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Evaluation of Residential Water Conservation Practice of Dhaka Bangladesh

Mahfuzur Rahman[1,2,3] and Md Monirul Islam[1*]

[1]Department of Civil Engineering, International University of Business Agriculture and Technology (IUBAT), Dhaka 1230, Bangladesh
[2]Key Laboratory for Mountain Hazards and Earth Surface Process, Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu 610041, China.
[3]University of Chinese Academy of Sciences, Beijing 100049, China

*Corresponding author: E-mail: mmislam@iubat.edu

ABSTRACT: *Rapid population growth along with contamination of water is adversely affecting Dhaka's water supply and making it difficult to meet the city's water demand. Proper measures should be implemented to overcome the abuse of water. This study has been accomplished using the fuzzy analytical hierarchy process (FAHP) to evaluate the residential water conservation practice in Dhaka city, Bangladesh. This research revealed various courses of action to improve residential water conservation. First, an index system was developed. Then, a pair-wise comparison was used to produce weights using Saaty's rating scale for each criterion. In this study, the highest assessment index value for multi-level AHP fuzzy comprehensive evaluation was 0.40, which can be termed as "Fair" based on the fuzzy comment set. The evaluated results exhibit a new opportunity for water resource management, planning, and design, and a means to target water abuses.*

KEYWORDS: *Analytic Hierarchy Process (AHP), Comment Set, Pair-wise Comparison Matrix, Random Consistency Index, Water Conservation.*

1. Introduction

Assuring the quality residential water has become an enormous problem in recent years with rapid growth of population and industrialization in the city. The current water demand of Dhaka city is about 2450 million liters per day (MLD) against a maximum supply capacity of 2420 MLD (DWASA, 2015). Figure 1 shows that during the years, 2013-2015, there was no excess demand of water in Dhaka City. The maximum daily demand in this period was around 2300 MLD, whereas the maximum capacity was 2420 MLD. But after 2015, excess demand has been returned and which could not be met up due to lack of existing water supply resources and depletion of groundwater level. The current supply deficit is around 380 MLD and it may increase further due to the growth of Dhaka city's population. Paul (2009) estimated that water demand for Dhaka city will be increased to 4990 MLD by 2030. Given this projection, both local authorities and consumers should take actions to reduce unnecessary consumption.

Water scarcity will be one of the major environmental challenges in the 21st century if improved management systems with adequate measures cannot be adopted in time (Brown, 1999). Water conservation measures entail many decisions: the implementing process, behavioral change by consumers, choice of technology, and enhanced design. To develop a sustainable water conservation system, however an option must be modeled and refined. Water conservation is one way of coping with increasing demand, for example; detecting and repairing leaks in residential water supply systems. Recycling wastewater and grey water (GW) is another way of preserving high-quality fresh water and reducing water pollution. GW represents the largest potential source of water savings in the domestic residence. Water metering can help, by billing customers onthe basis of their actual water use, which provides an incentive to conserve.

Promotion of full-cost pricing is the prime requirement for efficient use of water. In practice, however, water prices lag behind of full cost in cities, in both developed and developing countries (Dalhuisen et al., 2003, Bithas, 2008).The underpricing, non-metering and increasing use of block rates, which has been practicing in this city, restrain the pursuit of social equity in the long run. When prices are properly set to approach full costs, then equity will improve in the long run as well. The present generation should bear in mind conservation of water so that future generations with having sufficient water to meet their demand. Improving the efficiency of resource use is one of many means for meeting sustainable development goals. There is a strong imperative for the adoption of the conservative use of water with recycling technologies such as reuse of reclaimed water, rainwater harvesting, and so on. At the same time, the existing water supply system needs to be improved for the adequate supply of water in the city.

This paper carries out the study on the evaluation of residential water conservation practice in Dhaka city by adopting the fuzzy comprehensive evaluation method with analytical hierarchy process (FAHP). Some researchers focused on FAHP tools to analyze different issues. The analytical hierarchy process (AHP) refers to a structured technology to analyze difficult decisions, based on mathematics and psychology (Cho, Kim, Heo, 2015, Nguyen et al., 2015, Nguyen, Nguyen, Le-Hoai, et al., 2016, Saaty, 1990, and Saaty, 2000). The AHP approach was first proposed by Thomas L. Saaty. It continues to be highly regarded and widely used in many fields of engineering and business (Song and Hu, 2009, Șener and Șener, 2015, Ryu, 2009, Mardle, Pascoe and Herrero, 2004, and Loron, Loron and Peyvandi, 2015). The AHP has many applications in group decision making and has been adopted in various decision situations, for example government management, business management, industry management, healthcare monitoring, shipbuilding design, and so on (Li, 2008, Bulut, Duru and Koçak, 2015, Szűts and Krómer, 2015, and Maranate and Pongpullponsak, 2015). The AHP method and its extension FAHP is useful tools for approaching problems in water resources management (Ridgley,1993). The FAHP has been used for the development and application of a capital investment project (Tang and Beynon, 2005). Chan and Kumar employed the AHP framework to select a global supplier by considering risk factors [Chan and Kumar, 2007]. Weighting customer requirements in quality function deployment has been done using fuzzy-AHP techniques (Kwong and Bai, 2002, and Kwong and Bai, 2003). The FAHP is a useful way to define the "fuzziness" of the data involved in deciding the preferences of the different decision makers engaged in global supplier selection (Chan, Kumar, Tiwari, et al. 2008). Fuzzy-AHP is a multi-criteria decision-making technique of AHP. It has been used to compare the enterprise resource planning (ERP) system solutions (Cebeci, 2009). The rating of both qualitative and quantitative criteria based on fuzzy analytical hierarchy process was proposed by Güngör, Serhadlıoğlu, and Kesen (2009). Elaborating the priority of water resource projects through multi-criteria evaluation and fuzzy sets analysis has been proposed by Karnib (2004). Multi-objective programming method on the basis of systems analysis was used to solve an integrated watershed management problem for the Lake Qionghai watershed in China (Wang, Meng, and Guo, et al., 2006). An interactive fuzzy multi-objective linear programming (IFMOLP) approach was used to study water resources, integrated watershed management and water quality management in Yamuna river basin (Singh, Ghosh, and Sharma, 2007). Water management plans in part of the Paraguacu River Basin in Brazil were analyzed by FAHP (Srdjevic and Medeiros, 2008). Six water conservancy policies for Kuwait water conservation were analyzed by fuzzy-AHP (Hajeeh, 2010). To avoid the effect of subjectivity on water quality assessment, a new assessment method was proposed combining AHP with the fuzzy comprehensive (Wen-xi, LI-Di, and Yan-ping, 2011).

The key objectives of this study were to: (1) evaluate the residential water conservation practice in Dhaka city; (2) ensure household water availability for future generation; (3) reduce the residential water crisis in Dhaka city. The results of this study show that the analysis is more feasible and satisfied with the practical result. This assessment should help to assist the water experts, engineers, decision makers and the city planners for mitigating the water-related issues in Bangladesh as well as Dhaka city.

2. Materials and method

This study assesses the status of water conservation practice in Dhaka city from the viewpoint of reducing water scarcity, therefore, the importance of sustainable water use and conservation of water resources should be encouraged. Previous studies has evaluated the water conservation practice to improve the sustainable water use by using FAHP. Therefore, the research objectives quantitatively evaluated the water conservation indicators and provide policy implications for further development of conservation practice in sustainable water use. Moreover, there was no existing index system for evaluating the status of residential water conservation practice in Bangladesh. In this paper, a comprehensive index system was prepared from the viewpoint of evaluating the current situation of conservation practice in Dhaka city (shown in Table 1). A mathematical model with fuzzy theory and analytical hierarchy process (AHP) was also developed to complete the evaluation for

Table 1. Summary of the experts' score of each indicator for residential water conservation practice.

Target Layer	Criterion Layer	Index Layer	Experts' Assessment Summary				
			Excellent	Good	Fair	Poor	Very Poor
Residential water conservation practice [u]	**Scheme [u_1]** An analytical or ta bular statement to focus the whole networking, distribution process, ensuring the targeted works, social and economic adaption capability in household water conservation.	**Network and distribution [u_{11}]** Strong and efficient network and distribution is one of the most important assets because entire network and distribution intermediaries from the supplier to the consumer.	0	2	7	1	0
		Water supply target and task [u_{12}] Ensuring all the activities and implementing the process.	0	0	6	3	1
		Social and economic status [u_{13}] Population growth rate, per capita water consumption, water requirement, and water demand proportion etc.	0	0	3	5	1
	Resources [u_2] Resources mean how to use water resources in the process of water conservation practice and the present situation of water environment and also familiar with the common existing water sources, water saving as well as future water sources	**Water resources condition [u_{21}]** Overall condition of existing water resource (Surface Water + Ground Water).	0	1	2	5	2
		Water quality [u_{22}] Existing supply water quality	0	4	5	1	0
		Water consumption [u_{23}] Willing to adopt the water conservation practice.	0	2	3	5	0
		Alternatives for future water supply [u_{24}] Future project work and surface water treatment plant	0	1	5	4	0
		Significant of water saving [u_{25}] Significance of water savings to lead the development in future	1	1	5	3	0
	Engineering measures [u_3] Physical appliances in technical part to make the water conservation practices more consistent.	**Performance [u_{31}]** Existing water supply system performance	0	2	8	0	0
		Reliability [u_{32}] Develop the conservation measure reliable. Short term reliability may not be cost effective in the long run.	0	0	7	3	0
		Groundwater infiltration [u_{33}] The rate of groundwater infiltration	0	0	0	7	3

Table 1. Summary of the experts' score of each indicator for residential water conservation practice (continue).

Target Layer	Criterion Layer	Index Layer	Experts' Assessment Summary				
			Excellent	Good	Fair	Poor	Very Poor
		Water reuse and recycling [u_{34}] Reuse and recycling for alternative water supply sources	0	0	0	5	5
		Water saving devices and leakage control [u_{35}] Control water losses by using leakage control equipment.	0	0	2	6	2
		Rain water harvesting [u_{36}] Code and regulations for building rain water harvesting	0	0	1	6	3
	Non-Engineering measures [u_4] Non physical appliances to reduce risks and impacts, in particular through policies and laws, public awareness raising, training and education.	**Public education and awareness [u41]** Media, group discussion, seminar, and so on.	0	1	4	3	2
		Institutional cooperation [u_{42}] School, college, university, government and privet organization initiation for water conservation practice	0	2	4	2	2
		Pricing of the water [u_{43}] Water pricing policy and public willingness	0	2	4	2	2
		Water conservation fund and insurance [u_{44}] Status of available water conservation fund and insurance	0	0	2	4	4
	Policy [u_5] Initially focus the guidelines and handling mechanism for water users and in such areas where competition for accessing the household water is significant	**Rules and regulation [u_{51}]** To practice water conservation	0	1	1	6	2
		Water conservation investment policy [u_{52}] Current status of water conservation investment	0	2	3	2	3
		Guarantee mechanism [u_{53}] Water safety including environmental safety.	0	0	3	7	0
	Sustainability [u_6] It refers that the use of water for a long period of time with a continual process.	**Technical maintenance [u_{61}]** Regular maintenance for sustainable water supply	0	0	7	2	1
		Environmental compliance [u_{62}] As a life sustaining resource, water conservation affects the surrounding environment. As water supplies decrease, the need to conserve water to protect the environment increases.	2	3	2	2	1
	Effectuation [u_7] To understand the importance of water conservation.	**Potential economic benefits [u_{71}]** Cost effectiveness for water conservation	0	1	6	2	1
		Social influence affects the water conservation practice/Effect of social influence on water conservation[u_{72}]	0	2	5	2	1

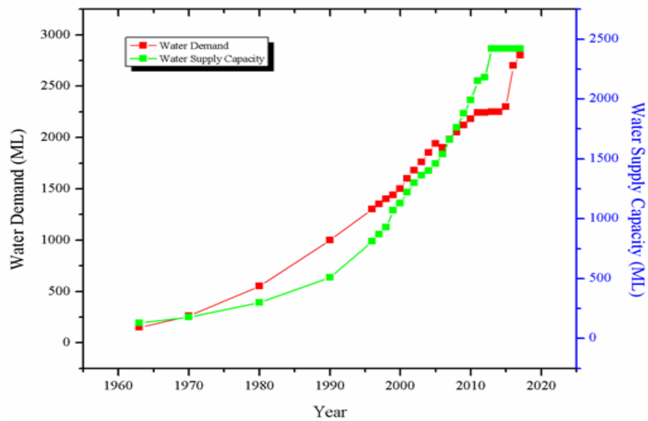

Figure 1. Year wise water demand and supply overview of Dhaka city.

water conservation practice in the city.
Then, to assess the effectiveness of the planned method, total 15 experts' assessment has collected from relevant field experts.

2.1 Study area

Dhaka, the capital of Bangladesh, is experiencing a worsening water supply trend. It is located in the southern part of Bangladesh and its latitudes and longitudes are 24º40´ N and 90º20´ E to 24º54´ N and to 90º30´ E, respectively (shown in Figure 2). The city is located on the higher elevated Pleistocene terrace feature of Bangladesh. Nearby low lying areas have recently been annexed to keep pace with the growth of the city.

2.2 Data collection and processing

Water planners, as well as different users, have to deal with many challenges to meet the up growing water demand in Dhaka city. The traditional response to water demand has been demonstrated for additional water supply. But significant attention has been given to understand the current water use patterns in Dhaka city to strengthen sustainable water use and conservation of water resources through the recent modern management tools, for example-economic incentives, water pricing policies, public participation and awareness, education and information strategies, and so on, those were powerful to control the subject issues (Mylopoulos and Mentes, 2002). In the context of the residential water conservation, a survey was conducted among the fifteen (15) experts with the set of questionnaires, where ten (10) valid questionnaires have taken for index system about the attitude on water conservation which is shown in Table 1. The objective of the questionnaires of the survey was to explore the attitudes of the sustainable water users of Dhaka city. The survey was conducted through the experts' evaluation and comments to compare the efficacy and the reliability of the utility's services and infrastructure, the acceptability of numerous water demand options, the willingness to pay of the suppliers, the level of public awareness, and so on. On the basis of the index system of residential water conservation practice, the weights of all criterion and sub-criterion were calculated from experts' evaluation and analytic hierarchy process (AHP). At first, the evaluation factors set and comments set were determined which was the foremost step of the fuzzy comprehensive evaluation method. In this work, we set five comments

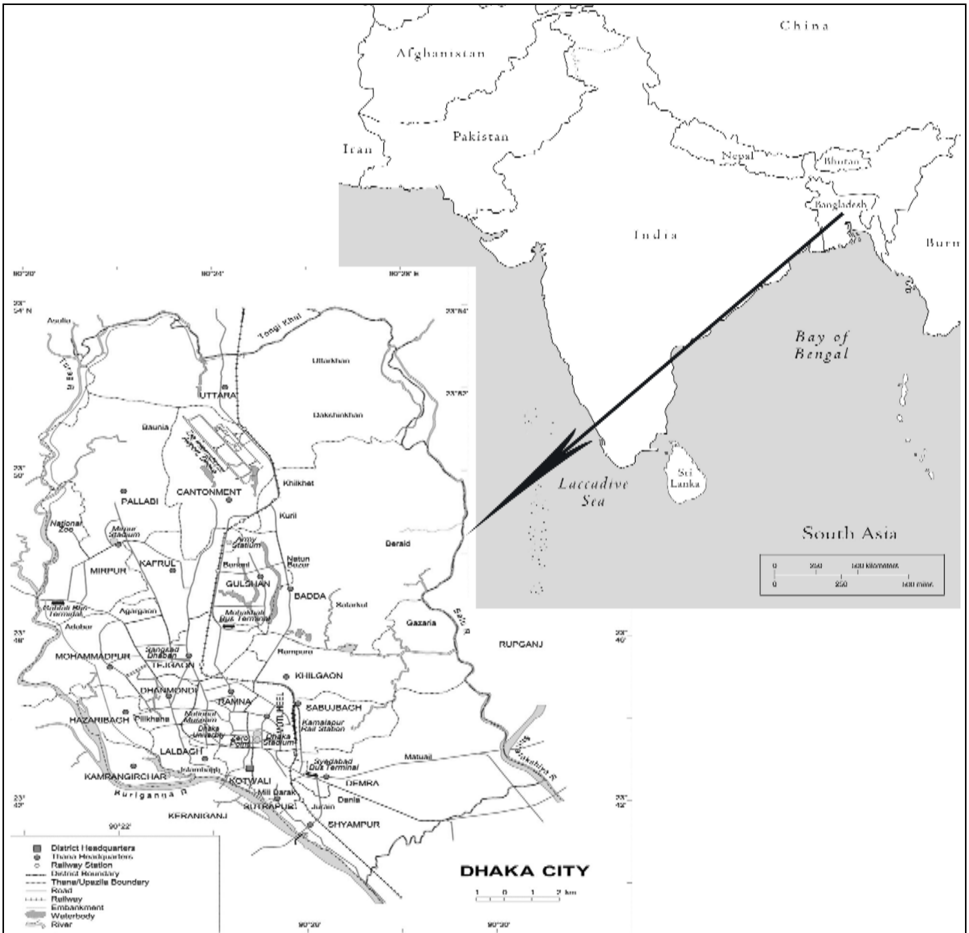

Figure 2. The area selected for the study.

including excellent, good, fair, poor and very poor.

Finally, the comment set can be denoted as v = [Excellent, Good, Fair, Poor, Very Poor]. After that, the membership degree of each factor and the fuzzy comprehensive relationship between evaluation factors and comments set were developed and the weight of each evaluation factor was calculated. The main steps of AHP method were to establish the pair-wise comparison judgment matrix before selecting the experts. After that, the experts give comments for each factor according to the rating scale developed by Saaty (2008) which is shown in Table 2.

2.3 Mathematical model

The mathematical expression of fuzzy comprehensive evaluation method is given in Eq. (1).

$$F = W.R \quad (1)$$

Table 2. Saaty's rating scale for pair-wise comparisons.

Explanation	Score
Extremely less important	1/9
Very strongly less important	1/7
Strongly less important	1/5
Moderately less important	1/3
Equal importance	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Intermediate values between the two adjacent judgments	2, 4, 6, 8, 1/2, 1/4, 1/6, 1/8

Where, **W** represents the input which was expressed $1 \times a$ order matrix indicating weights of the evaluation factors; **R** represents the comprehensive evaluation $\mathbf{a} \times \mathbf{b}$ order matrix of every single factor with evaluation set $\mathbf{r_1, r_2, r_3, r_4 ......r_{ab}}$

$$F = W.R = \left(w_1, w_2, w_3, w_4, ... w_a\right)_{1\times a} \cdot \begin{bmatrix} r_{11} & r_{12} & .... & r_{1b} \\ r_{21} & r_{22} & .... & r_{2b} \\ r_{31} & r_{32} & .... & r_{3b} \\ .. & .. & .. & .. \\ .. & .. & .. & .. \\ r_{a1} & r_{a2} & .... & r_{ab} \end{bmatrix}_{a\times b}$$

$$= \left(f_1, f_2, f_3, f_4, ... f_b\right)_{1\times b} \qquad (2)$$

F represents the output which is expressed $1 \times b$ order matrix and also termed as the fuzzy comprehensive evaluation result. Finally, ***F*** can be written as below:

$$\text{where } f_j = \sum_{i=1}^{m} w_i r_{ij} \qquad (3)$$

here f_j represents membership degree evaluated as a rank j.

2.4 Calculation of membership degree

$$r_{ij} = \frac{m_{ij}}{n} \qquad (4)$$

From the Eq. (4), r_{ij} is the membership degree for factor, E_i evaluated by experts comments through the rank vector v_j; m_{ij} is the number of given questionnaires for factor, E_i evaluated as rank vector, v_j; *n* stands for the total number of effect questionnaires. The membership degree for each indicator in the index system was calculated by using Eq. (4). According to experts' comment, tabulated in Table 1, membership degree of each indicator in index layer can be calculated by above mentioned formula. The result calculated from Eq. (4) is shown in Table 3.

2.5 Determination of weight of comprehensive evaluation by AHP

In this study, AHP method was used to determine the weight of every single indicator of the comprehensive evaluation index of residential water conservation practice. The processes of AHP analyses are as follows:

- Construct the comprehensive evaluation index system;
- Establish the pair-wise comparison judgment matrix;
- Estimate the principal eigen value from the pair-wise comparison judgment matrix by using the values from Saaty's rating scale;
- Calculate the weight and check the consistency ratio according to random consistency index (RI).

2.6 Consistency analysis

The consistency ratio and consistency index were determined by using Eqs. (5) and (6), respectively.

$$CR = \frac{CI}{RI} \qquad (5)$$

$$CI = \frac{\lambda_{max} - n}{n} \qquad (6)$$

Where **CR** represents the consistency ratio, **CI** represents the consistency index, and **RI** is the average random consistency index of the judgment matrix **R**, which is shown in Table 4.

2.7 Foundation of assessment matrix with AHP Fuzzy comprehensive evaluation method

The evaluation matrix **R** of criterion layer was obtained by using Eq. (4). The weight vector **W** of indicator layer was obtained by using AHP method which is shown in Tables 5, 6, and 7. Finally, the F_{u1} value was calculated by using Eq. (2) which is shown below:

$$F_{u1} = W_{u1}.R_{u1} = \begin{bmatrix} 0.44 & 0.06 & 0.50 \end{bmatrix} \begin{bmatrix} 0.00 & 0.10 & 0.80 & 0.10 & 0.00 \\ 0.00 & 0.00 & 0.60 & 0.30 & 0.10 \\ 0.00 & 0.00 & 0.50 & 0.40 & 0.10 \end{bmatrix}$$

$$= \begin{bmatrix} 0.00 & 0.04 & 0.64 & 0.26 & 0.06 \end{bmatrix}$$

Similarly, the rest of the weights were calculated applying AHP method. The calculated weights are shown in Table 7.

Table 3. Membership degree for each indicator in the index layer

Single Indicator	Membership Degree				
	Excellent	Good	Fair	Poor	Very Poor
u_{11}	0	0.1	0.8	0.1	0
u_{12}	0	0	0.6	0.3	0.1
u_{13}	0	0	0.5	0.4	0.1
u_{21}	0	0.1	0.2	0.5	0.2
u_{22}	0	0.2	0.7	0.1	0
u_{23}	0	0.2	0.4	0.4	0
u_{24}	0	0.1	0.6	0.3	0
u_{25}	0.1	0.1	0.5	0.3	0
u_{26}	0	0.1	0.6	0.3	0
u_{31}	0	0.2	0.8	0	0
u_{32}	0	0	0.7	0.3	0
u_{33}	0	0	0	0.7	0.3
u_{34}	0	0	0	0.5	0.5
u_{35}	0	0	0.2	0.6	0.2
u_{36}	0	0	0.1	0.6	0.3
u_{41}	0	0.1	0.4	0.3	0.2
u_{42}	0	0.2	0.6	0.1	0.1
u_{43}	0	0.2	0.4	0.2	0.2
u_{44}	0	0	0.2	0.4	0.4
u_{51}	0	0.1	0.1	0.6	0.2
u_{52}	0	0.2	0.3	0.2	0.3
u_{53}	0	0	0.3	0.7	0
u_{61}	0	0	0.7	0.2	0.1
u_{62}	0.2	0.3	0.2	0.2	0.1
u_{71}	0	0.1	0.6	0.2	0.1
u_{72}	0	0.2	0.5	0.2	0.1

Table 4. Random consistency indexes [7,9,34].

Number of Criteria	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.0	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 5. The pair-wise comparison of AHP judgment matrix of u_i relative to u (i = 1, 2, 3…n).

								RI=1.32				
	u_1	**u_2**	**u_3**	**u_4**	**u_5**	**u_6**	**u_7**	**n^{th} Root**	**Weight**	**λ_{max}**	**CI**	**CR**
u_1	1	0.33	0.33	0.66	0.2	0.66	0.66	0.48	0.06			
u_2	3.03	1	2	2	0.2	1.5	0.66	1.13	0.14			
u_3	3.03	0.50	1	2	0.25	2	1.5	1.12	0.14			
u_4	1.52	0.50	0.50	1	0.25	2	0.66	0.74	0.09			
u_5	5	5	4	4	1	1.5	1.5	2.64	0.33	**7.54**	**0.10**	**0.08**
u_6	1.52	0.67	0.50	0.50	0.67	1	0.66	0.73	0.09			
u_7	1.52	1.52	0.67	1.52	0.67	1.52	1	1.13	0.14			
									7.99			

Table 6. The pair-wise comparison of AHP judgment matrix of uij relative to u1j (j = 1, 2, 3…n)

	u_1	**u_2**	**u_3**	**RI= 0.58**				
				n^{th} Root	**Weight**	**λ_{max}**	**CI**	**CR**
u_1	1	9	0.67	1.82	0.44	**3.07**	**0.04**	**0.06**
u_2	0.11	1	0.17	0.26	0.06			
u_3	1.49	5.99	1	2.08	0.50			
				4.16				

Table 7. The pair-wise comparison of AHP judgment matrix results of u_{ij} (i , j= 1, 2, 3…n).			
Single Indicators	**Weights**	**Single Indicators**	**Weights**
u_{21}	0.27	u_{41}	0.42
u_{22}	0.17	u_{42}	0.29
u_{23}	0.06	u_{43}	0.21
u_{24}	0.18	u_{44}	0.09
u_{25}	0.12	u_{51}	0.73
u_{26}	0.21	u_{52}	0.17
u_{31}	0.24	u_{53}	0.10
u_{32}	0.25	u_{61}	0.86
u_{33}	0.26	u_{62}	0.14
u_{34}	0.05	u_{61}	0.88
u_{35}	0.07	u_{62}	0.13
u_{36}	0.13		

$$F = W.R = \begin{bmatrix} 0.06 & 0.14 & 0.14 & 0.09 & 0.33 & 0.09 & 0.14 \end{bmatrix} . \begin{bmatrix} 0.00 & 0.04 & 0.64 & 0.26 & 0.06 \\ 0.01 & 0.12 & 0.49 & 0.32 & 0.05 \\ 0.00 & 0.05 & 0.40 & 0.40 & 0.15 \\ 0.00 & 0.14 & 0.44 & 0.23 & 0.19 \\ 0.00 & 0.11 & 0.15 & 0.54 & 0.20 \\ 0.03 & 0.04 & 0.63 & 0.20 & 0.10 \\ 0.00 & 0.11 & 0.59 & 0.20 & 0.10 \end{bmatrix}$$

$$F = \begin{bmatrix} 0.004 & 0.10 & 0.40 & 0.37 & 0.14 \end{bmatrix}$$

2.8 Multi-level AHP Fuzzy comprehensive evaluation

The evaluation matrix R of the criterion layer was obtained by using Eq. (4). The weigh
vector W of criterion layer was obtained by using AHP method. Then the evaluation grade of fuzzy comprehensive evaluation, F, can be calculated by using Eq. (2) which assessment the results of the criterion layer.

In accordance with the principle of fuzzy judgment maximum membership degree, the water conservation practice in Dhaka city is fair, and this evaluation result is inconsistent with the qualitative judgment result in the study area, indicating that this model has good applicability, and providing a reference for evaluating water conservation practice of similar study area.

Table 8. Assessments result of criterion layer.					
Single Indicators	**Assessment Result**				
	Excellent	**Good**	**Fair**	**Poor**	**Very Poor**
Fu_1	0.00	0.04	0.64	0.26	0.06
Fu_2	0.01	0.12	0.49	0.32	0.05
Fu_3	0.00	0.05	0.40	0.40	0.15
Fu_4	0.00	0.14	0.44	0.23	0.19
Fu_5	0.00	0.11	0.15	0.54	0.20
Fu_6	0.03	0.04	0.63	0.20	0.10
Fu_7	0.00	0.11	0.59	0.20	0.10

3. Results

The study is to highlight the potential for saving residential water and its contribution to meet up the water shortage in Dhaka city. Therefore, the study has developed an index system where seven criteria were proposed; scheme, resources, engineering measures, non-engineering measures, policy, sustainability, and effectuation. The first, second, third, fourth, fifth, sixth, and seventh criterion were divided into three, six, six, four, three, two, and two index layer, respectively (shown in Table 3).

This paper examined the status of the residential water conservation practice in Dhaka city from the viewpoint of expert's opinion using FAHP method. Therefore, the research attempts to quantitatively assess the indicators which were responsible for improving the sustainable development of the present water resources and provide policy implications for reduction excessive residential water consumption. Keeping in view the multi-level AHP fuzzy comprehensive evaluation index calculated into the comment set, v= [Excellent, Good, Fair, Poor, Very Poor] for judgment, we found that the comprehensive evaluation results of residential water conservation practice in Dhaka city are adequate. The analyses revealed that the probability of "Excellent", "Good", "Fair", "Poor" and "Very Poor" were 0.004, 0.10, 0.40, 0.37 and 0.14, respectively (shown in section 2.8). The method of maximum membership degree was used to determine the rating results. According to the principle of the maximum membership degree, it was found that the evaluation result of the residential water conservation practice for Dhaka city is "Fair". Therefore, there is still some scope for development and there is still a huge way to work for scoring "Excellent".

4. Discussions

The foregoing discussion indicates that an examination of water conservation requires a multi-dimensional approach. The importance of efficiency in water conservation clearly varies across regions and nations, as well as it is time dependent. Reduction of the consumption of water will decrease water crisis, increase energy savings, and create more efficient use of our water resources.

Figure 3 represents the results for the maximum membership degree for the criterions, which were Fair (first to forth criterions accept the criteria third which consist of equal maximum membership degree for comment set "Poor"), Poor (criteria fifth), and Fair (sixth and seventh criterions), respectively. However, on the basis of the perspective of jurisdiction, the residential water conservation practice in

Dhaka city needs to be improved. The results suggest several policy implications: pricing of the water, water conservation investment, public education and awareness, water safety, water conservation fund and insurance, and so on for improving water conservation practice. Moreover, households that consume substantial amounts of water for drinking, bathing, toilet use, laundry, cooking, washing, and so on are needed to achieve greater residential water savings, through proper water conservation practice. A reduction in excessive water consumption could be achieved to mitigate the present water crisis in Dhaka city. The proposed index system in this paper could be beneficial for other areas of Bangladesh including the developing countries where the people are facing water crisis issues.

Moreover, the proposed method makes it simpler to explain the results to the reader and it also presents helpful information for concerned parties and policymakers. Finally, the results accumulated in the evaluation system can assist in improving the water conservation practice in each district and in the country as a whole.

Furthermore, the assessments (shown in Table 1) suggest several policy implications for improving sustainable water use and conservation of water resources in the long run. The results confirmed that several perceived benefits were positively associated with water conservation practices in Dhaka city. Moreover, the result, found in this study could be beneficial for other districts of Bangladesh by adopting the method discussed in this study.

5. Conclusions

In this research, it has been recommended that FAHP method is a reliable supporting tool which can be used by decision-makers in the field of water conservation to improve the sustainable water use and conservation of water resources in Dhaka

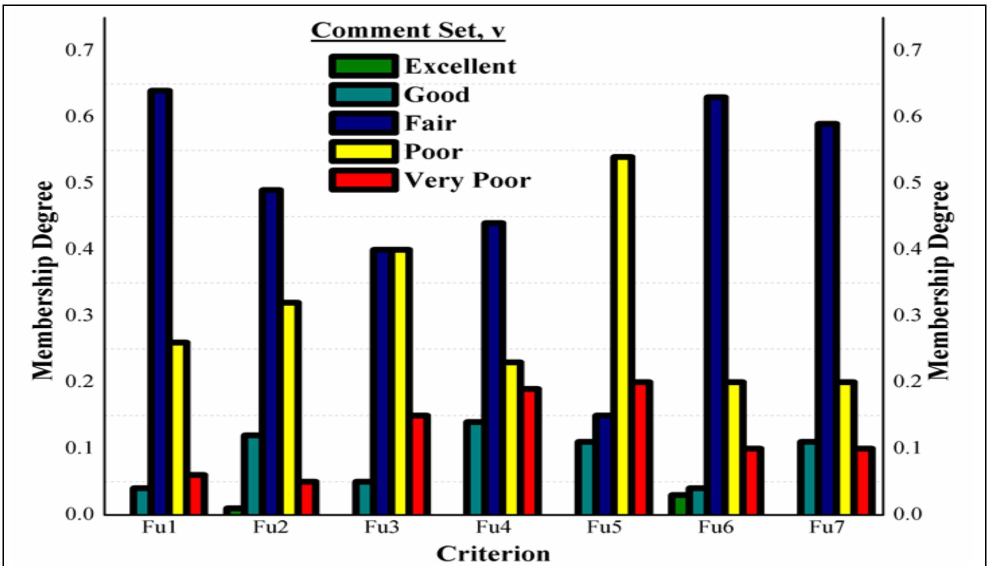

Figure 3. The evaluation index of the criterion layer.

city, Bangladesh. The summarized conclusions and recommendations are as follows:

(i) Evaluation of water conservation practice was established. Analytical hierarchy process is adopted to find the weight and fuzzy comprehensive evaluation index which was also established to calculate the membership degree of each criterion according to the evaluation of residential water conservation in Dhaka city.

(ii) Multi-level fuzzy comprehensive evaluation method was applied to evaluate the residential water conservation practice in Dhaka city. The evaluation results were significant with experts' assessment and present condition.

From the assessment result of index system, engineering measurement in particularly groundwater infiltration, water reuse and recycle, water saving and leakage control device, and rainwater harvesting should be strengthened, and the policy, basically the rules regulation and water conservancy policy should be modified. At the same time, public awareness for water conservation and sustainable water use need to be enhanced for economic benefits so that the future demand for water might be fulfilled properly**.**

6. Recommendation

Finally, the study revealed the following key initiates from analyzing the results found in this study:

(i) Increasing the role of School, College, University, Government and Private organization initiation for water conservation practice in Bangladesh as well as Dhaka city.

(ii) Enhancing water pricing policy and public willingness for water conservation.

(iii) Enhancing Public consciousness programs in order to educate water provider and the public of the personal and societal benefits of adequately using water, and reduce the waste.

(iv) Passing and enforcing water rules and regulation.

Conflicts of Interest: "The authors declare no conflict of interest."

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