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Strategic planning for exchanging treated urban wastewater for agricultural water with the approach of supplying sustainable urban water: a case study of Mashhad, Iran

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ABSTRACT

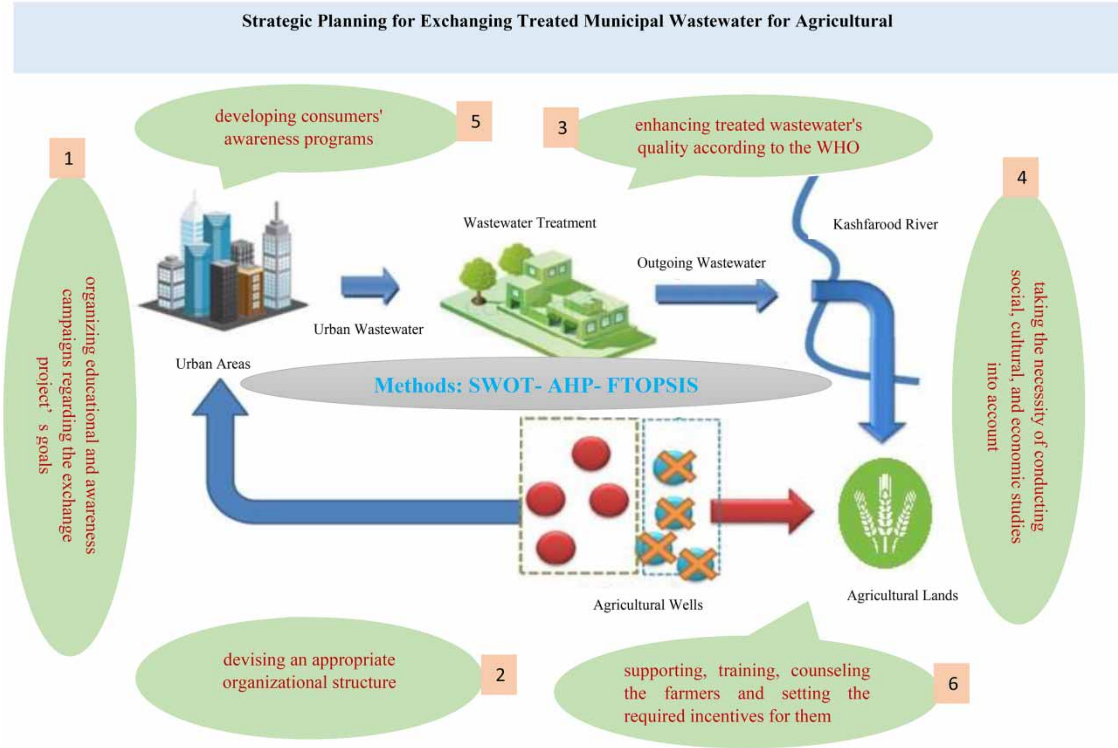
Considering the increasing demand for urban water and the low water-use efficiency in the agricultural sector, an exchange of treated urban wastewater for agricultural water could be a fundamental solution for administering sustainable management of water resources. However, implementing the intersectoral water exchange project is influenced by the economic, social, and environmental conditions of each region, especially in developing countries. Therefore, this study sought to identify the best possible strategies for exchanging treated urban wastewater for agricultural water in Mashhad city, located in Iran, a country that suffers from decreased urban water resources. Based on the interviews conducted with the experts and the strengths, weaknesses, opportunities and threats analysis, 28 influential factors were identified for the water exchange project, and eleven strategies were developed for its implementation. The results of the analytic hierarchy process (AHP) and F-TOPSIS indicated that organizing educational and awareness campaigns regarding the exchange project's goals, devising an appropriate organizational structure, enhancing treated wastewater's quality according to the WHO standards, taking the necessity of conducting social, cultural, and economic studies into account, developing consumers' awareness programs, and supporting, training, and counseling the farmers and setting the required incentives for them were among the main factors involved in the implementation of the water exchange project in Mashhad.

Key words: agricultural water, intersectoral water exchange, public awareness programs, SWOT analysis, strategic planning, treated urban wastewater

HIGHLIGHTS

- Disclosing information about recycled water has the most significant effect on public awareness and acceptance.
- Acceptance or rejection of the treated wastewater by farmers depends on specific cultural, religious, social, and economic conditions.
- Improving the treated wastewater's quality according to the World Health Organization's standards plays a very important role.

GRAPHICAL ABSTRACT



INTRODUCTION

The increasing growth of urbanization and industrialization worldwide has increased water supply demands, necessitating more efficient use of water and management of water resources. Therefore, it is necessary for urban planners and scholars to ensure that the citizens would have access to clean water and a healthy living environment (Wang *et al.* 2019). To achieve this goal, comprehensive management of urban water is highly required to devise and manage urban water systems (van der Steen 2011). Accordingly, future cities' water management must be done based on sustainable social, economic, and environmental perspectives. As mentioned by van der Steen (2011), with the growing population of cities and, consequently, the increasing demands for public utility services, the need for water supply and urban wastewater management would become more significant. This allows for urban wastewater reuse, as part of comprehensive urban water management, to be considered a viable alternative for securing required water resources (Rahman *et al.* 2016).

Most water resources have historically been controlled by the agricultural sector (Wang *et al.* 2019). In other words, irrigation has always been the biggest consumer of freshwater, with its share of the world's freshwater consumption being 70% on average (Wu *et al.* 2022). However, the agriculture sector is influenced by water shortages more than other sectors (Jägermeyr *et al.* 2015). Conversely, while in arid and semi-arid countries such as Iran, agriculture is responsible for approximately 92% of the extracted water (Khanpae *et al.* 2020), the water-use efficiency is low (Nazari *et al.* 2018). In addition, increased industrial, urban, and ecologic demands for water increase the opportunity cost of using water in the agricultural sector (Watson & Davies 2011). Thus, improving water-use efficiency and identifying alternative resources are required to reduce the added pressure on water resources and ensure the sustainable management of irrigating water in arid and semi-arid regions (Khanpae *et al.* 2020). In this regard, water-use efficiency could be enhanced in different sectors by efficiently reallocating water resources (Wang *et al.* 2019).

Considering water shortages, low water-use efficiency in agriculture, and increased opportunity cost of water use in farming, decision-makers are tempted to allocate the available water to urban and industrial consumption rather than the agriculture sector. This is because water has more economic and social value in urban and industrial consumption than agricultural ones (Heinz *et al.* 2011b). Moreover, as transferring agricultural water to cities is economically and environmentally less costly than exploring new surface or groundwater resources, it could widely be used to meet the increasing urban, industrial, and ecological water needs (Sun *et al.* 2017; Wang *et al.* 2019).

Transferring agricultural water to cities may negatively impact agricultural productions, which in turn would lead to decreased farm revenue (Heinz *et al.* 2011b). Therefore, many governments employ Integrated Water Resources Management (IWRM) strategies, which include treating urban wastewater and reusing it for irrigation purposes. According to the Swedish International Development Cooperation Agency (cited in Trinh *et al.* (2013), 30–70 million m^3 of wastewater produced annually by roughly one million people would be sufficient for irrigating 1,500–3,500 hectares of farmland (Khanpae *et al.* 2020). Reusing treated wastewater in farming releases freshwater for economic and social purposes. This type of exchange also has potential environmental advantages, such as decreasing downstream wastewater pollution and helping the plants absorb wastewater nutrients (Heinz *et al.* 2011a). Figure 1 shows how an intersectoral water exchange/transfer project at the basin level is compared with standard water use.

Despite the potential advantages of wastewater reuse in agriculture, it may bring about some health and environmental risks caused by the low quality of the treated wastewater, especially in developing countries that lack sufficient financial resources to adequately treat urban wastewater. Thus, there are still some concerns regarding the sustainability of treated wastewater-irrigated farming (Khanpae *et al.* 2020). Conversely, as the acceptance of the treated wastewater reuse projects depends on each region's cultural, religious, social, and economic conditions, successful implementation of such projects may take a variety of forms, varying from one region to another. In fact, the sociocultural conditions in developing countries like Iran are such that reusing wastewater may face some social resistance, especially in farming (Deh-Haghi *et al.* 2020). As a result, there are uncertainties concerning the effectiveness of wastewater reuse projects. In this regard, it is crucially important for managers and decision-makers to recognize the relative importance of the influential factors involved in wastewater reuse projects to develop practical plans and strategies for replacing recycled water with the agricultural freshwater to supply urban water. In particular, decision-makers could use the framework described in this study regarding the implementation of wastewater reuse and intersectoral water exchange projects to choose the best alternatives to overcome the projects' limitations.

Many studies have investigated urban wastewater reuse, with key studies summarized in Table 1. However, only a few studies have been conducted on intersectoral water exchange projects. Moreover, most previous studies have been carried out in developed countries such as Spain, the United States, and Australia, seeking to determine the added value of such

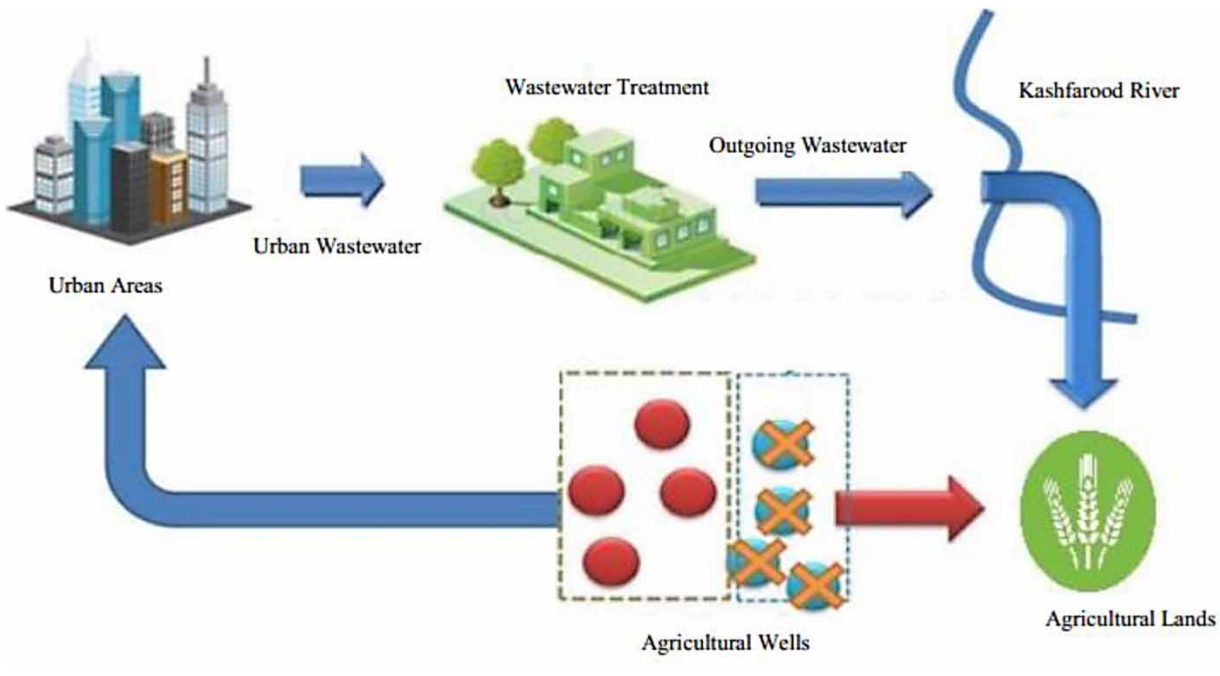


Figure 1 | Sample of intersectoral water exchange project during water shortages – source: (Winpenny *et al.* 2010).

Table 1 | Related literature on intersectoral water exchange development strategies

Authors	The study region	Methodology	Purpose of the study	Conclusions
Ricart *et al.* (2019)	Spain	Thematic analysis via semi-structured interviews	Exchanging water between farming and urban tourism	Water management method, water quality, and water charge were the main issues to be considered in developing water exchanges
Sanchis-Ibor *et al.* (2019)	Spain	Semi-structured interviews	The role of state governance in transferring water between agricultural and urban users	Transparency was low in Spain, and the current governing framework did not include some select stakeholders
Wang *et al.* (2019)	China	Production function	Measuring benefits of rural-to-urban water transfer	Rural-to-urban water transfer projects improved the allocative efficiency of water use in different sectors
Mainali *et al.* (2011b)	Australia	Items' analysis	Feasibility study on using recycled water for washing machine	The quality of the recycled water was highly important in the acceptance
Heinz *et al.* (2011b)	Spain and Mexico	Cost–benefit analysis	Economic evaluation of the costs and benefits of water exchange between cities and farmers	Projects on replacing recycled water with agricultural water were feasible and economically efficient
Heinz *et al.* (2011a)	Spain		Economic evaluation of the costs and benefits of water exchange between cities and farmers	Investments in water reuse and exchange were usually beneficial in the long term
Mainali *et al.* (2011a)	USA, Australia and Singapore	Items' analysis	Water reuse projects for irrigation and drinking purposes	Practical measures regarding the successful implementation of water reuse projects vary from one region to another. Social marketing of products, public awareness, and advanced technology are among the essential elements involved in the success of water reuse projects
Scott *et al.* (2007)	Mexico	A review article	Implications of allocating water to agriculture and city	Water exchange was an innovation in water resources institutionally. Farmers' participation plays a crucial role in water exchange, and that the farmers should be supported against possible losses

projects (Wang *et al.* 2019), evaluate their costs economically (Heinz *et al.* 2011b), and study the role of state governance in such projects (Sanchis-Ibor *et al.* 2019). The main methods used in those studies have been regression equations, semi-structured interviews, and the strengths, weaknesses, opportunities and threats (SWOT) analysis. These methods do not consider all influential factors involved in intersectoral water exchange projects, including social, environmental, technical, and political factors. Moreover, the studies mentioned have not taken into account the interdependence of such factors, the uncertainty of the real world, and decision-makers' judgments. Conversely, there could be great diversity in practical measures regarding the successful implementation of wastewater reuse projects, varying from one region to another. Therefore, the strategies must be specifically devised for each region based on economic, cultural, political, and climate conditions. In the current study, such gaps in devising strategies for developing intersectoral water exchange projects would be filled by applying a multi-criteria decision-making method (MCDM).

To this end, this study used the SWOT, Analytic Hierarchy Process (AHP), Fuzzy Technique for Order Performance by Similarity to Ideal Solution (F-TOPSIS) integrated method to identify the influential factors involved in implementing the project on exchanging the urban recycled water for agricultural water, determine the main strategies concerning the development of water exchange project, and prioritize those strategies. The SWOT analysis is an effective method used for issues regarding strategic water planning (Rezazadeh *et al.* 2017; Takeleb *et al.* 2020), enabling the decision-makers to effectively examine different aspects of developing an appropriate policy plan by identifying the internal (the strengths and weaknesses) and external factors (opportunities and threats). In the next phase, the AHP method is used to determine the weight of SWOT factors. Due to its simplicity and transparency, AHP is one of the most appropriate methods used by water planning specialists (Takeleb *et al.* 2020; Wang *et al.* 2020). Furthermore, this multi-criteria method could, together with the SWOT analysis, evaluate and compare the relationship between different factors (Wang *et al.* 2020). In the third phase, the F-TOPSIS method is used to determine the best strategies regarding the water exchange project (i.e., the alternative choices) by overcoming the complexities involved within the process of the exchange project. The fuzzy sets theory is a strong approach to resolving uncertainty when the data are incomplete, subjective, and unclear, easing the required evaluation for the water planning specialist via linguistic terms (Kaya & Kahraman 2010). Similar mixed methods have previously been used for devising strategies concerning water resources management. For instance, Rezazadeh *et al.* (2017) and Takeleb *et al.* (2020) used SWOT-AHP-QSPM methods for water resources management in protected areas and water resources management for urban water purposes, respectively.

Therefore, this study contributes to the current body of knowledge in five different ways. First, this is the first study that considers all influential factors (a comprehensive analysis) involved in the water exchange project between cities and agriculture, including social, environmental, technical, and political factors. Second, it determines the relevant strategies based on intersectoral water exchange project's strengths, weaknesses, opportunities, and threats. Third, it takes the factors' interdependence into account. Fourth, it accounts for the uncertainty of the real world, and the decision-makers' views. Finally, this study is focused on Mashhad city in Khorasan Razavi province, Iran, which has different conditions and characteristics compared to other regions and countries in previous studies.

MATERIALS AND METHODS

The study region

This study was carried out in Mashhad city in Khorasan Razavi province, located in the Kashafrood river basin in northeast Iran (Figure 2).

As a tourist destination and strategic city, Mashhad is located in an arid and semi-arid region. With its growing population and incoming tourists, Mashhad's need for water is continuously increasing. According to the city's predicted population in 2041, Mashhad would accommodate 4,900,000 citizens and 800,000 tourists who would need 396 million m^3 of urban water in that year. Mashhad's water is supplied from surface and underground resources. However, current resources do not suffice the city's growing needs, and it will face water shortages in the coming years. The predictions made regarding Northeastern Iran's industrial and urban water needs in 2041 indicate that Khorasan Razavi province would need 396 million m^3 water for urban purposes, taking the current resources into account (Heidari 2018). Currently, the Harirrud River-based Doosti

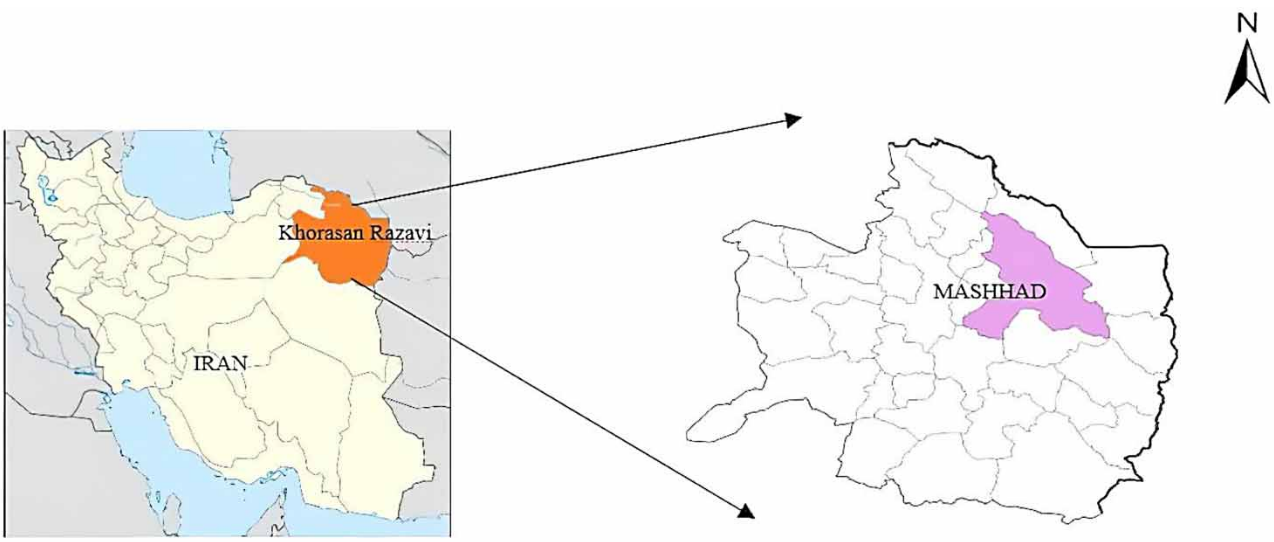


Figure 2 | The geographical location of the study region in Iran.

Reservoir dam, located on Iran's border with Turkmenistan, is the main supplier of Mashhad's water. This dam is influenced by the upstream basin's water extractions, more than 90% of which are located in Afghanistan. Conversely, Afghanistan is reluctant to participate in joint tripartite coordination meetings with Iran and Turkmenistan to discuss the exploitation of Harirod River's water resources. Following the construction of the Selma dam in Afghanistan and the recent droughts, the inflow of water into the dam has gradually decreased. Also, other dams are being constructed upstream of the Doosti dam, whose operation would directly affect the dam's water resources (Heidari 2018).

While there is a significant volume of treated urban wastewater in Mashhad that could be used as a sustainable water resource, the recycled water lacks the required quality to be used for supplying urban water due to the lack of advanced treatment plants in the city. In other words, many cities, especially in developing countries like Iran, are unable to afford the cost of wastewater treatment. Moreover, the cultural, social, and economic conditions prevailing in developing countries in general and the city of Mashhad, in particular, hinder the use of treated wastewater for urban purposes. So replacing treated urban wastewater with western Mashhad's high-quality agricultural water is one of the predicted ways to supply urban water. In fact, the alternative of exchanging the treated urban wastewater for the agricultural water of the western Mashhad basin has been planned to be implemented via a transfer system with a volume of 120 million m^3 annually, which would be transferred to three different areas located 30, 60, and 90 kilometers away from Mashhad's wastewater treatment plants. Taking the transmission line's losses into account, the volume of agricultural water return for urban purposes is predicted to be around 100 million m^3 per year. The numbers of active agricultural wells with high discharge to be exchanged for the treated urban wastewater in the three mentioned areas are 95, 140, and 74, respectively, with annual discharge rates of 50.5, 60, and 34 million m^3, respectively (Heidari 2018).

Participants selection

The tools used in this study include making field studies, reviewing the related literature, conducting interviews, and administering a questionnaire. First, in-person semi-structured interviews were carried out with different groups of stakeholders from various relevant organizations, including the supervisors of the project's implementation represented by Khorasan Razavi Regional Water Company's staff, the managers of Khorasan Razavi's Department of Environment, and the managers of Khorasan Razavi Agriculture Organization; the project's contractors represented by non-governmental organizations and the private sector; and the academia members who represented science and research community. Furthermore, some interviews were conducted with exemplary farmers. To examine different aspects of the relevant specialists' views, experiences, and perspectives concerning the water exchange project in Mashhad, the items of the administered questionnaire were mainly open-ended. After gathering the completed questionnaires, the researchers interviewed the respondents concerning the possible strategies for successful implementation of the water exchange project to identify the final strategies. In this regard, 20 interviews were conducted in total (Table 2), offering some information about the challenges and opportunities involved in implementing the project. Then, seven experts were asked to complete (score) a structured questionnaire individually. Finally, the geometric mean method was used to aggregate the experts' views.

SWOT–AHP–F-TOPSIS integrated method

Figure 3 shows the SWOT–AHP–F-TOPSIS integrated method used in this study to identify and prioritize the influential factors involved in the intersectoral water exchange project in Mashhad and to determine the best relevant strategies.

Table 2 | The frequency of the stakeholders who participated in semi-structured interviews

Participants Class	The number of participants
Managers and staff members of Mashhad Regional Water Company	7
Managers at Department of Environment	2
Agriculture Organization's Managers	4
Exemplary Farmers	2
The academia	3
Non-governmental organizations and the Private sector	2
Total	20

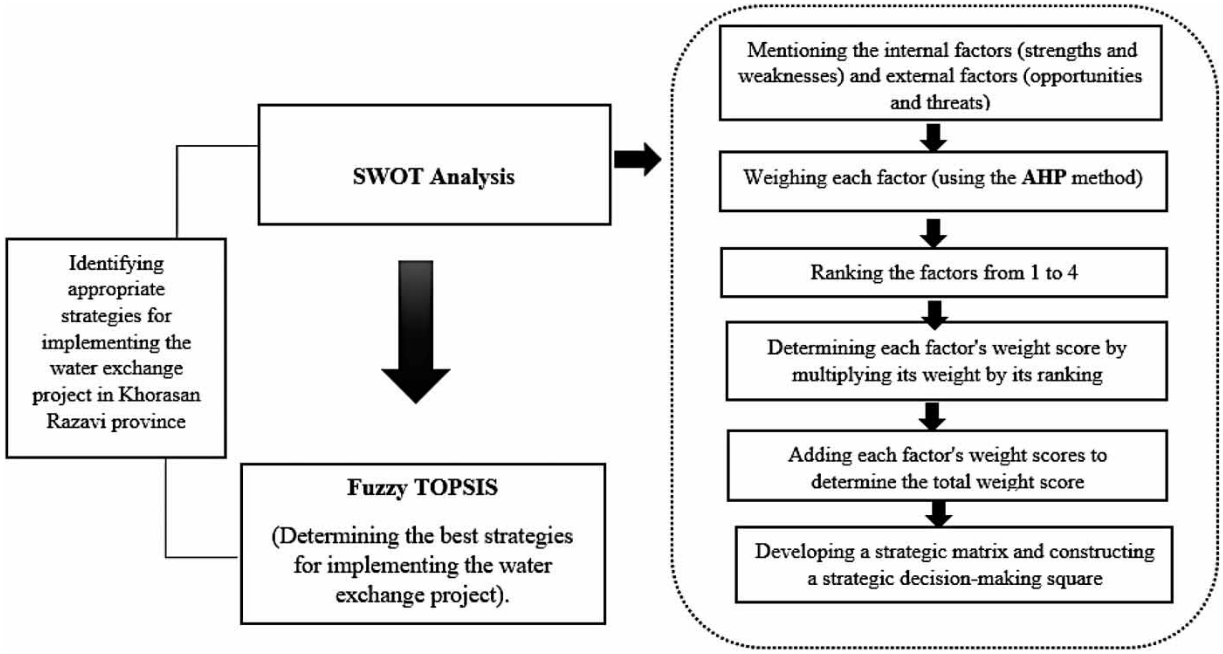


Figure 3 | The framework of SWOT–AHP–F-TOPSIS in this study.

SWOT analysis was used to determine the internal and external factors involved in the strategic planning of the water exchange project's implementation. AHP was used to gain the weight of each sub-factor specified in the Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrices. Finally, following the determination of the strategies for implementing the water exchange project in Mashhad based on the SWOT matrix, the F-TOPSIS method was used to prioritize the strategies. Each of these methods is elaborated in the following sections.

The SWOT analysis

The SWOT analysis is a method widely used in strategy development, strategic planning, and decision-making (Wang *et al.* 2020), including various factors involved in influencing a particular goal. SWOT stands for the strengths, weaknesses, opportunities, and threat (Gürel & Tat 2017). Strengths and weaknesses are known as the internal factors, and opportunities and threats are known as the external ones (Arsić *et al.* 2017; Aghasafari *et al.* 2020). In other words, the strengths and weaknesses are identified by assessing the internal system's environment, while the opportunities and threats are identified by assessing the external system's environment (Khan 2018). Therefore, the SWOT analysis provides a list of strengths, weaknesses, opportunities, and threats concerning the internal and external environments affecting the system. Internal and external factors are combined in the IFE and EFE matrix framework to formulate four types of strategies (Christodoulou & Cullinane 2019; Aghasafari *et al.* 2020). This matrix is an essential tool which can be used by managers for comparing the information with each other and proposing four types of strategies: SO strategy, WO strategy, ST strategy, and WT strategy. Known as offensive strategies, the SO strategies occur when strengths can be used to maximize opportunities, which is an ideal situation for any organization. However, in cases where an organization faces valuable opportunities but suffers from some weaknesses, the SWOT analysis would lead to WO strategies known as the conservative strategies, indicating that the organization must do its best to compensate for the weaknesses by seizing the environmental opportunities.

The SWOT analysis may display a situation in which an organization enjoys some strengths and reliable capabilities but faces some threats simultaneously. In case of such a situation, the organization can adopt competitive strategies (ST) by using its maximum available capabilities against external threats. If the weaknesses are faced with threats, the worst possible situation will occur, indicating that the external negative factors are strengthening the internal negative ones. In such cases, the organization needs to adopt defensive strategies (WT) to prevent negative internal weaknesses against external threats (Aghasafari *et al.* 2020).

Formation of IFE and EFE matrix

The phases of IFE and EFE matrix formation are as follows (Damani & Hashmi 2017; Rezazadeh *et al.* 2017; Takeleb *et al.* 2020):

(1) Mentioning the internal factors (strengths and weaknesses) and external factors (opportunities and threats)
(2) Weighing each factor (using the AHP method)
(3) Ranking the factors from 1 to 4
(4) Determining each factor's weight score by multiplying its weight by its ranking
(5) Adding each factor's weight scores to determine the total weight score
(6) Developing a strategic matrix and constructing a strategic decision-making square

Phase 1: Identifying important internal and external factors involved in the implementation of the water exchange project in Mashhad through questionnaires, interviews, field studies, and review of the related literature. Accordingly, it could be said that while it is the internal strengths and weaknesses of the organization's-controlled activities that may lead to the organization's well or poor performance, the external opportunities and threats are competitive trends that could benefit or harm an organization in the future (David 2011).

Phase 2: The AHP method is used to determine each internal and external factor's weight. It is a supportive decision-making method developed by Saaty (2008). According to Baby (2013) and Saaty (2008), the method could identify the stages involved in the subjective and objective evaluation and provide a mechanism for examining the compatibility of the alternative strategies, thereby reducing the decision-making bias. Moreover, AHP is a flexible and powerful tool which uses a 1–9 quantitative scale for binary comparisons, and it is widely used to deal with the problems regarding complex decision-making cases that have conflicting goals (Azarnivand & Banihabib 2017; Rezazadeh *et al.* 2017). In this method, respondents must first evaluate each criterion by comparing it with other criteria on a 9-point fuzzy scale. Then, the normalization of the AHP matrix is analyzed, followed by the calculation of eigenvalues. Finally, the prioritized weights are obtained using the eigenvalues (Saaty 2008). Typically, the value of each weight ranges from 0 to 1, where 0 means that the factor is not important and 1 (100%) means that the factor is highly important (Damani & Hashmi 2017; Rezazadeh *et al.* 2017; Takeleb *et al.* 2020). Also, the total weights must equal 1 (100%).

Phase 3: Ranking the intended factors is used to measure the importance of the internal and external factors involved in the water exchange project in Mashhad. Major and minor threats are ranked 1 and 2, respectively, and little and great opportunities are ranked 3 and 4, respectively.

Phase 4: To obtain each factor's weight score concerning the strengths, weaknesses, opportunities, and threats, each factor's weight obtained via the AHP method in step 2 is multiplied by the factor's rank determined in step 3.

Phase 5: The weights' average scores (2.5) were used as judgment scales. Weight scores over 2.5 indicate that the organization's strengths (opportunities) outweigh its weaknesses (threats). The weight scores that fall between 1 and 2.5 suggest that the weaknesses (threats) outweigh the strengths (opportunities).

Phase 6: After calculating the external and internal factors' scores and formulating a strategic matrix, a strategic decision-making square is made using the SWOT analysis. Based on the calculated scores, four strategies are developed via the SWOT method regarding different combinations of internal and external factors (Figure 4). The final total scores' cross-point regarding the internal scores' evaluation on the horizontal axis and the final total scores regarding the external factors' evaluation on the vertical axis determine the organization's strategic position.

This calculation method has previously been used in Mallick *et al.* (2020), Takeleb *et al.* (2020) and Kazemi *et al.* (2018) studies. All calculations were made using the Excel software package and Expert Choice software.

F-TOPSIS

Chen's proposed F-TOPSIS method (Chen, 2000) was used to rank the alternatives (strategies). The required stages are defined as follows.

Stage 1: First, the decision-making group is considered with K expert. Each alternative's score is calculated for each criterion via the following equation:

$$X_{ij} = \frac{1}{k}[X_{ij}^{i} + X_{ij}^{2} + \ldots + X_{ij}^{k}] \tag{1}$$

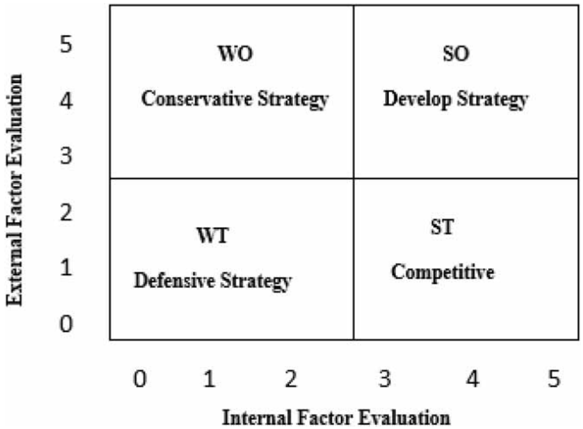


Figure 4 | Position of the IFE/EFE Matrix.

where $X = \{X_{ij} | i = 1,\ldots m; j = 1,\ldots,n\}$ is a set of fuzzy rankings, and $w = \{w_j | j = 1,\ldots,n\}$ is a set of fuzzy weights. In this method, $A = \{A_i | i = 1,\ldots,m\}$ shows the total set of alternatives and $C = \{C_j | j = 1,\ldots,n\}$ suggests the total set of criteria. Linguistic variables are described by triangular numbers Xij = (aij, bij, cij), assuming that Xij = (aij, bij, cij) is a triangular fuzzy number (TFN). Table 3 shows the linguistic variables and TFNs' ranking scale.

Stage 2: In this stage, the normalized values will be obtained from Equation (2):

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \quad i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n \tag{2}$$

Stage 3: The ranking of the normalized weights is determined through Equation (3), where it is required to calculate the indices' (criteria) weights using the AHP method and then multiply it in the unscaled matrix (rij):

$$\text{Vij} = \text{Wj} * \text{rij} \tag{3}$$

Stage 4: The following equations show the fuzzy positive ideal solution A^+ and fuzzy negative ideal solution:

$$\text{FPIS} = A+ = \{\max v1, \max v2, \max v3, \ldots, \max vn\}, \max v + j = (1, 1, 1) \tag{4}$$

$$\text{FPIS} = A- = \{\min v1, \min v2, \min v3, \ldots, \max vn\}, \min v - j = (0, 0, 0) \tag{5}$$

Table 3 | Linguistic variables scale

No.	Linguistic variables	TFNs
1	Very weak	(1, 1, 3)
2	Weak	(1, 3, 5)
3	Moderate	(3, 5, 7)
4	Good	(5, 7, 9)
5	Very good	(7, 9, 9)

Source: Solangi *et al.* (2019).

Stage 5: The distance between the alternatives is measured by their geometric distance. Separating each alternative from the positive ideal solution is determined through Equation (6):

$$d_i^+ = \sqrt{\left(\sum_{j=1}^{n} (v_{ij} - v_j^+)^2\right)} \quad i = 1, 2, \ldots, m \tag{6}$$

Similarly, separating the alternatives from the negative ideal solution A- is calculated by Equation (7):

$$d_i^- = \sqrt{\left(\sum_{j=1}^{n} (v_{ij} - v_j^-)^2\right)} \quad i = 1, 2, \ldots, m \tag{7}$$

Stage 6: Then, the coefficient of relative proximity to the ideal solution (C * i) is obtained for each alternative via Equation (8):

$$C_i^* = d_i^- / (d_i^+ + d_i^-) \quad i = 1, 2, \ldots, m \tag{8}$$

Alternatives (strategies) are ranked based on relative proximity (C * i), with the alternative having a larger (C * i) indicates a better solution.

RESULTS AND DISCUSSION

The SWOT analysis

The internal and external factors regarding Mashhad's water exchange project were identified by reviewing the related literature, carrying out field studies, conducting interviews, and administrating questionnaires. In total, 28 factors were identified and categorized into four groups: strengths, weaknesses, opportunities, and threats. Internal factors (strengths and weaknesses) are shown in the second column of Table 4, and the external factors (opportunities and threats) are displayed in the second column of Table 5.

The IFE and EFE matrix

Table 4 shows the ranking of the internal factors involved in the water exchange project made via the AHP method. As seen in Table 4, seven strengths and seven weaknesses were identified for the implementation of the water exchange project in Mashhad. Based on the internal factors' matrix, the S2 component with a score of 0.253 (the third column in Table 4), which is related to the required water supply from sustainable local water resources, has the highest priority among the strengths. According to the experts in this study, Mashhad's urban water is currently supplied from non-local sources. However, Mashhad desperately needs to supply its urban water from sustainable local resources. Mainali *et al.* (2011a) considered supplying Malaysian urban water from local resources by recycled water as a strong point of the project concerning supplying drinking water, which confirms the results of this study. After that, the S1 component, i.e., improving water-use allocative efficiency in different sectors (urban and agriculture), ranked second with a score of 0.087.

Among the weaknesses, 'lack of advanced wastewater treatment plants for treating wastewater in Mashhad' (W1), and 'quality problems and sustainability of the treated water's quality' (W6) were identified as the highly prioritized weaknesses of the project, with their scores being equal. According to the experts' views, the treated urban wastewater has a low quality for agricultural irrigation, and the water's quality lacks the required sustainability and the WHO's standards for irrigating different crops (Heidari 2018). Table 4 shows other identified factors with their obtained weights.

Following the determination of internal factors' weights via the AHP method, the rank of each factor was calculated and placed in the fourth column of Table 4. Then, each factor's final score was calculated by multiplying its weight by its rank (the fifth column of Table 4). Finally, the factors' weight scores were added together, and the internal matrix's total score was calculated as 2.870. As the total score calculated for the internal factors is more than 2.5, it could be argued that Mashhad's strengths in replacing the treated wastewater with agricultural water outweigh its weaknesses, and if appropriate strategies are adopted for this region, a promising future could be expected for the implementation of the project.

Table 4 | Matrix of the internal factors involved in Mashhad's water exchange project

No.	Internal factors	Weighing factor	Rank	Final score
S1	Improving water-use allocative efficiency in different sectors (urban and agricultural)	0.087	3.684	0.320
S2	Supplying the required water from sustainable local water resources	0.253	3.839	0.972
S3	Existence of agricultural water wells with safe and high-quality water	0.072	3.684	0.265
S4	A considerable volume of treated wastewater for replacement	0.070	3.394	0.237
S5	Lower costs of the exchange project compared with other urban water supply projects	0.085	3.536	0.301
S6	The greater willingness of the decision-makers (the managers of the relevant organization) towards the water exchange project and support of the water experts, academia, and researchers for this project	0.055	3.126	0.171
S7	Constant access of all users (in both urban and agricultural sectors) to safe and high-quality water (water security)	0.064	3.257	0.209
W1	Shortage of advanced wastewater treatment plants for treating wastewater	0.087	1.104	0.096
W2	Insufficient knowledge and inexperience of the staff working in the relevant organization responsible for recycled water (distribution management of the treated wastewater).	0.013	1.486	0.020
W3	Scarcity of special studies such as the farmers' and consumers' attitudes regarding the exchange project in the study area	0.030	1.219	0.037
W4	Inappropriateness of the treated wastewater's quality for irrigating different crops	0.045	1.346	0.061
W5	Delay in presenting adequate and understandable explanations regarding the new water resource for public understanding and training	0.025	1.486	0.037
W6	Quality problems and the sustainability of the recycled water's quality	0.087	1.104	0.096
W7	Lack of a precise mechanism for determining the replacement ratio and the contract term regarding the water exchange project	0.026	1.811	0.048
Total		1		2.870

Table 5 | The matrix of the external factors involved in Mashhad's water exchange project

No.	External factor	Weighing factor	Rank	Final score
O1	More willingness of the urban water's consumers to pay for higher quality water	0.038	3.536	0.133
O2	The possibility of attracting private sector's investments	0.029	3.394	0.100
O3	Writing the draft of law regarding the treated wastewater management and passing the enactment concerning supplying urban water from the intersectoral water exchange project	0.029	3.536	0.104
O4	A good possibility to introduce recycled water as an alternative resource	0.075	3	0.226
O5	Encouraging participation and increasing motivation of, and creating confidence in society concerning water recycling projects	0.19	3.536	0.067
O6	Reduced environmental degradation	0.042	3.126	0.131
O7	Job creation (existence of available cheap native labor)	0.010	3.394	0.036
T1	Possible social, ethnic, and cultural resistance to the implementation of the water exchange project	0.111	1.641	0.182
T2	Potential health risks for the farmers and consumers of the products irrigated with the recycled water	0.084	1.346	0.113
T3	Possibility of microbial contamination of the plants, the groundwater resources, and the environment	0.071	1.346	0.096
T4	Possible consumers' rejection of the products irrigated with recycled water	0.178	1.346	0.240
T5	Lack of organizational coordination among the relevant organizations involved in the exchange project	0.134	1.104	0.148
T6	The possible negative effect of recycled water on soil's quality in the long term	0.048	1.486	0.072
T7	Possible technical, economic, and sanitary rejection of the recycled water by the farmers	0.130	1.219	0.158
	Total	1		1.806

The weights and rankings of the sub-factors of opportunities and threats (external factors) obtained via the AHP method are shown in Table 5, based on which seven opportunities and seven threats were identified for the implementation of water exchange project in Mashhad. The results indicated that 'a good possibility of introducing recycled water as the alternative resource (O4)' was prioritized as the most important factor with a score of 0.075 (the third column in Table 5). According to the experts' views in this study, introducing recycled water as an alternative resource for water supply in a situation when Mashhad faces water shortages could significantly increase its residents' knowledge regarding the alternative resources and thus help implement the water exchange project. The next rank belongs to O1. The experts in this study argued that urban residents were more willing to pay for urban or ecological use of agricultural water than rural residents do, indicating that urban residents are more interested in improving the environment and the water quality, which would in turn lead to the increased water value in urban areas. Therefore, Mashhad's Regional Water Company can use this opportunity to implement the water exchange project. The study carried out by Wang *et al.* (2019) also points to the greater willingness of urban consumers to pay for agricultural water, which confirms this study's results.

On the other hand, the T4 component, which is related to the consumers' rejection of the products irrigated with recycled water, was ranked as the first priority among the threats, indicating that the experts were concerned about the consumers' rejection of the products irrigated with recycled water. For instance, in 2008, American consumers avoided using the blueberries produced from recycled water in the United States (Savchenko *et al.* 2018). The possibility of social, ethnic, and cultural resistance against the implementation of the water exchange project (T1) and the technical, economic, and sanitary rejection of the recycled water by the farmers (T7) were ranked second and third in terms of priority among the threats, respectively. Table 5 shows other identified external factors with their obtained weights.

After calculating the external factors' weights via the AHP method, the rank of each factor was calculated and placed in the fourth column of Table 5. Then, each factor's final score was calculated by multiplying its weight by its rank (fifth column of Table 5). Finally, the factors' weight scores were added together, and the external matrix's total score was calculated as 1.806, suggesting that the threats regarding the project of replacing the treated wastewater with agricultural water in Mashhad outweigh the project's opportunities. However, such threats could be reduced if appropriate strategies are devised.

SWOT matrix and strategic position

Figure 5 shows the matrix of the strategies of Mashhad's water exchange project. The total scores' cross-point regarding the internal and external scores of the factors involved in Mashhad's water exchange project, which are shown on horizontal and vertical axes, determine the position of the cross-point in the matrix of the strategies. The suitable strategy derived from the IFE and EFE analysis is a competitive strategy. Thus, ST strategies that are also called competitive strategies (gradual improvement) should be adopted in the development of Mashhad's water exchange project, indicating that decision-makers should seek strategies for improving the strengths to avoid external threats. Conversely, as the strategic position of Mashhad's water exchange project is close to ST and WT strategies' common line, which suggests the possibility of getting into the WT area with the slightest change, WT strategies were adopted for the project. Based on the above analysis and its

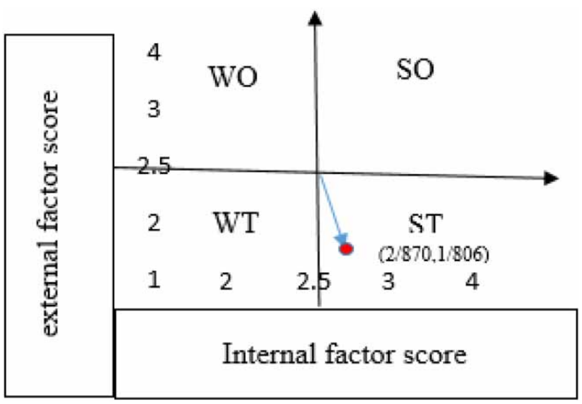


Figure 5 | Graphic display of the priorities of experts' decisions regarding the implementation of the water exchange project in Mashhad, Iran.

comparison with the previous study results, the most important ST and WT strategies involved in developing Mashhad's water exchange project were considered in Table 6.

F-TOPSIS

The F-TOPSIS method was used to prioritize the water exchange project's strategies following the development of a fuzzy decision matrix, normal fuzzy decision matrix, and normal balanced fuzzy decision matrix according to each internal and external factor identified in this study. The sixth column of Table 6 represents the ranking of the water exchange project's strategies in Mashhad, which are summarized in relation to their rankings as follows.

ST8 strategy: rank 1

Disclosing information about recycled water has the most significant effect on public awareness and acceptance. Thus, public awareness regarding water shortages, the necessity of using recycled water, and awareness concerning environmental responsibility can effectively enhance public acceptance of the recycled water (Hou *et al.* 2020). Different stakeholders involved in the process, including the government and regional water company, should concentrate on developing preventive measures in educating the public about the benefits of consuming recycled water before implementing the water exchange project and inform the society of the goals and benefits of the project (Van Rossum 2020).

ST4 strategy: rank 2

Considering the fact that the intersectoral water exchange project is implemented for the first time in Iran and Mashhad, the project is regarded as an innovation in water resources institutionally (Scott *et al.* 2007). Thus, it is necessary to devise an appropriate organizational structure for the intersectoral water exchange project by getting the relevant departments and stakeholders involved. Moreover, the implementation of the project should start by exchanging memorandums of understanding between the relevant organizations (Mainali *et al.* 2011a).

Table 6 | Final ranking of eleven water exchange strategies identified via FTOPSIS method

No.	ST strategies	d_i^+	d_i^-	C_i^*	Rank
WT1	Considering the necessity of social, cultural, and economic studies and including their results in the project	0.551	0.572	0.509	4
WT2	Improving the recycled water's quality according to the standards of the World Health Organization and the United States Environmental Organization by equipping and upgrading the urban wastewater treatment systems	0.552	0.592	0.517	3
ST1	Employing public health professionals in the water exchange project	0.613	0.522	0.460	11
ST2	Adopting a bottom-up approach to get the farmers to participate in implementing the exchange project by creating water unions as the sub-branches of the agricultural and rural cooperatives	0.578	0.550	0.488	6
ST3	Increasing adequate financial and non-financial incentives to encourage farmers to participate in the water exchange project	0.608	0.538	0.470	9
ST4	Devising an appropriate organizational structure and exchanging some memorandums of understanding concerning the water exchange project and requiring all parties involved to observe the agreements	0.523	0.623	0.544	2
ST5	Developing consumer awareness programs through social marketing of irrigated water products' benefits	0.576	0.559	0.492	5
ST6	Farmers' awareness about useful economic and non-economic aspects of using recycled water	0.616	0.547	0.470	8
ST7	Designing a cultivation pattern appropriate to the treated wastewater's quality and selecting a suitable irrigation method to reduce the farmers' and consumers' health risks	0.613	0.535	0.466	10
ST8	Organizing educational and awareness campaigns (information disclosure) and activating provincial and local media to present and publish useful information concerning the exchange project's goals	0.507	0.619	0.550	1
ST9	Appointing social consultants to change the farmers' attitudes towards recycled water	0.603	0.552	0.478	7

WT2 strategy: rank 3

Improving the treated wastewater's quality according to the World Health Organization's standards plays a very important role, being considered as one of the essential pillars of recycled water's public reception in society (Janeiro *et al.* 2020). However, as equipping and upgrading wastewater treatment systems is not guaranteed in developing countries like Iran due to insufficient financial resources, complementary strategies need to be adopted.

WT1 strategy: rank 4

Implementing an intersectoral water exchange project requires precise social and economic studies at the community and farm level before the implementation of the project, as in such projects, it is necessary to act based on social, economic, and cultural conditions of each region. For instance, in a study carried out by Australian researchers, this strategy was suggested as one of the most important priorities of the research (Mainali *et al.* 2011a).

ST5 strategy: rank 5

Since consumers have little information about agricultural processes, finding the best way to present information about recycled water as a safe and sustainable irrigation method is crucially important (Saliba *et al.* 2018). Therefore, social marketing of products is recommended in this regard, which includes increasing awareness concerning the benefits of this project and presenting sufficient knowledge about the products' origins and quality (Savchenko *et al.* 2018). In fact, consumers will pay more for products made from recycled water when they have the correct information regarding the processes related to using recycled water.

ST2 strategy: rank 6

Getting the farmers to participate is of crucial importance in water exchange projects (Mainali *et al.* 2011a). In this regard, adopting a bottom-up approach which is regarded as a participatory method could help recognize the demands of the local stakeholders and the region's reality. Thus, establishing water associations as sub-branches of the agricultural and rural cooperatives could pave the way for the participation of farmers in implementing the water exchange project.

ST9 strategy: rank 7

Acceptance or rejection of the treated wastewater by farmers depends on specific cultural, religious, social, and economic conditions, with the social factors being recognized as more important challenges in accepting the treated wastewater by farmers than the technical and economic ones (Ricart *et al.* 2019). Therefore, considering that many studies have emphasized the role of behavioral interventions in farmers' attitudes towards recycled water (Savchenko *et al.* 2018), holding consultation meetings with farmers regarding the treated wastewater can be helpful in the acceptance of the project in Mashhad.

ST6 strategy: rank 8

Farmers' acceptance of treated wastewater depends on their awareness of its benefits (Saliba *et al.* 2018). Therefore, making the farmers aware that using recycled water for irrigation could help save costs, build confidence in irrigation, increase in cultivated area and reduce the use of fertilizers due to the existence of nutrients in the treated wastewater is of crucial importance. Reducing costs and increasing the efficiency can increase the net income of the farm (Heinz *et al.* 2011b). In Spain, Mexico, and India, where the cities' officials informed farmers of the benefits of using treated wastewater, the farmers were willing to spend significantly more than before to enjoy such benefits (Deh-Haghi *et al.* 2020).

ST3 strategy: rank 9

Economic and non-economic incentives to use recycled water instead of conventional water can be very influential in the acceptance of treated urban wastewater (Heinz *et al.* 2011a). In other words, offering appropriate incentives such as allocating more treated wastewater to be exchanged for agricultural water, and non-financial incentives such as training courses can be effective in increasing farmers' willingness to use treated wastewater for irrigation (Deh-Haghi *et al.* 2020).

ST7 and ST1 strategies were ranked 10th and 11th in terms of priority, respectively. Practically, in cases where advanced wastewater treatment plants are not available in developing countries, product selection, irrigation methods, and post-irrigation harvesting methods are necessary for reducing pollution risks depending on the quality of recycled water (Janeiro *et al.* 2020). Thus, as the conditions for using treated wastewater for irrigation are limited in Mashhad, observing the above points is necessary. Moreover, according to the experts' views in this study, public health professionals must be employed in different stages of water reuse projects, from wastewater treatment to instructing safety tips to farmers.

Therefore, should the strategies mentioned above be appropriately implemented in order of their priority, Mashhad's water exchange project will be implemented successfully, and with the full implementation of prioritized strategies, the importance of subsequent strategies may decrease. Thus, the order of employing the strategies to implement the exchange project is of great importance.

CONCLUSION

This study investigated important factors influencing the exchange of the recycled wastewater with agricultural water to supply urban water of the city of Mashhad in northeast Iran. These factors were also used in devising effective strategies for supplying urban water to Mashhad. As part of the SWOT analysis, fourteen internal factors, including seven strengths and seven weaknesses, and fourteen external factors, including seven opportunities and seven threats regarding this case study were identified and scored. Supplying the required water from sustainable local water resources (S2), and a good possibility to introduce recycled water as an alternative resource (O4) are the most important factors among the strengths and opportunities that lead to the development of the implementation of the water exchange project. Quality problems, the sustainability of the recycled water's quality (W7), and consumers' rejection of the products irrigated by the recycled water (T4) are the most significant weaknesses and threats identified for the project, respectively.

In this study, the internal and external factors' scores were found to be 2.870 and 1.806, respectively. Based on the analysis of the position of the IFE/EFE matrix, competitive strategies (ST) need to be adopted for implementing Mashhad's water exchange project, indicating that the project's decision-makers should take the strengths into account in their devised strategies to avoid external threats. The results of F-TOPSIS showed that ST8, ST4, WT2, WT1, ST5, and ST2 were the best strategies for implementing the project, suggesting that developing educational and awareness-raising campaigns, devising an appropriate organizational structure and exchanging memorandum of understanding, enhancing the treated wastewater's quality according to international standards, taking the necessity of conducting social, cultural, and economic studies into account, developing consumers' awareness programs, and informing and supporting the farmers are among the main factors involved in the implementation of the water exchange project in Mashhad. Therefore, developing educational and outreach programs for farmers and consumers is highly important. Moreover, designing a cultivation pattern appropriate for the treated wastewater's quality and selecting a suitable irrigation method would reduce farmers' and consumers' health risks.

The method used in this study allows us to objectively consider the factors involved in the water exchange project in an Iranian city by combining quantitative and qualitative approaches. Future studies could conduct this study in other regions using other multiple-criteria decision-making (MCDA) methods, and compare the obtained results with the current study's findings.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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