Research Article

Evaluating the Bank Queuing Systems by Fuzzy Logic

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ARTICLE INFO	ABSTRACT
	Various models are used in the banking system to organize the queue structure of customers' banking transactions. The average waiting time for a customer in the queue generally varies depending on whether bank customer or not and the customer score it has. Different uncertain parameters are used to determine the individual queue group and average waiting time in bank queuing systems. This paper proposes a fuzzy logic-based approach in bank queuing systems. In this study, individual bank queue group and average waiting times are determined according to the number of waiting customers, customer score and credit score parameters. In addition, identification number is a determining factor for the priority of transactions in bank queuing systems. People who are not customers of the bank often have longer waiting times. As a new approach to the working structure of bank queuing systems, this study also suggests that non-bank customers should be given priority sequence numbers according to their credit scores.

1. Introduction

In banking transactions, the most common measure of customer satisfaction is the average waiting time [1]. Factors such as the number of customers waiting for transaction, the type of service to be received, the time of day, the number of staff at the box-office, and the queuing algorithm used by the bank queuing system determine the average waiting time [2]. Queuing management systems are used in many places such as banks, hospitals and government institutions [3]. Although fundamentally similar, there are queuing systems with different structure and working principle according to their usage areas. For example, queuing systems used in hospitals are based on the "First In First Out (FIFO)" working principle. However, due to the presence of different queue groups, the working structure of the queuing systems used in banks varies [4].

In general, the banking sector classifies its customers as retail and commercial customers. Customers in the commercial class have a higher priority in dealing with box-offices. In addition, individual customers are also classified with a "Customer Score" approach, thereby determining the priority of these customers to operate within themselves. Due to differences in individual and commercial customer classes, different queue groups are defined in the queuing systems [5]. These queue groups mainly consist of queue numbers. For example, while determining the next ten customers that going to have a transaction by the system, different numbers of customers are placed in the transaction queue from the groups. The waiting times of these groups for the transition to transaction differ. The groups have FIFO working structure within themselves, and the customer in the group with the highest priority has the least waiting time [6].

In Turkey in the current queuing systems, the queue number is taken with the identification number. The queue number is given from the last group by the queuing system to a person who is not a registered customer of the bank, so the average waiting time of the customer in the bank increases. Due to this situation that occurs ranking of unregistered customers, high-quality potential customer losses can be experienced [7].

The basic parameters used in bank queuing system transactions also contain uncertainties. In order to model uncertainties, a queuing system approach based on "Fuzzy Logic" is proposed in this study. Fuzzy Logic is a method that is used to solve problems involving uncertainty, tries to solve problems that are in uncertain decision mechanisms, based on judgment and intuition of experts. Fuzzy Logic has an important place in modeling uncertainty due to it is having the concept of being a gradual member. It also provides a meaningful representation of vague concepts expressed in our language [8-9].

As an innovative approach to the queuing systems used in banks; Credit Score (CRO) was used to place non-bank customers into the queue groups. The fuzzy system model that developed was created according to this new approach. CRO is a score that can be seen by entering the identification number by all banks. It will be a more effective approach to place the person in existing row groups who will have a transaction by looking at whether the status of this score is low-medium or good.

2. Fuzzy Logic

Fuzzy logic, unlike classical logic, operates with fuzzy sets that have uncertainty values such as less-normal-very, bad-normal-good, as in daily life. Therefore, it is a very convenient method to use for systems that hard to modeling mathematically and that system inputs or outputs contain uncertainty [10].

Fuzzy modeling is a new branch of system definition that deals with the structure of the fuzzy model and predicts and explains the behavior of an unknown system, defined by a sample dataset. System modeling based on classical mathematics is not suitable for systems that are incompletely defined and contain uncertainty. In contrast that, the fuzzy logic system; can model the qualitative aspects of human knowledge and approach courses without using sensitive quantitative analysis [11].

In classical logic, any object belongs to that set or not. This is briefly the logic 0 and 1. With the classical set theory shown in Figure 1, the credit score between 0-599 falls into the low, the credit score between 600-1400 falls in into normal, and the credit score above 1400 falls into the good class.
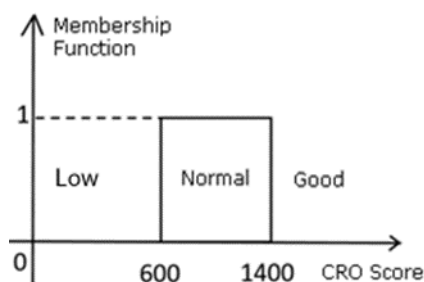
**Figure 1.** Demonstration of CRO score with the classical set

According to these rules, the CRO of a person with 1400 points is considered normal, while the CRO of a person with 1401 points is considered good. If we examine this situation with the fuzzy cluster shown in Figure 2, the credit score of a person with 1400 points is considered as 'normal' to a certain ratio and as 'good' to a certain ratio.
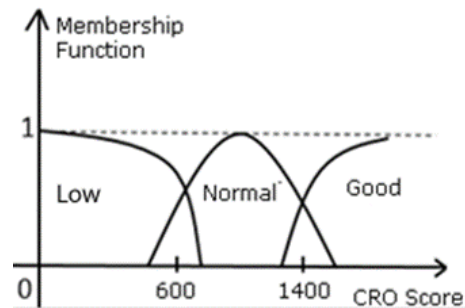
Figure 2. CRO score representation with fuzzy set theory

In fuzzy logic, there is no 0 and 1 logic with sharp lines as in classical logic, there is a more flexible approach as we use in daily life [12].

The first stage of fuzzy logic modeling is defining the problem and creating membership functions by selecting the appropriate parameters accordingly. Then, a set of rules or a rule base is created that contains the solution of the problem according to the related parameters and fuzzy subsets created. In the third stage, several inference methods (such as the largest, smallest, largest product, etc.) that developed by induction or deduction ways and from these rules are chosen. At the last stage, the method of clarification the fuzzy value again or converting it into classical numbers (center of gravity, weighted average, etc.) is determined. The operating structure of the fuzzy logic system is shown in Figure 3.
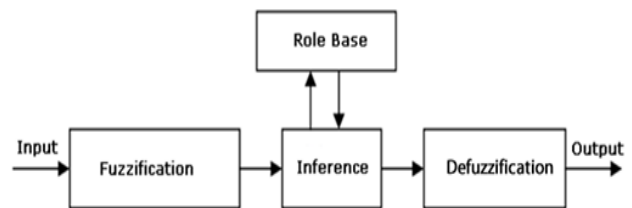

Figure 3. General structure of the fuzzy system [8]

As seen in Figure 3, first of all, inputs subject to fuzzification process by evaluating with membership functions. Then, according to the chosen inference method and by using the rule base the inference is made, and the fuzzy result obtained is converted into a classical number by clarifying. As understood from the above expression with the help of fuzzy logic, problems that particularly include uncertainties, non-linear, and including incomplete data can be easily modeled. Because of this structure, fuzzy logic is widely used in many areas, primarily in control, decision making and prediction problems [13].

3. Fuzzy Logic Model

In the fuzzy logic modeling of the queuing system, the number of customers waiting and the customer score for bank customers; for non-registered customers, CRO are the input parameters of the system; the individual queue group and the average waiting time constitute the output parameters. The general structure of the fuzzy logic model is given in Figure 4.
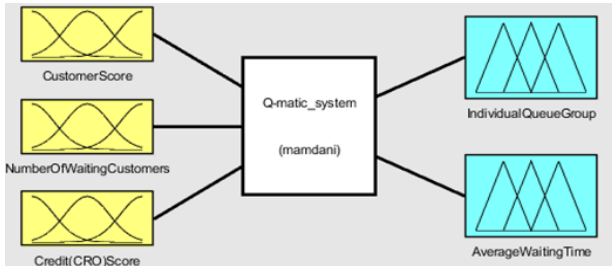
Figure 4: Input and output parameters of the developed Fuzzy Logic Model

Some of the sample rules for the input and output parameters of the developed fuzzy logic model are given in Table 1.

Table 1. Fuzzy rules of the developed model

Rule Number	Customer Score	Number of Waiting Customers	CRO (Credit Score)	Individual Queue Group	Average Waiting Time
1	Private customer	Many	--	Private Customer	0-5
…					
5	Commercial or multi-wealth customer	Normal	---	Commercial or multi-wealth	10-14
…					
8	Wealthy or good CRO customer	Normal	---	Wealthy or good CRO	13-19
…					
16	---	Few	Good	Wealthy or good CRO	4-10
…					
21	---	Many	Normal	Normal customer or normal CRO	30-40
…					

After determining the membership functions, lower and upper limit values of the input and output parameters required to create the fuzzy model, 24 rules were created to establish the necessary relationships between the parameters affecting the system. As an example, a few of these rules are given below;

• If the customer is "Private Customer" and number of waiting customers is "Normal"; individual queue group "Private Customer" and average waiting time "maximum 5 minutes"

• If the customer is "Commercial or Multi-wealth" and the number of waiting customers is "Normal"; individual queue group "Commercial or Multi-wealth Customer" and average waiting time "10-14 minutes"

• If the customer is "Wealthy Customer" and the number of waiting customers is "Few"; individual queue group "Wealthy or good CRO" and average waiting time "4-10 minutes"

• If the CRO is "good" and the number of pending customers is "Normal"; individual queue group "Wealthy or good CRO" and the average waiting time is "13-19 minutes"

• If the CRO is "low" and the number of waiting customers is "Many"; individual queue group "Mediocre customer or CRO is low" and the average waiting time is "more than 40 minutes"

• If the CRO is "normal" and the number of waiting customers is "Few"; individual queue group "Normal customer or CRO is normal" and the average waiting time is "5-11 minutes".

• If the customer is "Private Customer" and the number of waiting customers is "many"; individual queue group "Private customer" and average waiting time is "maximum 5 minutes".
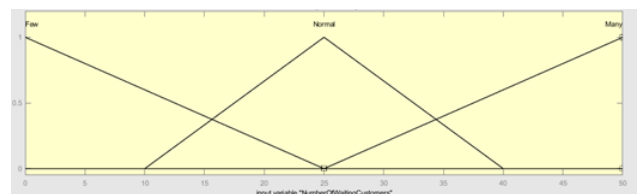
As an example, the membership functions of the few, normal and multi-linguistic expressions of the 'Number of Waiting Customers' input parameters are given in Equations 1, 2 and 3, respectively.

$$M_{few}(x) = \begin{cases} \dfrac{25 - x}{25} & 0 \le x \le 25 \\ 0 & \text{others} \end{cases} \tag{1}$$

$$M_{normal}(x) = \begin{cases} 0 & x \le 10 \\ \dfrac{x-10}{15} & 10 < x \le 25 \\ \dfrac{40-x}{15} & 25 < x \le 40 \\ 0 & x > 40 \end{cases} \tag{2}$$

$$M_{many}(x) = \begin{cases} \dfrac{x - 25}{25} & 25 \le x \le 50 \\ 0 & \text{others} \end{cases} \tag{3}$$

The graphical representation of the membership functions of the number of waiting customers, customer score, CRO input parameters are given in Figures 5,6 and 7, respectively.

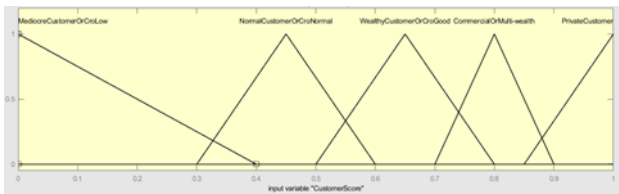**Figure 5.** 'Number of Waiting Customers' membership function

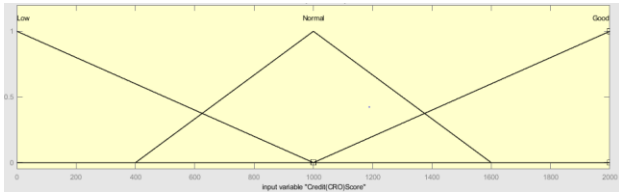**Figure 6.** 'Customer Score' membership function

Figure 7. 'CRO (Credit Score)' membership function

The graphical representation of the membership functions of the Average Waiting Time and Individual Queue Group output parameters are given in Figures 8 and 9, respectively.
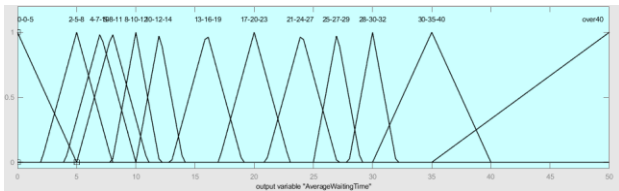

Figure 8. 'Average Waiting Time' membership function
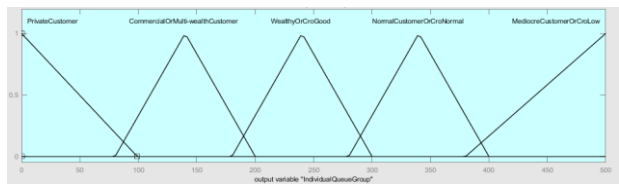

Figure 9. 'Individual Queue Group' membership function

While determining the membership parameters of the fuzzy system, in the queue management and calculation of the q-matic systems, an average bank branch is considered and an average transaction time of the customers is accepted as 3 minutes, and it's accepted that 3 officers operating at the box office. Increasing the number of officers will have a positive effect on the number of waiting customers and the average waiting time.

4. Results and Conclusion

As a result of developed fuzzy system model, change of Average Waiting Time according to the CRO and Number of Waiting Customers is given in Figure 10, change of Individual Queue Group according to the CRO and Number of Waiting Customers is given in Figure 11, the effect of the Customer Score and the Number of Waiting Customers on the Average Waiting Time is given in Figure 12, the effect of the Customer Score and the Number of Waiting Customers on the Individual Queue Group is given in Figure 13.
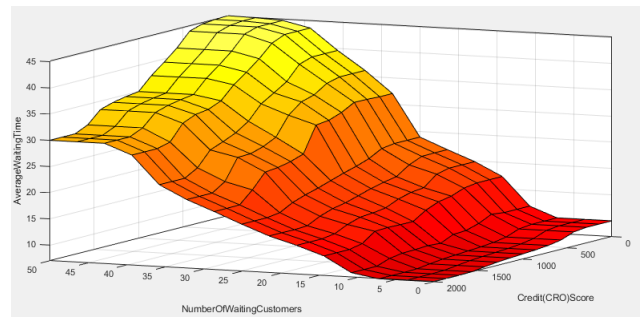

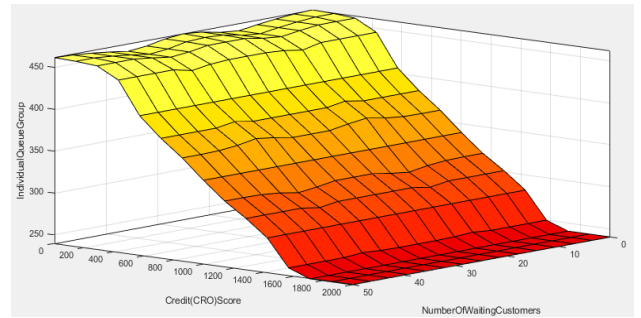**Figure 10.** Effect of CRO and Number of Waiting Customers on Average Waiting Time

Figure 11. Effect of CRO and Number of Waiting Customers on the Individual Queue Group

Figure 12. Effect of Customer Score and Number of Waiting Customers on Average Waiting Time

Figure 13. Effect of Customer Score and Number of Waiting Customers on the Individual Queue Group

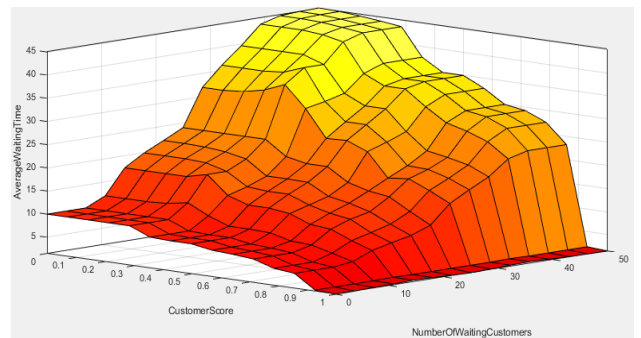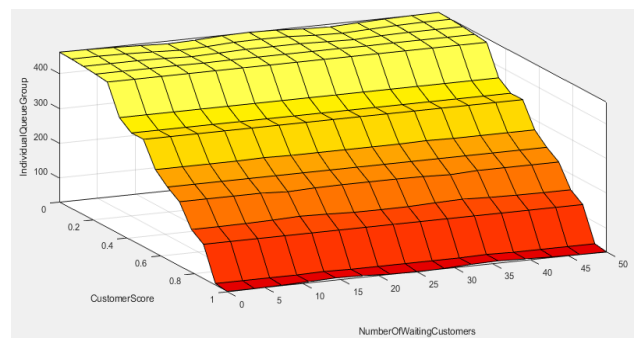Some input values given to the fuzzy model created using MATLAB R2017b software Fuzzy Logic Toolbox and corresponding output values produced by the model using membership functions and rules defined for input-output parameters are given in Table 2.

Table 2. Responses of the fuzzy model against some input values

INPUTS			OUTPUTS	
Customer Score	CRO (Credit Score)	Number of Waiting Customers	Individual Queue Group	Average Waiting Time (min.)
0.96	-	10	35	2
0.85	-	10	140	5
0.70	-	10	240	7
0.3	-	10	448	10
0.90	-	25	41	2
0.65	-	25	240	16
0.45	-	25	340	20
0.75	-	25	182	14
0.93	-	40	37	2
0.8	-	40	140	27
0.5	-	40	340	35
0.20	-	40	455	44
-	1400	10	286	7
-	1700	10	240	7
-	900	10	359	8
-	500	10	432	9
-	1800	25	240	16
-	900	25	357	21
-	300	25	459	24
-	1900	40	240	30
-	1200	40	311	34
-	250	40	457	45
-	1500	20	268	14

The responses given by the fuzzy model according to the input values are given in Table 2. According to the customer score, the persons who are special customers for the bank take a number from the first queue group that will wait for an average of 2 minutes regardless of the number of people waiting for (first customer in the queue); a customer who is not the bank customer but has good CRO wants to have a transaction and if the number of people waiting is normal (25), it is seen that a queue number is given by the fuzzy model from the third queue group, and waits for an average of 16 minutes. This person who is not a customer of the bank, receives a queue from the last group according to the classic queuing systems currently used under the same conditions, and waits an average of 24 minutes. When given a queue number according to his/her CRO to the same person, it is seen that is placed in the bank's wealthy customer queue group by the queuing system and waits an average of 8 minutes less.

In order for today's queuing systems, giving a queue number cannot be done by using the credit (CRO) score, and due to there is no customer score in the system, to people who are not the bank customers, the queue number is given from the last group. For example; when a wealthy or commercial class customer of bank A receives a queue with the ID number to perform any transaction in bank B, he/she receives numbers from the last queue groups since is not seen as the bank's own customer in the bank's

system. It is a negativity in terms of bank service to keep waiting for a customer who has the potential to carry out a high volume of transactions, for an average of half an hour by giving the order number from the last group. In order to overcome this negativity, it is proposed to give non-bank customers a queue number based on their CRO. In the new queuing system model designed, Customer Score, CRO (Credit Score) and Number of Waiting Customers are determined as input parameters, Individual Queue Group and Average Waiting Time are determined as output parameters. 5 different Individual Queue Groups have been defined and it is aimed to place the people who will perform transactions according to the Customer Score and CRO in the appropriate groups. During this placement process, while the process is done by taking the customer score as reference for the bank's customers, CRO is taken as reference for non-bank customers.

In addition, the queuing systems have to decide and generate numbers at that moment and assign them to a group according to the Customer Score. Due to this obligation, for the customer taking the queue number, a queueing process cannot be made between the customers waiting that taken the queue number before. Instead of having the queuing systems generate the numbers, the order of the customers' transaction can be determined by having random textual expressions output generated and having instant queueing for these expressions among the customers waiting with a second system.

Author's Note

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