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ORIGINAL ARTICLE

Mahshahr special economic zone emergency water supply program Using Analytic Hierarchy Process

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ABSTRACT

Fresh water is a natural, scarce, critical, and yet renewable resource which human being constantly needs it. Today many countries in the world face water crisis in various reasons such as population growth, industrial development, climate change and limited available water resources. Water crisis is one of the basic issues in arid and semi-arid areas such as Iran. Considerable part of the Iran's areas face water resources limitation and water resources protection is critical qualitatively and quantitatively for prevention from environmental crisis. Growing demands and needs in the community for access to water resources with suitable quality, increased costs of water supply and necessity for controlling water resources pollution create serious challenges for water resources management in various aspects. Thus, providing necessary programs for achieving sustainable development and preserving environment and quality of national water resources are necessities which should be considered. Minimizing water consumption, keeping water in the cycle through recycling and reuse and using alternative waters which are known as unconventional water resources instead of fresh water resources are solutions which are considered today by the managers. Unconventional water resources as alternative resources for supplying water need in Mahshahr special economic zone is investigated in this work. Considering importance of industries located in this region and necessity for supplying water, access to alternative resources which can guarantee qualitative and quantitative sustainability of water supply in normal and emergency conditions is always a management concern in the region. Current work aims at feasibility finding for using unconventional water resources as emergency alternative water supply resources for Karun river water. Results show this resource can be used as water quality modifier for Karun water in addition to supplying part of the water needed in emergency.

Keywords: *water supply, Mahshahr Special Economic Zone, analytic hierarchy process (AHP)*

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INTRODUCTION

Mahshahr Special Economic Zone located in one of the important and strategic ports of country is situated in Khuzestan province with 2,713 hectares area. It is the widest city of Khuzestan after Ahvaz.
This city is located in 18 km distance to Imam Khomeini port and 95 km to Abadan and 100 km to Ahvaz. Mahshahr Special Economic Zone includes several petrochemical plants, and it makes Mahshahr as a major petrochemical base in Iran. Figures 1 and 2 show aerial images of Mahshahr Special Economic Zone [1].

Fig 1. Situation of Musa bay and Mahshahr Special Economic Zone toward Persian Gulf [2]

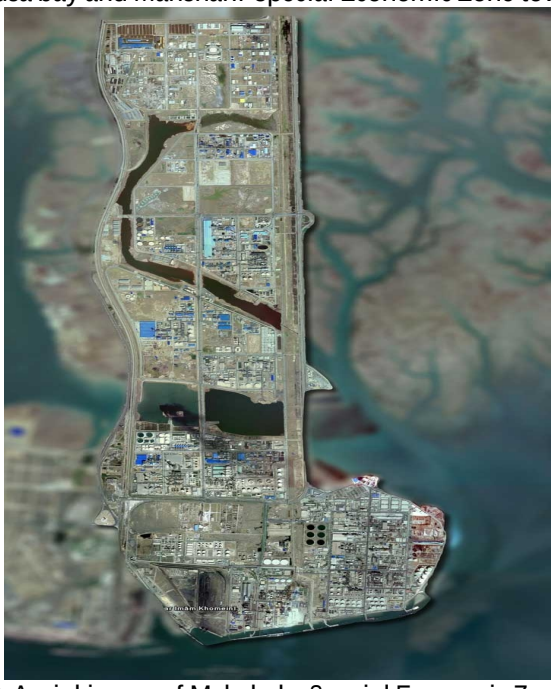

Fig 2. Aerial image of Mahshahr Special Economic Zone [3]

The water of complex in Mahshahr Special Economic Zone is currently supplied through Karun River and the Koot Amir Water Treatment Plant with over 100 km transmission lines and canals. Fig. 3 shows current status of water supply in special petrochemical economic zone. Current conditions of water supply with 400000 m^3 daily suffice in terms of volume for current consumption. However, high length of transmission line and probability for any accident on the route and potential drought which may affect Karun River water have created such conditions that enough water is not provided for the program and non-compensable damage will be incurred [3].

In order to determine economically and technically acceptable resources so that necessary water is provided at shortest time in case of water interruption or water supply reduction, it is totally justified economically [4].

Fig 3. Current status of water supply in Mahshahr Special Economic Zone [3]

Harvesting non-conventional water sources including sea water, bays of the region, wastewater effluent from the agricultural and wastewaters has no limitations for industrial use technically and if there is proper treatment according to the standards, respective usages is justifiable versus long paths of transmission.

In this research work, potential finding for surface waters and unconventional water resources for supplying water needed in petrochemical industries in Mahshahr special economic zone with passive defense perspective and production security regarding the design of existing water supply from Koot Amir Treatment Plant has been studied.

MATERIALS AND METHODS

Investigated Water Resources

According to studies, the main resources which can be planned for supplying water needed in special zone are as follows:

Karun River

Following primary treatment in Ahvaz's Koot Amir Treatment Plant, Karun water is transferred to Mahshahr through transmission lines. Quality of water during transmission route may be altered unintentionally due to high retention time and the possibility of direct entrance of pollutants or leakage, and given high length it may be subject to threats. Water of this river is classified as Chloride and sulfate waters which is found often at the bottom of river basin [3]. With construction of Gotvand Dam, Karun water gradually faced quality reduction and salinity due to technical problems and dissolution of salts found in natural walls of the dam reservoir.

Jarahi and Zohre Rivers

After Karun River, Zohre and Jarahi rivers are the other important rivers in vicinity to Mahshahr town. Harvest and pre-treatment measures are needed prior to using water of both rivers, which should be done in the location of harvest and with conventional distance to the river. Chemical quality of both rivers is currently lower than Karun River [3] and appropriated optimization and pre-treatment is needed for supplying treatment plant facilities in industrial units located in special zone.

Municipal Sewage Wastewaters

In Mahshahr, Imam Khomeini Port, Abadan, Khoramshahr and Shadegan treatment plants for municipal sewage will be constructed up to 2036, while input capacity of these treatment plants up to 2036 shows their output wastewater may reach to over 200,000 m^3 daily considering interest rate of 80%. It should be noted in addition to sanitary wastewater of the cities around Mahshahr, output wastewater of the treatment plant located in Site 1, sanitary wastewater of labor housing camps 2 and 3 located in Site 3 and wastewater of Mahshahr Special Economic Zone can also be used for supplying part of alternative water as well as saving in water consumption in the located complexes [3].

Industrial Sewage Wastewater

Industrial sewage wastewater under study include wastewater effluent from petrochemical complexes such as Razi, Farabi, Imam Khomeini port and other complexes located in the zone. Wastewater effluent from Desalination Reverse Osmosis Systems located in Fajr Petrochemical complex 1 and 2 can be considered also as industrial wastewaters which have lower TDS than wastewaters effluent from these communities. These R.O effluents are discharged to the bays in the region like other wastewaters. Thus, living of organisms such as fish, etc., and even the people living in the area is at risk due to the consumption of food contaminated by emissions from industries [3].

Main Branch of Musa Bay

Mahshahr is one of the cities with bay (branches from the sea leading to land) known as Musa Bay which is very important economically and strategically [1]. Musa Bay is located in South Mahshahr and has many branches.

Due to presence of various industries, Musa Bay has become one of the main economic assets in Northwest coast of Persian Gulf. Musa Bay is a half-closed ecosystem with limited connection to Persian Gulf with low capacity for its treatment and high solid material. High volume of swage discharge in the bay is the main factor for its high pollution. Tide is the main cause of pollution dispersion [5]. Iran Department of Environment reported Musa Bay is regarded as the sensitive offshore area in Iran and Gulf area (due to its unique ecosystem). Hence, Musa Bay is important for the whole Northwest coast of Persian Gulf [6].

Sub-branches of Musa Bay

Several bays are ramified from Musa Bay including Zangy, Jafari, Ghanam and Merimus bays. Since establishment of special zone, some parts of the Musa Bay (especially Zangy and Jafari bays) were surrounded by the roads and buildings or they have been divided [5]. Zangy and Jafari bays have flow regulation valves at the beginning and end of their area in special zone to control water volume in bays in tides. In terms of dimensions, Zangy Bay has wider width compared to Jafari Bay and the north - south connecting road stationed in special zone divides Musa Bay into two parts, East and West.

Factors Affecting Water Supply Resource Selection

In this research study, considering different water resources conditions and management policies of Mahshahr Special Economic Zone, and for prioritizing use of alternative water resources for supplying water in Mahshahr Special Economic Zone, it was decided to prioritize different alternative water resources in special zone by conducting an accurate poll including all influencing factors. Thus, using primary concepts and value engineering assumptions and the poll, alternative water resources were

prioritized and finally appropriate water resource was selected for supplying water needed in Mahshahr Special Economic Zone considering conditions and current technical, economic and social criteria. To this end, the activities which are considered as more effective in the view of experts and engineers in water and sewage field in Mahshahr Special Economic Zone, Shahid Beheshti University, Shahid Abbaspour Technical and Engineering Campus, and some consulting companies in water and sewage field are selected and results of which will be investigated [4].

In this regard, paying attention to 'spent money value' is important [7]. That is, the best alternative water resource for supplying water in Mahshahr Special Economic Zone necessarily is not the resource which minimizes costs of employer, rather the water supply resource is more suitable and better which maximizes spent cost value for supplying region's water.

Decision Making Process Implementation

Three key elements are needed for every selection including: goal, criteria, and options. These three elements are true also in evaluation and prioritizing use of alternative resources for supplying water in Mahshahr Special Economic Zone. To this end, the goal includes "prioritizing use of alternative resources for water supply"; criteria are the factors influencing prioritizing use of alternative resources (including harvesting sea water and using different wastewaters) for water supply, which will be discussed in the next section. Options include various potential water resources which were introduced previously.

Factors Affecting prioritizing Use of alternative resources for water supply and their importance

In order to identify factors affecting prioritizing use of alternative resources for water supply, relatively comprehensive studies including scientific documents in this field and poll of internal exports was done and ideas of a group of experts in water industry were collected using the questionnaire designed based on AHP methodology.

The major criteria in decision making on priority of the resources include: 1. Production safety, 2. Production unit cost, 3. Environmental value, 4. Water supply capacity.

Following determining 4 major and effective classes of factors in prioritizing use of alternative resources for water supply, the next step is constructing a decision making support system including determination of importance of the factors in decision making process. Here, since importance of these factors and sub-factors is not in binary state (0 & 1) and each factor has importance between 0 to 100 depending the type and characteristics of each project, thus their "relative importance" or "relative preferences" are criterion for decision making.

In this research, in order to determine relative importance, Delphi method (expert ideas) was used using the questionnaires which were designed based on pair-wide comparisons technique. To this end, the number of needed questionnaires was specified based on the statistical population composed of water industry experts and using "sample size determination with qualitative data in limited population" relation. Finally, 15 questionnaires were completed by the experts. In these questionnaires, the experts were asked to score relative importance or preference of each factor/criterion over the other factor/criterion (considering purpose of problem) and relative importance or preference of each water supply resource over the other resources(considering each influential criterion/factor) based on Table 1.

It should be noted that in order to preserve model reliability, cases such as minimum 10 years of working experience in fields related to water and sewage companies, familiarity with water supply and transmission lines and having education related to water industry were considered as the minimum inclusion criteria for the experts.

Results taken from completed questionnaires were analyzed for assessment and prioritization of alternative water resourcesfor supplying water in Mahshahr Special Economic Zone using *analytic hierarchy process* (*AHP).*

Table 1. Numerical scales of pair-wise comparisons [8]

Preference	Numerical Value
Extremely Preferred	9
Very Strongly	7
Strongly Preferred	5
Moderately Preferred	3
Equally Preferred	1
--	2,4,6,8

Analytic Hierarchy Process (AHP)

Basis of AHP is pair-wise comparisons. This technique was developed in 80s by*Thomas* L. Saaty and it has been used for solving multi-criteria decision making problems. As mentioned, AHP uses pair-wise comparison technique for selection. That is, in order to make decision nod select one option our of several available options, it divides them in two-member groups based on given criteria and obtains preference of one over the other criterion. Following weighting criteria, the options which have the highest score are

selected. This technique is based on four principles including: reciprocal Condition, *Homogeneity*, *Dependency*,and Expectation [8].

AHP Steps

Generally, following steps are taken in decision making program using AHP:

- Specifying relationship between elements and forming hierarchical structure,
- Calculating weight of options in relation with the goal and weight of options in relation with criteria (relative weight)
- Calculating final weight of options in relation with goal using multiplying changing of weights from option to goal
- Ranking criteria and options in relation with goal.

It should be noted for calculating relative weights, firstly the elements are compared in pair-wise manner and pair-wise comparison matrix is developed for elements of each level. Then, relative weight is calculated using this matrix. Generally, a pair-wise matrix is shown as Equation 1, where aij denotes i^{th} preference versus j^{th} element. With specifying aijs, weight of Wi elements is determined.

A=[aij] I,j=1,2,3,...,n Eq. 1

Inconsistency rate of pairwise comparison matrix is important here. Each pair wise comparison matrix may be consistent or inconsistent. If it is consistent, calculating weight of Wis is easy and it is obtained from normalization of elements in each column, while if the matrix is inconsistent, calculation of the weights is not simple and four main methods are used for obtaining the weights, including: least square, logarithmic least square, eigenvector, and approximate methods. It should be noted maximum acceptable inconsistency rate according to Saaty is 0.1. Pair wise comparison of options and determining the preferences should be done by the decision maker who is aware of the options and criteria [8].

Model Structure in AHP

Problem structure in AHP is called hierarchical. Hierarchy is a graphical representation of a real complex problem. The problem's goal is at the top and criteria, sub-criteria and options are in the lowerlevels, thus, a hierarchical model includes at least three levels (goal, criteria, and options). Fig 4 shows a schematic of hierarchical structure related to evaluation and prioritization of using alternative resources for supplying water in Mahshahr Special Economic Zone**.**

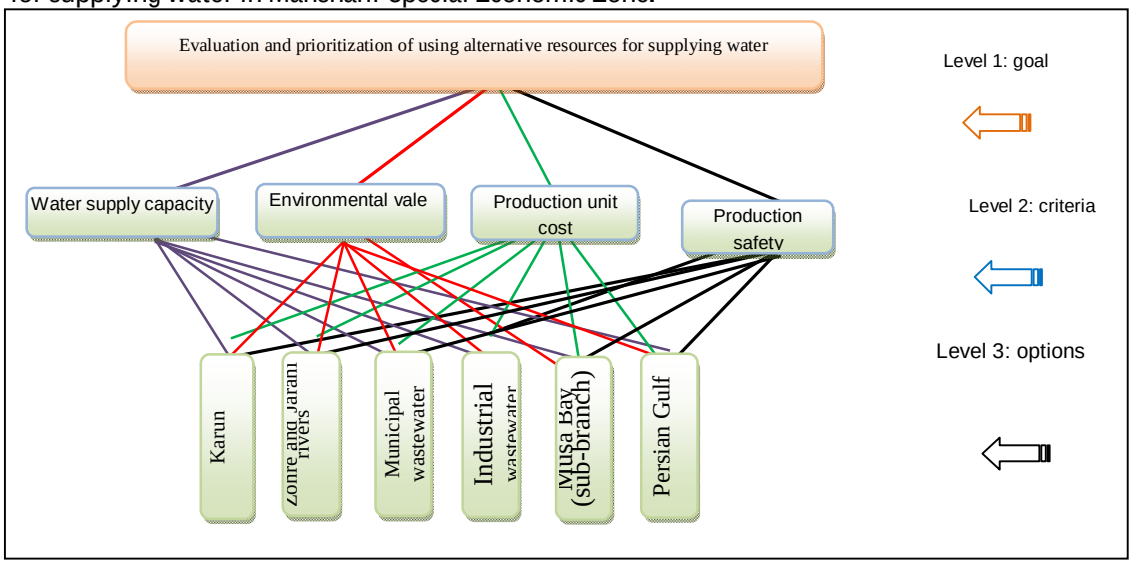

Fig 4. Hierarchical structure for prioritizing use of alternative resources for supplying water in Mahshahr Special Economic Zone

Analysis of AHP by EC Software

After collecting questionnaires and eliminating ultimate points (statistically unacceptable answers), results were concluded and given to EC software as primary input.

As mentioned, this software allows analysis in AHP method. Output results and analysis in this software are given in the following.

Analysis of Questionnaires

As mentioned, analysis of questionnaires was done using Expert Choice (EC) software. Output results of this software can be observed in Table and Fig 3. In this diagram, the main indexes influencing selection of alternative water resource for supplying water in Mahshahr Special Economic Zone is shown. These results are outcome of expert ideas and specify importance of four indexes. Final result for selection of

the best index suggests that in the view of respondents, production safety has the highest relative importance for alternative water resource. In addition, one of the most effective methods for prioritizing decision making indexes is using sensitivity analysis method. It will be discussed in the following.

Table 2. Main indexes influencing prioritizing water alternative resource for supplying water in Mahshahr Special Economic Zone

Description	Preference	No.
Production safety	0.429	1
Production unit cost	0.082	2
Environmental value	0.312	3
Water supply capacity	0.178	4

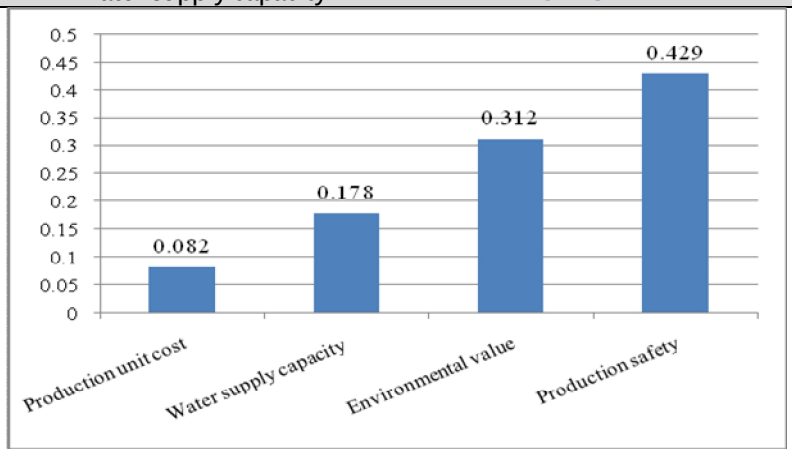

Fig 3. Main indexes influencing prioritizing water alternative resource for supplying water in Mahshahr Special Economic Zone

The reason for interest of respondents to water production safety is sensitivity of the region under study. Also, paying attention to preventing from wasting national capitals and lack of problem in water supply and distribution in the region has caused this index taking the highest priority.

The other important point in above results is selection of "environmental value" as the second main index in the view of respondents. It shows important of serious and rapid attention to issues and problems related to environment. Production unit cost has lower importance compared to other decision making indexes. In other words, it is preferred to have more effective actions in water supply area despite of high cost of the actions.

Analysis of Questionnaires

Six resources which were prioritized based on 4 indexes by the respondents finally lead to Table 7. As observed, main branch of Musa Bay (Persian Gulf) has the highest importance as the alternative resource for water supply in Mahshahr Special Economic Zone and using industrial wastewater is in the next place of importance. Also, Fig 8 shows prioritization of various alternative resourcesfor water supply in the region under study.

Table 7. Prioritization of alternative water resource for water supply in Mahshahr Special Economic Zone in the view of respondents

Factors (criteria)	Preference	No
Musa Bay (Persian Gulf)	0.281	1
Industrial wastewater	0.215	2
Water harvesting from Karun	0.163	3
Sub-branch of Musa Bay	0.140	4
Municipal wastewater	0.139	5
Venus rivers and Surgery	0.062	6

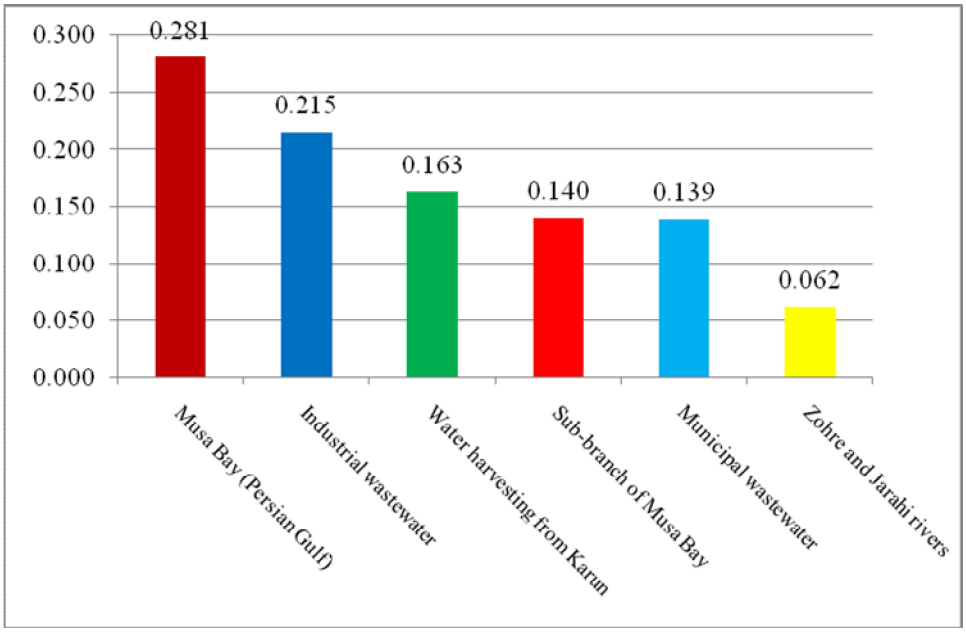

Fig 8. Comparing scores of water alternative resources for water supply in Mahshahr Special Economic Zone in the view of respondents

Inferences

Inference allows a kind of analysis in which importance of effective factors is changed versus its initial value and reaches to the highest level. In other words, one factor becomes the single decision making factor for selecting alternative water resource. For example, changing importance of "production safety" factor up to 100% means that only this factor is considered doe decision making. In this case, as shown in Table 8, "main branch of Musa Bay" would be the best water supply resource. It may be said it is because this water resource enjoys high safety and water supply capacity and it reduces risk of using this water resource. On the other hand, due to importance of water supply form Mahshahr Special Economic Zone, high costs of water supply from this water resource was less considered by the respondents.

If each of factors of production unit cost, environmental value, and water supply capacity are used as the singly decision making factor, using main branch of Musa Bay (Persian Gulf) as the first option for water supply would be considered. Using treated wastewater of industrial wastewater would be the next option.

Table 8. Relative weight of water supply alternative resources if factors are considered separately

Factors affecting decision making	Change in importance of factors	Relative weight percent of water supply alternative resources if factors are considered separately					
		Water harvesting from Karun	Zohre and Jarahi rivers	Municipal wastewater	Industrial wastewater	Sub-branches of Musa Bay	MAIN BRANCH OF MUSA BAY
Production safety	Increasing this factor to 100% and others to 0%	14.5	4.3	9	15.7	18.3	38.2
Production unit cost	Increasing this factor to 100% and others to 0%	29.3	7	16.3	20.8	12.4	14.3
Environmental value	Increasing this factor to 100% and others to 0%	11.9	8.4	23.8	37.3	7.9	10.8
Water supply capacity	Increasing this factor to 100% and others to 0%	22	6.1	5.2	4.8	15.8	46.1

Sensitivity Analysis

EC software provides sensitivity analysis by 5 different graphs known as performance analysis, dynamic analysis, portable analysis, 2D analysis and breakeven analysis. In order to sensitivity analysis by this software, it is possible to observe change in the selected option by changing importance of factors within

interval 0% to 100%. Increase in relative importance of each factor up to 100% (which will be accompanied by zero relative importance in other factors) is the same deductive property which was analyzed in the previous section. In this section, change (reduction) in relative importance of each factor up to 0% (meaning lack of involvement of the factor in decision making process) is investigated. It is clear in real conditions; respective selection is done by setting importance of factors at respective level.

As observed in Table 9, elimination of each of factors of "production safety", "production unit cost", "environmental value" and "water supply capacity" causes selection of the main branch of Musa Bay (Persian Gulf) as the best water alternative resource. Also, using industrial wastewater is in the next place.

Table 9.Relative weight of water supply alternative resources in case not considering each of factors

Factors affecting decision making	Change in importance of factors	Relative weight percent of water supply alternative resources if only one factor is considered					
		Water harvesting from Karun	Zohre and Jarahi rivers	Municipal wastewater	Industrial wastewater	Sub-branches of Musa Bay	MAIN BRANCH OF MUSA BAY
Production safety	Reduction of this factor to 0% and increasing others	17.7	7.5	17.6	25.9	10.8	20.5
Production unit cost	Reduction of this factor to 0% and increasing others	15.2	6.1	13.7	21.6	14.1	29.3
Environmental value	Reduction of this factor to 0% and increasing others	18.3	5.2	9.5	14.4	16.7	35.9
Water supply capacity	Reduction of this factor to 0% and increasing others	15.1	6.2	15.8	25.1	13.6	24.2

CONCLUSION

As mentioned, using each of potential water resources for water supply in Mahshahr Special Economic Zone has its own advantages and disadvantages, thus, the employer should seek for water resource which provides highest value for the spent cost in selection of suitable water alternative resource. Realization of this issue requires identification of water supply resources and their characteristics by the employer and then specific conditions of the project and existing capabilities should be specified.

To this end, some factors affecting decision making were identified in this projects and their relative importance was determined using expert ideas. An analytic approach based on AHP methodology was used for selecting the best alternative water supply resource. It was found using the main branch of Musa Bay and using industrial wastewater are in first and second places. Also, using sensitivity analysis, importance of factors in decision making process and change in the selected resources based on importance change in each of decision making factors was investigated. Importanceof each of factors could change within interval 0% to 100% (the factor without influence to the singly effective factor) and both limit states were investigated in this work.

In the condition of involvement of only one factor as the influential decision making factor, main branch of Musa Bay was selected as the best alternative water supply resource and using industrial wastewater was in the second place.

In the condition of eliminating factors influencing decision making, main branch of Musa Bay was selected as the best alternative water supply resource and using industrial wastewater was in the second place.

As mentioned, it can be due to importance of water supply in Mahshahr Special Economic Zone for decision makers. In addition, it is also because of risk reduction after selection of this water resource as the alternative for water supply in the region.

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