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Problems and obstacles of returning life to Qanats

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Qanats are the vital element of agricultural areas in arid and semi arid regions of Iran. The main reason of water shortage in qanats is due to drought and reduction of water resources in recent years and drilling of deep and semi deep wells in buffer zone of qanats, but lack of reconstruction in some cases caused to low and sometimes zero discharge in qanats, despite of groundwater existence in some parts of qanat's gallery. This study discussed about current situation, possibility of reorganization and reconstruction in 12 qanats in Isfahan province. Limited financial resources and productivity of the qanats after reconstruction are two important issues in determining the priority of funds allocation to rebuilding of qanats. In this study, Analytical Hierarchy Process (AHP) applied for prioritizing of qanats and selecting the best one for reconstruction in each city. Amount of discharge increase after reconstruction, reorganization costs, number of beneficiaries, etc. used as criteria. Results showed that Sifagh2, Deh Darrehbid and Mirzaebrahim qanats in Fereidonshahr, Fereidan and Khansar cities selected as the best qanats for reorganization.

Key words: Qanat, Groundwater resources, Reorganization, Reconstruction, AHP

Introduction

Qanat is a water management system used to provide a reliable supply of water to human settlements or for irrigation in hot arid and semi-arid climates. The technology is known to have developed in ancient Persia, and then spread to other cultures, especially along the Silk Road, indeed there are still many examples of qanat systems in Spain, most likely brought to the area by the moors during their occupation of the Iberian Peninsula. Qanat (Kariz or aqueduct) which means drilling is a method in ancient Iran and it known as "Iranian Labour" (Jamali, 1975). Qanat is one of the most important and profound inventions of the Iranian Hydraulic engineering. Use of this technique to utilize groundwater can be aged to more than 3000 years ago (Zeiari, 2000).

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Water resources of Earth planet are facing crisis and worrying challenges such as shortage of water, mismanagement and lack of integrity in management networks of water resources, existence of decreasing trend in allocated finance, and non existence of awareness among decision makers and farmers (Sadati *et al*., 2010). In the past, designers of a city could produce coordinated, balanced and residential environments for human with knowing and utilizing from natural laws and usage from natural elements. Including of them, qanat can be mentioned as a natural element in warm and dry climates (Zarabadi and Haeri, 2011).

Determining of suitable wet layer for digging a qanat and Fountain (qanat exit) location is a unique symbol of ancient Iranian engineering (Amin *et al*., 2009). Iranians had two goals for digging a qanat. More importantly, the main goal was to pour water on the ground and avoid of using bucket for bringing water to surface and saving of manpower. The second goal was preventing from water evaporation (Monzavi, 2009). Religious faith of ancient Iranians about fertilizing of lands caused to digging a lot of qanats (Hami, 1971). Qanats are composed of two main parts; underground tunnel (gallery) and vertical wells (shafts). Duty of gallery is collecting and directing of groundwater to land surface in fountain (Arab Khedry and Hakim Khani, 2003).

About eighty percent of Iranian activity is based on utilization of groundwater. In spite of advent of new techniques in use of groundwater, qanat has special privileges (Barimany *et al*., 2005). Still, in most areas, these qanats are supplier of water to people whose existence depends on the flow of groundwater (Jamali, 1975, and Bayat Movahed, 2002). Studies show that, still qanats can be use as an irrigation, productive, social and economical system in a wide area of Iran (Jomepour, 2006). In other hand, unfortunately reduction of precipitations and falling of groundwater, because of uncontrolled use by deep and semi deep walls, are main reasons of falling of groundwater table, decreasing of active qanats and their discharge (Jamali, 1975 and Bayat Movahed, 2002). Anyway, in recent years because of changing of traditional agriculture to industrial agriculture, farmers have not enough fund for digging a new qanat or repair, dredge or reconstruct old ones. Experts by study of natural, social and economical status of region must encourage farmers to restoration and reconstruction of qanats, provided that this action be cost effective (Jamali, 1975). Although technology can be a complementary of traditional irrigation system, but before every action, study of location and natural structure of study area is necessary. Otherwise every improper action will have a reaction and compensation of it would be impossible or very costly (Salim and Fallahi, 2009).

Therefore, pay attention to improve and reconstruction of qanats as a symbol of historical civilization of Iran is vital. Therefore, prioritizing of state funds is vital and social, economical and agricultural effects of qanats on affected areas after reconstruction can be effective in identifying priority of qanats improvement activities.

In this study, AHP used for prioritizing of qanats. This method let to select the best Alternative among several ones and also prioritizing based on effective criteria. AHP is a very useful tool and widely applied in multi-criteria decision making processes (Saaty, 2000). AHP is one of complete methods which designed for multi-criteria decision making with consider to qualitative and quantitative criteria. In this process, sensitivity analysis of criteria and sub criteria is possible. Moreover, it is based on dual comparisons that facilitate the judgment and calculations. Also it show the compatibility or incompatibility of decisions that are the superior advantages of this technique in multi-criteria decision making (Ghodsipour, 2006). This method presents a useful mathematical structure in modeling of a lot of problems. The deciding may include social, political, economical and technical factors (Randalla *et al*., 2004). Ghodosi Shahrezaee (2001) applied AHP method in evaluation of eight irrigation networks in Iran for determining of efficiency and criteria coefficients in management and technical viewpoint. Montazer and Behbahani (2007) presented a model to select optimum irrigation system due to affective physical, political, economical and environmental factors of irrigation efficiency. Ahmadi *et al*. (2005) applied AHP for regional modeling of mass movement using natural characteristics in Taleghan dam catchment. Okada *et al*. (2008) quantified the effects of improvements in management and structures in irrigation projects using AHP. Behbahani *et al*. (2006) used AHP in basins and sub basins of Lorestan province to investigate the effect of criteria in separate and combine forms. Ananda and Herath (2008) explained how to use AHP to combine priorities in determining of optimal land use alternatives of forest lands in Australia. Karami (2006) used AHP and Expert Choice software in selection of appropriate irrigation method. Also Zadbagher and Montazer (2008) using AHP and Expert Choice software, evaluate the efficiency of water use in 14 modern irrigation and drainage networks in Iran.

Materials and methods

Expert Choice Software which is a robust, desktop-based application that enables us to prioritize objectives and evaluate alternatives and achieve alignment, used as an applied tool in this study.

Expert Choice (EC) is a multi-objective Decision Support Systems (DSS) based on AHP which uses for analysis, synthesis and modifying of evaluations and complex decisions. This software has applied in various cases, including allocation of resources, selection of alternatives, analytical planning, benefit to cost analysis, performance management and etc.

This model has a lot of potential and in addition to its possibility in designing of hierarchical graphs and questions, making decision, determining of preferences and priorities, and Synthesis, also it is able to Sensitivity analysis of decisions to changes in the parameters of the problem.

Hierarchy in EC can be expressed in a few steps as follows:-
Step 1: Enter the name of the model and define its purpose,
Step 2: Enter the criteria,
Step 3: Enter the Alternatives,
Step 4: Pairwise Comparison of alternatives than each criterion and then each criteria than object,
Step 5: Improving of consistency,
Step 6: Calculation of relative weights ,
Step 7: Determine the final weight (Synthesis).

For using AHP, it is necessary to define the goal, criteria and alternatives. The aim of this study is prioritization and organization of qanats and criteria included five parameters of discharge increase after reconstruction, reorganization costs, number of beneficiaries, length of qanat and covering crop Area. Alternatives are 12 qanats in Fereidan (five qanats), Fereidonshahr (three qanats) and Khansar (four qanats) cities in Isfahan province which their characteristics are shown in Table 1.

Table 1. General characteristics of qanats*

qanat Name	**City**	**Village**	**Length of Qanat (km)**	**Branch**	**qanat Status**	**geographical coordinate of fountain**		
						longitude	**latitude**	Elevation (m)
Bozorg	Fereidan	Badejan	1.512	No	active	438658	3658351	2408
Bozorg	Fereidan	Mirabad	1.11	No	active	428490	3660049	2414
Deh	Fereidan	Darrehbid	3.248	Yes	inactive	438725	3659742	2446
Bozorg	Fereidan	Hadan	2.144	Yes	active	530420	3665885	2533
Koochak	Fereidan	Hadan	9.29	Yes	active	430792	3665244	2534
Chahkhalil	Khansar	Rahmatabad	0.887	Yes	active	458709	3670145	2382
Chenarak	Khansar	Ghodjan	0.891	No	active	434762	3681965	2137
Mirzaebrahim	Khansar	Arjanak	0.625	Yes	inactive	420433	3688972	2211
Ghebleei	Khansar	Arjanak	0.474	Yes	active	420177	3689699	2210
Khosh Kerood1	Fereidonshahr	Sangbaran	0.387	Yes	active	423297	3650492	2275
Sifagh1	Fereidonshahr	Khoigan olia	0.453	No	active	420766	3652270	2400
Sifagh2	Fereidonshahr	Khoigan olia	0.323	No	active	420759	3652241	2401

*Information presented in this study were obtained from Ab Pouyesh Bana Consulting Company (2009)

According to surveys, because of discharge decreasing and in some cases drying of qanats, they need to rebuilt and reconstructed. Although all of qanats were used for agricultural and animal husbandry purposes but quality of their water was acceptable for drinking. In some cases there were several qanats in a village, and even several wells have been drilled for irrigation. But Farmers are interested to maintain qanats and increase their discharge. The technical information of qanats were shown in Table 2.

Table 2. Technical information of qanats

qanat Name	Beneficiaries Number	Discharge(lit/s)		Irrigation canal status	Fountain status
		20 year ago	now		
Bozorg Badejan	70	75	8	concrete	unsuitable
Bozorg Mirabad	40	35	12	soil	unsuitable
Deh Darrehbid	144	100	0	concrete	suitable
Bozorg Hadan	80	150	33	concrete	suitable
Koochak Hadan	80	75	10	soil	suitable
Chahkhalil	50	50	18	Concrete & soil	unsuitable
Chenarak	28	25	11	Concrete & soil	unsuitable
Mirzaebrahim	50	25	0	soil	unsuitable
Ghebleei	50	15	1	concrete	suitable
Khosh Kerood1	100	90	3	soil	unsuitable
Sifagh1	73	90	2	Concrete & soil	suitable
Sifagh2	73	100	2	soil	suitable

For evaluation of qanats, first their characteristics obtained from Regional Water Authority, Agricultural Management Office and the village's councils by preparing of some questionnaires. Then, by consider to information and documents, a group of experienced pitmen collaborated to evaluate interior condition of galleries and shafts. In this way, the data of present structure of qanats and their stability collected. Gathered Data reviewed and clarified by help of experts and professionals pitmen.

Results and discussion

The information for AHP show the purpose, criteria, alternatives and their relationship in AHP (Fig.1). The gathered data used for weighting of criteria and alternatives as shown in Table 3.

Table 3. Necessary information for AHP of qanats

City	qanat Name	Village	Expected Discharge Increase (%)	Covering Crop Area(ha)	Beneficiaries (family)	reorganization costs ($)	Length of qanat (km)
Fereidan	Bozorg	Badejan	36	80	70	32670	1.512
	Deh	Darrehbid	46	100	144	109330	3.248
	Bozorg	Hadan	14	150	80	2070	2.144
	Koochak	Hadan	16	75	80	17730	0.929
	Bozorg	Mirabad	46	35	40	7000	1.11
Khansar	Chahkhalil	Rahmatabad	1	50	50	1470	0.887
	Chenarak	Ghodjan	26	50	28	7670	0.891
	Mirzaebrahim	Arjanak	47	25	50	9000	0.625
Fereidon shahr	Ghebleei	Arjanak	22	15	50	2870	0.474
	Khosh Kerood1	Sangbaran	34	150	100	10130	0.387
	Sifagh1	Khoigan olia	47	70	73	10800	0.453
	Sifagh2	Khoigan olia	54	90	73	6400	0.323

As described in AHP, alternatives and criteria compare with each other in binaty way. So, every pair of alternatives compare with each other and based on criterion, a number between 1 to 9 allocate to every alternative (weighting of alternatives) as also reported by (Ghodosi Shahrezaee, 2001; Montazer and Behbahani, 2007). As mentioned above there were 12 alternatives and 5 criteria, for comparison of alternatives 5 matrices of 12×12 pair comparison and for comparison of criteria a 5×5 matrix obtained. Then results of Matrices entered to the software and examined. In scoring of any criteria, the best alternative (qanat) showed more discharge increase, covering crop area, number of beneficiaries, less reorganization costs and shorter qanat length.

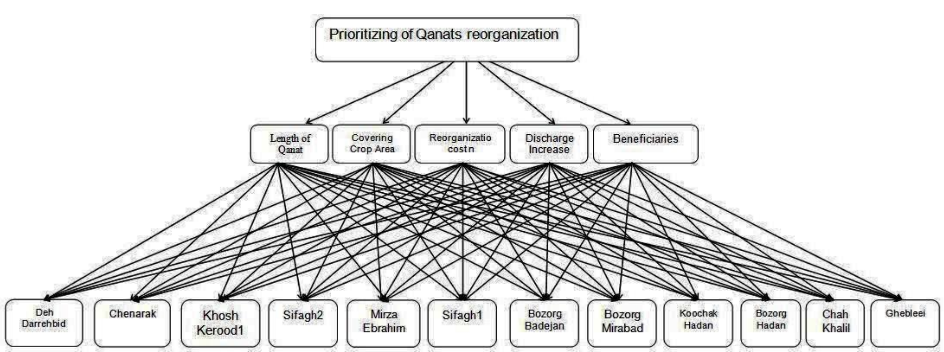

Fig. 1. AHP structure for prioritizing of qanat's reorganization

Relation of qanat length with better alternative is inverse, because reorganization of longer qanats is more difficult and their development is low. In other hand, the final goal of reconstruction and reorganization of qanats is improvement of socio-economical level of deprive regions and avoiding of villager's immigration, and criteria includ discharge increase, number of beneficiaries and covering crop area, respectively, are considered as the most important criteria in choosing of the best alternative.

Final results of combined weight of criteria and alternatives in the expert choice software were shown in Fig. 2 and Table 4. The final weight associated with each qanat is located in front of its name and indicate the priority of qanats. In this sorted diagram, the rate of overall inconsistency is equal to 0.02, because it must be less than 0.1, infer that consistency of decision is suitable. The sensitivity analysis in dynamic form which all of criteria and alternatives are shown as horizontal axles and associated numbers (Fig. 3). This chart shows the relative weights of the criteria in left graph and alternatives and their relative weights in right graph. Using this part of software, sensitivity of any alternatives to the criteria determined. Thus, by changing of any criteria, its effect on alternatives ranking can be viewed dynamically.

Although, there isn't any similar study in reviewed articles and references, but conclude that AHP is a suitable model for decision making about discrete data. This approach selected for present study by notice to ease of use and practicality of AHP.

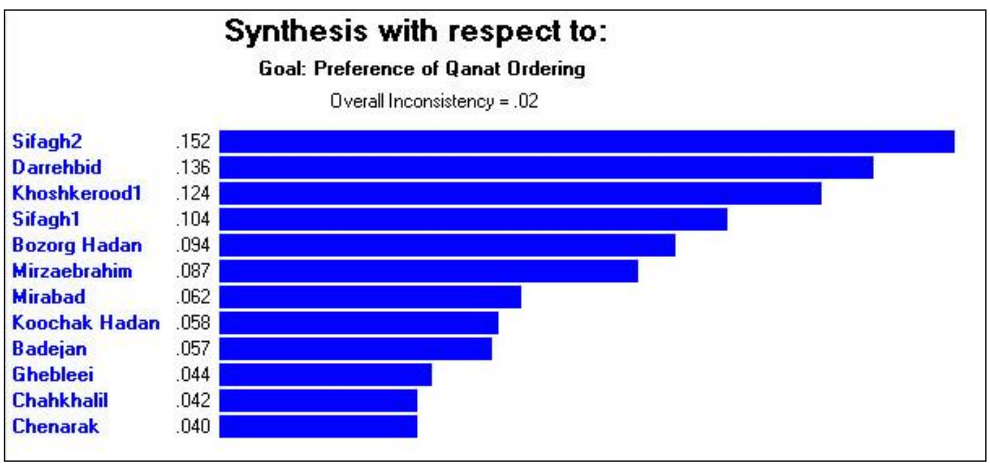

Fig. 2. Software output after prioritizing of qanats reorganization

Table 4. Ranking of qanats for reconstruction and reorganization

Rank	qanat Name	Village	Rank	qanat Name	Village	Rank	qanat Name	Village
1	Sifagh2	Khoigan olia	5	Bozorg	Hadan	9	Bozorg	Badejan
2	Deh	Darrehbid	6	Mirzaebrahim	Arjanak	10	Ghebleei	Arjanak
3	Khosh Kerood1	Sangbaran	7	Bozorg	Mirabad	11	Chahkhalil	Rahmatabad
4	Sifagh1	Khoigan olia	8	Koochak	Hadan	12	Chenarak	Ghodjan

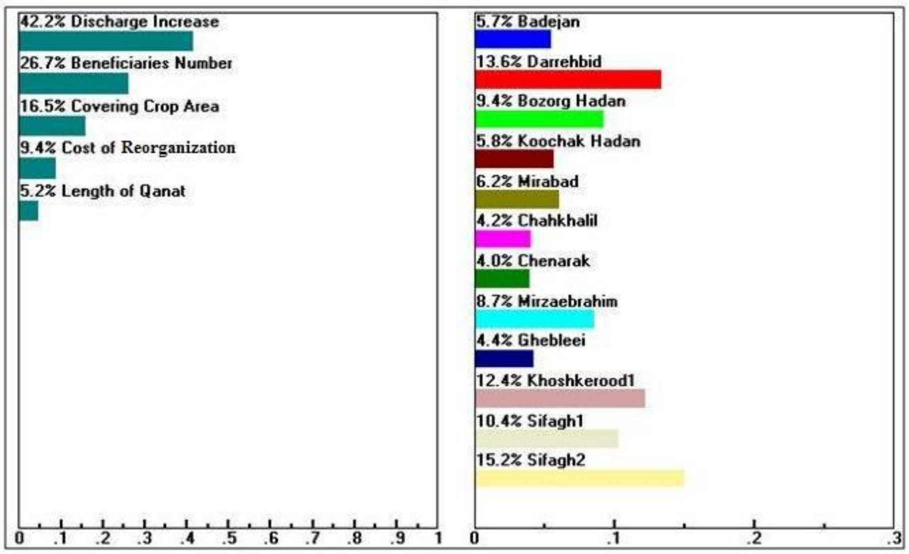

Fig. 3. Graphical illustration of sensitivity analysis in dynamic form

For reconstruction and reorganization of qanats which are important structures for groundwater using, there are some problems and obstacles such as fund limitations and reorganization costs. In this study, AHP is applied to assess the priority of qanats reorganization by consider to fund allocations to those projects that have more socio-economical efficiency. As Montazer and Behbahani (2007) presented a model to select optimum irrigation system due to affective physical, political, economical and environmental factors of irrigation efficiency. In this study one of priorities was economical and environmental factors. Ghodosi Shahrezaee (2001) evaluate efficiency and criteria coefficients in management of eight irrigation networks. So, for this study after determining of 5 criteria, they weighed by consider to reorganization and reconstruction of qanats, rising of welfare level of deprive regions and avoiding of villager immigration to cities. Software output indicat that, rate of discharge increase after reconstruction (with a weight of 42.2%), number of beneficiaries, covering crop area, reorganization costs, and qanat length (with a weight of 5.2%) were the most important criteria, respectively.

First, determination of location and natural structure of study area is necessary. Otherwise every improper action has a reaction and compensation is impossible or very costly (Salim and Fallahi, 2009). Therefore, by checking and approving of model results, Sifagh2 and Chenarak with 15.2% and 4% weights, respectively are the first and last qanats must try to reconstruct and organize them. In other hand, Sifagh 2, Deh Darrehbid and Mirzaebrahim qanats in Fereidonshahr, Fereidan and Khansar Cities selected as the best qanats in any city for reorganization. It is cleared that AHP nature and ability of quantification of affective parameters on objective functions is a suitable method for evaluation, ranking and prioritization. Obviously, if decision-makers want to evaluate another criteria, this method can still be useful as a good tool.

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