DETERMINATION THE PRIORITY OF MANAGERIAL DECISIONS USING FUZZY LOGIC

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Abstract

Management is one of the most critical factors for success, whether personally, in institutions, or even the country. The role of management, in general, is to make the best decisions within the available reality, and this matter requires decision-makers with high experience, clear data, and other things that help them to make a decision. We find that decisions based on quantitative numerical data are the most widespread for their ease of handling, and most of the time, the correctness is high. However, in other cases, the decision-maker handles linguistic variables, through which it can be reached to the right decision, which cannot be made using zeros and ones. Then, it may contain a graded outcome of the decisions that can select based on their priority. This paper introduces a novel idea based on artificial intelligence and machine learning in managerial decision-making. The fuzzy proposed approach is based on the linguistic data and the setting priority to help decision-makers in their tasks by simulating human thinking. Two scenarios are tested and compared to verify the applicability of the proposed approach.

Keywords: *fuzzy logic, uncertainty, managerial decision, linguistic variables, machine learning.*

1. Introduction

We find that systems operate based on the binary system zero and one in the digital world. This means that if we want to adopt the binary system and make the machine do the decision-making process, this means that we are forced to accept one of two options, and both of them may be wrong or far from right. Therefore, we are forced to resort to other methods that help the machine make a decision other than the binary system. This method is closer to simulating human thinking in reaching the correct decision. For example, if a person wants to buy a number of shares in a particular company, the result will be whether he buys or not in the binary system. As for human thinking, the matter is more complicated than this, as it may be for him to buy a certain number of shares, and this is considered a case between the two previous cases. And if the decision determines a specific number of shares that he will buy in this case, we will come up with an infinite number of possibilities that simulate human thinking.

Also, one of the important matters that must be pointed out is that in administrative decisions, in many cases, decision-makers may not have numerical data from which they can determine the right decision, but based on certain facts and his experience, he can determine the right decision. This would be more complex for the machine, so we tried to propose a fuzzy logic model of machine learning and help it prioritize managerial decisions.

Based on this, we tried in our topic in administrative decisions and trying to make the machine simulate the way of human thinking in making decisions. We tried to use fuzzy logic in the process of machine learning so that we can get more realistic decisions that help decision-makers save time and effort and reach the best-desired decisions.

The topic will be discussed in four sections, which are as follows: first, a literature review of the topic, then in the second section, the theory of fuzzy logic; thirdly, the practical model that we have applied, and finally, the results and discussion with future works.

2. Literature Review

Fuzzy logic is utilized in many engineering fields, such as solving load frequency control in multi-area power systems, H. A. Elaydi, et al. (2015), M. R. Tur, et al (2018) and M. Wadi, et al (2015). Furthermore, it is used in control design for renewable systems, M. Wadi, et al. (2018), M. Wadi, et al. (2019). In reliability and sensitivity studies, fuzzy logic is also utilized, M. Wadi, et al. (2017), M. Wadi, et al. (2018), Wadi & Shobole and Wadi & Baysal, (2017). Moreover, fuzzy logic applications can be found in renewable energy fields, Wadi & Elmasry (2021). In applications of fault detection in power systems, Wadi & Elmasry, (2021) and M. Wadi, (2021). Verónica Gurrea et al. (2014) mention the literature review of the application of fuzzy logic in performance management. Shuhadah Othman et al. (2010) explains that the rules of the fuzzy conditional of the decision support system were used in stock trading, and three linguistic variables were adopted to be the inputs to the rule and these variables were: view from the expert, the earnings per share, and the price-earnings ratio. The objective of this system was to assist investors in making the appropriate decision regarding their shares. This paper was based on helping the investor determine his decision according to five proposed outputs: sell and strongly, sell, hold, buy, buy strongly.

Himadri Shekhar et al. (2018) show that the current world depends on technical evaluation. A fuzzy-based model has been proposed, which is helpful for decision-making criteria. Through this model, the customer's surprise level is measured, which will be helpful to the business strategy maker for help in understanding the process of marketing the product and increasing the demand for it. Mamdani model is applied as the inference engine. The triangular membership function is used as a membership function. In the defuzzification process, the Max-membership method is applied.

N.H. MATEOU et al. (2005) propose a strategic management methodology using fuzzy Influence Diagrams to represent and model decision problems while describing influence diagrams, propose their extension via fuzzy logic, and demonstrate their use in crisis management and decision making. Using a different kind of fuzzy reasoning, such as scalable monotonic chaining, improved the flexibility of that method. A common technique for evaluating and solving an ID is based on the Bayesian Theorem. They had presented the empirical results of simulating the 1996 crisis at Imia between Greece and Turkey using a dedicated FID as proof for their suggested model.

Heinrich J. Rommelfanger (1998) represents a new method for solving multicriteria decision problems. The lowest level goals were evaluated using linguistic variables based on cardinal or ordinal scales that experts proposed. The evaluations of the subgoals were aggregated by using expert rules and fuzzy inference.

Marat Rakhmatullaev (2019), based on the principle of "Situation-Reason-Action" this system or model was proposed which was called Fuzzy Correspondence Models (FCM), the operation of fuzzy Inclusion of sets was used, as well as the method of priority coefficients were used to determine the priority of the chosen cause or action. Fuzzy correspondence models (FCM) are implemented in situational control systems; the main areas of application of the model are medicine. Diagnosis and treatment, technological or production tasks.

Yuan Yao et al. (2010) propose a fuzzy neural network (NN) system used for management decision-making and composed of three separate networks. It shows that people who make decisions use many factors influencing the decision and experience to take the appropriate decision. However, the diversity and complexity of the world always make the decision go in the wrong direction.

The causes of uncertainty generally arise due to three aspects. The first is that the information used in decision-making is not integrated. The second is that decision-making is a function of decision variables and contains subjective factors. Third, the identification process is often unclear.

The standard NN model ignores the ambiguity of the input vector and does not consider that one input vector can produce a variety of decision-making methods. In this paper, the fuzzy neural network provides a method to express membership function using fuzzy input vectors to resolve the problem. This approach would reduce the ambiguity of information and improve the quality of decision-making and network robustness. The method proposed in resolving management decision-making problems is exploratory research. The combination of fuzzy and neural networks has great significance in management science.

3. Fuzzy Logic

Fuzzy logic provides the general framework for solving the problem of representing approximate or not quite specific information and provides the mechanism for using this information.

It is known in classical logic that the variable takes one of two values , 0 and 1, or true and false. If we want to define a group of people, are they divided into the category of young people or the elderly, we will find that whoever exceeds the value separating the two groups will be considered elderly, and whoever is less than this value will be young as if the person suddenly shifted from the stage of youth to the stage of the elderly.

Therefore, fuzzy logic provides a suitable solution for such cases where the degree of belonging to the variable is assigned. This degree represents how much the variable belongs to a particular group within the real range of [0,1] instead of the {0,1} group. In this case, whoever is considered to be 15 years old, for example, will be in the youth group by 75%, for example, and so on. Figure 1 can illustrate this idea.

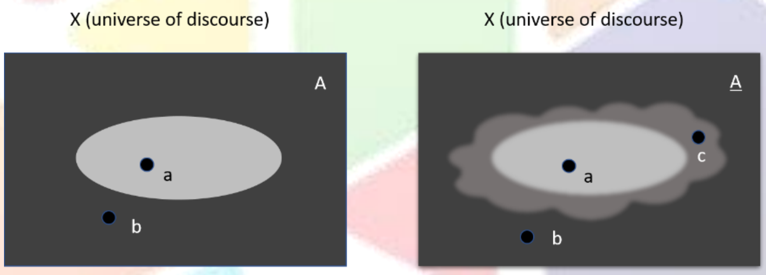

Figure 1: Difference between (a) crisp set boundary and (b) fuzzy set boundary

Vague or ambiguous properties prescribe a fuzzy set; hence its boundaries are ambiguous. Fuzzy set theory permits the gradual assessment of the membership of elements in a set, described with the aid of a membership function valued in the actual unit [0,1]. A membership degree is a real number on [0, 1]. In extreme cases, if the degree is 0, the element does not belong to the set, and if one, the element belongs 100% to the set.

The excluded middle axioms and De Morgan's principles are two unique properties of set operations. Let us suggest we have two sets, A and B. We use the excluded middle axioms to describe the given sets that are not valid for classical and fuzzy sets. We have two excluded middle axioms. The first one, called the axiom of the excluded middle, deals with the union of a set A and its complement; the second one, called the axiom of contradiction, represents the intersection of a set A and its complement.

Based on the preceding, it became clear that there is often overlap between ambiguous groups. Therefore, there was an urgent need to define relationships that control the element's affiliation to any group and the degree of its association with that group, which was expressed by the fuzzy relationships.

The type of the membership function is one of the following functions depending on statistical studies: polynomial, hyperbolic, triangular, sigmoid, trapezoidal, exponential, tangent, generalized bell-shaped, Gaussian, and any other functions can be used or could be chosen depending on the advice of the experts.

In our study we use Trapezoidal curves depend on four parameters and are given by:

$$f(X;a,b,c,d) = \begin{cases} 0 & for\ X < a \\ \dfrac{X-a}{b-a} & for\ a \le X < b \\ 1 & for\ b \le X < c \\ \dfrac{d-X}{d-c} & for\ c \le X < d \\ 0 & for\ d \le X \end{cases} \quad (1)$$

3.1. Managerial Data

In this table 1, a numerical scale appears from one to one hundred and twenty, and this scale represents the degree of priority in decision-making, as the lowest priority is the case that carries the value one and which corresponds to the four variables as follow: (Strength of interest: improvement, interest inclusion: special minor, the expectation of interest: expected, and field of interest: money.

As for the highest priority, it is the case that has the value one hundred and twenty, which corresponds to the four variables: (strength of interest: essential, Inclusion of interest: general, expectation of interest: current, and field of interest: religion).

Table 1: The used data

Power of Interest	Inclusion of Interest	Anticipating Interest	Fields of Interest				
			Religion	Soul	Brain	Race	Money
Essential	General	Current	120	119	118	117	116
Essential	General	Expected	115	114	113	112	111
Essential	Partially General	Current	110	109	108	107	106
Essential	Private Transitive	Current	105	104	103	102	101
Requirement	General	Current	100	99	98	97	96
Essential	Private minor	Current	95	94	93	92	91
Essential	Partially General	Expected	90	89	88	87	86
Requirement	General	Expected	85	84	83	82	81
Essential	Private Transitive	Expected	80	79	78	77	76
Essential	Private minor	Expected	75	74	73	72	71
Requirement	Partially General	Current	70	69	68	67	66
Requirement	Private Transitive	Current	65	64	63	62	61
Requirement	Private minor	Current	60	59	58	57	56
Requirement	Partially General	Expected	55	54	53	52	51
Improvement	General	Current	50	49	48	47	46
Improvement	General	Expected	45	44	43	42	41
Requirement	Private Transitive	Expected	40	39	38	37	36
Requirement	Private minor	Expected	35	34	33	32	31
Improvement	Partially General	Current	30	29	28	27	26
Improvement	Partially General	Expected	25	24	23	22	21
Improvement	Private Transitive	Current	20	19	18	17	16
Improvement	Private minor	Current	15	14	13	12	11
Improvement	Private Transitive	Expected	10	9	8	7	6
Improvement	Private minor	Expected	5	4	3	2	1

We have divided the outputs into five categories as fuzzy sets based on the recommendation of the experts. These five categories represent the outputs of the system, which is called the degree of priority. The five ranks are, respectively: lowest priority, low priority, medium priority, high priority, and the highest priority.

Table 2 below shows this division, which has been adopted, and this table has been applied and worked on using the MATLAB program, and the results obtained will be shown in the upcoming sections.

Table 2: The degree priority with fuzzy sets for the entered variables

Power of Interest	Inclusion of Interest	Anticipating Interest	Fields of Interest					Degree of Priority
			Religion	Soul	Brain	Race	Money	
Essential	General	Current	120	119	118	117	116	
Essential	General	Expected	115	114	113	112	111	
Essential	Partially General	Current	110	109	108	107	106	highest priority
Essential	Private Transitive	Current	105	104	103	102	101	
Requirement	General	Current	100	99	98	97	96	
Essential	Private minor	Current	95	94	93	92	91	
Essential	Partially General	Expected	90	89	88	87	86	
Requirement	General	Expected	85	84	83	82	81	high priority
Essential	Private Transitive	Expected	80	79	78	77	76	
Essential	Private minor	Expected	75	74	73	72	71	
Requirement	Partially General	Current	70	69	68	67	66	
Requirement	Private Transitive	Current	65	64	63	62	61	medium priority
Requirement	Private minor	Current	60	59	58	57	56	
Requirement	Partially General	Expected	55	54	53	52	51	
Improvement	General	Current	50	49	48	47	46	
Improvement	General	Expected	45	44	43	42	41	
Requirement	Private Transitive	Expected	40	39	38	37	36	low priority
Requirement	Private minor	Expected	35	34	33	32	31	
Improvement	Partially General	Current	30	29	28	27	26	
Improvement	Partially General	Expected	25	24	23	22	21	
Improvement	Private Transitive	Current	20	19	18	17	16	
Improvement	Private minor	Current	15	14	13	12	11	lowest priority
Improvement	Private Transitive	Expected	10	9	8	7	6	
Improvement	Private minor	Expected	5	4	3	2	1	

3.2. Membership Functions

As we defined earlier, the membership function is a function that maps elements in a domain of concern into their membership value in a set. All membership functions of our study for all inputs and outputs can be shown in figures 2-6.

3.2.1. The Membership Function of Strength of Interest (SOI)

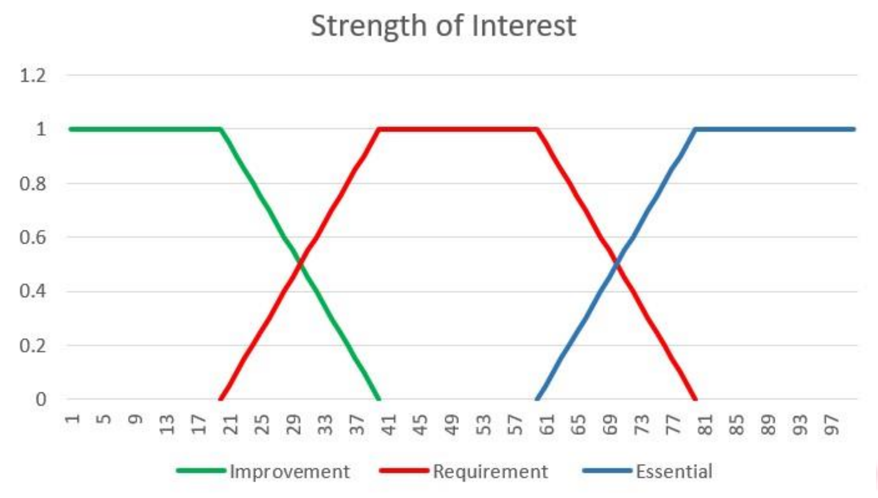

Figure 2: The membership function of SOI

$$Improvement – SOI = (1/20, 0.5/30, 0/40) \quad (2)$$

$$Requirement – SOI = (0/20, 0.5/30, 1/40, 1/60, 0.5/70, 0/80) \quad (3)$$

$$Essential – SOI = (0/60, 0.5/70, 1/80) \quad (4)$$

3.2.2. The Membership Function of Inclusion of Interest (IOI)

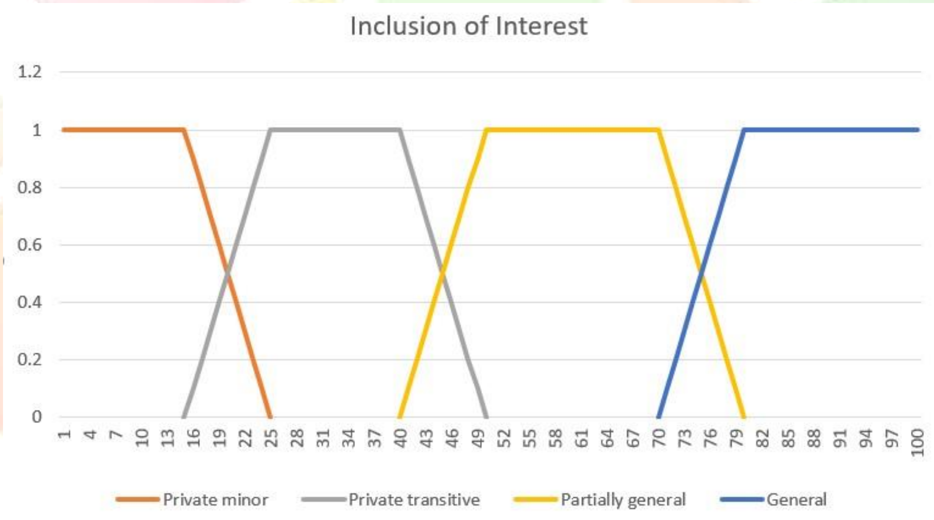

Figure 3: The membership function of IOI

$$Private\ minor – IOI = (1/15, 0.5/20, 0/25) \quad (5)$$

$$Private\ transitive – IOI = (0/15, 0.5/20, 1/25, 1/40, 0.5/45, 0/50) \quad (6)$$

$$Partially\ general – IOI = (0/40, 0.5/45, 1/50, 1/70, 0.5/75, 0/80) \quad (7)$$

$$General – IOI = (0/70, 0.5/75, 1/80) \quad (8)$$

3.2.3. The Membership Function of Expectation of Interest (EOI)

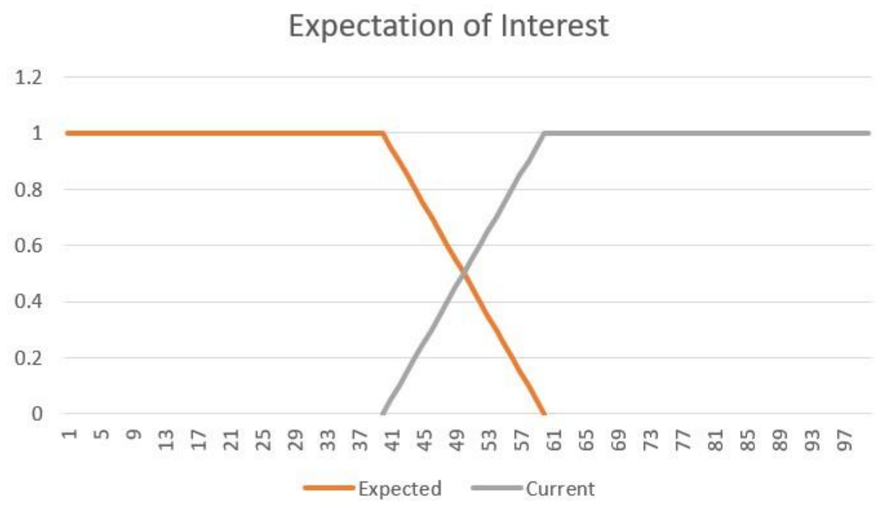

Figure 4: The membership function of EOI

Expected – EOI = (1/40, 0.5/50, 0/60) (9)

Current – EOI = (0/40, 0.5/50, 1/60) (10)

3.2.4. The Membership Function of Fields of Interest (FOI)

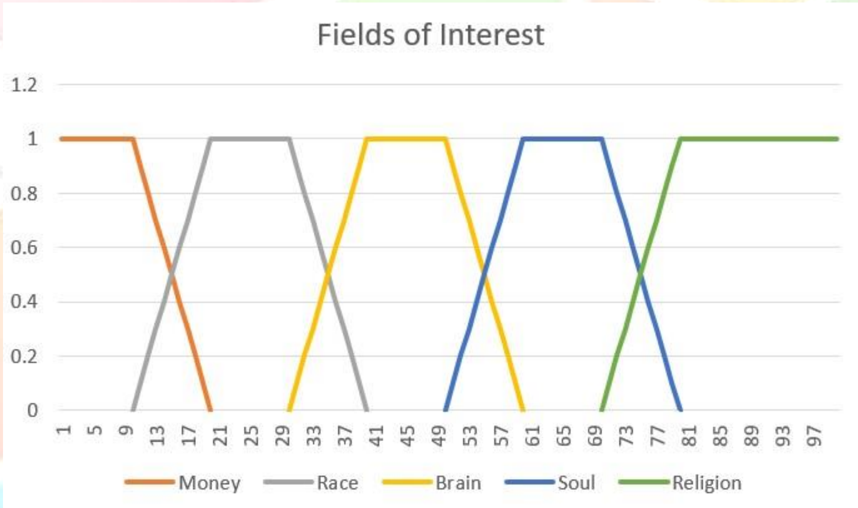

Figure 5: The membership function of FOI

Money – FOI = (1/10, 0.5/15, 0/20) (11)

Race – FOI = (0/10, 0.5/15, 1/20, 1/30, 0.5/35, 0/40) (12)

Brain – FOI = (0/30, 0.5/35, 1/40, 1/50, 0.5/55, 0/60) (13)

Soul – FOI = (0/50, 0.5/55, 1/60, 1/70, 05/75, 0/80) (14)

Religion – FOI= (0/70, 0.5/75, 1/80) (15)

3.2.5. The Membership Function for Outputs Is Degree of Priority (DOP)

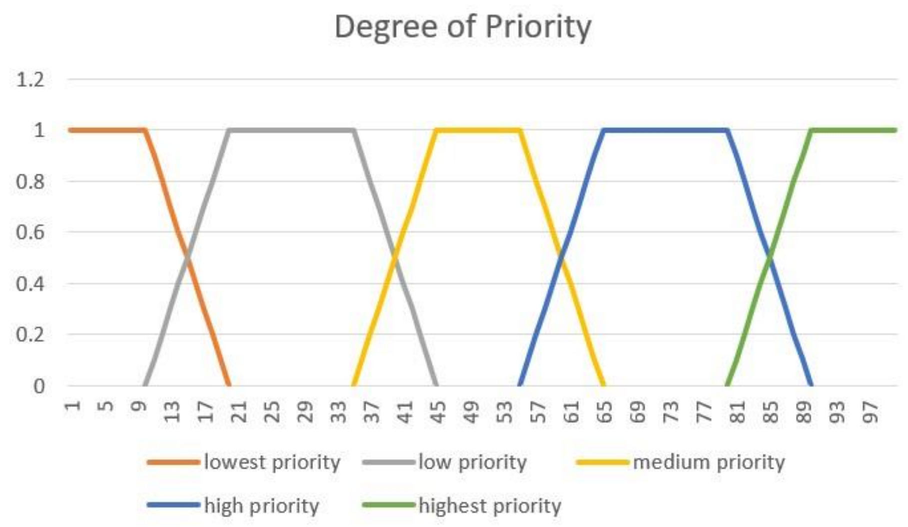

Figure 6: The membership function of DOP

3.3. The Rules That Were Used

The rules were developed to include all cases based on the division suggested in Table 3.

Several scenarios were made to show the effect of the inputs on the results obtained in case the weights used or the data entered were different.

The basic rules that were used in the base scenario are as follows:

Table 3: The representation of the used rules

	Power of Interest		Inclusion of Interest		Anticipating Interest	Fields of Interest						Degree of Priority
						Religion	Soul	Brain	Race	Money		
IF	Essential	AND	General	AND		ALL WEIGHTS ARE EQUAL (1)					THEN	highest priority
	Essential		Partially General		Current							
	Essential		Private Transitive		Current							
	Requirement		General			ALL WEIGHTS ARE EQUAL (1)						high priority
	Essential		Private minor									
	Essential		Partially General		Expected							
	Essential		Private Transitive		Expected							
	Requirement		Partially General			ALL WEIGHTS ARE EQUAL (1)						medium priority
	Requirement		Private Transitive		Current							
	Requirement		Private minor		Current							
	Improvement		General			ALL WEIGHTS ARE EQUAL (1)						low priority
	Requirement		Private Transitive		Expected							
	Requirement		Private minor		Expected							
	Improvement		Partially General									
	Improvement		Private Transitive			ALL WEIGHTS ARE EQUAL (1)						lowest priority
	Improvement		Private minor									

In this scenario, the weights related to the fields of interest are proposed to be equal and of the same value ,which equals one, meaning that no one has preference over the other, and they are all of the same ranks of priority.

Compared to them, some results will be reviewed for the proposed cases of twenty inputs and presented in tables like table 4 below.

In this scenario, the previously mentioned rules in table 3 will be used unchanged and tested with many different inputs, and the results will be observed and then compared with other scenarios later.

Table 4: the proposed cases of twenty inputs (1st scenario)

Case no.	Power of Interest	Inclusion of Interest	Anticipating Interest	Fields of Interest	Degree of Priority
1.	20	10	30	10	7.52
2.	30	20	50	15	31
3.	50	30	70	25	50
4.	70	45	30	35	50
5.	80	60	50	45	78.8
6.	20	75	70	55	27.5
7.	30	90	30	65	49.9
8.	50	10	50	75	37.5
9.	70	20	70	85	69
10.	80	30	30	10	72.2
11.	20	45	50	15	21
12.	30	60	70	25	37.4
13.	50	75	30	35	62.5
14.	70	90	50	45	78.9
15.	80	10	70	55	72.4
16.	20	20	30	65	8.56
17.	30	30	50	75	31
18.	50	45	70	85	50
19.	70	60	30	10	62.4
20.	80	75	50	15	78.8

3.4. Other Scenarios

In the second scenario, the weights of the fields of interest will be determined, each according to the strength of its influence in the decision-making and the priority of the decision.

The religion will be given a weight of 1, the soul 0.7, the mind 0.5, the race 0.3, and the money 0.2.

In the third scenario, weights were imposed in proportions appropriate to each case, meaning that each rule for the hundred and twenty cases we are studying took a different weight.

This scenario calculated the weights by dividing the weight from one hundred by one hundred and twenty existing cases and then converting it to a percentage. The first case, which represents the least priority cases in our study, was taken, and the weight was 0.0083333, and each case bears the same difference from the next case. The highest priority condition was carrying one full weight, meaning one hundred percent.

4. Results

Table 5: the comparison between the three scenarios for the same twenty inputs

Case no.	Degree of Priority			The result as a fuzzy value
	1st scenario	2nd scenario	3rd scenario	
1	7.52	9.26	9.5	lowest priority
2	31	31.8	38.2	low priority
3	50	50	50	medium priority
4	50	50	56.8	medium priority
5	78.8	78.2	79.6	high priority
6	27.5	27.5	27.5	low priority
7	49.9	49.9	56.4	medium priority
8	37.5	37.5	40.7	low priority
9	69	69	71.6	high priority
10	72.2	72.3	72.4	high priority
11	21	21.8	23.7	low priority
12	37.4	37.4	42.7	medium priority
13	62.5	62.5	64.9	high priority
14	78.9	78.4	79.7	high priority
15	72.4	72.3	72.4	high priority
16	8.56	8.89	9.5	lowest priority
17	31	31	37.8	low priority
18	50	50	50	medium priority
19	62.4	62.4	65.2	high priority
20	78.8	78	80.1	high priority

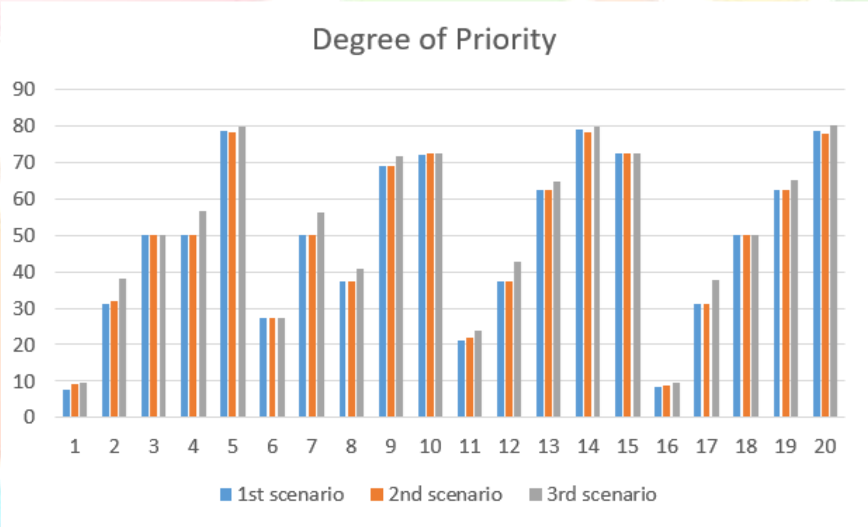

Figure 7: The representations of the three scenarios as column chart

Based on Table 5, we find that the difference between the first and second scenarios is simple and negligible, based on the selected cases because, in the first scenario, there is no difference between the weights concerning the areas of interest. This is because all domains have the same weight, whose value is one. We understand that the areas of interest do not influence the decision, so the priority does not change no matter how much the area of interest changes.

In the second scenario, the weights differed according to the values that we explained earlier in the second scenario section, but we note that some of the cases shown were less than the first scenario, some of them completely equal, and some slightly higher than them, due to the difference in the location of the selected values from the data table used. Meaning if the experimental values change, we also get similar results, and the reason for this is the location of the case for the areas of interest.

In the last scenario, we do not find this fluctuation present, but the cases take constant non-vibrating values because each case had the weight that affects the case itself only. So, the more accurate the used weights and the more accurate classification of cases for user data that we get from the experts, we will be able to simulate human decisions better and get better results. The machine will have the ability to determine which decisions are first in the implementation based on which gets the highest value according to our proposed model.

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