Control and Optimization in Applied Mathematics (COAM)
DOI. 10.30473/COAM.2021.58392.1160
Vol. 5, No. 2, Summer - Autumn 2020 (25-37), ©2016 Payame Noor University, Iran

Research Article

Application of Fuzzy Logic for Advertising Marketing Campaigns

Abbas Bashiri[1], Seyed Mehdi Mirhosseini-Alizamini[2*], Mohammad Mehdi Nasrabadi[3]

[1,2,3]Department of Mathematics, Payame Noor University (PNU),
P.O. Box. 19395-4697, Tehran, Iran.

Received: April 01, 2021; **Accepted:** June 27, 2021.

Abstract. Evaluation of advertising marketing campaigns is a very important and complex task, so far no comprehensive model has been presented in this regard. The present study aims to provide a decision framework for evaluating marketing campaigns. This article collects real-world data from an Iranian bank deposit marketing campaign. For this purpose, 250 cases were considered to extract the rules and 60 cases were considered as test data. Information is provided on 15 important parameters of marketing education, defaults, age, occupation, marriage, day, contact, balance, housing, loans, previous contact, previous outcome, month, call duration and campaigns. A fuzzy expert system was designed with 12 rules after reviewing the rules and removing similar and contradictory rules by using their degree calculation. In this system, by integrating some factors, finally 6 input variables and one output variable were considered that were used by product inference engine, singleton fuzzifier and center average defuzzifier. It was observed that the designed fuzzy expert system provides very good results.

Keywords. Fuzzifier, Defuzzifier, Fuzzy expert, Input-output.

MSC. 03B52; 90B50.

* Corresponding author
bashiri.abbas.73@gmail.com, m_mirhosseini@pnu.ac.ir, nasrabadi1974@gmail.com
http://mathco.journals.pnu.ac.ir

1 Introduction

The marketing of agriculture products plays an important role in achieving the common aims of food security, poverty reduction [2], and sustainable agriculture [3], especially among smallholder farmers in the rural area [7, 19]. The problem with classical communication rules is that any data that is available cannot be used for extraction. Rules are derived only from data containing binary data, whereas an item either exists in the transaction or does not exist in the transaction [6]. When dealing with a quantitative database, no communication rules can be extracted. This fact led to the invention of the laws of quantitative communication, in which quantitative features are divided into distances, and the individual elements are either members or non-members of each of these intervals. With this approach, a binary database can be created from a small database. The quantitative method allows a member to be an interval or not. To deal with this problem, a fuzzy rules approach has been developed. This allows time intervals to overlap, creating a fuzzy set instead of a fragility. Details can show a minor membership for more than one set, which is called the sharp boundary issue. The membership of an item is defined by a membership function and a fuzzy theoretical set that is performed to calculate the qualitative criteria of the discovered rules. In this way, rules may be discovered that could not be discovered with the quantitative approach standard [11].

Consider targeting fuzzy logic experts to target customers for fixed deposit subscriptions, six age inputs, average annual balance, marital status, loan availability, previous call result and call duration. This data shows the degree of ambiguity in the information provided by the customer and collected by banks from various sources. Fuzzy logic is a powerful tool that deals with human decision-making and reasoning, which includes inaccuracy, uncertainty, ambiguity and approximation. Fuzzy logic can be used to quantify the share of a set of information in various parameters in terms of fuzzy membership. Fuzzy logic emerges as an attractive tool for various applications such as time series forecasting [1], finance [5], determine the risk management in electronic banking activities [8], determine the retentive causes of pulse body the pulse parameters [9], Coronavirus disease diagnosis [10, 17], decision analysis [15], digital marketing performance measurement [16], decision making [21, 23] and designing a model for evaluating marketing channels [4, 22].

In this study, we create customers who are the target of marketing calls to subscribe. Expert system based on fuzzy logic consists of four components: fuzzifier, inference engine, defuzzifier and the rule base [14, 18].

The role of the fuzziffier is to convert the crisp input variable into linguistic variables that are ready to be processed by the inference engine. The inference engine processes the inputs and rules stored in the input data rule using a fuzzifier and generates a linguistic output. Once the output linguistic values are available, the defuzzifier generates the final clear values of the output linguistic values. The validation process begins with entering two sets of data; one is provided by the customer and the other by bank marketing that reviews the customer's profile. The data are obtained from the direct marketing of the activities of an Iranian banking institution. Marketing campaigns are based on whether or not telephone calls are made to access whether the product (term

deposit) is shared (or not). Information that is very important in making decisions to select target customers is taken in terms of impact factor. Similarly, the values of other inputs can be specified. The normal values of these measurements are used as input to the expert system. The degree of membership related to the input value is determined using the trapezoidal membership functions due to their simplicity and good result by simulation. Membership functions are designed based on available information.

This paper is organized as follows. Section 2 reviews some preliminaries about fuzzy set theory. Section 3 is dedicated to the development of the fuzzy based expert system. In this section, we introduce general input variables and output variable. Finally, we end this paper with conclusions in Section 4.

2 Preliminaries

In this section, we provide an overview of some basic concepts and results of fuzzy set theory [10, 11].

Definition 1. A fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is called a triangular fuzzy number if its membership function is given as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ \frac{a_3-x}{a_3-a_2}, & a_2 \leqslant x \leqslant a_3. \end{cases} \tag{1}$$

Definition 2. The $\alpha-$cut of a fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ is denoted by $[A_\alpha^L, A_\alpha^U]$ and defined as

$$[a_1 + (a_2 a_1)\alpha, a_3(a_3 a_2)\alpha] = [a_2\alpha + a_1(1\alpha), a_2\alpha + a_3(1\alpha)]. \tag{2}$$

Definition 3. A fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ is called a trapezoidal fuzzy number if its membership function is given as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ 1, & a_2 \leqslant x \leqslant a_3, \\ \frac{a_4-x}{a_4-a_3}, & a_3 \leqslant x \leqslant a_4. \end{cases} \tag{3}$$

Definition 4. The $\alpha-$cut of a trapezoidal fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ is defined as

$$[A_\alpha^L, A_\alpha^U] = [a_2\alpha + a_1(1\alpha), a_3\alpha + a_4(1\alpha)]. \tag{4}$$

Definition 5. A triangular fuzzy number $\tilde{A} = (a_1, a_2, a_3)$ or a trapezoidal fuzzy number $\tilde{A} = (a_1, a_2, a_3, a_4)$ is said to be non-negative if for every $\alpha \in (0, 1]$,

$$[A_\alpha^L, A_\alpha^U] \subset R^+ = [0, \infty),$$

i.e., $a_1 \geq 0$. In addition, they are said to be positive if for every $\alpha \in (0, 1]$, $[A^L, A^U] \subset R^{++} = (0, \infty)$, i.e., $a_1 > 0$. The set of all non-negative and positive triangular fuzzy

numbers are denoted by $TF(R^+)$ and $TF(R^{++})$, respectively. Similarly, the set of all non-negative and positive trapezoidal fuzzy numbers are denoted by $TrF(R^+)$ and $TrF(R^{++})$ respectively.

Definition 6. The support of a fuzzy set $\tilde{A}$ is defined:

$$Supp(\tilde{A}) = \{x \in X; \mu_{\tilde{A}}(x) > 0\}. \tag{5}$$

Definition 7. The height of a fuzzy set $\tilde{A}$ denoted by $h(\tilde{A})$ is the largest degree of membership obtained by each element in the set.

$$h(\tilde{A}) = sup(\mu_{\tilde{A}}(x)) \quad x \in X. \tag{6}$$

Definition 8. A fuzzy number is a convex normalized fuzzy set of real line $\mathbb{R}$ whose membership function is partially connected.

Fuzzy set theory is primarily concerned with how quantitatively deal with inaccuracies and uncertainties, and offers the decision maker other tools in addition to the classical definite and probabilistic mathematical tools used in modeling real-world problems.

3 Results and Discussion

We now show the design of the fuzzy decision support system, membership functions, fuzzy rule base, fuzzification and defuzzification. Fuzzy logic is a very effective tool that can be used in uncertain situations. Determining input and output variables is the first step in designing a fuzzy decision support system. There are sixteen input variables and one output variable. After that, we designed the membership functions of all variables. Therefore, the designed membership functions determine the membership of objects in fuzzy sets. First, the input of the variables will be described along with their membership functions. Furthermore, the variable output will be introduced with its membership functions. Finally, we will describe the rules used in the system, the process of fuzzification and defuzzification. Sample data are related to the direct marketing - telemarketing campaigns of Iranian banking institutions. The goal is to predict whether the customer will subscribe to a term deposit (variable y). Data is from a general data source.

This data includes 15 input variables related to customer data:

1. Education
2. Defaults. Does the credit exist by default?
3. Age
4. Occupation: Job type
5. Marriage: Marital status

6. Day: The last day of contact in the month
7. Contact: Type of contact communication
8. Balance: Average annual balance, in Dollar
9. Housing: Does it have a mortgage?
10. Loans: Does it have a personal loan?
11. Previous: The number of contacts that have been done for this customer before this campaign
12. Putcome: The result of a previous marketing campaign
13. Month: The last month of contact in the year
14. Duration: The last call time duration in a few seconds
15. Campaigns: The number of audiences that have been gathered during this campaign and for this customer.

To design a fuzzy expert system, first the membership functions according to the latest findings the science that has determined the range of disease variables as follows was defined. In order to fuzzy the input variables, first the range each parameter was extracted by examining texts and guides and functions with their help membership for each variable was considered as follows. Finally, using the fuzzy belonging functions, the fuzzy system was designed as follows. To do that, suppose a fuzzy set in rules "IF-THEN" fuzzy with center is a natural set. Now, fuzzy systems with an if-then fuzzy system with inference engine (7) and singleton fuzzifier (8) as well as defuzzifier mean center (9) is considered as follows:

$$\mu_B(y) = \max_{L=1}^{M} \left[\sup_{x \in U} \left(\mu_A(x) \prod_{i=1}^{n} \mu_{A_i^L(x)} \mu_{B^L(y)} \right) \right], \tag{7}$$

$$\mu_A(x) = \begin{cases} 1, & x = x^\star, \\ 0, & x \neq x^\star, \end{cases} \tag{8}$$

$$y^\star = \frac{\sum_{L=1}^{M} \bar{y}^L w^L}{\sum_{L=1}^{M} w^L}. \tag{9}$$

Also, the output of the system is obtained as follows:

$$f(x) = \frac{\sum_{L=1}^{M} \bar{y}^L (\prod_{i=1}^{n} \mu_{A_i^L}(x))}{\sum_{L=1}^{M} (\prod_{i=1}^{n} \mu_{A_i^L}(x))}, \tag{10}$$

where $x \in U \subset \mathcal{R}^n$ is the fuzzy system input and $f(x) \in U \subset \mathcal{R}$ is the fuzzy system output. We also do the following to calculate the degree of each law and rule:

$$D(rule) = \prod_{i=1}^{n} \mu_{A_i^L}(x_{oi}^p)\mu_{B^L}(y_o^p). \tag{11}$$

Also, after determining the degree of rules based on the values of higher degrees, similar and contradictory rules with lower degrees are removed.

In this study, the y variable predicts whether the customer is subscribing to the deposit plan or not. In the model, significant input variables are designed, which are: education x_1, age x_2, balance x_3, existence of loan x_4, result of previous call x_5 and duration of call x_6.

Hence, the membership functions of input and output variables are defined as follows:

A. Input variables

1. Education

The input variables have four fuzzy sets, "Diploma", "Expertise", "Master of science (M.Sc)" and "Ph.D". Their membership functions are trapezoidal. Fuzzy sets of education domains and functions of fuzzy sets are specified in Table 1 and Figure 1.

Table 1: Fuzzy sets of Education

Input variable	Rang(0-100)	Fuzzy set
Education	0-25	Ph.D.
Education	25-50	Diploma
Education	50-75	Master of Science
Education	75-100	Expertise

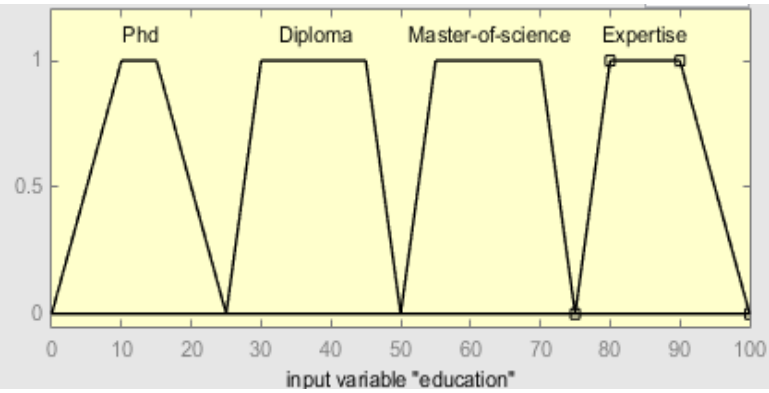

Figure 1: Membership functions for Education.

2. Age

This input variable has four fuzzy sets: “Child”, “young adult”, “middle-aged”, “old-aged”. The membership of their functions is trapezoidal, the Age area of fuzzy sets in Table 2 and the membership functions for fuzzy sets in Figure 2 has been specified.

Table 2: Fuzzy sets for Age

Input variable	Rang	Fuzzy set
Age	<=16	Minor
Age	16-40	Young
Age	33-60	Middle
Age	55-100	Old

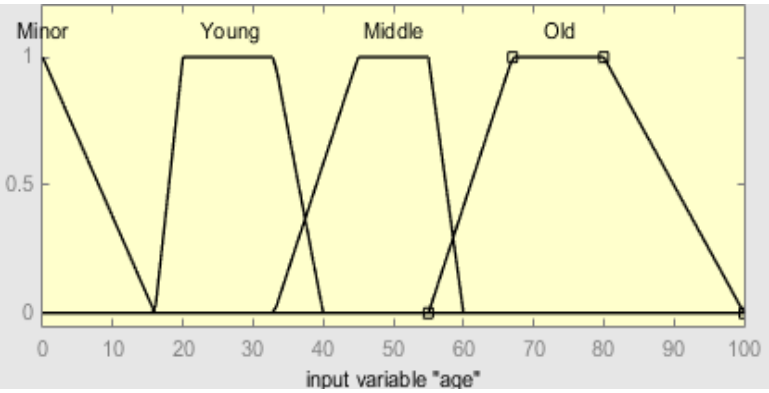

Figure 2: Membership functions for Age.

3. Equilibrium

The average balance is the annual balance available in the customer bank. This input variable has three fuzzy sets, namely “low”, “medium”, and “high”. Their membership functions are trapezoidal. The equilibrium range of fuzzy sets is shown in Table 3 and the membership functions for fuzzy sets are shown in Figure 3.

Table 3: Fuzzy sets of Equilibrium

Input variable	Rang	Fuzzy set
Balance	<=18000	Low Balance
Balance	15000-70000	Average Balance
Balance	55000-100000	High Balance

4. Existence of loans

This fuzzy set has three possibilities: low, medium and high. This description is high,

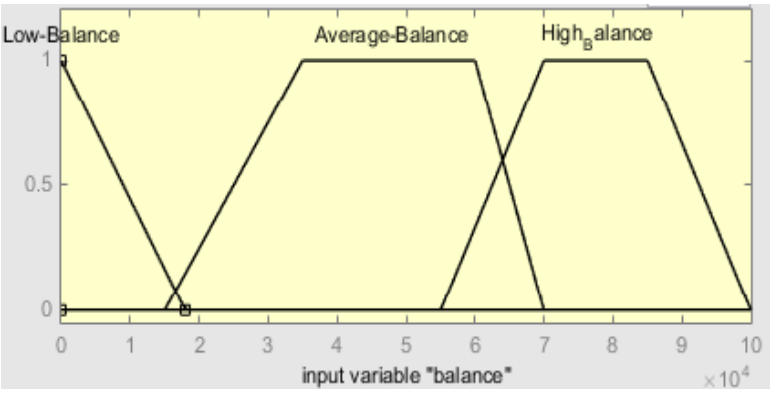

Figure 3: Membership functions for Equilibrium.

medium, low and average down. The history without any loans will be described only briefly. The range and the membership functions are described in Table 4 and in Figure 4.

Table 4: Fuzzy sets of Existence of loans

Input variable	Rang	Fuzzy set
Existence Loan	0-50000	Low
Existence Loan	40000-80000	Medium
Existence Loan	<=75000	High

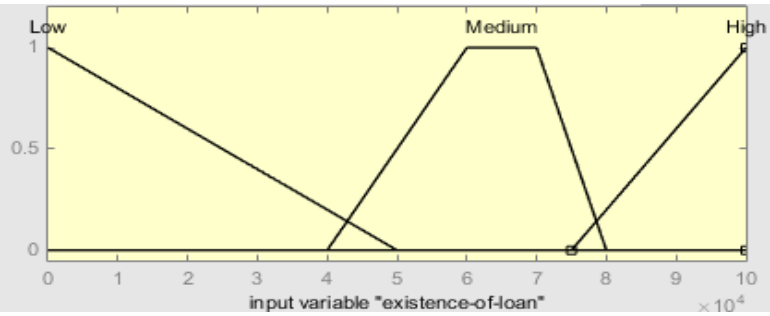

Figure 4: Membership functions for Existence of loans.

5. Previous contact results

The result of the previous contact is the result of previous campaigns, whether this policy was purchased or not. It has only two members, success or failure. The range and the membership functions are described in Table 5 and in Figure 5.

6. Call duration

Call duration is the last call made in a few seconds. It has three features. The domain is again described in Table 6 and Figure 6.

Table 5: Fuzzy sets of Previous contact results

Input variable	Rang	Fuzzy set
Previous contact Outcome	0-0.5	Success
Previous contact Outcome	0.5-1	Failure

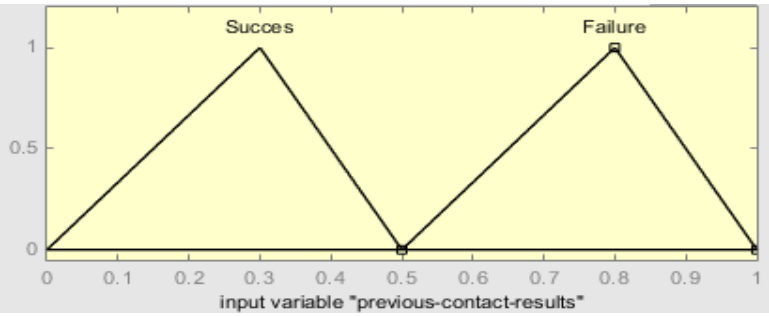

Figure 5: Membership functions for Existence of Previous contact results.

Table 6: Fuzzy sets of Call duration

Input variable	Rang	Fuzzy set
Time contact	0-400	Low
Time contact	300-900	Medium
Time contact	<=800	High

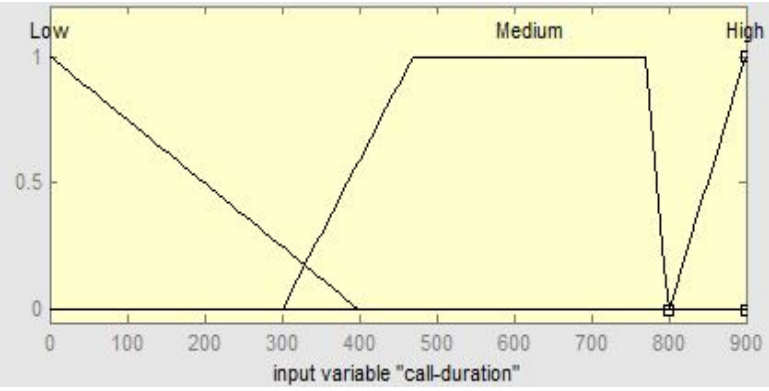

Figure 6: Membership functions for Existence of Call duration.

B. The output variable

The output variable is: Deposit-Subscription. The purpose of this system is to identify customers who subscribe to a bank deposit. The output variable is divided into three variables: high chance, very high chance and low chance. Table 7 identifies these fuzzy

sets and their amplitudes. The fuzzy membership functions of sets are triangular as shown in Figure 7.

Table 7: Output variable of tested values

Input variable	Rang	Fuzzy set
Deposit-Subscription	0-0.3	Low Chance
Deposit-Subscription	0.2-0.8	High Chance
Deposit-Subscription	0.7-1	very High Chance

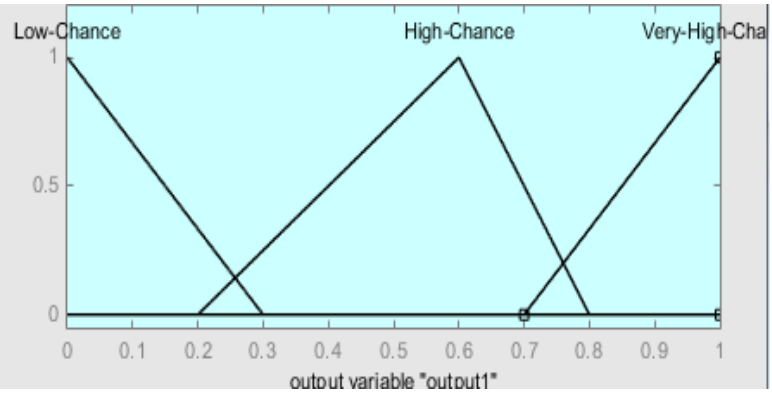

Figure 7: Output variable of tested values

The basis of the law is determined after consultation with prominent banking officials. Out of the 50 fuzzy rules discovered, we randomly selected 12 rules and consulted with banking officials as well as the definition of linguistic terms. Rules as they are judged on their usefulness and unexpectedness are also assessed by the domain of expertise. The basis of the law consists of 12 rules that determine the deposit subscription status by evaluating the input variables mentioned above (Low chance, high chance, very high chance). The rule of law is shown in Table 8.

There are 6 inputs and one output in the designed system. This fuzzy system was designed with multiplication inference engine, singleton fuzzifier and center average defuzzifier. Figure 8 shows the user interface of the fuzzy inference system designed to diagnose marketing and also, some of the rules used and the fuzzy system knowledge base designed to diagnose this marketing are displayed. The system has been tested by banking experts and one of the tested values has been considered which is depicted in Figure 8.

The notations in Figure 8 are indicates as: C1, C2, C3, C4, C5 and C6 are related for age=50, balance=5e+04 per year, education=50, equilibrium=5e+04, previous contact results=08 and call duration=450 respectively and finally output variable is set to 0.5.

Table 8: Rules for determining advertising contacts

Rule No.	x_1	x_2	x_3	x_4	x_5	x_6	y
1	Young	High	Expertise	Low	Success	High	Very High Chance
2	Young	High	Phd	Medium	Success	Medium	Very High Chance
3	Middle	Medium	MSC	Low	Success	High	High Chance
4	Young	High	Diploma	Medium	Success	High	High Chance
5	Middle	High	Expertise	Low	Success	High	Very High Chance
6	Middle	Medium	MSC	High	Failure	High	Less Chance
7	Middle	Medium	Expertise	Medium	Success	High	High Chance
8	Old	High	MSC	Low	Success	Medium	High Chance
9	Old	High	Diploma	Low	Success	Low	High Chance
10	Young	Low	Diploma	Medium	Failure	High	Less Chance
11	Young	Medium	MSC	Low	Failure	High	Less Chance
12	Middle	High	MSC	High	Failure	High	High Chance

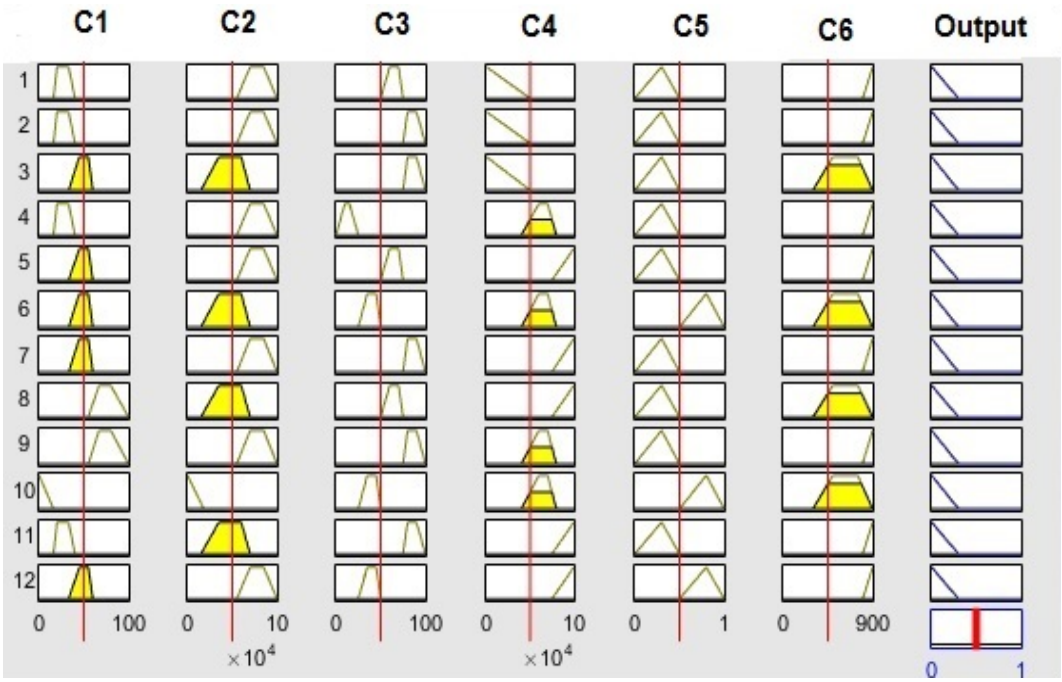

Figure 8: Evaluation results of tested values

4 Conclusion

The use of a fuzzy-based expert system aiming at a specific customer has been considered. In this study, the design of a fuzzy decision support system to identify potential customers in terms of data diversity and inaccuracies, which can be used by banking experts to improve marketing campaigns has been described. According to Figure 8 in the provided customer data was a person around 50 years of age, balance 5e+04 per

year, education, no previous loan, never contacted earlier by marketing person, duration of contact by marketing person around 450 s. These inputs represent the degree of ambiguity in the information furnished during various time periods. The degree of ambiguity in the information and the level of judgement used by the marketing person in deciding to approach this customer for subscribing the deposit scheme are always challenges. At this type of problem fuzzy based expert system is a very good tool for decision making for both customer and marketing managers to invest on directed campaigns with a strict and rigorous selection of contacts.

References

[1] Abdoli M., Sheykhesmaeli S. 2015. "Identification of factors influencing the evaluation of marketing channels", Second National Conference on Marketing Research, Tehran. (in Persian)

[2] Achrol R. S., Etzel M. J. 2003. "The structure of reseller goals and performance in marketing channels", Journal of the Academy of Marketing Science, 31 (2), 146-163.

[3] Agatz N. A., Fleischmann M., van Nunen J. A. 2008. "E-fulfillment and multi-channel distribution-A review", European Journal of Operational Research, 187 (2), 339-356.

[4] Alptekinoglu A., Tang C. S. 2005. "A model for analyzing multi-channel distribution systems", European Journal of Operational Research, 163 (3), 802-824.

[5] Bond D. 2017."Advertising agencies squeezed by tech giants", The Financial Times, Available https://www.ft.com/content/9a9ac60a-575a-11e7-9fed-c19e2700005f.

[6] Chen G. Q., Wei Q. 2002. "Fuzzy association rules and the extended mining algorithms", Information Sciences, 147, 201-228.

[7] Chiv R., Nie F., Wu S., Tum S. 2020. "Analysis of Factors Influencing Marketing Channel Choices by Smallholder Farmers: A Case Study of Paddy Product in Wet and Dry Season of Prey Veng Province, Cambodia", Journal of Sustainable Development, 147, 201-228.

[8] Dashore P., Kumar-Jain S. 2009. "Fuzzy Rule Based System and Metagraph for Risk Management in Electronic Banking Activities", International Journal of Engineering and Technology, 1 (1), 1793-8236.

[9] Dehghandar M., Khaloozadeh H., Soltanian F., Keshavarz M. 2016. "Application of Fuzzy Logic to determine the retentive causes of pulse body the pulse parameters", Iranian Traditional Medicine, Journal of Multidisciplinary Engineering Science and Technology, 3 (2), 3881-3884.

[10] Dehghandar M., Pabasteh M., Heydari R. 2021. "Diagnosis of COVID-19 disease by fuzzy expert system designed based on input-output", Journal of Control, 14 (5), 71-78. (in Persian)

[11] Deshmukh A., Lakshminarayana T. 1998. "A rule-based fuzzy reasoning system for assessing the risk of management fraud", International Journal of Intelligent Systems in Accounting, Finance & Management, 4, 231-41.

[12] Ebrahimnejad A., Jafarnejad Ghomi S., Mirhosseini-Alizamini S. M. 2018. "A revisit of numerical approach for solving linear fractional programming problem in a fuzzy environment", Applied Mathematical Modelling, 57, 459-473.

[13] Ebrahimnejad A., Jafarnejad Ghomi S., Mirhosseini-Alizamini S. M. 2017. "A new approach for solving fully fuzzy linear fractional programming problems", 4th International Conference on Knowledge-Based Engineering and Innovation (KBEI-2017), 1-4.

[14] Ghen G. Q. 1998. "Fuzzy Logic in Data Modelling: Semantics, Constraints and Database Design", Kluwer Academic Publishers, Boston.

[15] Guo S., Zhao H. 2017. "Fuzzy best-worst multi-criteria decision-making method and its applications", Knowledge-Based systems, 121, 23-31.

[16] Jarvinen J., Karjaluoto H. 2015. "The use of Web analytics for digital marketing performance measurement", Industrial Marketing Management, 50, 117-127.

[17] Kamarzarrin M., Eghbal N. 2021. "Modeling of self-assessment system of COVID-19 disease diagnosis using Type-2 Sugeno fuzzy inference system", Journal of Control, 14 (5), 49-57. (in Persian)

[18] khan N., Khan F. 2013. "Fuzzy Based Decision Making for Promotional Marketing Campaigns", International Journal of Fuzzy Logic Systems (IJFLS), 3 (1), 65-77.

[19] Kyaw N. N., Ahn S., Lee S. H. 2018. "Analysis of the Factors Influencing Market Participation among Smallholder Rice Farmers in Magway Region, Central Dry Zone of Myanmar", Sustainability, 10, 4441. https://doi.org/10.3390/su10124441

[20] Lewis R. A., Reiley D. H. 2013. "Down-to-the-minute effects of super bowl advertising on online search behavior", Proceedings of the 14th ACM Conference on Electronic Commerce, Philadelphia, PA, Array, 639-656. https://doi.org/10.1145/2492002.2482600.

[21] Meng F., Chen X. 2019. "A robust additive consistency-based method for decision making with triangular fuzzy reciprocal preference relations", Fuzzy Optimization and Decision Making, 17 (1), 49-73.

[22] Nasrollahi M., Fathi M. R., Faghih A. 2018."Designing a Model for Evaluating Marketing Channels based on the Fuzzy Best-Worst and Fuzzy EDAS Methods", Journal of Business Management, 10 (3), 695-712. (in Persian)

[23] Saura J. R., Palos-Sanchez P., Cerda Suarez L. M. 2017. "Understanding the digital marketing environment with KPIs and web analytics", Future Internet. 9 (76), 1-13.