Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2023) 00–00

Urban water pricing based on location-based factors in GIS (Study area: Dehno Yazd)

Mohammad Ali Arasteh[a*]

[a]*Head of GIS group on Water and wastewater company, Yazd 8915937555 ,Iran*

Received 00 September 2018; revised 00 November 2018; accepted 00 November 2018

Abstract

Water and wastewater companies faces a substantial challenge in covering the costs of infrastructure development and maintenance while maintaining fair pricing. This paper proposes a new pricing model for urban water that considers the development costs, distribution, and maintenance of the urban water network and factors such as pressure, water quality, and location factors. The study used GIS analysis to determine the impact of location factors, taking the length of the pipeline route to reach each customer as a distance factor. Experts were consulted, and a multi-criteria decision-making (MCDM) approach was used to determine the weight of each factor. The proposed pricing formula was compared to the current pricing system by comparing water bills from subscribers in Yazd province. The results showed that with the proposed pricing, water revenues align with its costs. Additionally, only 20% of subscribers experience an increase in their bills, while 30% see a decrease, resulting in relative satisfaction among subscribers.
Keywords: Dynamic pricing, urban water, multi-criteria decision-making, location-based factors

[*] Corresponding author. Tel:09133522952.

E-mail address: ma.arasteh@gmail.com

Research Background:

Water pricing plays a crucial role in sustainable water resource management. Traditionally, water pricing has been determined based on factors such as cost recovery and demand management. However, recent advancements in Geographic Information Systems (GIS) have provided an opportunity to incorporate location-based factors in water pricing strategies. GIS allows the analysis of spatial data and the identification of areas with varying water availability and demand patterns. This spatial analysis can contribute to more accurate and efficient water pricing models.

Research Objective:

This study aims to develop a water pricing model for the city of Dehno in Yazd, Iran, based on location factors using GIS. By incorporating spatial data, such as water availability, population density, land use patterns, and infrastructure, the study aims to develop a comprehensive understanding of the water situation in the area. The results will then be used to develop a pricing model with the spatial variations in water demand and supply.

Methodology:

The study will collect relevant data on water availability, population density, land use, and infrastructure in Dehno. This data will be analyzed using GIS techniques to identify spatial patterns and relationships. Statistical analysis and modeling techniques will be applied to develop a water pricing model that considers location-based factors. The model will be validated using historical data and tested for its effectiveness in managing water resources and promoting efficient water use.

Expected Outcomes:

The research is expected to provide valuable insights into the role of location factors in water pricing. The developed model can assist policymakers and water managers in determining appropriate prices that reflect the spatial variations in water demand and supply. This can lead to more efficient water allocation, conservation, and sustainable water resource management in Dehno, Yazd.

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

1. Introduction

Scientists have recognized for over two decades that water resource management should focus more on demand management than supply management; hence, they have introduced the concept of integrated water management (Carroll et al., 2014). Two general policies and one main objective are present in integrated management. Policies include water treatment as an economic, social, and environmental product and analysis of water management policies and options within a complete framework. The main objective is to achieve sustainable, efficient, and equitable water resource development through integrated management. Cultivating water conservation, educating farmers on modern irrigation methods, using wastewater recycling methods, cultivating water-efficient plants, improving plant species, considering water conditions in areas where factories are to be built, water pricing, adopting new water supply methods, and more are among the methods of integrated management (Yaghoub, 2016).

Dynamic pricing is considered an effective method for efficient water consumption in urban areas among the various programs for managing water resources. Water pricing requires consideration of more than just cost and revenue, factors like the amount of surface water and groundwater in the region, water quality, consumption efficiency, societal culture, consumption rate, consumption hours per day, distance to water sources, and more.

Managing the factors affecting the price of drinking water should be done in a way that promotes water efficiency, does not put pressure on households, and, most importantly, helps optimize the costs of water supply and maintenance. To achieve this, it is necessary to anticipate the situation of a price decrease or increase, or other indicators. It is crucial to use simulation tools that accurately model the future based on the current situation.

2. Literature Review

2.1. Subject Description

In urban water distribution management, there is often an insufficient willingness to reform existing policies, establish necessary guidelines, or incorporate water-related issues into long-term planning (Elfikrie et al., 2020). Shifting the focus of water management approaches from supply to demand can promote water efficiency and sustainability. In this regard, specific adaptive management policies are needed to cover the costs of maintaining groundwater resources, water infrastructure, and urban water networks (Yusuf et al., 2020). Achieving this goal involves various strategies such as pricing mechanisms, public awareness, education, technical tools for consumption control, and water and wastewater recycling systems (Hof et al., 2018).

A water pricing system is a systematic framework in which the appropriate price for water supply, transfer, and distribution is determined, regarding various costs and consumers' willingness and ability to pay for different uses. The payment methods and market dynamics associated with water pricing are also defined. The aim of establishing such a system is to optimize water allocation among different uses, increase efficiency, and reduce water waste. Demand management, in essence, encompasses a set of economic, technical, social, and similar strategies, with past experiences highlighting pricing strategies as the most effective approach (Zarandi et al., 2020).

2.2. Problem statement

The main problem with water pricing in the Dehno, Yazd region is ignoring location-based factors. Today, water pricing is based on production costs and demand management without considering location-specific factors such as water distribution, usage patterns, and population distribution. This oversight can lead to unfairness in water pricing and an inefficient and unsustainable pricing system. Therefore, it is necessary to assess and integrate location-based factors in water pricing in the Dehno, Yazd region to provide fairer and more efficient water prices and to ensure sustainable management of water resources.

Much research has been done on pricing management as one of the most important means of controlling revenues and expenses (as the main factor of the cost-benefit system). The development of information technology has led to intelligent consumption measurement, efficient management methods, and changing customer behavior. Various models have been used for water pricing. The majority of articles that are more than ten years old have used mathematical models, regression and statistics, economic models, and management decisions, but in new research, methods, and tools related to information technology, such as system dynamics, smart measurement, data mining, demand forecasting, simulation, and game theory have been used.

In some articles, methods such as social networks and games have been used to create a culture that reduces and manages consumption. Baba Miri et al. conducted a financial analysis of sustainable management strategies of urban water distribution networks under an enhanced block tariff structure with a system dynamics approach (Baba Miri et al., 2020). Sidan has examined the estimation of the economic value of drinking water in Hamedan province. Sidan's study used Heckman's model to manage demand and allocation and encourage the protection of water resources.

To achieve the goal of protecting water resources and determining the economic value of water, the willingness to pay for drinking water has been investigated using the dual conditional valuation approach. The present study used Heckman's model to illustrate households' willingness to pay for drinking water. The data was collected from 329 families in Hamadan, Kabudarahang, and Nahavand cities in 2016. The results showed that the factors of Bartkefel's variables, the level of infrastructure, and income are among the factors that influence the households' decision to pay more for water to use higher quality drinking water. The determining factors in the willingness to pay are age, number of family members, and the area of the house (Sidan et al., 2022). Vafai deals with determining the minimum price of drinking water and optimizing the replacement time of urban water distribution network pipes. Using the system dynamic method, the water supply network of Hamedan City was simulated, and then the best time to replace the network pipes was optimized using the analytical solution of the net present value equation and the combined method of system dynamics-present value. Also, the study used Powell's optimization algorithm to improve the financial balance of Hamedan City Water and Sewerage Company, and the optimal price of drinking water was determined. The results of this research showed that determining the optimal price of drinking water makes it possible to increase the company's financial balance and, in addition to preventing the losses of the water and sewerage company, by increasing the pipe renovation factor, the level of social welfare can also be increased. Therefore, the system dynamics method and Powell's algorithm can optimize the minimum price of drinking water, reduce losses to water and sewage companies, and reduce the number of water supply pipe failures (Vafai et al., 2021).Al-Khatib et al.'s study aimed to analyze the factors that can affect water consumption in Jericho province, Palestine. Exploring social perceptions of alternative water sources; and identifying areas that need to be re-examined for tariff revision or changes in the source and delivery of water (Al-Khatib et al., 2023). The study used tariffs as a factor to control consumption. Zhang examines the price and affordability of water in the United States and compares public versus private ownership in the economics of water (Zhang et al., 2022). Rojas et al. examined economic policies and their role as a tool for sustainable water management (Pérez et al., 2019). Mercadier and Brenner analyzed tariff stability in Buenos Aires water and sewage concessions amid economic instability. (Mercadier & Brenner, 2020).. Favre and Montginol examined economic models in Tunisia for the sustainability of municipal services and showed that the principle of cost recovery is highly dependent on water-rich households. The cost-effectiveness principle only applies to households that use piped water. The average principle does not indicate the amount of local water scarcity (Favre & Montginoul, 2018). This research has not provided practical solutions and implementation, but it shows the effect of different economic principles. Al-Saeidi reviews urban water economic models for sustainable service development in Yemen. He compares the increase of block tariffs with other pricing schemes (Al-Saidi, 2017). The results of his research show that block tariffs are effective on consumption, but this is not enough. It is necessary to examine the effects of fines, taxes, consumption incentives, and amnesties, and finally lead to the balance of current expenses with the incomes resulting from the increase of

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

block tariffs. Lehmann considers pricing the root of solving water quality and quantity problems in developing countries and proposes an analytical framework to understand the challenges related to the pricing of water and wastewater supply (Lehmann, 2010). Donoso has investigated the pricing of municipal water in Chile with the aim of cost recovery, consumption optimization, and protection of water resources (Donoso, 2017; Rougé et al., 2016). Reyhan's research, which led to his doctoral research in 2011 at the University of Waterloo, Canada, is about the sustainability of water and sewage systems using fiscal self-sufficiency policy. For this purpose, he examines different water and sewage systems, including drinking water distribution systems, drinking water supply systems, sewage collection systems, and wastewater collection systems separately, and based on the dynamics of the system, he simulates them in a way that by charging different taxes and duties to make each department self-sufficient. The water system management department divides the different sectors in such a way that it draws the consumer, financial, infrastructure, distribution, and sewage cycles separately and combines them. He implemented all his results in a software called Stella, which he provided for the integrated management of water resources (Rehan, 2011; Rehan et al., 2011). Donoso has investigated the pricing of municipal water in Chile with the aim of cost recovery, consumption optimization, and protection of water resources (Donoso, 2017; Rougé et al., 2016). Reyhan's research, which led to his doctoral research in 2011 at the University of Waterloo, Canada, is about the sustainability of water and sewage systems using fiscal self-sufficiency policy. For this purpose, he examines different water and sewage systems, including drinking water distribution systems, drinking water supply systems, sewage collection systems, and wastewater collection systems separately, and based on the dynamics of the system, he simulates them in a way that by charging different taxes and duties to make each department self-sufficient. The water system management department divides the different sectors in such a way that it draws the consumer, financial, infrastructure, distribution, and sewage cycles separately and combines them. He implemented all his results in a software called Stella, which he provided for the integrated management of water resources (Rehan, 2011; Rehan et al., 2011). The financial self-sufficiency system in water resources management needs a complete culturalization at the community level, otherwise, we will face severe withdrawals. But in this long-term solution, it is inevitable and must be done. There is a need for medium-term planning for financial self-sufficiency, changing policies, pricing based on the cost, and reducing the cost. Benjak believes that the principle of full cost recovery should be covered in water pricing. In his opinion, it is important for consumers to use water more wisely or to transfer the use of water to non-peak hours. In this case, it is technically possible to improve resource consumption by applying dynamic water pricing. His proposal is the daily pricing of water resources based on smart measurement and demand forecasting. He has divided the financial self-sufficiency system into three parts. A part that collects and stores information. The communication part communicates with households and the pricing part sets prices through the collected data (Vašak et al., 2014).Research gap and innovation

3. **Many articles have introduced correct pricing as a solution for managing water and sewage consumption and achieving financial self-sufficiency in related companies. Different pricing methods have been discussed in the justice of the pricing, the amount of water consumption or the time of water consumption as well as the quality of water. Also, the total cost is taken into account, if in a city, the cost of water for each household is different because the amount of investment and the cost of transferring and using water are different in different places. Creating a water pricing formula that takes into account the quality criterion, along with the consumption ladder and the operating cost per household, is an innovation of current research.Methodology**

The present research method is the survey method. The study used library studies and face-to-face interviews with the stakeholders of the problem to collect data. In the modeling phase, it was first necessary to identify, collect, categorize, and rank the determining factors in drinking water consumption using multi-criteria decision-making methods, focusing on rural areas in Iran. Then, the optimal stability of underground water in drought conditions was achieved by changing the consumption pattern of households leading to a decrease in their demand. Finally, the economic dimensions and pricing should be investigated as one of the most important solutions for consumption management. Dehno villages of Yazd province are considered as a case study for the implementation of the model. The necessary operations to solve the problem and its modeling include three smaller problems choosing indicators that affect consumption, modeling the problem by combining the simulation of the basis factor and system dynamics, and examining the issues of economics and water pricing. The method of data collection to determine the indicators affecting the price of urban water is a library and inferential thinking method. Sampling is not used to collect data, of course, the aggregate information on water consumption during different years is used to measure the model validity, adjusting and adapting the model and modeling scenarios. To determine the pricing formula, the principles of cost-benefit and cost-benefit stability were used. It was also used to compare the results of using the new pricing formula with the current status of all the subscribers' bill records.Based on this, the research hypothesizes that the price of water can be considered as a coefficient of factors of the cost of operation (based on the distance of the household from the supply sources), the amount of consumption, the value of water in the region and the quality of water, and for the coefficient of this Factors can be used in the multi-indicator decision-making method. Since the multi-indicator decision-making method is used in this research, the hypothesis test is meaningless and the validity of the results is checked based on the inconsistency rate.

Delphi methods and network analysis processes have been used to select and rank the determining criteria for consumption. Multi-indicator decision-making methods (MADM) have been chosen for several reasons:

1- In cases where the data is uncertain or cannot be extracted, the multi-criteria decision-making method is suitable (Nguyen et al., 2014).

2- The details of drinking water consumption cannot be separated because there is no separate meter for each consumption component. It is also impossible to determine the influence of all factors on consumption behavior because there are uncertainties. Therefore, we are forced to use aggregate consumption variables that are recorded in the subscribers' meter and also in the consumption data of Abfa Company (Xu, 2015).

3.1. 3- Since the factors affect each other, it is appropriate to use a method that can calculate the effect of these interactions. Criteria should also be ranked in terms of impact and importance (Chen & Ren, 2018).Selection of indicators with the Delphi method

The Delphi group was used to select and classify indicators (Kalantari et al., 2017). The fuzzy Delphi method is derived from the Delphi method, along with the fuzzy set theory, which was first proposed by Ishigawa.

Table 1: Comparison based on the Likert scale

I strongly disagree	1
I disagree	2
I have no opinion	3
I agree	4
I strongly agree	5

Then, it was based on triangular fuzzy numbers, trapezoidal fuzzy numbers, and Gaussian fuzzy numbers to select fuzzy membership functions. It is assumed that the criterion value of j from the point of view of n expert is $w_{ij}= (a_{ij}+b_{ij}+c_{ij})$, so that j is equal to j = 1, 2,..., m and i is equal to I, i= 1, 2,..., n; Therefore, the fuzzy value of criterion j is calculated with the following equations:

$$w_j = (a_j + b_j + c_j) \quad (١)$$

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

$IA_j = \min\{a_{ij}\}$ (۲) $B_j =$

$\frac{1}{n}\sum_{i=1}^{n} bij$ (۳)

$C_j = \max\{c_{ij}\}$ (۴)

The following equation is also used for diffusion:.

$S_j = \frac{a_j+b_j+c_j}{3}, j = 1,2,\ldots,m$ (۵)

Then, a criterion number was obtained to accept or reject the criteria..

$sj \geq a, sj < a$ (۶)

:Finally, the criteria with higher scores were selected. Based on this, the following six steps were carried out

1– .Forming the Delphi monitoring group: it contains trainers and consultants

2– Formation of the expert group: 10 participants, including members of the board of executive experts in the development and operation of the Yazd Water Company, resources expertise of the country's water and wastewater engineering company, engineering students and graduate students and science professors (each with a thesis related .to water resources)

3– Setting the interview questions: The questions were asked in an open and general way. Then, problems .were identified through more detailed multiple-choice questions

4– Written interview survey questions and inferential ambiguity questions: The result was sent to three experts .to evaluate their answers and impressions

5– Completing the interview questions: According to the pilot study, an interview question was sent to the .experts

3.2. 6- Answer analysis: The answers of step one were analyzed, and standard criteria were extracted and scored. Other criteria with the lowest score were also discarded (Kamanroodi & Jafarpour Ghalehteimouri, 2020).Rating the impact of indicators using the Analytical Network Process (ANP)

There are various multi-criteria decision-making methods, each has its characteristics and conditions of use. In this treatise, the ANP method designed by (Tadić et al., 2014) is used. As one of the most important multi-criteria decision-making methods, the network analysis process method can be expanded in numbers and gray numbers. When experts' opinions are ambiguous and uncertain, the network analysis process method can be used (Atashgah et al., 2021).

One of the ways to perform calculations in the ANP method is to place the weights obtained from pairwise comparisons in a supermatrix. A supermatrix is a matrix of relationships between network components that are obtained from the special vectors of these relationships. The supermatrix can be divided into blocks, each representing a weight obtained from a pairwise comparison of rows (e.g., indices) concerning columns (ego options or indices).

The ANP method is useful when the interdependence of the selection criteria is very high. This thesis uses the logarithmic least squares method as the basis for calculating the fuzzy weights. In this method, triangular fuzzy weights can be used for criteria and options. The output weights calculated by this method can be used in another method to rank the options. The method of logarithmic least squares to calculate the fuzzy weights is shown below:

triangular fuzzy number can be defined as a triple (a1, a2, a3). ding verbal expressions and fuzzy numbers are presented in Table 2. The fuzzy number membership function is as follows: $f_{\widetilde{A}}(x) =$

$$\begin{cases} 0, x \le a1 \\ \frac{(x-a1)}{a2-a1}, a1 \le x \le a2 \\ \frac{(a3-x)}{s3-a2}, a2 \le x \le a3 \\ 0, x > a3 \end{cases} \quad (۷)$$

A and B are two TFNs respectively, which are parameterized by three times (a1, a2, a3) and (b1, b2, b3) respectively. Then, the operating rules of these two TFNs are as follows:

$$\widetilde{A}(+)\widetilde{B} = (a1, a2, a3)(+)(b1, b2, b3) = (a1 + b1, a2 + b2, a3 + b3) \quad (۸)$$

$$\widetilde{A}(-)\widetilde{B} = (a1, a2, a3)(-)(b1, b2, b3) = (a1 - b1, a2 - b2, a3 - b3) \quad (۹)$$

$$\widetilde{A}(\times)\widetilde{B} = (a1, a2, a3)(\times)(b1, b2, b3) = (a1b1, a2b2, a3b3) \quad (۱۰)$$

$$\widetilde{A}(\div)\widetilde{B} = (a1, a2, a3)(+)(b1, b2, b3) = (a1/b1, a2/b2, a3/b3) \quad (۱۱)$$

Since fuzzy set theory is similar to human thinking, it was combined with ANP.

$$\tilde{a}_{ij} = \frac{1}{n} \otimes (\tilde{a}_{ij}^1 \otimes \tilde{a}_{ij}^2 \otimes \ldots \otimes \tilde{a}_{ij}^n) \quad (۱۲)$$

In the above equation, $\tilde{a}_{ij}$ is a unified TFN$\widetilde{A}_{ij}^n$ Is the answer on the net expert for the it criterion over the j criteria. It can be displayed as TFN as follows:

$$\tilde{a}_{ij} = [l_{ij}, m_{ij}, u_{ij}] \quad (۱۳)$$

$$l_{ij} = \frac{\sum_{k=1}^n l_{ij}^k}{n} \quad (۱۴)$$

$$m_{ij} = \frac{\sum_{k=1}^n m_{ij}^k}{n} \quad (۱۵)$$

$$u_{ij} = \frac{\sum_{k=1}^n u_{ij}^k}{n} \quad (۱۶)$$

I represent the lower boundary of TFN, m represents the middle boundary of TFN, and u stands for its upper boundary. Then a pairwise comparison matrix is created.

$$\widetilde{A} = \begin{bmatrix} \tilde{a}_{11} & \cdots & \tilde{a}_{1j} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{i1} & \cdots & \tilde{a}_{ij} \end{bmatrix} \quad (۱۷)$$

The corresponding fuzzy weight of each comparison matrix is calculated by the logarithmic least squares method as follows:

$$\widetilde{W}_k = (w_k^l, w_k^m, w_k^u), k = 1,2, \ldots, m \quad (۱۸)$$

$$W_i^s = \frac{\left[\prod_{j=1}^n a_{kj}^s\right]^{\frac{1}{n}}}{\sum_{i=1}^n \left[\prod_{j=1}^n a_{kj}^s\right]^{\frac{1}{n}}}, s \in \{l, m, u\} \quad (۱۹)$$

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

Then, the center of gravity is used to remove the fuzzy weights as follows:

$$F_i = \frac{\left[\left(w_i^u - w_i^l\right) + \left(w_i^m - w_i^l\right)\right]}{3} + w_i^l \quad (۲۰)$$

Where Fi represents the weight of the earth criteria in the fuzzy pair comparison matrix. The initial matrix is produced to calculate the relative weights. Once the pairwise comparison is established and the eigenvector is evaluated, it is necessary to check whether the consistency ratio (CR) of the pairwise comparison matrix conforms to the transitional law. CR and CI are defined as follows: $CI = \frac{\lambda_{max} - n}{n-1}$

(۲۱)

$$CR = \frac{CI}{RI} \quad (۲۲)$$

CI is a consistency index, RI is a random index, and n is the number of criteria. If the compatibility ratio does not match perfectly, the result of the pairwise comparison needs to be corrected or adjusted.

$$\left\{\begin{matrix} CI = 0 \text{ Full compliance with consistency} \\ CI > 0 \text{ Not in full compliance with consistency} \\ CR \leq 0.1 \text{ Acceptable consistency} \end{matrix}\right\} \quad (۲۳)$$

Next, the following steps were taken to understand the effect of the options on the behavior (criteria) of water consumption (goal) using the ANP method:

1. Identifying the goal, criteria and options and determining the relationships between them
2. Determining the structure of the model
3. Preparation of questions from the experts: Based on criteria and alternative factors, a pairwise comparison table is completed for ranking.
4. Collecting and integrating the responses of experts who have evaluated and verified the results
5. Disambiguation: normalized pairwise comparison table.
6. Calculations: A Super decision software program was used to perform the calculations.
7. If the CR is less than 0.1 and greater than zero, the operation is acceptable.
8. Formation of a super matrix
9. Normalization of weight of results
10. Determine the impact of each option

4. Results

۱. The operation was carried out in 4 stages. The first stage was based on the Delphi method and the opinion of water experts, the criteria and options that affect the price were selected. In the second step, the impact coefficient of the criteria was determined by ranking them based on the multivariate decision system method. In the third stage, the formula of how to calculate the water price of ABFA subscribers was determined based on the specified criteria and its coefficients. In the last stage, the results obtained in the Dehno Yazd region were calculated as a case study to determine the results of the proposed strategy.

۵. 1.1. Determining factors and price coefficients

۲. Before choosing the criteria, it is necessary to collect all the criteria that can be effective and then these criteria are available to the experts for the final selection. For this purpose, it was selected from the previous studies conducted in the country relating to consumption-affecting indicators. To ensure the appropriateness of the collected data for analysis and checking the criteria, the results of the reviewed literature, and numerous meetings with experts in this field were reviewed. Finally, different criteria were determined for each assumption. The experts who participated in the selection and rating of criteria included five engineers from Abfa company, three professors in water resources management, and two experts in the preservation and maintenance of underground water. The names of these people are reserved. During several round-trip stages, the experts rated all the criteria between 0 and 10. Finally, criteria whose average score was higher than 7 were selected.

۳. After defining the criteria and options involved in water consumption, an expert panel was selected to build an ANP structure. Since the pairwise comparison process is done with Super decision software, the experts needed to describe each criterion, dimension dependence, and feedback. Through this process, an ANP model with a feedback system was built. The purpose of this work is to manage consumer behavior. Water consumption criteria including drinking, air conditioning, hygiene, and irrigation, and the options influencing factors on consumption, including cultural, religious interactions and wealth were selected. Figure 1 shows the purpose, criteria, and options in Super Decision software.

۴. Then, the ranking process was done by experts using numbers. They also compared the two pairs. A table for comparing two pairs was also entered into the software. Figure 2 shows two examples of pairwise comparison of different criteria and a pairwise comparison matrix in Super decision software. The red arrows show the ratio of the top factors to the left factors, and the blue arrow shows the effects of the left factors on the top factors. Finally, the weight of each criterion is shown after comparing two pairs. Also, the relationship between the internal and external factors of each cluster is known.

۵. The normalized supermatrix was then calculated. As can be seen, since the CR values were less than 0.1 and greater than zero, the operation was acceptable. In the last step, the weights of the results were normalized and the influence of each alternative was replaced. In multi-criteria decision-making methods, given that the data is obtained through interviews with experts, it can be obtained by comparing the results of pairwise comparisons, which is done through the inconsistency rate. Calculations were performed automatically by Super decision software. Since it was between zero and one, the comparison results and prepared two-pair matrix are acceptable.

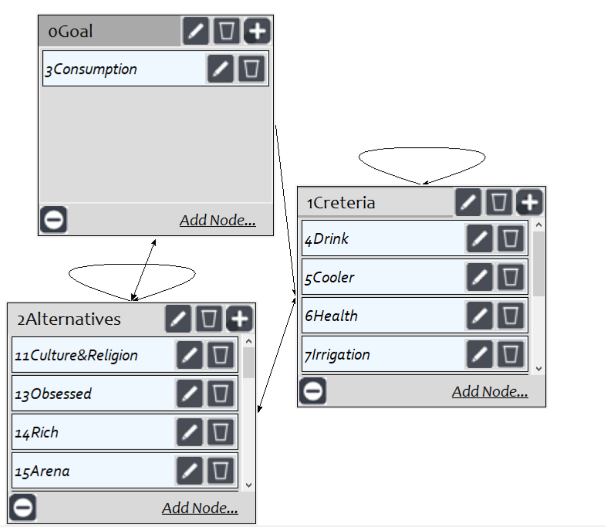
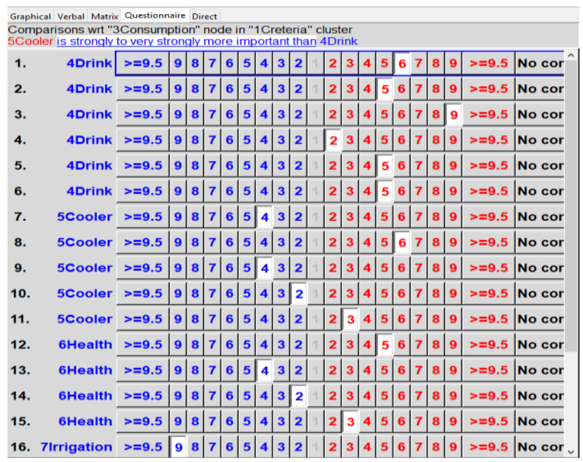


Figure 1: Objective, criteria and options

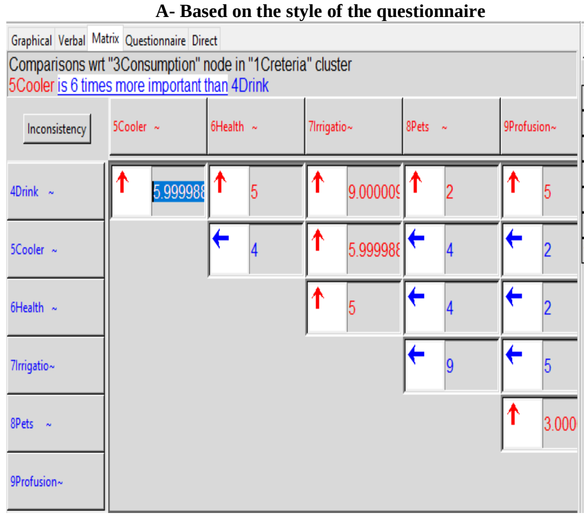
Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00



A- Based on the style of the questionnaire



B- Based on the decision matrix

Figure 2: Pairwise comparison between price-related criteria (target)

In the last step, the influence of consumption factors and components were ranked as criteria and options. Finally, the influence coefficients of the factors were determined based on Table 2. As it is clear from the table, the total cost has the highest coefficient, and network pressure has the least effect on the price of water.Table 2: Water pricing impact coefficients

Agent name	Nick name	Normalized with cluster	Limitation
Price		1. 00000	0. 131966
Stepping factor	s	0. 26906	0. 02406
Distance factor	d	0. 20720	0. 013530
Pressure coefficient	p	0. 10318	0. 010499
Balance factor	b	0. 44289	0. 060950

5.1. The proposed formula for determining the price of water

At the last stage, the water price formula for the subscribers of Abfa is proposed as follows:

$$Bill = (Price * Consumption * Scale * s) + ((Cost * distance * d) * (p * Pressure) * (b * Balance)) \quad (۲۴)$$

In Table 3, there are descriptions of the components of the pricing formula.

Table 3: Pricing formula details

Indicator	**Calculation method**	**Description**
Bill	Multiply the main factors below	Bill
Price	According to the announcement instructions	The base price of water that the government determines annually.
Cost	(Production cost + distribution cost + maintenance cost) / network length	Total cost per network meter
Pressure	The pressure behind the meter divided by the standard pressure	Pressure coefficient
Scale	According to the announcement instructions	Price scaling factor
Consumption	Meter reading	The amount of shared consumption
Distance	The amount of distance to supply sources divided by	Based on geographic information system
Balance	The ratio of total demand to total supply	Supply and demand balance

5.2. Implementation in a case study

Dehno is one of the rural areas in Yazd province (Fig. 3), and about 5000 people live in 1000 households. This region has a dry climate with low rainfall and high evaporation. As shown in Figure 4, this place is located far from the seas (500 km from the Persian Gulf and 700 km from the Caspian Sea), in the vicinity of a vast desert with low relative humidity and high temperature. The dispersion of the urban water network is high, and the quality of service provision is not the same in different areas (Figure 5). Due to the consumption of urban water for greenhouse purposes, water consumption in the region is high, and the amount of water and sewage accumulation losses is increasing. The area has more than 30 wells supplying the drinking water networks of Dehno and around Yazd. Therefore, water management in the region is vital for water and sewage companies in Yazd province.

Figure 3: The geographical location of Yazd in the world

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

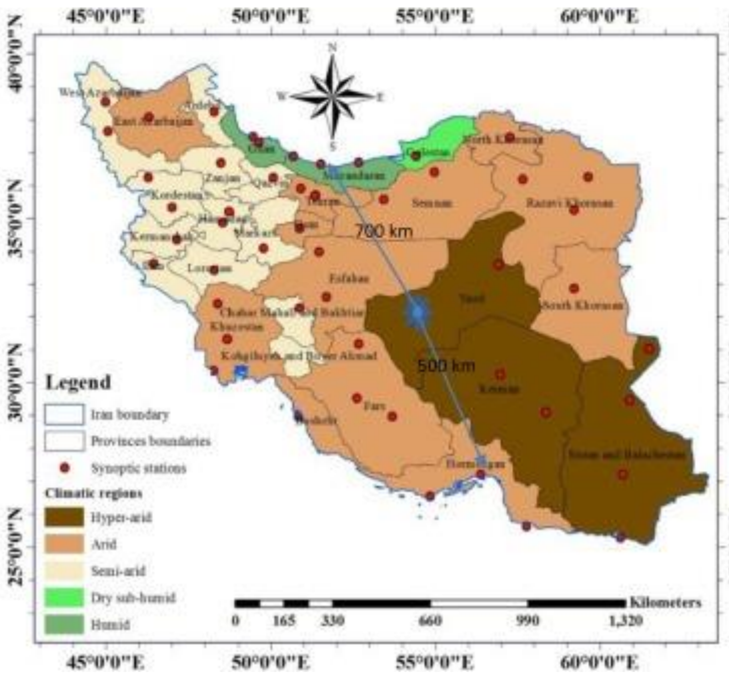


Figure 4: Distance between mouth and open water

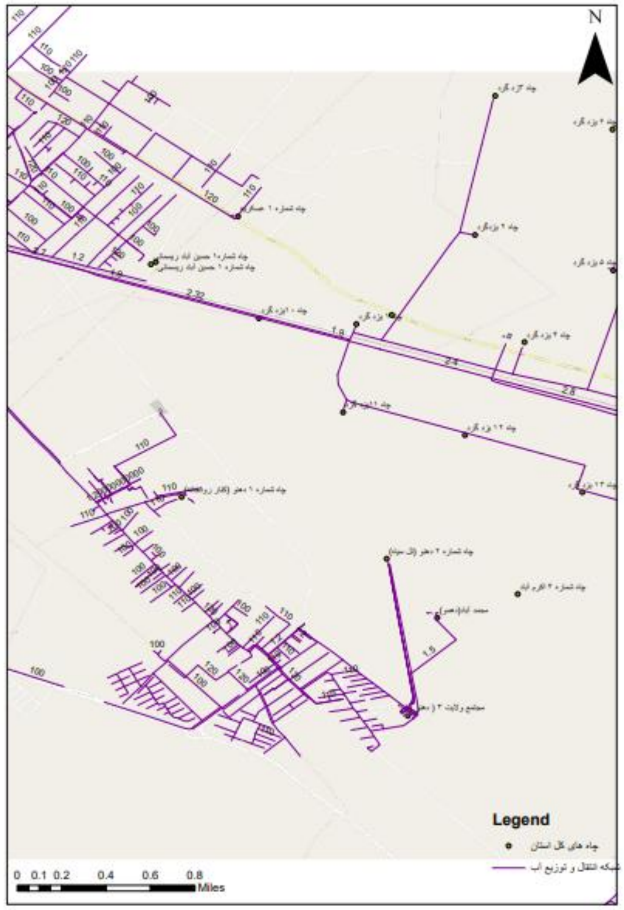


Figure 5: Distribution of urban water network and underground water resources in Dehno region

6. For calculation in the Dehno region, the pressure behind the meter of all subscribers was measured using a handheld sphygmomanometer. The distance of each branch to the supply sources was calculated based on the geographic information system. Yazd Province Waterworks provided the data related to the consumption and water price of the subscribers (including six periods). The water price of all subscribers was calculated based on the new formula. Discussion and conclusion

In Iran, the "two-tariff" pricing method is used in urban water pricing. In this method, two prices are determined, one is for the right to use water (under the title of branching right), and the other is for the amount of water consumed (under the title of water price). Due to the limitation of water resources, block pricing applies to the pricing of consumption amounts to encourage less consumption and to pay attention to the criticality of water consumption as much as necessary. The water price is lower for low-consumption blocks and higher for high-consumption blocks. This article proposed a new formula for water pricing in which, apart from the location-based factors, network pressure and supply/demand balance also play a role in pricing. The present study used a geographic information system to determine the distance of each subscriber from supply sources. The distinguishing point of this article compared to previous similar studies is the consideration of different factors in the pricing of water for each household, which was not seen in the results of the works of researchers Rahan, Rasak, Al-Saeidi, and Walhman. Also, the study used the multi-attribute decision-making method to determine the price coefficients. Other studies rarely have used this method.

Available online at www.jrors.ir

Journal Of Radar and Optical Remote Sensing

JRORS 00 (2018) 00–00

Based on this, the pricing model in the Dehno area of Yazd was checked with the consumption data of the last two years, and the following results were obtained.

- More than 30% of subscribers had a reduction in water prices.
- ٪۲۰ of subscribers had an increase in water prices, of which 7% had more than doubled.
- ٪۵۰ of subscribers have not had a noticeable change (changes of more than 15%) in water prices.
- ABFA's revenues from bills increased by nearly 30%

7. This article had limitations in practice. Firstly, the percentage of water without revenue and unauthorized use in the region is high, resulting in problems in pricing justice. Also, in the pricing discussion, one of the essential criteria is the price elasticity of water. There is insufficient information about the price elasticity of water in the region, suggesting further research on this topic. It is also necessary to test the presented formula in more areas and cities (with different weather conditions or distribution network dispersion) of the pricing model. If new resources are added to the region, the impact on the bills (considering the decrease in the network distance but the increase in the network pressure and the cost of the facilities) should be investigated in future studies. It is better to measure customer satisfaction in research before and after implementing the new pricing policy.References

Zarandi, T. P., Khazaei, Kolivand, and Fataneh. (2020). Examining the tariff system and the economic value of water in Iran's industrial sector. Water and sustainable development, 6(3), 19-30.

Seidan, Moghadam, D., Jafari, and Barzin, B. (2022). Estimating the economic value of drinking water in Hamadan province with Hackman's model. Irrigation Science and Engineering, 45(3), 1-14.

Kalantari, Khalil, Hemti, Golshan, and Pour, J. (2017). Localization of the model of water-sensitive cities (case study: Tehran metropolis). Urban Planning Geography Research, 5(3), 469-493.

Wafai, Nozari, Hamed, Maroufi, and Safar. (2021). Determining the minimum price of drinking water and optimizing the replacement time of urban water distribution network pipes. Water and Wastewater Journal, 32(3), 21-39.

Lahmar, A., Pfeiffer, N., Habouti, S., & Es-Souni, M. (2015). Microstructure and property control in TiO2-Pt nanocomposite thin films. Ceramics International, 41(1, Part A), 443-449. doi: http://dx.doi.org/10.1016/j.ceramint.2014.08.089

Wang, Y., Chen, J., Zhou, C., Zhou, L., Kong, Y., Long, H., & Zhong, S. (2014). A novel self-cleaning, non-enzymatic glucose sensor working under a very low applied potential based on a Pt nanoparticle-decorated TiO2 nanotube array electrode. Electrochimica Acta, 115(0), 269-276. doi: http://dx.doi.org/10.1016/j.electacta.2013.09.173

Al-Saidi, M. (2017). Urban water pricing in Yemen: A comparison of increasing block tariffs to other pricing schemes. Water international, 42(3), 308-323 .

Al-Khatib, I. A., Ali, A. A., & Hung, Y. T. (2023). Analysis of a current water tariff and attitudes towards change: A representative study from a Palestinian city. Water and Environment Journal .

Atashgah, M. H., Yasi, M., & Takaldani, E. A. (2021). Economic Valuation Framework in Inter-Basin Water Transfer Projects Based on Network Analysis Process) ANP) Method. Water Resources, 14(48), 98-113 .

Babamiri, A. S., Pishvaee, M. S., & Mirzamohammadi, S. (2020). The analysis of financially sustainable management strategies of urban water distribution network under increasing block tariff structure: A system dynamics approach. Sustainable Cities and Society, 60, 102193 .
Carroll, J., Lyons, S., & Denny, E. (2014). Reducing household electricity demand through smart metering: The role of improved information about energy saving. Energy Economics, 45, 234-24 .۳
Chen, L., & Ren, J. (2018). Multi-attribute sustainability evaluation of alternative aviation fuels based on fuzzy ANP and fuzzy grey relational analysis. Journal of air transport management, 68, 176-186 .
Donoso, G. (2017). Urban water pricing in Chile: Cost recovery, affordability, and water conservation. Wiley Interdisciplinary Reviews: Water, 4(2), e1194 .
Elfikrie, N., Ho, Y. B., Zaidon, S. Z., Juahir, H., & Tan, E. S. S. (2020). Occurrence of pesticides in surface water, pesticides removal efficiency in drinking water treatment plant and potential health risk to consumers in Tengi River Basin, Malaysia. Science of The Total Environment, 712, 136540 .
Favre, M., & Montginoul, M. (2018). Water pricing in Tunisia: Can an original rate structure achieve multiple objectives? Utilities Policy, 55, 209-223 .
Hof, A., Blázquez-Salom, M., & Garau, J. M. (2018). Domestic urban water rate structure and water prices in Mallorca, Balearic Islands. Boletín de la Asociación de Geógrafos Españoles(77), 52-79 .
Kamanroodi, M., & Jafarpour Ghalehteimouri, K. (2020). The effect of rent in urban land and housing value and the building violations in Sanandaj city in Iran .
Lehmann, P. (2010). Challenges to water pricing in developing countries .
Mercadier, A. C & ,.Brenner, F. S. (2020). Tariff (un) sustainability in contexts of price (in) stability: The case of the Buenos Aires water and sanitation concession. Utilities Policy, 63, 101005 .
Nguyen, H.-T., Dawal, S. Z. M., Nukman, Y., & Aoyama, H. (2014). A hybrid approach for fuzzy multi-attribute decision making in machine tool selection with consideration of the interactions of attributes. Expert Systems with Applications, 41(6), 3078-3090 .
Pérez, A., Hurtado-Patiño, J., Herrera, H., Carvajal, A., Pérez, M., Gonzalez-Rojas, E., & Pérez-García, J. (2019). Assessing sub-regional water scarcity using the groundwater footprint. Ecological indicators, 96, 32-39 .
Rehan, R. (2011). Sustainable Municipal Water and Wastewater Management Using System Dynamics .
Rehan, R ,.Knight, M., Haas, C., & Unger, A. (2011). Application of system dynamics for developing financially self-sustaining management policies for water and wastewater systems. Water research, 45(16), 4737-4750 .
Rougé, C., Harou, J., Garrone, P., Pulido-Velazquez, M., Marzano, R., Giuliani, M., Cominola, A., Lopez-Nicolas, A., Castelleti, A., & Rizzoli, A.-E. (2016). Smart Meter Enabled Dynamic Pricing of Water .
Tadić, S., Zečević, S., & Krstić, M. (2014). A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection. Expert Systems with Applications, 41(18), 8112-8128 .
Vašak, M., Banjac, G., Baotié, M., & Matuško, J. (2014). Dynamic day-ahead water pricing based on smart metering and demand prediction. Procedia Engineering, 89, 1031-1036 .
Xu, Z. (2015). Uncertain multi-attribute decision making: Methods and applications. Springer .
yaghoub, z. (2016). Water demand management in the agricultural sector (Case Study Lyshtr plain). Journal of Soil and Water Conservation, 5(2), 83-98 .
Yusuf, A., Sodiq, A., Giwa, A., Eke, J., Pikuda, O., De Luca, G., Di Salvo, J. L., & Chakraborty, S. (2020). A review of emerging trends in membrane science and technology for sustainable water treatment. Journal of Cleaner Production, 266, 121867 .
Zhang, X., González Rivas, M., Grant, M., & Warner, M. E. (2022). Water pricing and affordability in the US: public vs. private ownership. Water Policy, 24(3), 500-516 .