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Assessing the water sector in Kuwait using SWOT analysis and the analytic network process

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ABSTRACT

Natural water resources in Kuwait are very limited and do not meet the ever-increasing demand. This has compelled the government to construct desalination plants to compensate for the shortage of freshwater. However, desalination plants are not only capital-intensive but also consume a huge amount of energy in the form of fossil fuel, and hence inflict immense pressures on the country's economy. This paper examines different challenges facing the water sector in Kuwait in an attempt to recommend corrective actions for encountering and minimizing their adverse effects. Hence, a model is proposed, and the most important internal and external factors have been identified by implementing strategic factors such as strengths, weaknesses, opportunities and threats provided by the SWOT matrix. While the SWOT analysis is a powerful tool in exploring factors, it possesses deficiencies in the measurement and evaluation. Therefore, the analytic network process (ANP) is utilized to augment the SWOT analysis. Unlike other decision-making methods, ANP allows for measurement of dependency among factors and examines whether the dependency changes the priorities of strategies.

Keywords: Strategies; Decision-making; Internal factors; External factors

1. Background

Scarcity of water is a problem, to some degree, in every continent. While certain countries have abundance of natural water resources, others have paucity in such resource. Water scarcity leaves some countries with no choice but to look for alternatives to meet the increasing demand. Rich and affluent countries in water-stressed regions have resorted to desalination plants to compensate water shortages. Desalination technologies utilize not only seawater but also brackish water to produce clean and potable water.

Kuwait is a small country bordering the Arabian Gulf in the Middle East with a population of around 3.8 million and covers an area of 17,800 km^2. Kuwait is a rich, oil-producing country with a gross domestic product (GDP) per capita of $56,367. Water is Kuwait's most limited and strategically vital resource. Kuwait has no significant natural resources of freshwater, except a very limited and essentially nonrenewable resource of brackish groundwater, which is presently used for blending with the distillate and watering gardens in residential areas. Therefore, Kuwait relies heavily on seawater desalination to provide freshwater to all the sectors of the country. The increase in freshwater demand is fueled by the normal growth of population, continuous strive to better standards of living, and the need to sustain socioeconomic development. Freshwater is lavishly used in Kuwait for both potable and nonpotable purposes. The rate of freshwater consumption in Kuwait is one of the highest in the world (currently, over 600 L per capita per day), and it is escalating at a staggering rate of about 7.9% annually, leading to the production of large quantities of wastewater. As per the available statistical records, the amount of wastewater presently generated in Kuwait exceeds 200 million imperial gallons per day (MIGD). Definitely, desalination of seawater and wastewater treatments offer reliable access to freshwater resources for Kuwait and also present the means to remedy environmental impacts on the existing brackish water aquifers through artificial recharge.

The total annual water consumption in Kuwait has increased over the past 20 years from 70,560 to 161,019 MIGD between 1993 and 2012. This amounts to an increase of 230% over the span of 20 years, i.e., compounded annual growth rate (CAGR) of 4.5%. This rise corresponds to the population growth from 1,537,714 in 1993 to 3,823,728 in 2012, i.e., 240% increase during the same time span at an average annual rate of 12.4%. The per capita consumption has almost leveled between 125.7 and 115.4 MIGD (571 and 525 L/d) during the same period, but it did actually peak to all times high of around 145 MIGD (659 L/d) during the period from 1997 to 2003. Such per capita levels of water consumption are considered excessively high, especially where there are limited agricultural and industrial activities. Moreover, the water production pattern has changed significantly during that period. In 1993, the share between brackish and desalinated water resources was 29.5% and 70.5%, respectively. The ratio in 2012 became 13.1% from brackish water and 86.9% from desalinated water. This substantial shift underscores the decline in the natural brackish water resources and the increased dependence on the man-made resource for water from the sea by desalination [1].

2. Introduction

Kuwait's water-related issues and problems have been addressed in the literature by many scholars. Darwish and Al Awadhi [2] called for exploring other means for meeting the freshwater demand in Kuwait to replace the existing multi-stage flash (MSF) desalting technology, which is highly capital-intensive and very costly. The paper advised to replace MSF by more energy-efficient and less-costly alternative systems such as reverse osmosis desalination technology and treated wastewater systems. Meanwhile, Al-Otaibi and Abdel-Jawad [3] recommended storing water in groundwater aquifers in order to encounter the everlasting freshwater demand in Kuwait. The study proposed a strategy for storing water by means of artificial recharge technology.

Meanwhile, Al-Ruwaih and. Almedeij [4] investigated the availability of groundwater in Kuwait with the objective of developing an integrated management system for the country. The study recommended exploring other water supply alternatives such as recycling of wastewater to compensate for the limitation of water resources and the increase of population. Likewise, Al-Khalifa and Abdul-Wahab [5] endorsed developing a water management plan and establishing a unified water authority in Kuwait. On the other hand, Al-Shammari et al. [6] assess the municipal wastewater treatment plants in Kuwait. Data analysis confirmed the high reliability of the plants and the excellent quality of water produced. Alhumoud et al. [7] conducted cost-benefit analysis on the wastewater reuse in Kuwait. The paper reported Kuwait national's willingness to use wastewater effluent for different purposes. Similarly, Abusam [8] recommended using greywater wastewater in Kuwait to compensate for the high depleting rates of brackish water resources and the increasing costs of seawater desalination. Greywater comes from showers, baths, clothes-washing machines, dishwashing machines and kitchen sinks, which is not as contaminated as toilet wastes. It is claimed that greywater could be used in the agriculture sector since it consumes 60% of the total available freshwater.

Lightbridge Corporation [9] conducted an economic feasibility for using renewable energy in power generation and water desalination in Kuwait. The study was carried out using a bottom-up power and water model, which was developed by the international atomic energy agency, while the data were provided by the Ministry of Electricity and Water in Kuwait and the Kuwait Petroleum Company. Meanwhile, Darwish et al. [10] examined the possibility of using less-costly technology such as nuclear technology in power production and water desalination in Kuwait. The study asserted that such an option is viable in light of high cost of fossil fuel and its adverse effect on the environment. While in another paper [11], Darwish explored the prospects of utilizing renewable energy such as wind and specifically solar energy in power production and water utilization. In fact, solar energy is abundantly available throughout the year in Kuwait. The study addressed the economic feasibility of using these options as a supplement to the existing systems. The paper compared these options with the business as usual of using fossil fuel. Analysis indicated that in light of high solar power cost, it is advised to consider wind energy (WE) or solar cells photovoltaic solar cells (PV) power plant (PP) as fuel savers, and their output should be taken by the grid. This decreases the load on the conventional PP and thus reduces their fuel consumptions.

The remainder of the paper is organized as follows: the methodology is in section 3. In section 4, the problem description is presented followed by analysis and results in section 5. Results are discussed in section 6, and the last section is allocated for final remarks and recommendations.

3. Methodology

The main objective of this research is to develop strategies for addressing the challenges facing the water sector in Kuwait. This study starts by characterizing the various features of the sector and using SWOT analysis to identify the internal factors and the external environment including the strength, weakness, opportunities and threats. Subsequently, experts were consulted to assist in the strategies selection process. Afterward, the appropriate decision tools were selected to analyze the planning process. For the purpose of decision-making, the analytic network process (ANP) is utilized. ANP is a powerful decision-making technique, and unlike other methods, it can handle problems with complex interrelationships (feedback) among decision levels and attributes.

In this paper, pairwise comparisons are conducted at all levels of the hierarchy to prioritize the selected strategies. The analyses are complex and rigorous, begin with the SWOT main factors and end with comparing strategies.

3.1. SWOT analysis

Organizations nowadays utilize strategic planning methods to properly design future activities to confront the rapid challenges and retain an edge over competitors. Strategic planning is a comprehensive method used to allocate various resources for the long-term goals of an organization. Different methods are utilized for designing a solid and robust strategic plan. SWOT (strengths, weaknesses, opportunities and threats) is an important support tool for decision-making and is used to analyze an organization's internal and external environments analysis, and for evaluating the strategic position of an organization. The concept of SWOT analysis was introduced into the literature in the 1960s followed by the work of the Business Policy School at Harvard Business School and American Business Schools [12]. SWOT analysis helps in characterizing the strengths, weaknesses, opportunities and threats of an organization [13]. Specifically, SWOT analysis is the process of identifying the factors that play a major part in an organization's success and pinpointing their role in strategic decisions [14]. The first step toward the diagnostic of a system is the collection and systematization of existing information and the characterization of different systems.

According to SWOT analysis, the core of any strategy is to develop the resources of the organization and enhance its capabilities to capture the external environmental opportunities. In other words, SWOT analysis is not an analytical tool for determining the relative importance of each of these factors and to prioritizing the options for the strategy. SWOT matrix must have the ability to rank the different factors in relation to a decision, hence providing opportunity for decision makers to analyze the importance of strategic factors in comparison with each other [15]. Therefore, one has to use analytical tools capable of comparing the various factors within SWOT and prioritizing them in order to determine the best strategy.

SWOT analysis has been utilized in addressing several water-related issues. For example, de Souza and da Silva [16] proposed a management scheme to efficiently use water resources in water supply systems in Brazil. Meanwhile, Belay et al. [17] focused on using SWOT analysis in identifying the challenges faced on the Nile Basin Initiative (NBI) in terms of integrated use of the river. In this study, results revealed that the river had faced complex environmental, social, economic and political problems for decades. Recommendation called for developing a proper management and sustainability plan for Nile water. Meanwhile, Mainali et al. [18] applied SWOT analysis in assessing the feasibility of using recycled water in washing machine applications in Australia. On the other hand, Bakopoulou et al. [19] evaluated the prospects of utilizing reclaimed municipal wastewater for irrigation purposes in a Greek region. Hence, a multi-criteria decision-making methodology was used in formulating the model.

SWOT analysis is not an analytical tool that determines the relative importance of the different factors, and hence, it cannot enable an organization to make effective strategic decisions. Therefore, ANP is used to indemnify for the lack of analytical capability of SWOT analysis.

3.2. Analytic network process

Several analytical techniques, such as the analytic hierarchy process (AHP), have been used in SWOT analysis. Although the AHP can resolve some of the issues in the measurement process, nonetheless, it is incapable of tackling problems where dependency exists among the different factors [20]. AHP can only handle problems when factors are independent in the hierarchical structure. However, in many real life problems and systems, dependency exists among SWOT factors. ANP is a developed form of AHP, it can model and analyze feedbacks (interdependencies) among the different element of a decision-making process. [20]. The ANP is a general theory in the ratio scale that measures influence based on methodology that deals with dependence and feedback [21]. The ANP has been applied in many fields; examples are: total quality management [22], information technology [23], strategic alliance partner selection [24], selection of technology acquisition [25] and foreign investment [26] among others.

This paper presents a complete analysis of the water sector in Kuwait in an attempt to recommend strategies to improve the efficiency of the sector and reduce its financial burden on the economy.

3.3. Analytic network process and SWOT analysis

The structural differences between ANP and AHP are illustrated in Fig. 1. In this figure, clusters represent decision levels, and straight lines symbolize the interactions among these levels. The direction of arcs indicates the dependencies, while loops signify the interdependency among elements in each cluster.

The priorities obtained from pairwise comparison matrices are presented as parts of the columns of a super-matrix. A super-matrix exemplifies the influence priority of an element on the left of the matrix on an element at the top of the matrix with respect to a particular control criterion. The super-matrix (W) of the SWOT analysis with four levels is defined as follows:

$$W = \begin{matrix} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub-factors} \\ \text{Alternatives} \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ w_{21} & 0 & 0 & 0 \\ 0 & w_{32} & 0 & 0 \\ 0 & 0 & w_{43} & I \end{bmatrix} \quad (1)$$

where w_{21} is a vector that represents the impact of the goal on the criteria; w_{32} is a matrix that represents the impact of the criteria on each of the sub-criteria; w_{43} is a matrix that represents the impact of the sub-criteria on each of the alternatives and I is the identity matrix. A hierarchical representation of the SWOT model is shown in Fig. 1(a), and its general network representation is presented in Fig. 1(b). The network model illustrates the case of a hierarchy with inner dependence within clusters but no feedback. In this case, the SWOT factors, SWOT sub-factors and strategies are used in place of criteria, sub-criteria and alternatives, respectively, and the SWOT factors have inner dependencies. The main steps of the proposed framework can be summarized as follows: the first step of the study is the identification of the SWOT factors, SWOT sub-factors and alternatives. The importance of the SWOT factor, which corresponds to the first step of the matrix manipulation concept of the ANP, is determined based on the works of Saaty and Takizawa [27]. Next, and according to the inner dependencies among the SWOT factors, the inner dependency matrix, weights of SWOT sub-factors and priority vectors for alternative strategies based on the SWOT sub-factors are determined.

Based on the schematic representation of Fig. 1(b), the general sub-matrix notation for the SWOT model used in this study is as follows:

$$W = \begin{matrix} \text{Goal} \\ \text{SWOT factors} \\ \text{SWOT sub-factors} \\ \text{Alternatives} \end{matrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ w_1 & w_2 & 0 & 0 \\ 0 & w_3 & 0 & 0 \\ 0 & 0 & w_4 & I \end{bmatrix} \quad (2)$$

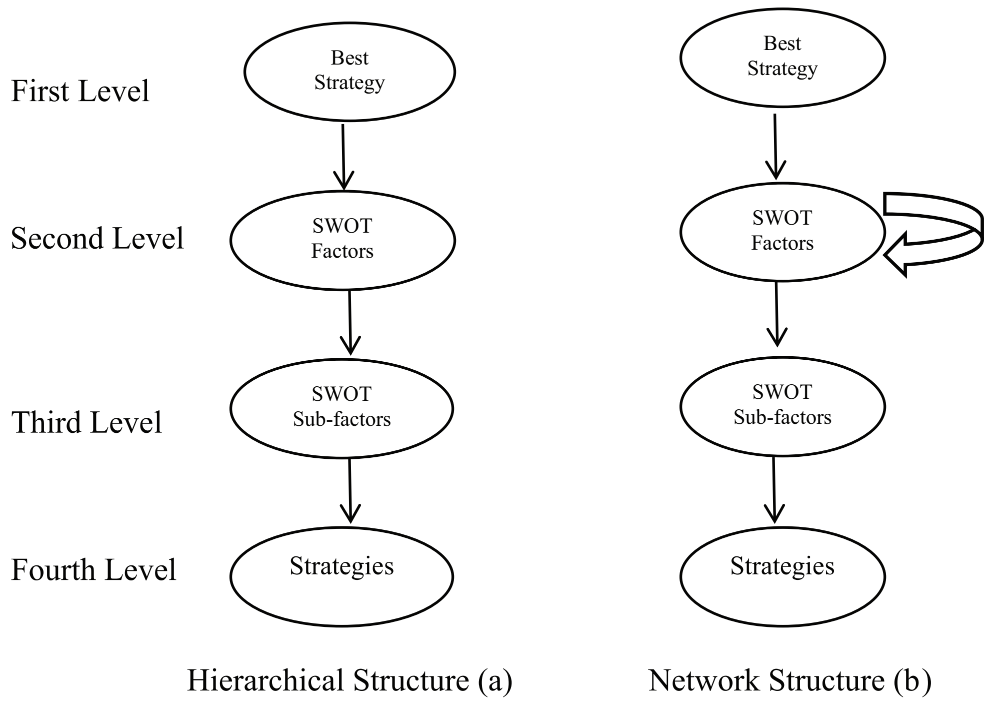

Fig. 1. (a) Linear structure and (b) nonlinear structure or network structure.

where w_1 is a vector that represents the impact of the goal, namely selecting the best strategy according to SWOT factors; w_2 is a matrix that represents the inner dependence of the SWOT factors; w_3 is a matrix that denotes the impact of the SWOT factor on each of the SWOT sub-factors and w_4 is a matrix that denotes the impact of the SWOT sub-factors on each of the alternatives. Using matrix operations is preferred in order to show the details of the calculations in this algorithm. The following proposed algorithm is used in order to apply the ANP to matrix operations for determining the overall priorities of the alternative strategies identified with SWOT analysis:

Step 1: Identify SWOT sub-factors and determine the alternative strategies according to SWOT sub-factors.
Step 2: Assume that there is no dependence among the SWOT factors; determine the importance degrees of the SWOT factors with a 1–9 scale (i.e., calculate w_1).
Step 3: Find, with a 1–9 scale, the inner dependence matrix of each SWOT factor with respect to the other factors by using the schematic representation of inner dependence among the SWOT factors (i.e., calculate w_2).
Step 4: Determine the interdependent priorities of the SWOT factors (i.e., calculate $w_{factors} = w_2 \times w_1$).
Step 5: Determine the local importance degrees of the SWOT sub-factors with a 1–9 scale (i.e., calculate $w_{sub\text{-}factors(local)}$).
Step 6: Determine the global importance degrees of the SWOT sub-factors (i.e., calculate $w_{sub\text{-}factors(global)} = w_{factors} \times w_{sub\text{-}factors(local)}$).
Step 7: Determine the importance degrees of the alternative strategies with respect to each SWOT sub-factor with a 1–9 scale (i.e., calculate w_4).
Step 8: Find the overall priorities of the alternative strategies, reflecting the interrelationships within the SWOT factors (i.e., calculate $w_{alternatives} = w_4 \times w_{sub\text{-}factors(global)}$).

4. Problem description

In applying SWOT analysis to assess the water sector in Kuwait and propose strategies for enhancing its performance, both the internal and external factors are systematically scrutinized. The internal factors are strength and weakness, and the external factors are opportunities and threats. These factors are specifically defined as follows:

1. Internal factors
   - Strengths: Positive tangible and intangible attributes that are usually under control by the organization.
   - Weakness: Factors that detract the organization from achieving its goal. These are under control and should be improved.
2. External factors
   - Opportunities: Factors that propel the organization and represent a reason to develop in order to survive and compete.
   - Threats: Risky factors that might hinder the organization to achieve its intended mission. The organization should benefit from them and develop contingency actions to minimize their adverse effects.

The main internal and external factors pertinent to the Kuwaiti water sector are identified by seeking advices from experts, specialists, and stakeholders with vast experience in the Kuwaiti water sector. The different factors are presented in Table 1.

Table 1
SWOT analysis of the water sector in Kuwait

Strength	Weakness
1. An efficient network and water transmission system. 2. Provides fresh and brackish water services to all sectors. 3. Regardless of the weather conditions, the nonconventional desalination system is securing the water demand for all sectors.	1. Highly subsidized sector. 2. Most of the water sector's infrastructure is outdated and, in some areas, deteriorating. 3. Lack of an organized long-term approach to awareness raising activities. 4. Operation and maintenance costs of water sector infrastructures are high. 5. Limited private sector participation.
Opportunities	**Threats**
1. Investment in new and sustainable technologies utilizing renewable energy sources. 2. Installing advanced water metering systems and water-saving irrigation technologies. 3. Savings by using treated wastewater for agricultural, industrial and other purposes. 4. Privatizing the sector provides investment opportunities.	1. Overemployment in the sector. 2. No properly mentoring systems. 3. The costs of producing abundant water are growing beyond governments' abilities. 4. Increasing demand for the water sector services because of population growth and urbanization.

As discussed previously, robust strategies have to be formulated and implemented in order to enhance any sector. These strategies should emphasize maximizing strength and seizing opportunities, while minimizing weakness and eliminating threats. The strategies are generally defined as follows:

SO: Utilize the sector's internal strength to take advantage of the external opportunities (maxi-maxi strategy).
WO: Overcome the sector's internal weakness by pursuing internal opportunities (mini-maxi strategy).
ST: Identify ways that the sector can use its strength to reduce its vulnerability to external threats (maxi-mini strategy).
WT: Develop defensive tactics aimed at preventing the firm's weakness from being susceptible to external threats venting (mini-mini).

In this study and with the assistance of experts, eight strategies have been proposed as given in Table 2.

5. Analysis and results

Several pairwise comparison matrices are constructed by the help of experts; first and assuming no inner dependence among the factors, pairwise comparison among the various factors is constructed as given in Table 3. It should be mentioned that that the priority is based on a scale from 1 to 9. Factors of the same importance are assigned number 1; the other numbers represents the number of times one factor is more favorable to the other. For example, in Table 3, weakness is three times more favorable than strength, it is the same importance as opportunity, and is two times more favorable than the threats.

In the ANP approach, the eigenvalue method is used to compute the relative weight of elements in each pairwise comparison matrix. The relative weight (*W*) of matrix A is obtained from the following relationship:

$$A \times W = \lambda_{max} \times W \quad (3)$$

where λ_{max} is the largest eigenvalue of matrix A. Afterward, and in order to ensure the consistency of the judgments, the consistency index (*CI*) is calculated as follows:

$$CI = (\lambda_{max} - n)/(n - 1) \quad (4)$$

where *n* is the size of the matrix.

Next, *CI* value is compared with the random consistency index (*RI*) obtained as an average *CI* of a large number of randomly generated reciprocal matrices of the same order (Table 3).

A comparison matrix is designated as consistent if the value of consistency ratio $RC = CI/RI$ is less or equal to 0.1. In Table 4 below, the main factors of the SWOT are compared, and the relative importance (weights) is obtained.

Next, within each factor, the sub-factors are pairwise compared, and their relative weights are computed; details are presented in Tables 5–8.

As mentioned previously, the analysis is based on the existence of inner dependency. Feedback or inner dependency may exist between some or all factors and within each factor. However, according to the analysis, inner dependency is assumed to exit only between the main factors as portrayed in Fig. 2.

The pairwise comparison matrices representing dependency among the various factors of the SWOT are depicted in Tables 9–12. In this context, one factor is taken at a time as the independent factor and pairwise comparisons are carried among the other dependent factors. Moreover, the normalized weight for each of the dependent factors is computed.

As assumed previously, inner dependency is allowed only among the main factors. Based on the above-mentioned analysis, the matrix below (W_2) was constructed:

Table 2
SWOT analysis

External factors	Internal factors	
	Strength (T)	Weakness (W)
	S1: An efficient network and water transmission system. S2: Provides fresh and brackish water services to all sectors. S3: Regardless of the weather conditions, the nonconventional desalination system is securing the water demand for all sectors.	W1: Highly subsidized sector. W2: Most of the water sector's infrastructure is outdated and, in some areas, deteriorating. W3: Lack of an organized long-term approach to awareness raising activities. W4: Operation and maintenance costs of water sector infrastructures are high. W5: Limited private sector participation.
Opportunities (O)	SO strategies	WO strategies
O1: Investment in new and sustainable technologies utilizing renewable energy sources. O2: Installing advanced water metering systems and water- saving irrigation technologies. O3: Savings by using treated wastewater for agricultural, industrial and other purposes. O4: Privatizing the sector provides investment opportunities.	SO1: Using renewal energy in order to increase water production and reduce energy cost. SO2: Utilize sophisticated wastewater treatment system to reduce freshwater consumption.	WO1: Use renewable energy to lower the cost of water production and reduce the financial burden on the government. WO2: Privatizing the water sector will eliminate the subsidy provided by the government.
Threats (T)	ST Strategies	WT Strategies
T1: Overemployment in the sector. T2: No properly monitoring systems. T3: The costs of producing abundant water are growing beyond governments' abilities. T4: Increasing demand for the water sector services because of population growth and urbanization.	ST1: Using renewal energy to lessen dependence on the governmental support. ST2: Utilizing advanced conservation instruments with the purpose of increasing the efficiency of the network and water transmission.	WT1: Implement measures to reduce subsidies provided by the government. WT2: Encouraging public/private partnership will effectively reduce overemployment in the water sector.

Table 3
Random consistency index for matrices of size *n*

n	*RI*
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48

Table 4
Fuzzy pairwise comparison of SWOT factors

	S	W	O	T	Local weights
S: Strength	1	1/3	1/3	1/2	0.109
W: Weakness	3	1	1	2	0.351
O: Opportunities	3	1	1	2	0.351
T: Threats	2	1/2	1/2	1	0.189

$\lambda_{max} = 4.010$; $RC = 0.004$.

$$W2 = \begin{bmatrix} 1 & 0.548 & 0.243 & 0.547 \\ 0.577 & 1 & 0.544 & 0.225 \\ 0.159 & 0.194 & 1 & 0.228 \\ 0.263 & 0.258 & 0.213 & 1 \end{bmatrix} \quad (5)$$

Table 5
Fuzzy pairwise comparison of strengths

	S1	S2	S3	Local weights
S1	1	4/5	1/5	0.133
S2	5/4	1	1/5	0.154
S3	5	5	1	0.713

λ_{max} = 3.006; *RC* = 0.005

Table 6
Fuzzy pairwise comparison of weaknesses

	W1	W2	W3	W4	W5	Local weights
W1	1	2	7	3	2	0.393
W2	1/2	1	5	2	1	0.225
W3	1/7	1/5	1	1/4	1/3	0.050
W4	1/3	1/2	4	1	2/3	0.141
W5	1/2	1	1	3/2	1	0.192

λ_{max} = 5.150; *RC* = 0.033

Table 7
Fuzzy pairwise comparison of opportunities

	O1	O2	O3	O4	Local weights
O1	1	4	1	1/2	0.246
O2	1/4	1	1/4	1/5	0.070
O3	4	4	1	1/2	0.246
O4	2	5	2	1	0.438

λ_{max} = 4.03; *RC* = 0.0103

Table 8
Fuzzy pairwise comparison of threats

	T1	T2	T3	T4	Local weights
T1	1	7	7	9	0.714
T2	1/7	1	1	3/2	0.108
T3	1/7	1	1	3/2	0.106
T4	1/9	2/3	2/3	1	0.074

λ_{max} = 4.123; *RC* = 0.046

Table 9
Inner dependence matrix of the SWOT factors with respect to strength

Strength	W	O	T	Local weights
Weakness (W)	1	4	2	0.577
Opportunities (O)	1/4	1	2/3	0.159
Threats (T)	1/2	3/2	1	0.263

λ_{max} = 3.012; *RC* = 0.010

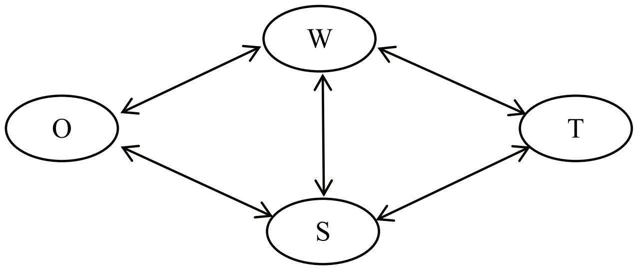

Fig. 2. Dependency among SWOT factors.

Table 10
Inner dependence matrix of the SWOT factors with respect to weakness

Weakness	S	O	T	Local weights
Strength (W)	1	3	2	0.548
Opportunities (O)	1/3	1	4/5	0.194
Threats (T)	1/2	5/4	1	0.258

λ_{max} = 5.004; *RC* = 0.004

Table 11
Inner dependence matrix of the SWOT factors with respect to opportunities

Opportunities	S	W	T	Local weights
Strength (W)	1	1/3	3/2	0.243
Weakness (O)	3	1	2	0.544
Threats (T)	2/3	1/2	1	0.213

λ_{max} = 3.074; *RC* = 0.064

Table 12
Inner dependence matrix of the SWOT factors with respect to threats

Threats	S	W	T	Local weights
Strength (W)	1	3	2	0.547
Opportunities (O)	1/3	1	6/5	0.225
Threats (T)	1/2	5/6	1	0.228

λ_{max} = 3.04; *RC* = 0.033

The number 1 presented in the matrix is indicative of the independent factor, i.e., the factor influence on itself.

In the third step and in order to find the exact weight of each factor, two weights have to be considered: the factor weight, when compared with the other factors (Table 3), and its weight due to the dependency (feedback). Hence, the vector matrix as shown below is computed:

$$\begin{bmatrix} 1 & 0.548 & 0.243 & 0.547 \\ 0.577 & 1 & 0.544 & 0.225 \\ 0.159 & 0.194 & 1 & 0.228 \\ 0.263 & 0.258 & 0.213 & 1 \end{bmatrix} \begin{bmatrix} 0.109 \\ 0.351 \\ 0.351 \\ 0.189 \end{bmatrix} = \begin{bmatrix} 0.245 \\ 0.324 \\ 0.240 \\ 0.192 \end{bmatrix} \quad (6)$$

In step 4, the overall weights of the sub-factors are computed; it is the product of multiplying of the weight of factors as calculated in (6) by the relative weights of the sub-factors obtained in the previous tables, details are shown in Table 13.

In the next step (step 5), pairwise comparisons are performed among all of the strategies defined previously with respect to each sub-factor starting from the strength sub-factors to ending by the sub-factors of the threat factor. Detailed derivations of the local weights are provided in Tables 14–29 presented in Appendix I.

In step 6, from the local weight of the pairwise comparisons between the strategies tables in Appendix I, the matrix W4 is constructed as follows:

W4 =

	S1	S2	S3	W1	W2	W3	W4	W5	O1	O2	O3	O4	T1	T2	T3	T4
SO1	0.197	0.174	0.233	0.096	0.075	0.147	0.096	0.062	0.180	0.120	0.101	0.077	0.079	0.103	0.171	0.135
SO2	0.072	0.307	0.177	0.032	0.058	0.250	0.152	0.059	0.149	0.125	0.276	0.056	0.063	0.071	0.047	0.050
WO1	0.197	0.133	0.166	0.098	0.062	0.153	0.105	0.173	0.171	0.101	0.107	0.084	0.089	0.089	0.106	0.104
WO2	0.111	0.060	0.094	0.237	0.180	0.117	0.107	0.192	0.093	0.120	0.101	0.231	0.0183	0.107	0.204	0.188
ST1	0.189	0.176	0.134	0.123	0.065	0.17	0.101	0.070	0.187	0.091	0.099	0.107	0.084	0.089	0.141	0.093
ST2	0.048	0.067	0.071	0.050	0.227	0.068	0.223	0.061	0.077	0.259	0.107	0.066	0.058	0.289	0.084	0.054
WT1	0.112	0.046	0.065	0.184	0.068	0.081	0.122	0.136	0.083	0.084	0.099	0.078	0.168	0.124	0.106	0.131
WT2	0.073	0.037	0.069	0.179	0.266	0.073	0.092	0.246	0.060	0.101	0.101	0.302	0.276	0.118	0.141	0.244

(7)

From matrix 3 and the overall W sub-factors in Table 13, the weight of the different strategies is determined as shown in (8):

$$W_{\text{alternatives}} = \begin{bmatrix} SO1 \\ SO2 \\ WO1 \\ WO2 \\ ST1 \\ ST2 \\ WT1 \\ WT2 \end{bmatrix} = W_4 \times W_{\text{sub-factors}} = \begin{bmatrix} 0.125 \\ 0.112 \\ 0.120 \\ 0.156 \\ 0.115 \\ 0.093 \\ 0.110 \\ 0.169 \end{bmatrix} \tag{8}$$

Table 13
Fuzzy pairwise comparison of weaknesses

Priority of factors	Priority of the sub-factors	Overall priority of the sub-factors (W sub-factors)
Strength (S) = 0.245	0.133	0.032
	0.154	0.037
	0.713	0.173
Weakness (W) = 0.324	0.393	0.126
	0.225	0.072
	0.050	0.016
	0.141	0.045
	0.192	0.062
Opportunity (O) = 0.240	0.246	0.059
	0.070	0.017
	0.246	0.059
	0.438	0.104
Threats (T) = 0.192	0.741	0.141
	0.108	0.020
	0.106	0.020
	0.074	0.014

6. Discussion

Experts and experienced specialists in Kuwait's water sector recommended that the weakness and opportunity factors should be stressed in the analysis. Therefore, the decision makers should take advantage of the existing opportunities to reduce the sector's weakness and lessen external threats. On the other hand, in the analysis of the sub-factors, the following were the utmost important ones: S3: regardless of the weather conditions, the nonconventional desalination system securing the water demand for all sectors with weight of 0.173; followed by T1: overemployment in the sector; next was the sub-factor W1: highly subsidized sector; and lasts comes O4: privatizing the sector provides investment opportunities. In fact, all of the aforementioned analyses were conducted to prioritize the various strategies.

Lastly, the different strategies were prioritized as given in (8); it is noticeable that the weight of WT2 (0.169) is the highest followed by WO2, SO1, and WO1 with weight 0.156, 0.125, and 0.120, respectively.

7. Conclusion and recommendations

The main goal of this study is to assess the water sector in Kuwait and propose strategies for enhancing its capabilities and reducing the burden on the country's economy. SWOT analysis is conducted to identify the weakness and mitigate the threats by exploiting and enforcing the strength and capturing the prevailing opportunities. A close look at results in (8) clearly indicates that implementing renewable energy, as an energy source, for the desalination partially or totally is the most favorable strategy; three strategies in the analysis are energy-related and in total constitute around 36% of the total weight. Privatization constitutes 32.5%, while instrumentation-related strategies come third with 20.5% followed by the remaining strategies. Accordingly, the study recommends that privatization/private public partnership strategy should be considered in any efforts for refurbishing the water sector. Furthermore, since fossil fuel costs is very high, plans for using alternative energy in the water sector should be encouraged. The implementation of these strategies will contribute to the diversification of the economy and reduction of the pollution caused by using fossil fuel. Other recommendations are as follows:

- building national capacity through training of human resources and boosting managerial capabilities;
- promoting an integrated water management system for all available water resources;
- establishing a solid regulatory and enabling policy body, e.g., Water Resources Council to control and coordinate policy and planning;
- developing an awareness program to educate the public in efficiently using this invaluable resources; and
- modifying the existing subsidy system in light of the current oil prices.

A realistic transformation in the Kuwaiti water sector cannot be achieved immediately; hence, a two-phase change should be considered: a short-term strategy with a 5–10 years span and a long-term outlook of 10–20 years.

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Appendix I

Table 14
Pairwise comparisons between the different strategies with respect to S1

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	3	1	2	1	4	3/2	3	0.197
SO2	1/3	1	1/3	1/2	1/4	1	2	1	0.072
WO1	1	3	1	3	1	2	3	3	0.197
WO2	1/2	2	1/3	1	2/5	3/4	1	1	0.111
TS1	1	4	1	2.5	1	4	1	2	0.189
TS2	1/4	1	1/2	4/3	1/4	1	3	2	0.048
TW1	2/3	0.5	1/3	1	1	1/3	1	2	0.112
TW2	1/3	1	1/3	1	1/3	1/2	1/2	1	0.073

λ_{max} = 7.706; *RC* = 0.0891

Table 15
Pairwise comparisons between the different strategies with respect to S2

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1/2	1	4	1	3	5	6	0.174
SO2	2	1	1/3	5	2	1	5	8	0.307
WO1	1	3	1	3	1	2	3	4	0.133
WO2	1/4	1/5	1/3	1	3/4	1	1	2	0.060
ST1	1	1/2	1	4/3	1	4	5	4	0.176
ST2	1/3	1	1/2	1	1/4	1	3/2	2	0.067
WT1	1/5	1/5	1/3	1	1/5	1/6	1	1	0.045
WT2	1/6	1/8	1/4	1/4	1/4	1/2	1	1	0.037

λ_{max} = 7.61; *RC* = 0.077

Table 16
Pairwise comparisons between the different strategies with respect to S3

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	4	1	3	1	2	3	3	0.223
SO2	1/4	1	2	3	3	2	2	3	0.177
WO1	1	1/2	1	4	1	3	3	2	0.166
WO2	1/3	1/3	1/4	1	3	1	1	1	0.094
ST1	1	1/3	1	1/3	1	3	1	3	0.134
ST2	1/2	1/2	1/3	1	1/3	1	1	1	0.071
WT1	1/3	1/2	1/3	1	1	1	1	1/2	0.065
WT2	1/3	1/3	1/2	1/3	1/3	1	2	1	0.069

λ_{max} = 7.706; *RC* = 0.089

Table 17
Pairwise comparisons between the different strategies with respect to W1

	SO1	SO2	WO1	WO2	STS1	STS2	WT1	WT2	Local weight
SO1	1	5	1	1/3	1	2	1/2	1/3	0.096
SO2	1/5	1	1/3	1/5	1/3	2/5	1/7	1/4	0.032
WO1	1	3	1	2/5	1	5/2	1/2	1/3	0.098
WO2	3	5	5/2	1	4	5	1/2	1	0.237
ST1	1	3	1	1/4	1	3	1	3/4	0.123
ST2	1/2	5/2	2/5	2/5	1/3	1	1/4	1/2	0.050
WT1	2	7	2	2	1	4	1	2/3	0.184
TW2	3	4	3	1	4/3	2	3/2	1	0.179

λ_{max} = 7.54; *RC* = 0.0677

Table 18
Pairwise comparisons between the different strategies with respect to W2

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1	2	1/2	1	1/3	1	1/3	0.075
SO2	1	1	1/2	2/5	1	1/4	4/5	1/4	0.058
WO1	1/2	2	1	1/3	2/3	1/5	3/2	1/4	0.062
WO2	2	5/2	3	1	2	1	3	2/3	0.180
ST1	1	1	3/2	1/2	1	1/5	1	4/5	0.065
ST2	3	4	5	1	5	1	4	1	0.227
WT1	1	5/4	2/3	1/3	1	1/4	1	2/5	0.068
WT2	2	4	4	5/4	5/4	1	5/2	1	0.266

λ_{max} = 7.78; *RC* = 0.098

Table 19
Pairwise comparisons between the different strategies with respect to W3

	SO1	SO2	WO1	WO2	STS1	ST2	WT1	WT2	Local weight
SO1	1	1/2	1	1	1	3	3	2	0.147
SO2	2	1	2	2	3	2	3	3	0.250
WO1	1	1/2	1	2	1	3	2	2	0.153
WO2	1	1/2	1/2	1	2	2	1	1	0.117
STS1	1	1/3	1	1/2	1	2	3	2	0.127
STS2	1/3	1/3	1/3	1/2	1/2	1	1/2	1/3	0.053
WT1	1/2	1/3	1/2	1	1/3	2	1	3/2	0.081
WT2	1/2	1/3	1/2	1/2	1/2	2	1/6	1	0.073

λ_{max} = 7.77; *RC* = 0.097

Table 20
Pairwise comparisons between the different strategies with respect to W4

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1/2	1	1	1	1/3	1	1	0.096
SO2	3/2	1	3/2	1	2	2/3	1	3/2	0.152
WO1	1	2/3	1	1	1	1/2	1	1	0.105
WO2	1	1	1	1	1	1/2	1	1	0.107
ST1	1	1/2	1	1	1	1/2	1	1	0.101
ST2	3	3/2	2	2	2	1	2	2	0.223
WT1	1	1	1	1	1	1/2	1	2	0.122
WT2	1	2/3	1	1	1	1/3	1/2	1	0.092

$\lambda_{max} = 7.77$; $RC = 0.097$

Table 21
Pairwise comparisons between the different strategies with respect to W5

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1	1/3	1/4	1	1	1/2	1/3	0.062
SO2	1	1	1/3	1/4	1	1	1/2	1/4	0.059
WO1	3	3	1	1/2	3	3	2	1/2	0.173
WO2	4	4	2	1	2	3	1	1/2	0.192
ST1	1	1	1/3	1/2	1	1	1/2	1/2	0.070
ST2	1	1	1/3	1/3	1	1	1/2	1/4	0.061
WT1	2	2	1/2	1	3	2	1	1/2	0.136
WT2	3	4	2	2	2	4	2	1	0.246

$\lambda_{max} = 7.54$; $RC = 0.068$

Table 22
Pairwise comparisons between the different strategies with respect to O1

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1	1	3	1	2	2	3	0.180
SO2	1	1	1/2	1	1/2	1	2	2	0.149
WO1	1	2	1	4	1	3	2	2	0.171
WO2	1/3	1	1/4	1	1/3	2	2	1	0.093
ST1	1	2	1	1	1	3	2	3	0.187
ST2	1/2	1	1/3	3	1/3	1	1/2	2/3	0.077
WT1	1/2	1/2	1/2	1/2	1/2	2	1	1	0.083
WT2	1/3	1/2	1/2	1/2	1/3	3/2	1	1	0.060

$\lambda_{max} = 7.58$; $RC = 0.073$

Table 23
Pairwise comparisons between the different strategies with respect to O2

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	4/3	1	4/3	1	1/2	1	3/2	0.120
SO2	4/5	1	2	1	3/2	1/3	2	1	0.125
WO1	1	1/2	1	3/2	1	1/3	1	1	0.101
WO2	4/5	1	2/3	1	2	1/2	2	1	0.120
ST1	1	2/3	1	1/2	1	1/3	4/3	1	0.091
ST2	2	3	3	2	3	1	3	2	0.259
WT1	1	1/2	1	1/2	4/5	1/3	1	1	0.084
WT2	2/3	1	1	1	1	1/2	1	1	0.101

λ_{max} = 7.66; *RC* = 0.083

Table 24
Pairwise comparisons between the different strategies with respect to O3

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1/3	1	1	1	1	1	1	0.101
SO2	3	1	2	3	3	2	3	3	0.276
WO1	1	1/2	1	1	1	1	1	1	0.107
WO2	1	1/3	1	1	1	1	1	1	0.101
ST1	1	1/3	1	1	1	1	1	4/5	0.099
ST2	1	1/2	1	1	1	1	1	1	0.107
WT1	1	1/3	1	1	1	1	1	4/5	0.099
WT2	1	1/3	1	5/4	5/4	1	1	1	0.110

λ_{max} = 8.14; *RC* = 0.0144

Table 25
Pairwise comparisons between the different strategies with respect to O4

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1	1	1/3	1/2	1	2	1/3	0.077
SO2	1	1	1/2	1/3	1/2	1	1/2	1/4	0.056
WO1	1	2	1	1/4	1	2	1/2	1/3	0.084
WO2	3	3	4	1	3	3	3	1	0.231
ST1	2	2	1	1/3	1	2	2	1/4	0.107
ST2	1	1	1/2	1/2	1/2	1	1	1/3	0.066
WT1	1/2	2	2	1/3	1/2	1	1	1/4	0.078
WT2	3	4	3	4	4	3	4	1	0.302

λ_{max} =8.133; *RC* = 0.0135

Table 26
Pairwise comparisons between the different strategies with respect to T1

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	1	1	1/4	1	2	1/2	1/3	0.079
SO2	1	1	1/2	1/2	1/2	1	1/2	1/4	0.063
WO1	1	2	1	1/3	1	2	1/2	1/3	0.089
WO2	4	2	3	1	2	2	2/3	1	0.183
ST1	1	2	1	1/2	1	1	1/2	1/3	0.084
ST2	1/2	1	1/2	1/2	1	1	1/3	1/5	0.058
WT1	2	2	2	3/2	2	3	1	2/3	0.168
WT2	3	4	3	3	3	5	3/2	1	0.276

λ_{max} = 8.02; *RC* = 0.002

Table 27
Pairwise comparisons between the different strategies with respect to T2

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	2	2	1	1	1/3	1/2	1/2	0.103
SO2	1/2	1	1	1/2	1	1/3	1/2	1/2	0.071
WO1	1/2	1	1	1	1	1/4	1	1	0.089
WO2	1	2	1	1	1	1/3	1	1	0.107
ST1	1	1	1	1	1	1/3	1	1	0.098
ST2	3	3	4	3	3	1	2	3	0.289
WT1	2	2	1	1	1	1/2	1	1	0.124
WT2	2	2	1	1	1	1/3	1	1	0.118

λ_{max} = 8.01; *RC* = 0.0615

Table 28
Pairwise comparisons between the different strategies with respect to T3

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	4	3	1/3	1	3	2	1	0.171
SO2	1/4	1	1/2	1/5	1/3	1	1/2	1/3	0.047
WO1	1/3	2	1	1/2	1	2	1	1	0.106
WO2	3	5	2	1	1	1/2	3	1	0.204
ST1	1	3	1	1	1	3	1	1	0.141
ST2	1/3	1	1/2	2	1/3	1	1/2	1/3	0.084
WT1	1/2	2	1	1/3	1	2	1	1	0.106
WT2	1	3	1	1	1	3	1	1	0.141

λmax = 8.61; RC = 0.0616

Table 29
Pairwise comparisons between the different strategies with respect to T4

	SO1	SO2	WO1	WO2	ST1	ST2	WT1	WT2	Local weight
SO1	1	3	1	1/2	1	3	2	1/2	0.135
SO2	1/3	1	1/3	1/4	1/2	1	1/2	1/3	0.050
WO1	1	3	1	1/2	1	2	1/2	1/2	0.104
WO2	2	4	2	1	2	3	1	1	0.188
ST1	1	2	1	1/2	1	2	1/2	1/3	0.093
ST2	1/3	1	1/2	1/3	1/2	1	1/2	1/3	0.054
WT1	1/2	2	2	1	2	2	1	1/2	0.131
WT2	2	3	2	3	3	3	2	1	0.244

λ_{max} = 8.12; *RC* = 0.0112