outuput "supplier" indicator according to the variation of the two input indicators which are Reliability, Cost.

The figure below shows the Surface viewers of example N°2:

- ✓ One indicator is fixed: Proximity of Operation and Maintenance Teams: Average
- ✓ Two are changed: Reliability, Cost.

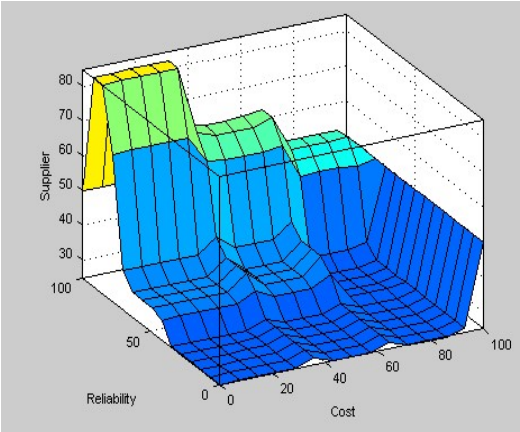

Figure 12: Surface viewers 3D of example N°2.

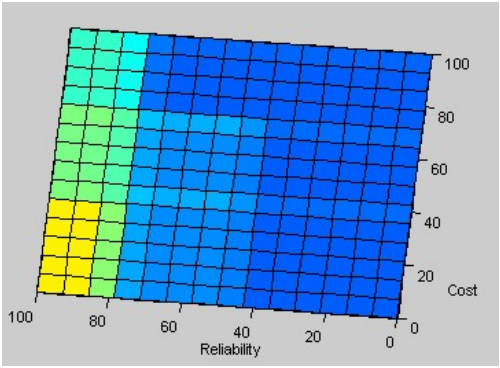

Figure 13: Surface viewers 2D of example N°2.

Discuss curve of the example N°2:

- ✓ The first result which supplier is Not accepted is where Reliability is Negligible or Medium and the Cost is Less or Medium or High.
- ✓ The second situation is the case where the "supplier" criterion is under-consider. This situation is characterized by the fact that the "Reliability" criterion is Important and the "Cost" criterion is Medium or High
- ✓ The last situation represents the case where the supplier criterion is accepted. This case occurs when we have a " Reliability " criterion is Important and the cost criterion is less.

As we can see from the figure below, Rules View for" Reliability " and "cost" when the Proximity of Operation and Maintenance Teams is fixed at 60.

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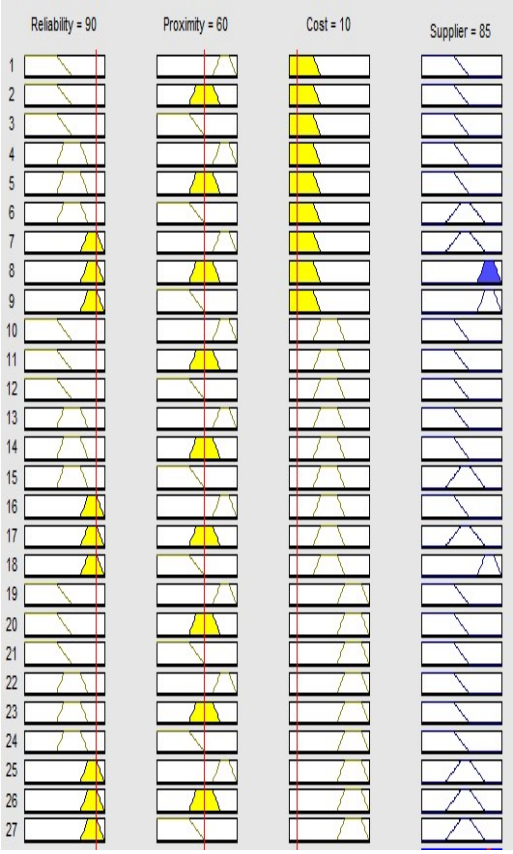

Figure 14: Rules View for" Reliability " and "cost" when the Proximity of Operation and Maintenance Teams cost is fixed at 60.

As we can see from the figure above, and following the defuzzification when the Reliability is important and fixed at 90 ,and the cost is fixed at 38, that gives us an accepted Supplier with a net numerical value of 85. The change of the two parameters have an impact on the selection of the supplier.

4.1.3Example3:

We will perform the analysis of how our system reacts if we give a Medium value to the Reliability.

We will precisely make an interpretation of the outuput "supplier" indicator according to the variation of the two input indicators which are Proximity of Operation and Maintenance Teams indicator, Cost.

The figure below shows the Surface viewers of example N°3:

- One indicator is fixed: Reliability: Medium
- Two are changed: Proximity of Operation and Maintenance Teams , Cost

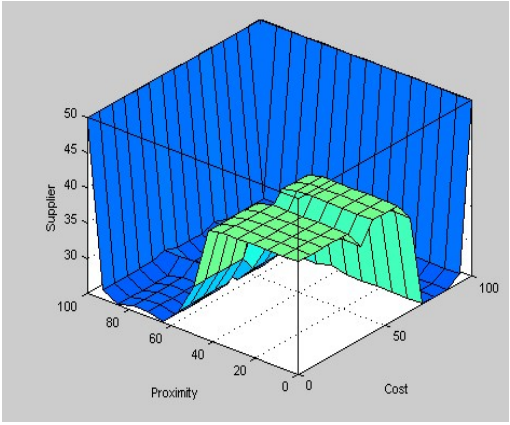

Figure 15: Surface viewers 3D of example N°3.

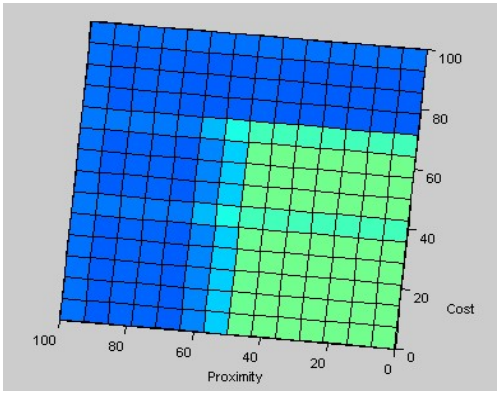

Figure 16: Surface viewers 2D of example N°3.

Discuss curve of the example N°3:

- ✓ The first result which supplier is Not accepted: is where Proximity is Bad of whether the cost is Less, Medium, High or the Cost is High whatever the Proximity is Bad or average or Good .
- ✓ The second situation is the case where the "supplier" criterion is under-consider. This situation is characterized by the fact that the "Cost" criterion is Less or Medium and "the Proximity of Operation and Maintenance Teams" criterion is average or Good .
- ✓ The last situation represents the case where the supplier criterion is accepted. when the Reliability is fixed at Medium we don't have the case where the supplier is accepted.

As we can see from the figure below, Rules View for "cost" and " the Proximity of Operation and Maintenance Teams " when the Reliability is fixed at 50.

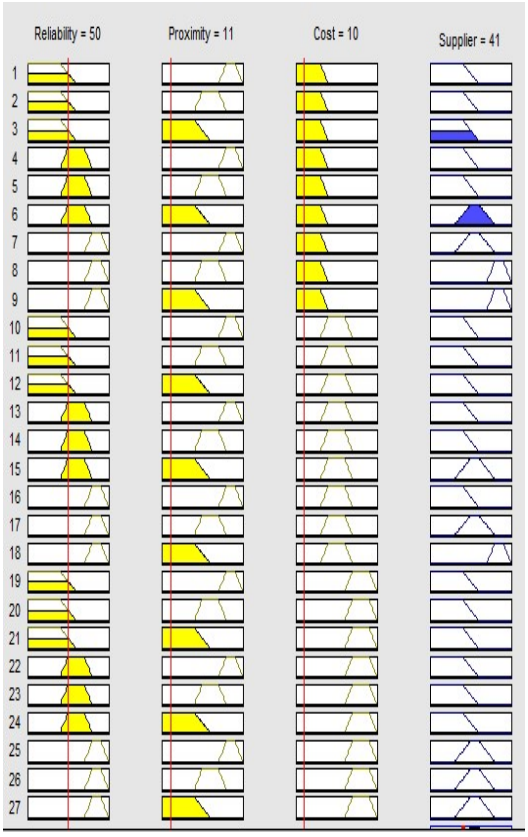

Figure 17: Rules View for "cost" and " the Proximity of Operation and Maintenance Teams when reliability is fixed at 50

Following the defuzzification, We conclude that in the case where we set a criterion Reliability at 50 the Rules View for "cost" is fixes at 10 and " the Proximity of Operation and Maintenance Teams is fixed at 10 , that gives us an accepted Supplier with a net numerical value of 41.

4.2 Two Indicators Are Fixed And One Is Changed

4.2.1 Example1:

We set the criterion of "Cost "and the criterion of " Proximity of Operation and Maintenance Teams " at the value 90.

The table below shows the change of Reliability with Supplier:

Table 8: The change of Reliability with Supplier

Reliability	Supplier
0	25,1
10	25,1
20	25,1
30	25,1
40	25,1
50	25,1
60	25,1
70	25,1
80	55
90	55
100	50

The figure below shows the change of supplier with Reliability while considering that the two other parameters are fixed in advance:

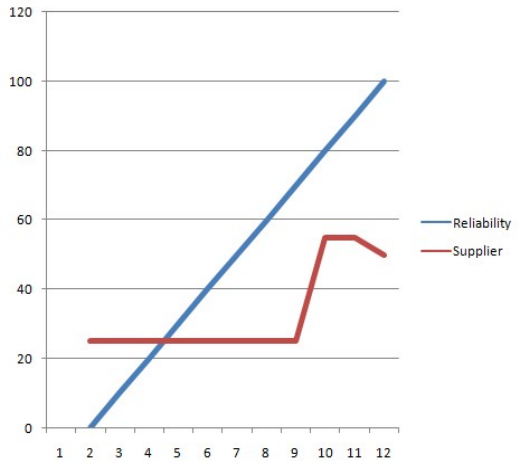

Figure 18: the change of supplier with Reliability

Initially, the value of the supplier is fixed at 25,1 despite the fact that the parameter: Reliability increases linearly, then the value of the supplier also increases linearly between [25,1-55] with Reliability.

After, the value of the supplier remains fixed again at 55 and Finally the supplier curve goes down to a value of 50 knowing that the reliability curve remains linear from the beginning.

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The following figure shows the curve of the supplier according to the reliability while considering that the two other parameters are fixed:

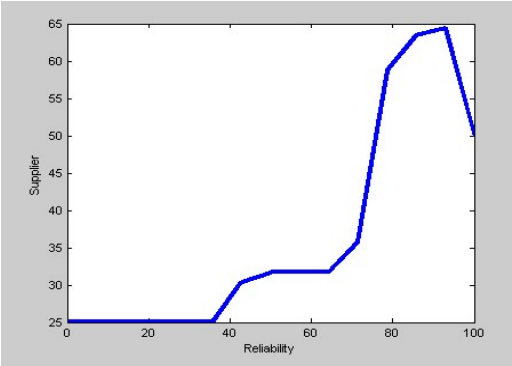

Figure 19: Curve of the supplier according to the reliability

The difference between the two figures is that the first figure 18 shows the difference only when the two parameters Cost "and the criterion of " Proximity of Operation and Maintenance Teams " are set to a given numerical value 90.

While figure 19 is completely general and it is not at all restricted to a fixing of a given numerical value, it shows the curve of the supplier according to the reliability while considering that the two other parameters are fixed .

At the start, the curve of the supplier according to the reliability is fixed at the value 25 then there is a slight increase when the numerical value of the reliability is included in the interval of [38-90]. Then there is a descent of the curve of the supplier when the value of the reliability is approximately between [90-100].

4.2.2 Example2:

We set the criterion of "Cost "and the criterion of " Reliability " at the value 90.

The table below shows the change of Proximity of Operation and Maintenance Teams with Supplier:

Table 9: The Change Of Proximity Of Operation And Maintenance Teams With Supplier

Proximity of Operation and Maintenance Teams	Supplier
0	55
10	55
20	55
30	55
40	55
50	55
60	55
70	55
80	55
90	55
100	50

The figure below shows the change of supplier with Operation and Maintenance Teams while considering that the two other parameters are fixed in advance:

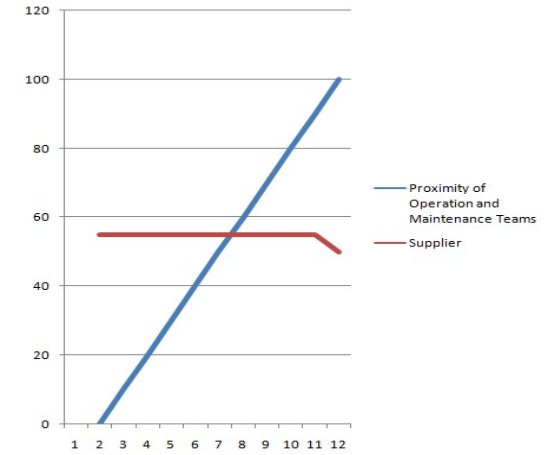

Figure 20: The change of Proximity of Operation and Maintenance Teams with Supplier

Initially, the value of the supplier is fixed at 55 despite the fact that the parameter: Proximity of Operation and Maintenance Teams increases linearly, then the value of the supplier also decreases linearly when the reliability is fixed at 90.

The following figure shows the curve of the supplier according to the Proximity of Operation and Maintenance Teams while considering that the two other parameters" cost" and Reliability are fixed.

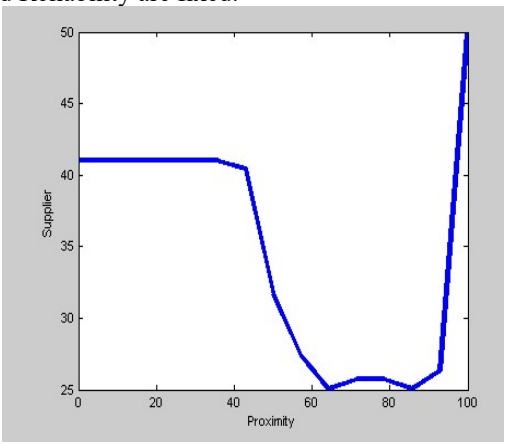

Figure 21: Curve of the supplier according to the Proximity of Operation and Maintenance Teams

The difference between the two figures is that the first figure 20 shows the difference only when the two parameters "Cost" and the criterion of "Proximity of Operation and Maintenance Teams " are set to a given numerical value 90.

While figure 21 is completely general and it is not at all restricted to a fixing of a given numerical value, it shows the curve of the supplier according to the Proximity of Operation and Maintenance Teams while considering that the two other parameters are fixed.

At the start, the curve of the supplier according to the Proximity of Operation and Maintenance Teams is fixed at the value 41 then there is a slight decrease when the numerical value of the Proximity of Operation and Maintenance Teams is included in the interval of [38-62].

Approximately in the interval [62.82] of the Proximity of Operation and Maintenance Teams, the supplier curve increases again and reaches its maximum at 26, then it goes down slightly to go up linearly again.

4.2.3 Example3:

We set the criterion of " Reliability "and the criterion of " Proximity of Operation and Maintenance Teams " at the value Reliability 90.

The table below shows the change of Cost with Supplier:

Table 10: The Cost and Maintenance Teams with Supplier

Cost	Supplier
0	55
10	55
20	55
30	55
40	25,1
50	25,1
60	25,1
70	55
80	55
90	55
100	50

The figure below shows the change of supplier with Cost while considering that the two other parameters are fixed in advance:

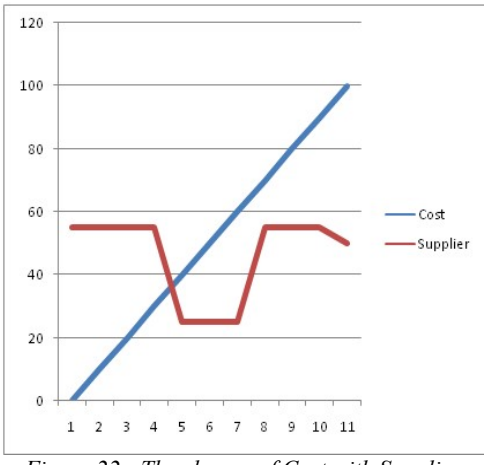

Figure 22: The change of Cost with Supplier

Initially, the value of the supplier is fixed at 55 despite the fact that the parameter: Cost increases linearly, then the value of the supplier also decreases linearly until reaching the value 25,1.

After, the value of the supplier remains fixed again at 25,1 and Finally the supplier curve goes up again to a value of 55 knowing that the cost curve remains linear from the beginning.

The following figure shows the curve of the supplier according to the Cost while considering that the two other parameters" Proximity of Operation and Maintenance Teams" and Reliability are fixed.

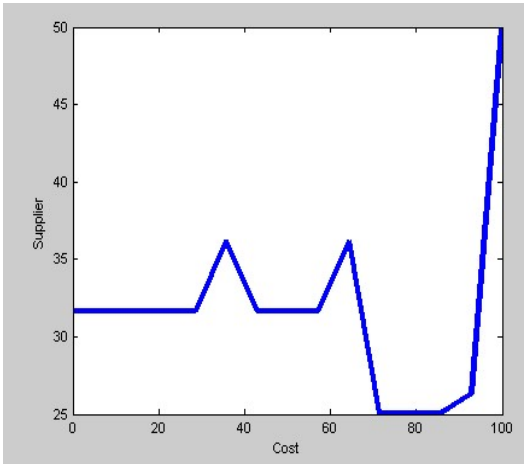

Figure 23: Curve of the supplier according to the Cost

The difference between the two figures is that the first figure 22 shows the difference only when the two parameters Reliability "and the criterion of "Proximity of Operation and Maintenance Teams " are set to a given numerical value 90.

While figure 23 is completely general and it is not at all restricted to a fixing of a given numerical value, it shows the curve of the supplier according to the cost while considering that the two other parameters are fixed.

At the start, the curve of the supplier according to cost is fixed approximately at the value 31,5 then there is a slight increase and decrease until reaching the value of cost of approximately 83 then the curve of supplier is increasing linearly until reaching the value of 50.

4.3 Merits Of Research:

We list some advantages of our research:

- ✓ We found ease in applying fuzzy logic in our research because it is a simple and uncomplicated method according toGarcia et al. [34] and Ng [35], El mkhalet et al.[36]
- ✓ Through this research, we have been able, thanks to the fuzzy logic method, to solve the difficulty of linguistic uncertainty and ambiguity between the decision-makers for the choice of supplier for the purchase of a wind turbine.
- ✓ We were able to visualize the fuzzy rules through Matlab in the different figures in our study, we were able to see the relationship and the correlation between the inputs (Reliability, Cost, Proximity) that we used in the study and the output which is the supplier [37]. This visualization is very important for managers and decision makers because they can detect the best accepted supplier quickly and without complication if they have in advance a criterion fixed or two criteria fixed in advance.

4.4 Overall limitations Of The Study

There are certain limits that we can confront:

- ✓ The analysis of the nature of the reaction of our study system (cost, Proximity, Reliability) and the variation of the output which is the choice of the best supplier can prove to be difficult if we consider in a future continuity of research sub-parameters for each parameter whether for the input or the output for example for cost we can consider the maintenance price and the purchase price of the wind turbine and so on.
- ✓ If we increase the number of criteria for example up to five criteria, the application of the fuzzy logic method will be a little more difficult because the more criteria we will consider, the more the number of fuzzy rules will increase and even in the interpretation of 3D simulations and graphs, it will become more complicated, because there will be several parameters in consideration according to El mkhalet et al.[36] .
- ✓ The application of fuzzy logic is difficult, in the case where the study required, it may be that for each criterion for example Cost, there are beyond three membership functions, in the step of fuzzification and we can spread that for the other criteria, whether input or output, for example (little less, less, little medium, medium, high). We can also add the case where we will have more than one output.

4.5 Research Contributions:

We have contributed at the scientific level by applying fuzzy logic in Morocco for the selection of the best supplier for the purchase of wind turbines. The effectiveness of the model lies in the fact that it is simple to use by any decision maker or manager in the company without exception. It is enough just to see the visualizations and the simulations in three dimensions for the decision-making concerning the confronted case.

The effectiveness of the model developed, for decision-making assistance, also lies in the fact that it reflects reality because it basically deals with imprecision.

4.6 Comparison With Another Search:

If we compare our research that we conducted on the application of fuzzy logic for the selection of suppliers for the purchase of wind turbines in Morocco with the research of Spherical Fuzzy Multicriteria Decision-Making Model for Wind Turbine Supplier Selection in a Renewable Energy Project from the author Nguyen et al. [19], we find that there are some differences which we can list as follows:

We used three criteria, while for the research of Nguyen et al. [19] there were four criteria with detailed sub-criteria in the table below:

Table 11: Difference Between the criteria of our research and criteria of Nguyen et al.[19]

three criteria	Four criteria and sub-criteria	
Cost	Machine Feature (MF)	-Operations of wind turbine and Power Ratio (MF1) -Available of maintenance (MF2) -Turbine efficiency and Turbine speed (MF3)
Reliability	Environmental (EN)	-Area use (EN1) -Environmental impact (EN2) -Fuss/air and water

		pollution (EN3)
Proximity of Operation and Maintenance Teams	Technological (TE)	-Time of Allocation (TE1) -Capacity of System integration (TE2)
	Monetary (MO)	-Investment cost (MO1) -Operation and Maintenance cost (MO2) -Profit (MO3)

- ✓ Regarding our study, we only used the logic fuzzy approach for decision support while for the research of Nguyen et al.[19] he used Spherical Fuzzy combined with the AHP and WASPAS models to rank turbine suppliers
- ✓ There was a difference between the nature and the application of the individual approach of fuzzy logic in our research, we interpreted the graphs in 3D, with the nature and application of the research Nguyen et al.[19] where there was the application of the combined method Spherical Fuzzy combined with the AHP and WASPAS models.
- ✓ About the results obtained, they were up to the desired objectives at the beginning of the study whether for our research or for the research of Nguyen et al. [19], since both were able to have a decision-making aid model for the managers and determined the case where we can select the best supplier.

4.7 Future Work:

According to the discussions above, the work can be further improved by adding sub-criteria related to each criteria for the selection of the best supplier for the purchase of wind turbines.

We can also better improve the study while combining fuzzy logic with another approach like SAW method or AHP method in order to have a clear weighting of the sub-criteria and criteria to make the right choice finally.

We can carry out in a future research, the application of the approach of the fuzzy logic for the selection of the suppliers of the solar panels for other companies.

The usefulness of our study will make it easier for us to choose a supplier for the purchase of turbines that will allow us to generate electrical energy thanks to wind energy with a good rate, this aims to create a management system for blockchain-based electric power in future research.

5. CONCLUSION

The purpose of this research that we have conducted through this present work is to overcome the difficulty of imprecision and ambiguity of decision makers while applying the technique of fuzzy logic, which allowed us to specify the best supplier for the purchase of wind turbines according to the cases studied. We have shown throughout the study that we have provided a clear answer to the question of the problem posed in the introduction.

Secondly, we do fuzzification: We model the criteria chosen by membership function after determining the linguistic values of each criterion which are: the Reliability, The Cost, The change of Proximity of Operation and Maintenance Teams. Furthermore, we construct 27 fuzzy-rule and for decision making and we apply defuzzification : The fuzzy values is converted to crisp value.

In the discussion part, we examined the different cases where we set a single criterion and we have the interpretations of the different curves, then we carefully examined the various cases where we set two criteria. All these diagrams and graphs were established in order to be like a database for the decision makers and the managers of the company if they are confronted with one of these cases; and to facilitate quick and easy selection of the best supplier in a given case.

Moreover, we have shown the advantages of applying the fuzzy logic approach for the selection of suppliers for the purchase of a turbine, and we have shown the various limitations: We will have certain difficulties if we increase the number of criteria beyond 3 or if we consider other sub-criteria for each criterion chosen at the base, the number also of fuzzy rules will also change which will make the interpretation of the three-dimensional graphs for makers less easy and a bit complicated.

. We discussed about the contribution of our research at the level of our country: Morocco and it was the first time that such a study was carried out with such a technique. After, we discussed about our perspectives and how we are going to carry out the continuation of this study in the future.

Finally, fuzzy logic was easy to apply for our study, thanks to the different cases studied we found the best supplier to choose, knowing that we were able to deal with the difficulty of imprecision and vagueness linked to the thinking of decision-makers. This piece of research is like a database for managers. In future research, we may add sub-

criteria and combine fuzzy logic with another approach.

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