Journal of Hydrosciences and Environment
Available online at http://jhe.usb.ac.ir/

ISSN: 2345-5608

Application of Fuzzy Logic in Calculation of Urban Water Tariff in Iran

M. Hekmatnia[*1], *S. M Hosseini*[2], *M. Safdari*[3]

1. PhD Candidate of Agricultural Economics, University of Sistan and Baluchestan, Zahedan, Iran.
2. Assistant Professor of Agricultural Economics, University of Sistan and Baluchestan, Zahedan, Iran.
3. Associate Professor of Agricultural Economics, University of Sistan and Baluchestan, Zahedan, Iran.

ARTICLEINFO

Article history:

Received: *8 April 2018*
Accepted: *10 October 2018*

Keywords:
Fuzzy Logic,
Increasing Block Tariffs.
Water Consumption,
Iran.

ABSTRACT

Water consumption has increased in urban areas, so it is important to calculate its tariff. In Iran, Increasing Block Tariffs (IBT) is used to calculate the water tariff. The first disadvantage of this approach is that many hidden subsidies are given to wealthy and high-income people, which consequently leads to an unequal distribution of income. The next drawback is that consumers at the beginning of a higher block should pay their total water prices according to the price of that block. This paper proposes a fuzzy inference system (FIS) to tackle these problems. The results showed that when the FIS was used, the hidden subsidies for low-income and low-consumption households were increased when compared to the IBT method. This increase in subsidies is due to lower water tariffs for low-energy subscribers and tariff increases for high-consumption customers. The monthly water tariff was calculated for 5 m3 of consumption as to be 7,095 and 1,715 IRR (Iranian Rials) using the IBT and FIS, respectively. These values were calculated to be 370040 and 254960 IRR by these methods for a consumption of 40 m3/month, respectively. As it can be seen, the application of FIS indirectly shifts the hidden subsidies to low-cost subscribers. Another important finding is that FIS simplifies computational complexity of calculating water tariffs as compared to IBF and, at the same time, it does not cause a sharp increase in tariffs in a higher-consumption block; besides, the price is calculated more equitably. The results showed that the water tariff accounting system in Iran is more likely to result in the waste of resources and unequal distribution of water subsidies. It is suggested to make reforms in water pricing policies and to raise public awareness of water consumption reforms.

1. Introduction

Dealing with water scarcity is one of the main challenges of the United Nations Development Program's (UNDP) Sustainable Development Goal (SDG) in the 21st century [12]. The World Bank anticipates severe social conflicts in regions like the Middle East due to water scarcity and water stress. Also, economically, water scarcity can put GDP at risk by 2050. The World Bank predicts that due to climate change and agricultural and industrial production, water resources will decline by two thirds by 2050 (24).

In the last 50 years, the exploitation of water resources has tripled. Meanwhile, the world population grows by 80 million each year. In recent years, changes in lifestyle and food habits have led to an increase in per capita consumption of water (25).

Due to the rapid growth of the population and the supply of food they demand, global demand for water has increased rapidly (42). It is anticipated that by 2025, 1.8 billion people in the world will live with water shortages and water stress (44). Therefore, water is a fundamental issue for developing countries, so that the lack of it can pose economic and social problems (45).

According to a report published by the United Nations Food and Agriculture Organization (FAO), 90 percent of Iran's climate is arid and semi-arid and it is desirable in terms of long-term water resources (9). Iran is subject to frequent droughts and water scarcity. The total water resources of the country account for 130 billion m3. The average annual rainfall is about 250 to 300 mm, which is less than one-third of the world's average rainfall. The cumulative annual rainfall in Iran is 415 billion m3 (46), and 70% evaporation of atmospheric precipitation is one of the most important factors responsible for the shortage of renewable resources (13). Uncontrolled exploitation has reduced the volume of renewable resources in Iran (20).

In recent decades, there has been an increase in the pricing policy for controlling and managing water consumption in many countries, including Iran. The main goal of the pricing policy is to modify the pattern of consumption, partially

[*] Corresponding author's email:
mehranhekmatnia@gmail.com

reimbursing the cost of consumption and increasing efficiency (47). The pricing of water is particularly related to political, socio-economic, and cultural influences. Water pricing policy can pursue several goals, one of the most important ones being to increase economic efficiency (22). In European countries, water pricing policies provided by the states allow for full cost recovery of drinking water and water services, water treatment, and environmental and resource costs (16). Proper water pricing can enhance social welfare, and the claim that water should be priced low is false so that rising water prices can help maintain the sustainability of water resources (29). There are many ways to improve efficiency and sustainability in the water sector, but pricing is the most appropriate method (28).

Empirical evidence suggests that the level and the structure of water prices rarely correspond to welfare optimality (11). To determine water tariffs, there are factors that should be taken into consideration by policymakers including the ability to pay, willingness to pay, and expense (48). In fact, water tariffs should be set in such a way that low-income consumers can pay the fees on a monthly basis. In water pricing policies, cost efficiencies should be a priority because the tariff should suffice to cover costs (14).

Tariff structure is a set of rules used to determine the terms of service and monthly charges for water users in different categories or classes. The monthly bill for water users may include two distinct components – one part is based on the volume of water consumption and the other part includes factors other than water intake (22).

In Iran, increasing block tariffs (IBT) and a two-tariff pricing method are used to price urban water consumption. So, two prices are set, one for the right to use water (under the right of the split) and the other for water consumption (named as the water rate). Given the limited water resources, an application of water pricing is to encourage consumers to note the importance of water limitations and consume less water. Water prices are lower for lower blocks and higher for higher blocks (44).

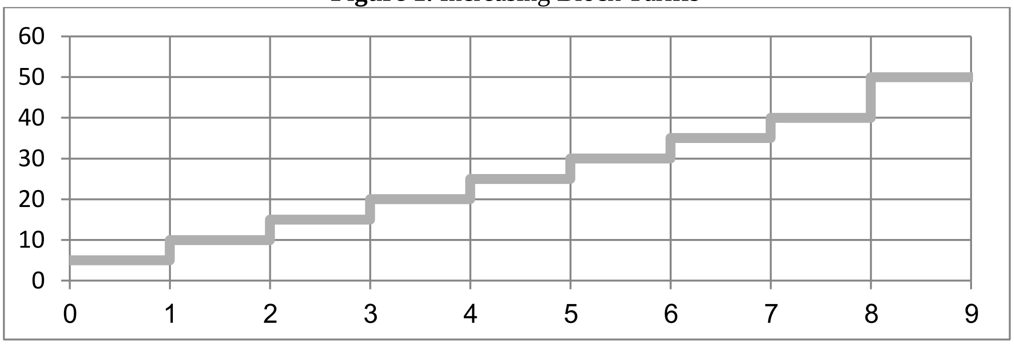
Table 1: Blocks of water Consumption in Iran

$0 < X \leq 5$
$5 < X \leq 10$
$10 < X \leq 15$
$15 < X \leq 20$
$20 < X \leq 25$
$25 < X \leq 30$
$30 < X \leq 35$
$35 < X \leq 40$
$40 < X \leq 50$
$X > 50$

Source: Water and Wastewater Company of Tehran Province, Iran

Table (1) shows water consumption blocks in Iran. It contains 10 blocks of consumption. Water tariffs are based on these blocks. Consumers are placed within a block in terms of their volume of water consumption, and the water tariff is calculated based on the consumption block.

Figure 1. Increasing Block Tariffs



Source: Water and Wastewater Company of Tehran Province, Iran

In the block pricing system applied in Iran, the price of water is calculated for consumers in terms of the block that they are in so that the price is the same for a whole block. For example, consumers at the beginning of a higher block should pay for their water use according to the price of that block. This is a disadvantage of IBT. One of the main goals of the present research is to deal with this problem.

Like other block-type tariffs, IBT provides two or more prices for water use, so that each price is defined for consumer use in a block. In this case, prices rise along the successive blocks. Some tariff structures have as many as ten blocks, each with a different price. In the design of IBT, serious attention is given to the size and price of the first block (3).

IBTs, by which higher-income consumers cross-subsidize poorer consumers, prevail (10). This is another disadvantage of the IBT systems so that they grant more indirect subsidies to the rich and over-rich people than to the low-income people, creating a disproportionate income and unequal income distribution.

Considering what was mentioned, the first objective of this research is to provide a pricing method aimed at shifting indirect subsidies on water pricing from high- and low-income households to households with lower water consumption in the community. The second objective is to provide a method to eliminate the sudden rise in water prices for households when water consumption is increased.

Considering the importance of water and water pricing, a lot of research has focused on these subject matters, each pursuing a method for the optimal pricing of water by economic means. But the novelty of the present work is that no research has used the fuzzy logic approach for water pricing. Also, other studies have spent a lot of time on exploring the details of water pricing, ignoring these pricing contribute to fair distribution of subsidies. But, the present research is seeking to transfer indirect and direct subsidies from the wealthy households to poor families.

2. Literature review

Many studies have been conducted on urban water pricing in the context of IBTs, e.g. Chen and Yang (2009), Ruijsa and Zimmermann (2008), and Binet et al. (2012). Urban water pricing has been examined by applying a decreasing block tariff (DBT) and an increasing block tariff (IBT).

Fotros et al. (2013) concluded that the incremental block pricing policy did not work effectively. It will control drinking water consumption in Iran.

Lopez et al. (2018) designed equitable water tariff for Valencia, Spain, Firstly, they calculated the marginal value of water, derived a function for domestic water demand, and evaluated the cost of water services. Finally, they proposed a dynamic tariff policy that, based on the results, could reduce the cost of water scarcity by 34% and reduce water consumption by 18%.

Klassert et al. (2018) estimated residential water demand function and examined the factors affecting water intake. The results of this study showed that the size and composition of households is one of the most important factors affecting water demand. Also under the estimated price elasticity, just a few IBT designs achieved a full recovery of the financial costs of water provision.

Deyà-Tortella et al. (2017) analyzed water tariff reform on water consumption in different housing typologies in Calvià, Mallorca. They indicated that total water consumption decreased only in the year when the reform was implemented, but it was increased in the following year. The increase in the amount of water consumed by the houses of higher standards of living was greater than the decrease in water consumption by families with medium and low-middle income. Therefore, water tariff reform has had a very negative effect on water consumption, and most households, despite higher prices, increased their consumption.

Sajjadifar et al. (2017) measured drinking water prices in Arak City. Their results showed that domestic water sales cost only 33% of the final cost and it had economies of scale. In order to calculate the optimal bid price, they proposed a census method and, in order to maximize social welfare, they suggested that the price of water in summers and springs be higher than the final cost and it be lower in autumns and winters than the final cost.

Nauges and Whittington (2017) showed that the use of incremental step-by-step balances did not take social justice into account and failed to lead to targeted subsidies spending.

Tahami pour et al. (2017) determined an optimal water price for home use using a coded model. Their results showed that the final cost per m^3 of water was 6,719 IRR and the optimal price for each m^3 of water was 2,209 IRR for the first floor consumption and 25,373 IRR for the last category consumption.

Sjödin et al. (2016) investigated water pricing instruments for sustainable water management in Australia and South Africa. Their results showed that the performance of water pricing instruments was generally imperfect in terms of ensuring economic efficiency, re-allocating water between users and recovering supply costs. Also, the use of water pricing instruments was inevitably and strongly influenced by the political and economic interests in the society, as well as the prevailing water management situation.

Razumova et al. (2016) addressed the role of water tariffs in saving water in hotels. The results showed that tariffs designed according to the cost reimbursement policy did not contribute to any water saving in hotels. Water could be saved in hotels by very stringent water tariffs.

García-Rubio et al. (2015) reviewed urban water tariffs in Spain, a country subject to high water stress. They concluded that the amount of reimbursement for urban water services was not enough. In addition, the wholesale water supply was heavily subsidized. This will undermine the true cost of urban water services and will lead to a decline in water resource productivity, in terms of efficiency and stability. Extreme water stress is expected in most parts of Spain and water resources are expected to decline due to climate change.

Suárez-Varela et al. (2015) identified determinants of price escalation of water tariffs in Spain with a view to identify the environmental, political and social factors, or water scarcity, that had the greatest impact on the price escalation of water tariffs. The results showed that environmental factors have had the greatest impact on the price escalation of water tariffs and that strategic decisions by decision makers were in the second rank.

Steven Renzetti et al. (2015) addressed distributional impacts of water pricing reforms in British Columbia, Canada. They estimated the household water demand functions using the model of Stone-Geary and double-log. According to their results, the Stone-Geary model indicates a worsening of the inequality of water expenditures and the double-log model shows no change in the distribution of water expenditures.

Rahimi et al. (2013) examined the water tariff system in European countries to manage water demand. Their research showed that waterless income management and the use of appropriate tariffs had a positive impact on demand management and that Belgium, Germany and the Netherlands had replaced the system of tariff-based economic accounting system.

Giulia Romano et al. (2015) examined the new water tariff setting in Italy for 2014-2015. Their results showed that in the new tariff-setting method, the cost of water services and revenues were increased by 3.8%.

Yazdani et al. (2015) investigated the effect of various pricing scenarios with the aim of determining the appropriate water rate in urban consumption in Golestan Province. They reported that the production cost per m^3 of water was 3,458 IRR while the average water tariff was calculated to be 1,472 IRR. Also, urban water users in Golestan Province were willing to pay 7,518 IRR/m^3 for purified water.

David Zetland et al. (2012) examined the relationships between tariffs and sustainability, and efficiency and equity, using a unique dataset for 308 cities in 102 countries. Their results showed that aggregating to the national level, higher tariffs were correlated with higher GDP and better governance. A different country-level analysis showed that a higher percentage of the population with water service was correlated with better governance, higher GDP and a greater risk of water shortage. The relationship between water prices and service coverage was statistically inconsistent.

Most studies have examined the effects of water tariffs on economic and econometric approaches, panel data, and financial and accounting methods. But this study uses a fuzzy inference system (FIS) to estimate water tariffs for urban consumption. The pricing range was se so as to transfer the hidden subsidies of water prices from high-income and high-consumption households to low-income and low-consumption households.

3. Methodology

3.1. Fuzzy Inference System

Also known as fuzzy rule-based systems, fuzzy model, fuzzy expert system, and fuzzy associative memory, the fuzzy inference systems (FISs) formulate the suitable rules, and the decision is made based on the formulated rules. This is mainly based on the concepts of the fuzzy set theory, fuzzy IF-THEN rules, and fuzzy reasoning. FIS uses If-Then statements, and the connectors present in the rule statement are “OR” or “AND” to make the necessary decision rules. The basic FIS can take either fuzzy inputs or crisp inputs but the outputs always produce fuzzy sets. Fuzzy logic system is commonly mentioned in the literature (26).

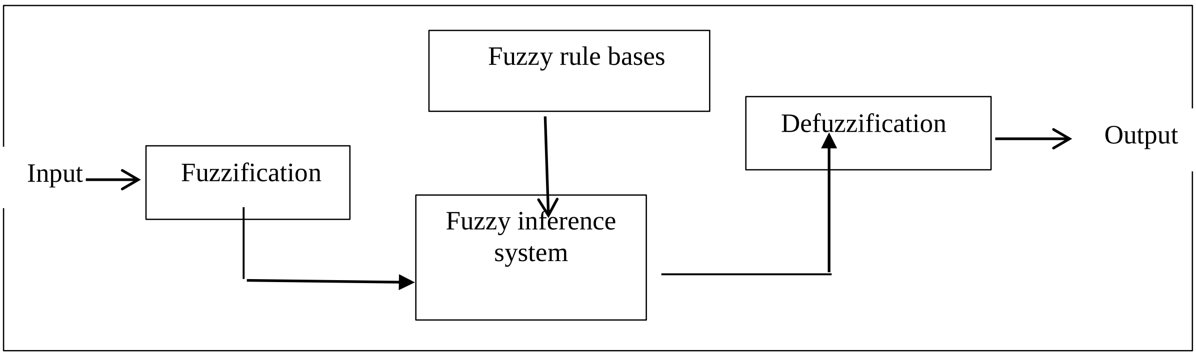
The steps of fuzzy reasoning (inference operations upon fuzzy IF–THEN rules) performed by the FISs are as below:

Fuzzification converts the crisp input to a linguistic variable using the membership functions stored in the fuzzy knowledge base. In this step, for each input variable, we consider membership functions to determine definite entries to be fuzzy and to be in the FIS.

Fuzzy inference uses If-Then type fuzzy rules to convert the fuzzy input to the fuzzy output.

Defuzzification converts the fuzzy output of the inference system to crisp values using membership functions analogous to the ones used in the fuzzification step (10).

Figure 2. Structure of a Fuzzy Inference System



A set is a collection of elements with similar properties. The elements that belong to the crisp set are considered as 1; otherwise, they are considered as 0. There is no indistinctness or vagueness in the crisp dataset. Some of the related elements may moderately belong to the same set and therefore, vagueness appears in the decision whether the element belongs to the set or not. Zadeh (1968) used the crisp set membership degree which had a value between 0 and 1. An element with membership value 1 means that the element completely belongs to the set.

The elements which do not belong to the set have the membership value of 0. The elements which have an in-between membership value describe that the elements partially belong to the set. For example, “lower” is a membership degree in which the object belongs to the set less than the others. Linguistic words are expressed in the fuzzy set. In practice, many linguistic words are used such as good, standard, medium, high, low, dry, wet and small.

In this research, the input variables become triangular fuzzy numbers.

Definition 1: A fuzzy set can be defined as $\tilde{A} = (X, \mu\tilde{A}(x))$ where *X* is the space on which the fuzzy set is defined, and $\mu\tilde{A}(x) \rightarrow [0, 1]$, $x \in X$, and the membership function of the set.

Definition 2: As shown in Fig 2, a triangular fuzzy number $\tilde{A}$ can be depicted with a triplet (a1, a2, a3) whose membership function is denoted as follows:

$$\mu_A(x) = \begin{cases} \frac{x - a_1}{a_2 - a_1}, & a_1 \leq x\ a_2, \\ \frac{x - a_3}{a_2 - a_3}, & a_2 \leq x\ a_3, \\ 0, & \end{cases}$$

Definition 3: The triangular fuzzy number $\tilde{A}$ = (a, b, c) is positive if and only if $0 \leq \alpha$.

Definition 4: The two triangular fuzzy numbers $\tilde{A}$ = (a, b, c) and B = (e, f, g) are equal if and only if c = g, b = f, and a = e.

Using the triangular fuzzy number is due to its simplicity compared to trapezoid or sigmoid fuzzy numbers and intuitively easy for decision-makers to utilize. Furthermore, modeling according to triangular fuzzy numbers is a competent approach for organizing the decision-making problems [2].

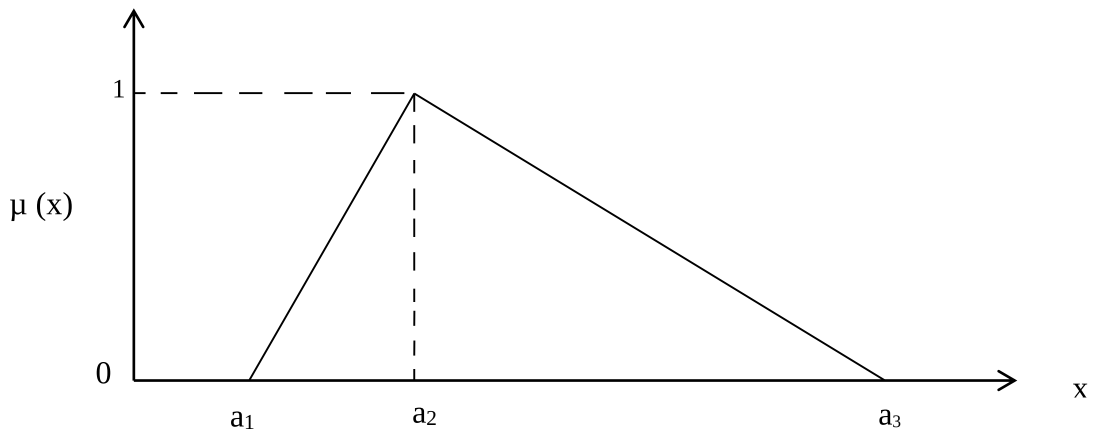


Figure 3. A triangular fuzzy number $\tilde{A}$

In this research, the required data were collected from the Water and Wastewater Company of Tehran province, Iran. The research period was confined to 2017, and data analysis was done using the Fuzzy Toolbox MATLAB software package.

The FIS used in this research has the following steps:

Step 1: Selecting the input and output variables

Given that the purpose of this research is to use fuzzy logic to calculate residential water tariff, the input and output variables are, in fact, the same variables that are taken into account in calculating the water bill. Therefore, the input variable in this study, the amount of water consumption volume blocks, and the output variable are also the intended cost for each consumption blocks.

Step 2: Fuzzification

To fuzzification, after the input and output variables are determined, fuzzy sets are specified for the above variables. For the input variable, linguistics variable is life line, low, medium, high and very high and for the output variable, linguistics variable is life line, cheap, medium, expensive and very expensive have been determined. In the next step, the membership functions for the iput and output variables were determined (Tables 2 and 4). In this paper, triangular membership functions have been used as explained above.

For the input variable, the volume of consumption of five membership functions is considered, which is based on the average consumption of subscribers in the following intervals:

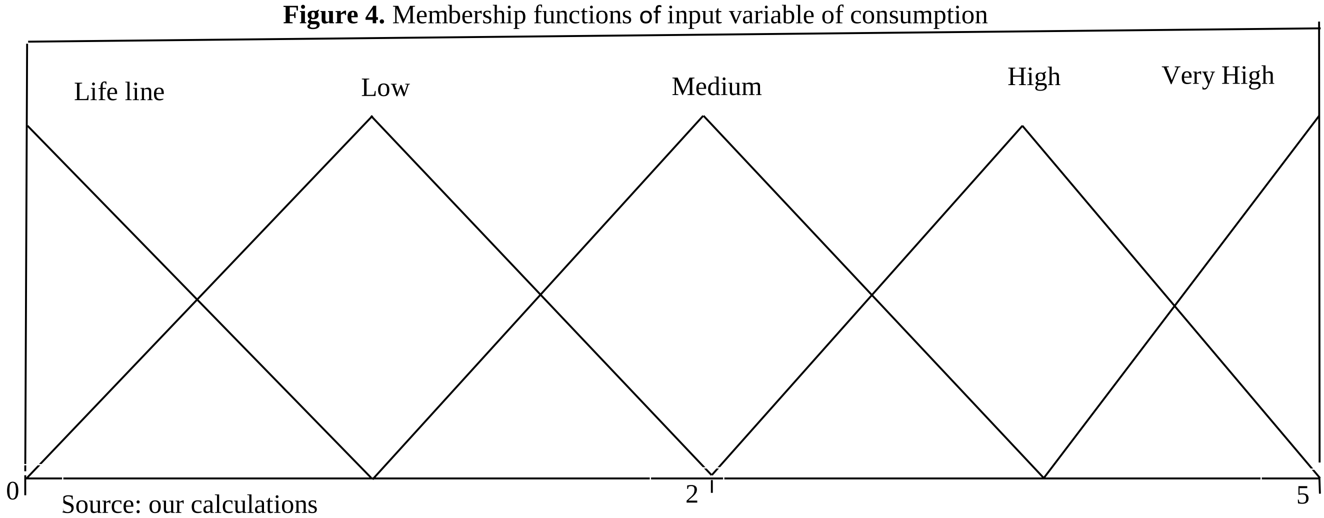
Table 2. Water consumption

linguistic variable	Min	Top	Max
Life line	-12.5	0	12.5
Low	0	12.5	25
Medium	12.5	25	37.5
High	25	37.5	50
Very high	37.5	50	62.5

Source: our calculations

Table 2 shows the fuzzy set and membership functions for the input variable. The type of entropy in the input membership functions is based on the choice of pricing policies that we consider to be linear or triangular in this analysis. In this way, the membership functions of input variable consumption are set to what is shown in Fig. 4.

Figure 4. Membership functions of input variable of consumption



Source: our calculations

In Table 3, X is the amount of water used. If the consumer is placed in the first consumption block, the water tariff is calculated according to the formula 1419x, and if the consumer is in the second block, then it is calculated based on the formula 2123 x- 3520, and the consumption block 10 is the same. Based on Table 3, we proposed fuzzy pricing with fuzzy logic.

Table 3. Blocks of water tariff in Iran

Block	water tariff
1	1419 x
2	2123 x- 3520
3	2827 x- 10560
4	3703 x- 23700
5	5400 x- 57640
6	8496 x- 135040
7	11580 x- 227560
8	15444 x- 362800
9	33462 x- 1083520
10	66924 x- 2756620

Source: Water and Wastewater Company of Tehran Province, Iran

The policy of choosing the type of tariff should be so as to reduce the sudden rise in price at the beginning of the higher consumption steps, and in the second stage to be fairly calculated based on the volume of consumption, and in the third stage, the water tariff should be determined so as to discourage water consumption. In this way, we consider five membership functions for the output variable, and we select the intervals for consumers who are in high consumption per m^3 of water than those consuming less water. Table 4 shows the selected intervals.

Table 4 shows the fuzzy set and membership functions for the output variable. In Iran, consumption blocks are used to calculate water tariffs of 10 blocks. The pricing range in this article is based on water pricing in Iran. In Iran, based on consumption, there are 10 blocks for water pricing. Table 3 shows the water pricing blocks in Iran.

Table 4. Membership functions of output variable of price

linguistic variable	Min	Top	Max
Life line	-1176	1419	4014
Cheap	1419	4014	6610
Medium	4014	6610	9205
Expensive	6610	9205	11800
Very expensive	9205	11800	14400

Source: our calculations

We use the triangular model in choosing the type of membership functions as our linear changes. Of course, this is precisely related to the type of tariff policy. The membership functions of output variable tariffs are set to what is shown in Fig. 5.

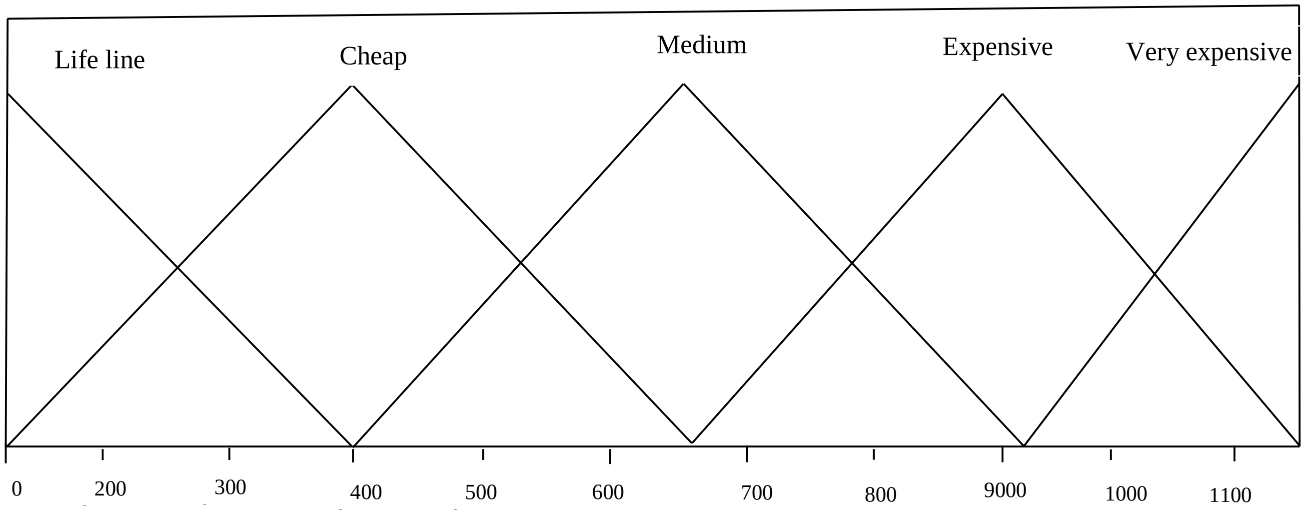
Step 3: Fuzzy rules

After the fuzzy membership functions for linguistic variables have been determined, a set of logical rules is created using the knowledge and experience of specialized people. The set of these rules, which are expressed in the form of if-then, are called fuzzy rules. The number of fuzzy rules is obtained from the equation n^t where n is linguistic variable and t is independent variable (42). Based on this, the number of fuzzy rules in this research is 5. The rules actually represent the type of communication between the membership functions of the input variables in determining the membership function of the output variable. Fuzzy rules are provided below:

1. IF water consumption is Life line, THEN price is life line.
2. IF water consumption is low, THEN price is cheap.
3. IF water consumption is medium, THEN price is medium.
4. IF water consumption is high, THEN price is expensive.

5. IF water consumption is Very high, THEN price is very expensive.

Figure 5. Membership functions of tariffs



Source: Investigator calculations

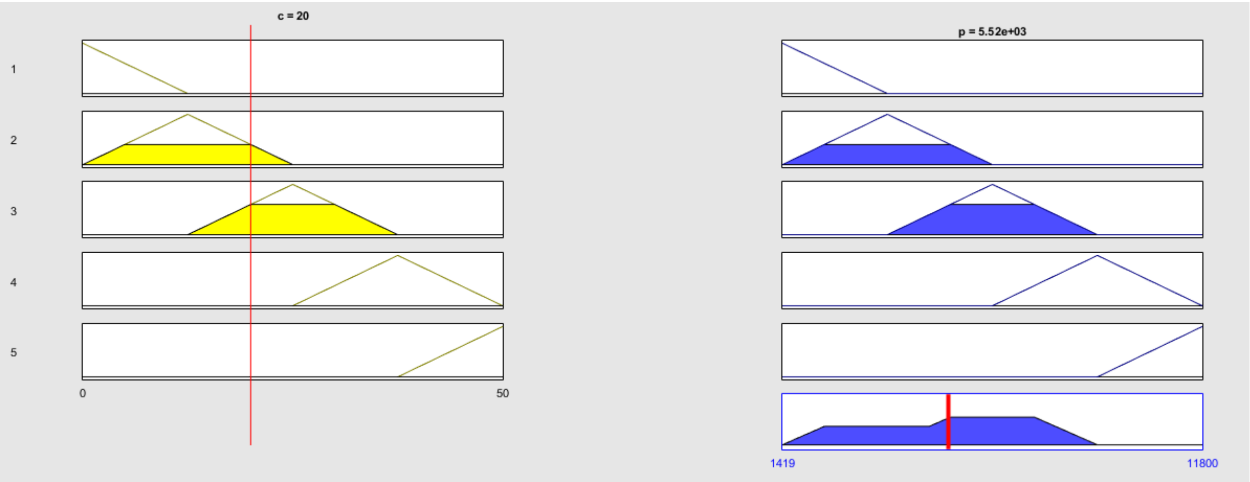


Figure 6. Rule viewer of the Mamdani model

Source: Investigator calculations

Step 3: Fuzzy rules

After the fuzzy membership functions for linguistic variables have been determined, a set of logical rules is created using the knowledge and experience of specialized people. The set of these rules, which are expressed in the form of if-then, are called fuzzy rules. The number of fuzzy rules is obtained from the equation n^t where *n* is linguistic variable and *t* is independent variable (42). Based on this, the number of fuzzy rules in this research is 5. The rules actually represent the type of communication between the membership functions of the input variables in determining the membership function of the output variable. Fuzzy rules are provided below:

1. IF water consumption is Life line, THEN price is life line.
2. IF water consumption is low, THEN price is cheap.
3. IF water consumption is medium, THEN price is medium.
4. IF water consumption is high, THEN price is expensive.
5. IF water consumption is Very high, THEN price is very expensive.

Step 4: Fuzzy Inference

After the fuzzy rules were created, FIS uses If-Then type fuzzy rules to convert the fuzzy input to the fuzzy output. FIS is developed for the Mamdani model. The rule viewer of the Mamdani model is shown in Figure 6.

Step 5: Defuzzification:

Defuzzification is the process of converting a fuzzified output into a single crisp value with respect to a fuzzy set (21).

4. Result

In this research, the fuzzy logic was used to calculate the water tariff in the household sector. Water consumption was considered as input, and water prices per m^3 of consumption as output variables. Then, fuzzy sets and fuzzy membership functions were created for variables. Eventually, the Mamdani model gave the output after fuzzification, fuzzy inference, and defuzzification. Figure 6 clearly shows that using the FIS, the problem of sudden tariff changes in the IBT method is well resolved when the consumer is placed at the beginning of the higher consumption block and has to pay the full cost of that block. In Figure 6, when the consumer consumes 20 m^3 of water, intelligent fuzzy logic shows the amount of consumer presence in second and third section. So, the fuzzy logic determines the tariff on the basis of it intelligently.

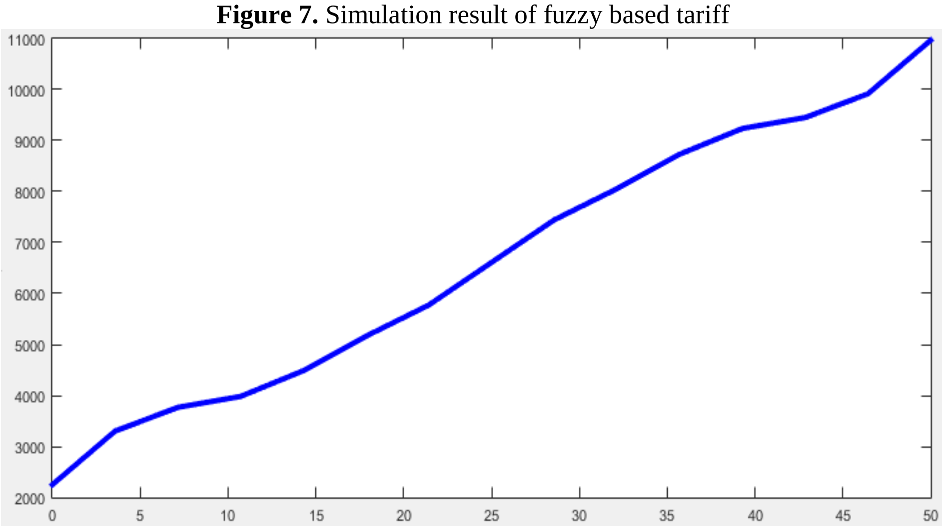
Table 4 shows the tariff calculated by the fuzzy system and the tariff calculated by the method of IBT. The fuzzy system is designed to reduce the cost of water for low-consumption households, which are often low-income households in the community, so that they can afford to pay and the indirect subsidies is transferred to low-income households. Also, in the system for high-consuming households, which are often among the rich people of the community, the price range is designed and implemented with the help of a pricing tool that can be used to control consumption and modify the pattern of consumption as well as subsidies to low-income households.

Table 4. Fuzzy based tariffs and IBT tariffs

FIS C m^3	FIS P Rial	IBT C m^3	IBT P Rial
5	1715	5	7095
10	39500	10	17710
15	69750	15	31845
20	110000	20	50360
25	165500	25	77360
30	231000	30	119840
35	301000	35	177740
40	370040	40	254960

Source: our calculations

Figure 7. Simulation result of fuzzy based tariff



Source: Investigator calculations

The results shown in Figure 7 clearly show that fuzzy logic has partially resolved the problems encountered in ITB. As the result of the simulation of fuzzy based tariffs is clear, the problem of sudden and steady changes in the tariff rate has been resolved. There are some advantages in using fuzzy logic in comparison with IBT to calculate water tariffs:

- *Ability to calculate multiple factors*: In fuzzy logic, by changing the number of input and output variables, one can change the computational factors, the only point of which is the increase in the number of fuzzy rules. But this is not easy in mathematical computational methods and incremental tariff methodology.
- *The lack of steady and sudden changes in tariffs*: According to the results the simulation results and the results of Figures 5 and 6, it was shown that fuzzy logic solves the problem of sudden price change but in the computational method of IBT, this problem still persists.
- *Lack of computational complexity*: The advantages of fuzzy logic are the lack of computational complexity compared to computational mathematical methods, as

well as the high flexibility in the number of computing factors.

- *Understanding the general way of calculating the agreement among the general public*: In fuzzy logic, consumers can easily calculate their water tariffs manually according to their consumption.

5. Conclusion

Fuzzy based tariff is developed in this paper. In mathematical methods of calculating tariffs, which are very complex and sometimes impossible to decide, the use of fuzzy logic can be effective. In this paper, after reviewing the IBT method and the comparison between the two methods, it is suggested that to make fair decisions for calculating water tariffs, the use of fuzzy logic has shown to be promising. One of the results of this study is that the use of fuzzy logic is more appropriate than the IBT due to the high flexibility associated with the type of factors and the number of effective factors in calculating tariffs in the former method. Also, fuzzy-based tariffs shift the governmental subsidies on water to the poorest sectors of the society and contributes to managing high-income, high-consumption groups by pricing tools.

According to the results of the research, for better management of water resources, the best way to correct the consumption pattern is through public education to enhance community awareness. It is also proposed to modify the pricing policies and system in order to modify the consumption pattern, to set water tariffs on the basis of the actual economic value of water, and finally, to design local contours with the capability of making fuzzy calculations.

6. References

1. Aronson, J., Blignaut, J.N., Milton, S.J. and Clewell, A.F., 2006. Natural capital: the limiting factor.
2. Balamurugan, S., Shanthini, B.M., Lekshmi, R.R. and Chandrakala, K.R.M., 2014. Fuzzy Based Tariff. Journal of Electrical Systems, 10(4).
3. Binet, M.E., Carlevaro, F. and Paul, M., 2014. Estimation of residential water demand with imperfect price perception. *Environmental and Resource Economics*, *59*(4), pp.561-581.
4. Boland, J.J. and Whittington, D., 1998. Political economy of increasing block tariffs in developing countries. EEPSEA special paper/IDRC. Regional Office for Southeast and East Asia, Economy and Environment Program for Southeast Asia.
5. Boland, J.J. and Whittington, D., 2000. Water tariff design in developing countries: disadvantages of increasing block tariffs (IBTs) and advantages of uniform price with rebate (UPR) designs. World Bank Water and Sanitation Program, Washington, DC, 37.
6. Crase, L., O'Keefe, S. and Burston, J., 2007. Inclining block tariffs for urban water. Agenda: A Journal of Policy Analysis and Reform, pp.69-80.
7. Deyà-Tortella, B., Garcia, C., Nilsson, W. and Tirado, D., 2017. Analysis of Water Tariff Reform on Water Consumption in Different Housing Typologies in Calvià (Mallorca). Water, 9(6), p.425.
8. Esmailifard. Maryam, kaveh firouz. Hasan, 2017. Pathology of the Water Policies in IR Iran, socio-cultural journal.
9. FAO. (2008). “AQUASTAT survey. ” < www.FAO.org /nr/water/aquastat/main/index/stm> (Act. 2015).
10. Fotros, M.H., Yari, M.H. and Maboudi, R., 2013. The Impact of increasing block pricing on the residential water consumption in Iranian Provinces.
11. García-Rubio, M.A., Ruiz-Villaverde, A. and González-Gómez, F., 2015. Urban water tariffs in Spain: What needs to be done? Water, 7(4), pp.1456-1479.
12. García Vali~nas, M.A., 2006. Demanda urbana en la region de Valencia. Un enfoque econometrico. In: En Pulido, M. y., Andreu, J. (Eds.), International Workshop on “Hydro-Economic modelling and tools for the implementation of the EU Water.
13. Garshasbi, P. (2014). “Drought conditions and management strategies in Iran.” Jihad Agriculture Minsitry, Tehran, Iran. (In Persian).
14. Groom, B., Liu, X., Swanson, T. and Zhang, S., 2008. Resource pricing and poverty alleviation: the case of block tariffs for water in Beijing. In Coping with Water Deficiency (pp. 213-237). Springer, Dordrecht.
15. Jang, J.S.R., Sun, C.T. and Mizutani, E., 1997. Fuzzy inference systems. Neuro-fuzzy and soft computing: a computational approach to learning and machine intelligence, pp.73-91.
16. Kanakoudis, V., Tsitsifli, S., Gonelas, K., Papadopoulou, A., Kouziakis, C. and Lappos, S., 2016. Determining a socially fair drinking water pricing policy: the case of Kozani, Greece. Procedia engineering, 162, pp.486-493.
17. Khoshbakht, A., Raghfar, H. and Khiabani, N., 2011. The Estimation of Water Demand Function of Household Sector According to Non Liner Pricing Through Discrete – continues Choice Model (The Case Study of Tehran City During 2002 to 2006).
18. Klassert, C., Sigel, K., Klauer, B. and Gawel, E., 2018. Increasing Block Tariffs in an Arid Developing Country: A Discrete/Continuous Choice Model of Residential Water Demand in Jordan. Water, 10(3), p.248.
19. Lobbrecht, A.H. and Dibike, Y.B., 2002. Applications of neural networks and fuzzy logic to integrated water management. IHE.

20. Lopez-Nicolas, A., Pulido-Velazquez, M., Rougé, C., Harou, J.J. and Escriva-Bou, A., 2018. Design and assessment of an efficient and equitable dynamic urban water tariff. Application to the city of Valencia, Spain. *Environmental Modelling & Software*, *101*, pp.137-145.

21. Le Blanc, D., 2008. A framework for analyzing tariffs and subsidies in water provision to urban households in developing countries. UN.

22. Mahajan, R., 2015. Application of Fuzzy Logic in Automated Lighting System in a University: A Case Study. International Journal of Engineering and Manufacturing, pp.11-19.

23. Mazyaki, A. (2017). 'Public-Private Partnership in Water and Wastewater Industry Transaction Costs, Antitrust, and Nonlinear Pricing', *Journal of Water and* Wastewater (parallel title); Ab va Fazilab (in persian *)*, 28(1), pp. 18-30. doi: 10.22093/wwj.2017.39471.

24. Mutlu, B., Sezer, E.A. and Nefeslioglu, H.A., 2017. A defuzzification-free hierarchical fuzzy system (DF-HFS): Rock mass rating prediction. *Fuzzy Sets and Systems*, *307*, pp.50-66.

25. Nauges, C. and Whittington, D., 2017. Evaluating the performance of alternative municipal water tariff designs: Quantifying the tradeoffs between equity, economic efficiency, and cost recovery. World Development, 91, pp.125-143.

26. Nasiri, Parvaneh; Raja'i, Ida; 2011. Water pricing in water resources management, Quantitative studies in management, - Issue 4 (23 pages - from 118 to 140).

27. Olmstead, S.M., Hanemann, W.M. and Stavins, R.N., 2007. Water demand under alternative price structures. Journal of Environmental Economics and Management, 54(2), pp.181-198.

28. Pal, M., 2007. Triangular fuzzy matrices. Iranian Journal of Fuzzy Systems, 4(1), pp.75-87.

29. President Deputy Strategic Planning and Control. (2009). Guide to determining the economic value of water for agriculture, 567 No., Tehran, Iran. (In Persian).

30. Rafee H, Kohansal M, Ghorbani M, Sabouhi M, 2017. Hydro-Economic Modeling in the Analysis of Water Resources Management Strategies: Neyshabur Catchment. (99) :41-77 .

31. Rahimi, A., Mahmoudi, R., Kalantari, M., Davoodabadi, M. and Seyyedzadeh, S.A., 2013. Review water tariff systems in European countries in order to water demand management strategies.

32. Razumova, M., Rey-Maquieira, J. and Lozano, J., 2016. The role of water tariffs as a determinant of water saving innovations in the hotel sector. International Journal of Hospitality Management, 52, pp.78-86.

33. Renzetti, S., Dupont, D.P. and Chitsinde, T., 2015. An empirical examination of the distributional impacts of water pricing reforms. Utilities Policy, 34, pp.63-69.

34. Rogers, P., de Silva, R., and Bhatia, R. (2002). “Water is an economic good: How to use prices to promote equity, efficiency, and sustainability.” Water Policy, 4(1), 1-17.

35. Ruijs, A., Zimmermann, A., and Vanden Berg, M, 2008. “Demand and distributional effects of water pricing policies.” Ecological Economics, 66 (2-3), 506-516.

36. Sajjadifar, S., pakrouh, S., Ghane, A., Fathi, B. (2017). 'Effective Drinking Water Pricing, A Case Study of Arak City', Journal of Water and Wastewater(parallel title); Ab va Fazilab (in persian), 28(1), pp. 95-103. doi: 10.22093/wwj.2017.39478

37. Sjödin, J., Zaeske, A. and Joyce, J., 2016. Pricing instruments for sustainable water management. (Working Paper No. 28).

38. Sivanandam, S.N., Sumathi, S. and Deepa, S.N., 2007. Introduction to fuzzy logic using MATLAB (Vol. 1). Berlin: Springer.

39. Suárez-Varela, M., Martinez-Espineira, R. and González-Gómez, F., 2015. An analysis of the price escalation of non-linear water tariffs for domestic uses in Spain. Utilities Policy, 34, pp.82-93.

40. Tahami pour .M., Molaei, F. and Moshredi, R., 2017. Determination of optimal price of domestic water consumption in Tehran city by using Ramsey model

41. United Nations Development Program (UNDP). UNDP Support to the Implementation of Sustainable Development Goal 6: Sustainable Management of Water and Sanitation; United Nations High Commissioner for Refugees (UNHCR): New York, NY, USA, 2016

42. Van Heerden, J.H., Blignaut, J. and Horridge, M., 2008. Integrated water and economic modelling of the impacts of water market instruments on the South African economy. Ecological economics, 66(1), pp.105-116.

43. Wan, F., Shang, H., Wang, L.X. and Sun, Y.X., 2005. How to determine the minimum number of fuzzy rules to achieve given accuracy: a computational geometric approach to SISO case. *Fuzzy Sets and Systems*, *150*(2), pp.199-209.

44. Water and Wastewater Company of Tehran Province. https://www.tpww.ir/

45. World Economic Forum (WEF). The Global Risk Report 2017 12th Edition; WEF: Geneva, Switzerland, 2017.

46. Worldometers real time world statistics. http://www.worldometers.info.

47. Yazdani, S. and Tahamipour, M., 2015. Simulating the Effects of Various Pricing Scenarios on Water Tariff System.

48. Zetland, D. and Gasson, C., 2013. A global survey of urban water tariffs: are they sustainable, efficient and fair? International Journal of Water Resources Development, 29(3), pp.327-342.