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A framework for optimal water allocation considering water value, strategic management and conflict resolution

Meraj Sohrabi[1] · Zeynab Banoo Ahani Amineh[2] · Mohammad Hossein Niksokhan[1] · Hossein Zanjanian[1]

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Abstract
This paper proposes a new framework to optimize the allocation of water resources considering two perspectives of water value and strategic management which is one of the novelties of this study. After identifying agricultural, industrial, and domestic water demands, a water allocation model is developed to maximize the net benefit of water delivered to each sector. Based on the characteristics of the study area which is the Namak Lake basin, water transfer from Dez tributaries can be considered as an uncertainty depending on the climate and political issues. So, the model is initially performed without considering water transfer and then water transfer is considered to enhance the flexibility. In addition, the initial model does not assign the weights to the plain. In the novel model, weights derived from questionnaires are applied to reflect experts' opinions and consider the priorities of the plains. Transferred water is then allocated from the strategic management perspective and the water value perspective (six possible combinations of perspectives and scenarios), and eleven independent variables are considered in the model. Also, GMCR+, the new version of the Graph Model for Conflict Resolution, is applied to visualize the possible scenarios and equilibrium states based on the status quo of the conflict. Based on the results, the first scenario of water value perspective is chosen which results in a significant water allocation to the industry and agriculture sectors (approximately 94% and 96%, respectively). Also, 94.6% of potable water is satisfied compared to the initial water needs.

✉ Mohammad Hossein Niksokhan
niksokhan@ut.ac.ir

Meraj Sohrabi
meraj.sohrabi@ut.ac.ir

Zeynab Banoo Ahani Amineh
zbahani@gmail.com

Hossein Zanjanian
h_zanjanian@ut.ac.ir

[1] School of Environment, College of Engineering, University of Tehran, Tehran, Iran

[2] Civil Engineering Department, Sharif University of Technology, Tehran, Iran

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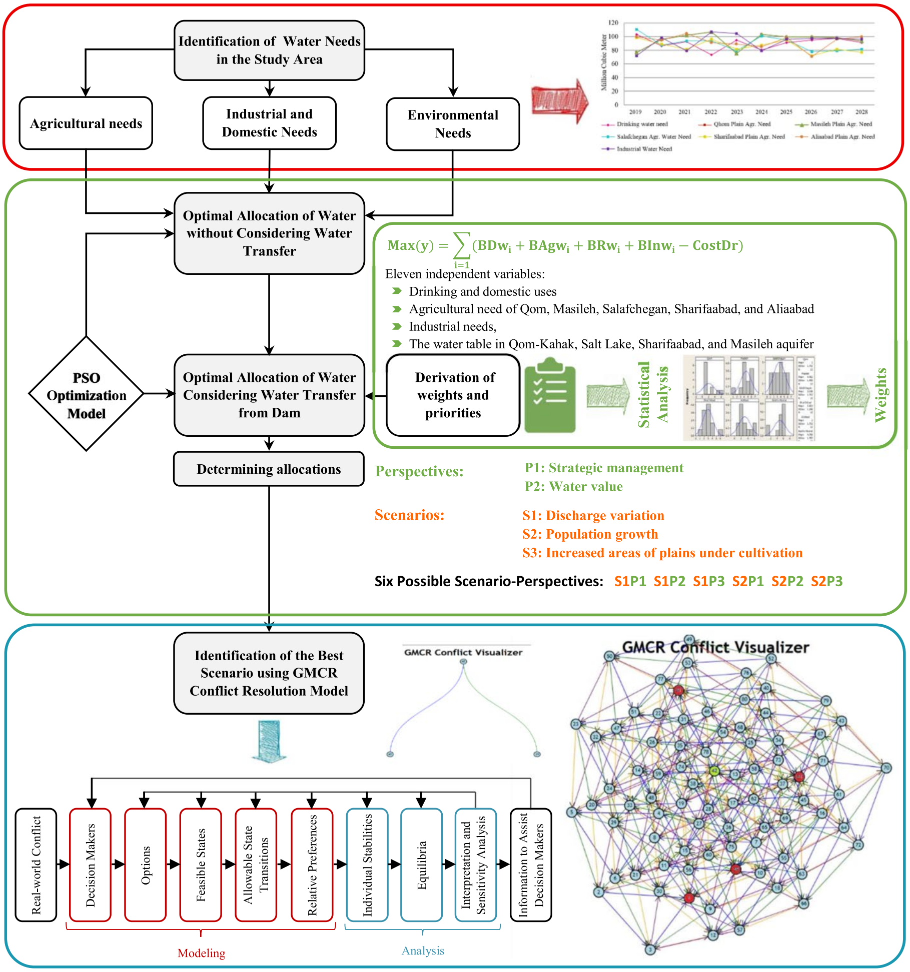
Graphical Abstract



Keywords Water management · Demand · Value · Game theory · Optimization

1 Introduction

Nowadays, water allocation is a major problem in water resources planning and management considering water limitation and scarcity, population growth, agriculture and industrial uses, and food security (Dinar et al., 1997). There are many goals, stakeholders, and researchers are trying to improve allocation criteria. Among these criteria, economic issues are important parts in which researchers benefit from multi-objective optimization to deal with the problem (Guo et al., 2014; Roozbahani et al., 2015). In addition, water demand varies per nation due to variations in hydrological parameters (Wang et al., 2016). For example, climate change has raised certain plants and animals' water needs. Economic growth and decreasing precipitation have limited human water availability (Yao et al., 2019). So, water scarcity problems arise as *demand for water hits the* limits of finite supply. Water allocation especially in water transfer projects implemented to overcome such a crisis often results in water conflicts among water users and stakeholders. Therefore, conflict resolution is an essential component of water resource management, particularly in the case of water transfer systems, and various quantitative and qualitative methods have been proposed for it. Game theory provides a framework for studying the strategic actions of individual decision-makers to develop more broadly acceptable solutions to conflict resolution (Madani, 2010).

There are some scholars related to multi-objective optimization of water allocation. Davijani et al. (2016) presented a two objective socioeconomic model to optimize water resources allocation in the agricultural and industrial water sector based on productivity and price and fulfill the municipal water requirements. Jamshidi et al. (2016) developed a waste load allocation model considering economic issue and water market. Feng (2021) developed a multi-objective dynamic model to achieve optimal allocation of water resources by considering maximizing the efficient utilization, economic benefits, and minimum satisfaction in the different water sectors at the same time. Li et al. (2020) try to find an answer for improving irrigation water use efficiency under different water scarcity and uncertainty levels. Liu et al. (2020) defined water safety allocation conception based on natural flow direction and artificial transferring of water resources between sub-basins. Aalami et al. (2020) developed a multi-objective water allocation model based on first maximizing water allocation equality and secondly, minimize the risk of fluctuations in available water in the economic efficiency.

In the previous studies, in water allocation among water users and stakeholders, some tools such as optimization models or economic goals have been applied to solve the water resources problems. Economic goals encompass increasing the efficiency and economic benefits of local water resources, as well as increasing the GDP (Guo et al., 2014). So, in water allocation problems, researchers benefited from economic goals to increase economic benefit which is defined by the production value of each stakeholder (Zhang et al., 2021). Lack of integrated approach in water allocation incorporating the preference of water users as stakeholders (player), water economic value, and strategic criteria could be distinguished. Thus, the methodology of this study has been proposed for doing this idea.

Also, based on different stakeholders and conflicting goals, in the proposed methodologies of past researches, game theory, and conflict resolution has been considered. In this regard, non-cooperative game theory deals with non-cooperative games in which players compete and make decisions independently, whereas cooperative game theory deals with cooperative games in which groups or coalitions of players make decisions together and involves the allocation of benefits from cooperation. Carraro et al. (2005), Parrachino et al. (2006), and Zara et al. (2006) reviewed studies related to game theoretic water conflict resolution. Thoyer et al. (2001) and Simon et al. (2007) used non-cooperative game theory and performed a quantitative analysis to model negotiations over-irrigation quotas, water price, and reservoir sizes among seven aggregate players. Loaiciga (2004) studied the role of cooperation and non-cooperation on the sustainability of groundwater extraction. Ambec and Ehlers (2008) used cooperative game theory for the efficient apportioning of a river among satiable agents. Wang et al. (2008) applied cooperative game theory to allocate water equitably and efficiently among users at the basin level.

In addition, some studies indicated the application of multi-objective optimization and game theory in water resources management. Madani (2010) tries to explain why predicted results by game theory usually differ from outcomes suggested by optimization models. He employed game theory to address conflict resolution through non-cooperative water resource games in water resources management. Sustainable polices for water allocation must consider environmental needs as well as other stakeholders. Akbari et al. (2014) defined environment as an independent water user in their optimization model and as an independent player in the cooperative game theory study. Behboudian et al. (2021) considered various aspects of hydrological ecosystem services for evaluating their water resources management (WRM) scenarios. They used and prioritized WRM scenarios based on evidential reasoning game theory technique with multiple decision-makers. Janjua and Hassan (2020) introduced a new methodology in a complex system to allocate water resources using stochastic game theory under water scarcity conditions. The conflict over water resources between rural and agricultural sectors has been an increase during the last decades. Therefore, the importance of using optimized solutions for water allocation models is unavoidable. Chen et al. (2020) and Wang et al. (2020) try to address this problem using a different optimization algorithm. Comparing AHP and symmetric methods showed water allocation could be more efficient in the use of cooperative bargaining games (Hemati & Abrishamchi, 2020).

Graph Model for Conflict Resolution (GMCR) is considered as the non-cooperative approach that resolves the conflicts based on the status quo to reach a probable equilibrium. To use GMCR in water resources management, Madani and Hipel (2007) applied this model and non-cooperative solution concepts considering the conflict between Israel and the Arab nations over the Jordan River and determined the most likely outcomes of the conflict problem. In Iran, GMCR has been employed to solve the conflict in Zayandehroud basin. The sustainable water allocation scenarios are extracted by GMCR and used in a simulation model to supply consumers' water demand (Mehrparvar et al., 2019). Also, Zanjanian et al. (2018) analyzed the conflict of water allocation in the Ilam dam among organizational stakeholders using GMCR +.

Moreover, the first versions of GMCR were released in 1990 and 1997 named GMCR I (or GMCA) and GMCR II, respectively. In GMCRII model (Hipel et al., 1997), the conflict analysis has conducted indirectly based on the status quo, while after the software development, known as GMCR + (Kinsara et al., 2015), the output of the conflict analysis could be visualized by graph and tree modes, and it would be possible to reach the probable equilibrium based on the status quo of the conflict by post analysis feature. Furthermore, unlike GMCRII, which can only model the conflict for a maximum of 5 actors and 100 feasible states, GMCR + can model the conflict for an unlimited number of actors and conflict states (depending on the system processor) (Kinsara et al., 2015). So, the mentioned capabilities of GMCR + have led to using this version in this study. Also, due to the goals of this study which are to maximize the net benefit and reducing conflicts among stakeholders, GMCR + could be visualized the outcome of the conflict resolution in which decision makers having a clear understanding of the future of the conflict (probable equilibrium).

In this study, an optimization model for allocation of water resources based on two perspectives (1) water economic value and (2) strategic management perspective is developed under existing situations and considering transfer projects. The optimal water allocation has been identified with and without considering the transfer of water from the dam. The goal is to maximize the net benefit of using water in different sectors and decreasing conflicts. Three scenarios: discharge variation, population growth, and increased areas of plains under cultivation have been designed in this research. Finally, the best scenario has been selected using GMCR + based on the preference of decision-makers and status quo of the conflict.

2 Materials and methods

The process of conducting the study involves the following steps represented in Fig. 1.

In the next parts, detail of the methods is described.

2.1 Particle swarm optimization (PSO)

Advances in computing systems are leading to broader adoption of modern optimization models compared to classical models. In recent years, modern optimization modeling techniques, particularly particle swarm optimization model, have found widespread application in the quantitative–qualitative management of water resources.

Particle swarm optimization, developed by Kennedy and Eberhart, is a method for optimizing complex numerical functions on the metaphor of social behavior of flocks of birds and schools of fish (Kennedy & Eberhart, 1995, 1997; Shi & Eberhart, 1998). A swarm consists of individuals, called particles, which change their positions over time. Each particle represents a potential solution to the problem. In a PSO system, particles fly around in a multi-dimensional search space. During their flight, each particle adjusts its position according to its own experience and the experience of its neighboring particles, using the best location encountered by itself and its neighbors. The effect is that particles move toward the better solution location while still searching a wide area around the better solution areas. The performance of each particle is measured according to a pre-defined fitness function related to the problem to be solved. The PSO is a robust and fast method of solving non-linear, non-differentiable, and multi-modal problems (Fan, 2002).

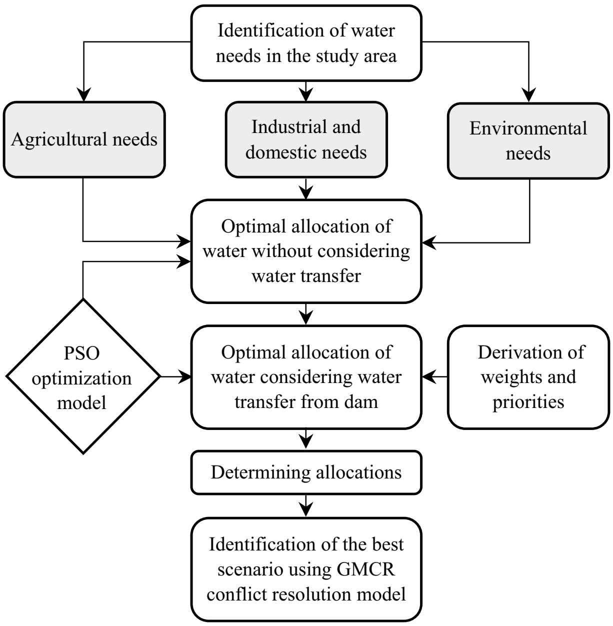


Fig. 1 The Proposed framework of the study

2.2 Game theory

Game theory is a field of applied mathematics providing a better understanding of water resource conflicts and their effective management in positive and strategic ways (Madani, 2010). It is trying to obtain the mathematical behavior of a system in a strategic or game-based manner in which the individual's success in the choosing process depends on the choice of others. (Madani & Hipel, 2011).

In the game theory, potential resolutions to a conflict are found through stability analysis, based on stability definitions having precise mathematical structures. A stability definition reflects a decision maker's behavior in a game, predicts how the game is played and suggests the resolutions or equilibria of the dispute (Madani & Hipel, 2011).

Due to the increasing water shortage and the growing disputes over water withdrawal, it is almost impossible to employ cooperative games to solve water allocation problems and satisfy the stakeholders, especially stakeholders with contrasting interests and opposed political orientations. This has motivated non-cooperative games for developing sustainable scenarios and solutions for water allocation problems. The application of cooperative games is restricted to situations in which coalitions can be established among stakeholders by a single decision-maker with sufficient authority and power, while non-cooperative games are applied to conflicts in which no interaction or agreement can be envisioned among the players or stakeholders who have their independent powers in the decision-making process. In such situations, players usually seek their interests and desire to gain more authority and a louder voice in making decisions. (Mehrparvar et al., 2016).

2.3 The GMCR model

In game theory, based on the concept of quantitative and non-quantitative models, Graph Model for Conflict Resolution (GMCR) is an approach for modeling the non-quantitative conflicts (Kilgour & Hipel, 2005). Modeling of the conflict by this method encompasses 6 stages, including definition of conflict, choosing key players, investigation of players' strategies, the elimination of infeasible states, the definition of allowable state transitions, and ranking relative preferences. Moreover, this model benefits from 4 stability concepts, including Nash Stability (Nash, 1951), General Meta-rationality (GMR) (Howard, 1971), Sequential stability (SEQ) (Fraser & Hipel, 1979), and Symmetric Meta-rationality (SMR) (Howard, 1971) which related definitions and formula can be found in the references. If a conflict state is stable for all involved players in a stability concept (e.g., Nash stability), it will be an equilibrium state. So, this method can display 4 equilibria, and it can reveal probable equilibrium state by the status quo of conflict. The reason for choosing the GMCR as a framework is the simplicity and flexibility of its approach while maintaining robustness and practicality in predicting outcomes (Fang et al., 1989, 1993; Inohara, 2011; Kilgour et al., 1987).

2.3.1 Procedure

The basic procedure of GMCR involves two main stages: modeling and analysis. In the modeling stage, the user identifies the conflict parameters as decision-makers (DMs), options for each DM, infeasible states (such as mutually exclusive states), allowable transitions among states, and relative preferences (Kinsara et al., 2014).

After identifying the conflict parameters, the user will analyze the conflict from each DM perspective to determine the likely final resolution. This stage includes the following (Kinsara et al., 2014):

(1) Determining individual stability for each DM.
(2) Overall equilibria.
(3) Sensitivity analysis.

The flow chart in Fig. 2 illustrates the forgoing basic GMCR procedure (adapted from Fang et al., 1993). The feedback loops indicate how to update the model.

3 Notation and Definitions

The graph model representing a real-world conflict includes DMs, options, and preferences. These parameters are defined as following (Kinsara et al., 2014):

Definition 1 Let $N=\{1, 2,..., n\}$ represent the set of DMs. For each $DM_i \in N$, the set O_i is i's options. Let $S=\{s_1, s_2,..., s_m\}$ represent the set of feasible states. An option is Yes (Y) or No (N) choice controlled by a particular DM. Each DM has at its disposal at least one option.

The set of possible states in a conflict is represented by the expression 2^O where $O=O_1 \cup O_2 \cup \ldots \cup O_n$. Some possible states may be infeasible, such as when options are mutually exclusive options. The remaining states are the feasible states for the model.

Definition 2 Let $i \in N$ and $s \in S$. The reachable list of DM_i from state $s \in S$ is defined as:

$$R_i(s) = \{s_a \in S : (s, s_a) \in A_i\} \tag{1}$$

The move in one step, by DM_i from a state s to a state s_a in $R_i(s)$, is called a unilateral move (UM).

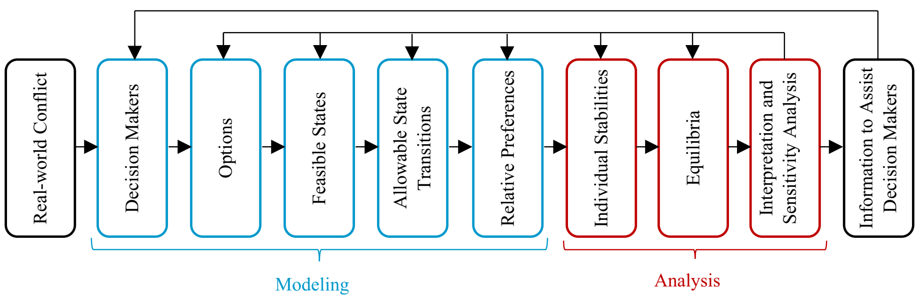


Fig. 2 Basic procedure of applying the GMCR methodology to a real-world conflict (adapted from Fang et al, 1993)

Definition 3 For each $DM_i \in N$, a directed graph $D_i = (S, A_i)$ can be used to model the possible moves of the conflict and the feasible states of a conflict are represented by vertices in the graph model. In graph D_i, an arc A_i exists between states sa and $s_b \in S$ if DM_i can move unilaterally in one step from s_a to s_b. It is called a directed graph because the arc has an orientation that can be one-way (irreversible move) or two-way (reversible move).

The preference information of DM_i is a binary relation $\{\succ i, \sim i\}$ over S, where $s_a \succ i\ s_b$ means that DM_i prefers sa to sb and $s_a \sim i\ s_b$ means that DM_i is indifferent between states sa and s_b. The binary relations $\{\succ i, \sim i\}$ are assumed complete. Each DM has a preference information in the form of states ordered from the most preferred state to the least preferred state and equally preferred states are denoted by a bar above them. Strict ordinal preferences mean no equally preferred states are allowed.

Definition 4 Let $i \in N$ and $s \in S$. The unilateral improvement (UI) list for DM_i from state $s \in S$ is defined as:

$$R_i^+(s) = \{s_a \in R_i(s) : s_a \succ \text{is}\} \tag{2}$$

The move in one step by DM_i from a state s to a state sa in $R^+{}_i$ (s) is called an UI.

According to different kinds of mentality, different types of DMs may behave differently, so several different stability definitions were proposed, including Nash Stability (Nash), General Meta-rationality (GMR), Symmetric Meta-rationality (SMR), Sequential Stability (SEQ (Kilgour & Hipel, 2005). For identifying these stability definitions, a unilateral improvement concept is defined to offer a rule to judge whether a DM would stay at the current state or unilaterally move to another state from the current state. If the focal DM is not motivated to move from the current state to another state, the current state is called a stable mode according to an appropriate stability definition. A mode fixed for all DMs in the conflict is called equilibrium. The methodology has been used to analyze the real-world case (Hipel et al., 1993).

In this study, agricultural, industrial, and domestic water demands were identified. The water allocation model was developed without considering water transfer from Dez tributaries using these values. The allocation was made from water value and strategic management perspectives. The importance of water for the region's future and the project profitability from the economic resiliency point of view were the reasons for selecting these perspectives. The allocation was again made considering the transfer of the water from Dez Dam. Finally, the best strategy was identified by applying game theory to the conflict; the output of the models was presented and discussed.

4 Study area

The Namak Lake Basin is located in the western part of the central desert of Iran, between the 52° 31′ to 48° 10′ eastern longitude and 32° 51′ to 36° 31′ north latitude, having an area of 92,560 km^2 (Fig. 3).

This basin accounts for 5.6% of Iran's total area which most of it located in the Markazi and Qom provinces having a climatic, geomorphological, and geological diversity. The existence of the metropolis Tehran and critical military, political, industrial, and agricultural centers emphasizes the importance of this basin. In addition to strategic importance, the existence of the Namak Lake in the outlet of this basin and its drying in recent years

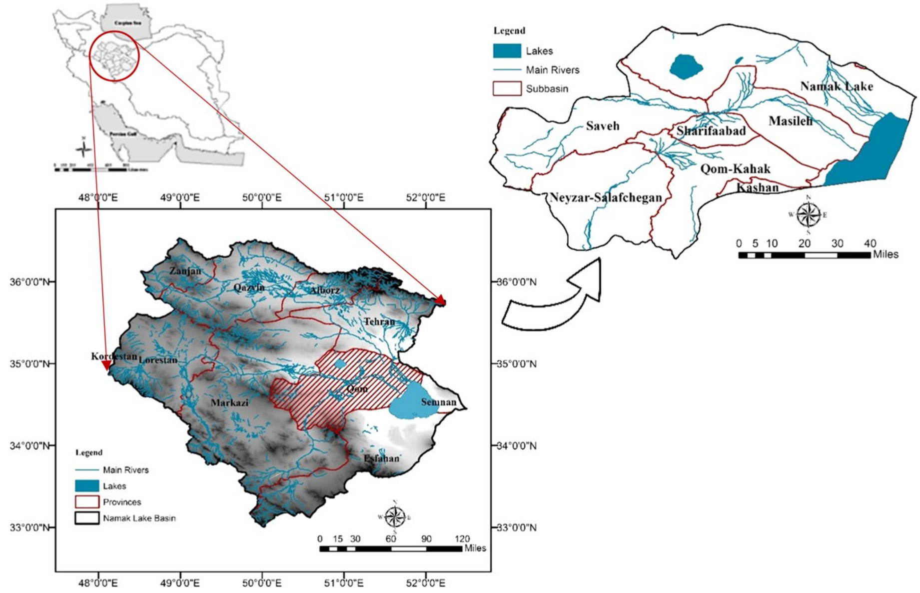


Fig. 3 Location map of the study area (Namak Lake Basin)

has become an important environmental, social, and economic crisis in the region, affected a large part of the country. It comprises six major rivers including Karaj, Jajrood, Shoor, Qara-Chai, Qom-Rood, and Bon-Rood. Qom province is part of the main central plateau basin of the six main basins of the country and part of the Namak Lake basin. The province covers the entire or part of the seven study areas of Masileh, Sharifaabad, Qom, Namak Lake, Saveh, Salafchegan-Neyzar, and Kashan.

5 Results and discussion

In recent years, the increasing rate of population growth and global economic development has raised the demand for water resources and has led to serious conflicts and disputes over the watershed and river basin management. Meanwhile, shared water resources used by two or more stakeholders complicate their management and planning further. Asymmetrical information, power, and authority are the source of existing conflicts among users. This asymmetry gives more strategic power to some stakeholders in making decisions about distributing and using the water resources of the basin. Different steps for preparing the prescribed models are explained in the following sections:

5.1 Determining the region's water needs

The first step in allocation problems is the delineation of the existing conditions and demands of the area under study. These demands are classified into three main classes: domestic, agricultural, and industrial.

5.1.1 Drinking water use

The amount of drinking water consumption in recent decades has significantly increased. Therefore, devoting more attention to drinking water and hygiene sectors are of great importance, and though drinking water accounts for a lower percentage of total consumption, its supply is more crucial. Two percent of the urban and one percent of the rural population resides in Qom province. The province population and household consumption have increased by 11 and 7 percent, respectively, in recent four years due to the welcoming immigration system of the province (Regional Water Company of Qom, 2019).

The water treatment plant in the proximity of the 15-Khordad Dam treats 55 Million Cubic Meters (MCM) of dam lake water annually and transfers it to Qom city through pipelines. Around 56 wells provide part of the water needs in the study area. A summary of the number of consumers and average consumption volume is represented in Tables 1, 2 and 3.

5.1.2 Agricultural water use

Identification of agricultural water needs depends on the types of crops and the region under study. Only four types of strategic crops (wheat, barley, cotton, and sunflower) in the study area are considered to simplify and reduce required calculations.

In the year 2015, the lowest crop production share was for Qom province (0.4 percent), which proves its insignificant role in the country's agriculture. According to the statistical data, 50,703 hectares of Qom province lands are under cultivation, of which 6 percent is dryland farming (Jihad Agriculture Organization of Qom, 2015). The total area under dryland farming is allocated to wheat production because only dryland farming of this crop is possible in the area. Thus, 96 percent of cultivation in Qom province is by irrigation, which proves that the agricultural sector relies on water supply. The largest area under cultivation belongs to barley (43.55%), wheat (17.44%), and alfalfa (16.41%). In other word, 77.4 percent of agricultural cultivation belongs to barley, wheat, and alfalfa (Jihad Agriculture Organization of Qom, 2015). Gross agricultural water needs per hectare for each crop are given in Table 4. Due to the great importance and the role of water in this study, monthly water resource limitations are imposed and presented for each crop.

5.1.3 Industrial water use

Industrial water is water used for drinking purposes, landscape irrigation, and production processes. Qom province comprises 1390 active decentralized trade units, located in a land of 814 hectares having 1780 workers. In addition, three industrial parks exist in Qom province, having over 468 active industrial units and 6300 employees. The Shokoohieh industrial park has the maximum number of active units (77 percent) of the industrial parks in Qom province. Three thousand five hundred and sixty-nine persons are working in modern animal husbandry units of the region, with poultry farms having the highest share. Details of Qom modern animal husbandry alongside a summary of Qom industries and mines are provided in Tables 5 and 6, respectively.

Industrial water was estimated to be 22.69 MCM in 2010 and has doubled over the next five years. This comprises 2.2 percent of the province's total water use.

Table 1 Number of consumers and average consumption volume of domestic drinking water in Qom province compared to the entire country (Regional Water Company of Qom, 2019)

Region	Title	Urban				Rural			
		2013	2014	2015	2016	2013	2014	2015	2016
Qom province	Number of consumers (1000 s)	292	300	308	324	25	25	27	30
	Consumption volume (MCM/month)	9.7	13.6	10.4	10.4	1.2	0.9	0.9	0.9
	Monthly Per capita (MCM)	16.6	22.6	16.9	16	24.4	17.2	15.5	13.5
National average	Number of consumers (1000 s)	12,488	13,338	14,071	14,706	3221	3452	3624	3807
	Consumption volume (cubic meter/month)	487	496	493	461	112	115	123	106
	Monthly per capita (MCM)	19.5	18.6	17.5	15.7	17.4	16.6	17	14

Table 2 Number of consumers and average consumption volume of urban non-domestic drinking water in Qom province compared to the entire country (Regional Water Company of Qom, 2019)

Year	Number of consumers							Consumption volume (Cubic Meter)
	2013	2014	2015	2016	2013	2014	2015	2016
Industrial	162	161	160	164	216,618	371,115	179,605	161,321
Public and official	515	538	564	584	152,706	185,102	182,587	147,750
Educational	1592	1560	1637	1648	528,276	698,901	556,463	536,829
Constructional	49	46	49	56	113,730	137,062	520,467	344,952
Commercial	11,227	11,367	11,963	12,253	234,547	318,459	250,937	246,522
Others	533	425	524	628	114,760	282,868	116,528	82,705
Sum	14,078	14,097	14,897	15,333	1,360,637	1,993,507	1,806,587	1,520,079

Table 3 Number of consumers and average consumption volume of rural non-domestic drinking water in Qom province compared to the entire country (Regional Water Company of Qom, 2019)

Year	Number of consumers							Consumption volume (Cubic Meter)
	2013	2014	2015	2016	2013	2014	2015	2016
Industrial	846	859	918	958	56,545	55,859	58,377	62,687
Public and official	255	239	254	268	31,668	34,104	11,786	31,852
Educational	477	472	513	536	33,961	20,794	23,705	16,072
Constructional	0	0	0	0	0	0	0	0
Commercial	483	529	550	625	34,240	26,328	17,870	15,706
Others	3	8	12	9	200	416	205	14
Sum	2064	2107	2247	2396	156,614	137,501	111,943	126,331

Table 4 Gross agricultural water needs per hectare for selected crops (m^3) (Jihad Agriculture Organization of Qom, 2015)

Crop name	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Annual sum
Wheat	1300	0	0	0	60	380	1820	2520	2040	0	0	0	8120
Barley	1120	0	0	0	60	380	1820	2340	1040	0	0	0	6760
Cotton	520	0	0	0	0	0	1000	280	2460	4100	4020	2580	14,960
Sunflower	0	0	0	0	0	0	0	1000	2060	4980	5300	2400	15,740

Table 5 Details of Qom Modern Animal Husbandry (Regional Water Company of Qom, 2019)

Water use (m3/yr)	Drinking and hygiene water use (m3/yr)	Employees	Cattle	Poultry
1,322,021	53,535	3569	24,883	6,574,000

Table 6 The Summary of Qom Industries and Mines (Regional Water Company of Qom, 2019)

Employees		Mines	Industrial units	
Mines	Industry		Industrial parks	Decentralized trade units
790	11,649	58	468	1390

Drinking water use and industrial and agricultural water use are derived 121.49 and 891.52 MCM, respectively, with agriculture water use being the highest. Qom's water needs met through wells and the 15-Khordad dam water supply. Thus, drought condition makes the water shortage more critical. Population growth, the welcoming city to immigrants, industrial and agricultural development have further amplified the imbalance between resources and uses.

Since drinking and industrial water use have priority, the lack of agricultural water has attracted more attention. Overexploitation of water from aquifers has been the inevitable approach of farmers to the water shortage problems. Excessive groundwater extraction is not enough to fulfill all agricultural needs and has led to qualitative and quantitative degradation of underground resources.

5.2 Mathematical structure of the allocation model without considering transfer water and weights

The allocation model in this study is a linear optimization model to maximize the net benefit of using water in different sectors. This model initially performed without considering the importance of plains and weighting them. Then, the model performed once more using weights derived from questionnaires filled by experts of the Regional Water Company and Agriculture Jihad Organization of the province; the results presented and compared.

In the model, 11 independent variables are selected as follows:

- Drinking and domestic uses,
- Agricultural need of Qom, Masileh, Salafchegan, Sharifaabad, and Aliaabad,
- Industrial needs,
- The water table in Qom-Kahak, Salt Lake, Sharifaabad, and Masileh aquifer

Each of these variables has 120 variables itself. Their values are for each month for the next ten years.

The objective function of the model is the sum of benefits to different water uses. Needs with no benefit are inserted with a negative sign in the model. The objective function maximized using the optimization model, and the values of variables computed as outputs.

$$\mathrm{Max}(y) = \sum_{i=1} \left(\frac{\mathrm{BInw_i}}{\mathrm{Inw_i}} + \frac{\mathrm{BAgQw_i}}{\mathrm{AgQw_i}} + \frac{\mathrm{BAgSaw_i}}{\mathrm{AgSaw_i}} + \frac{\mathrm{BAgMw_i}}{\mathrm{AgMw_i}} + \frac{\mathrm{BAgShw_i}}{\mathrm{AgShw_i}} + \frac{\mathrm{BAgAw_i}}{\mathrm{AgAw_i}} - \frac{\mathrm{CDw_i}}{\mathrm{Dw_i}} \right) \tag{3}$$

Subject to :

$$\mathrm{Inw_{min}} \le \mathrm{Inw_i} \le \mathrm{Inw_{max}} \tag{4}$$

$$AgQw_{min} \le AgQw_i \le AgQw_{max} \tag{5}$$

$$AgSaw_{min} \le AgSaw_i \le AgSaw_{max} \tag{6}$$

$$AgMw_{min} \le AgMw_i \le AgMw_{max} \tag{7}$$

$$AgShw_{min} \le AgShw_i \le AgShw_{max} \tag{8}$$

$$AgAw_{min} \le AgAw_i \le AgAw_{max} \tag{9}$$

$$Dw_{min} \le Dw_i \le Dw_{max} \tag{10}$$

where $BInw_i$, $BAgQw_i$, $BAgSaw_i$, $BAgMw_i$, $BAgShw_i$, and $BAgAw_i$ are the benefits of water allocated to the industrial and agricultural (Qom, Salafchegan, Masileh, Sharifaabad, and Aliaabad) sectors in the ith month. Moreover, CDw_i is the cost of allocating water to drinking water uses in the ith month. Also, Inw_i, $AgQw_i$, $AgSaw_i$, $AgMw_i$, $AgShw_i$, $AgAw_i$, and Dw_i are the amount of water allocated to the industrial, agricultural (Qom, Salafchegan, Masileh, Sharifaabad, and Aliaabad), and drinking sectors in the ith month, respectively. Due to the final production in the agricultural and industrial sectors, the benefits of these water use sectors are calculated by the difference between the value of production (e.g., crops) and the cost of water allocated per cubic meters of water.

In each optimization model, it is necessary to define some constraints. Here, the drinking water supply is the main constraint of the model. The minimum and maximum drinking and domestic water uses are equal to and triple its global standard, respectively, knowing that per capita consumption of drinking water in Iran is approximately three times higher than its international standard value.

The volume of water transferred annually is 143 MCM, with 173 MCM of surface water to which 70 percent of drinking water volume added as treated wastewater. The annual volume of groundwater in Namak Lake, Masileh, Qom, and Sharifaabad is 12.3, 21.6, 337.9, and 122.8 MCM, respectively. The model output was obtained for each month in 10 years.

In the objective function (Eq. 3), total benefits gained from water use, crop production, and their costs are considered for per cubic meters of water. The objective function variables are values assigned to different monthly water uses for ten years, regarding the horizon of 2028. A mathematical model in which the share of different needs from the allocation of surface water, groundwater, and water transfer are identified in this research. The output of the model without considering water transfer is represented in Tables 7 and 8.

In Fig. 4, it is assumed that water discharge has decreased by 5 percent of its previous year's value, and groundwater abstraction equals groundwater recharge. According to the model results, water needs are higher than water supply resources until the year 2023. These values are equal in the fourth and fifth years. From the sixth year onward, water needs exceed existing water resources. It is clear from the model output that discharge is less than water needs without considering water transfer, and existing resources are not enough to meet demands due to population growth and increased production of agricultural and industrial products over the next ten years. If the plains get irrigated like now, these values will increase further. It is clear from Fig. 4 that resource instability will happen in 2021.

Table 7 The output of the model related to water needs (average monthly values) without considering water transfer and weights from questionnaires (MCM)

Year	Drinking water needs	Agricultural water needs					Industrial water needs
		Qom plain	Masileh plain	Salafche-gan plain	Shari-faabad plain	Aliaabad plain	
2019	8.6	6.4	6.4	9.2	8.2	8.3	6
2020	7.2	8	8	7.3	7.4	7.9	8.2
2021	7.7	8.5	8.5	7.8	6.8	8.7	6.6
2022	6.1	8.9	8.9	7.8	8	7.6	8.9
2023	7.9	6.3	6.3	6.6	6.8	7.4	8.7
2024	6.7	8.6	8.6	8.4	7.3	7.1	6.6
2025	7.6	8.3	8.3	7.9	7.9	8.2	8
2026	7.9	8.3	8.3	6.5	6	5.9	8.1
2027	8.1	8.2	8.2	6.6	6.8	8	8.1
2028	7.6	7.8	7.8	6.8	6.4	8.3	8

Table 8 Average groundwater table fluctuation in aquifers of the study area (meter)

Year	Aquifer			
	Qom-Kahak	Namak Lake	Sharifaabad	Masileh
2019	−4.1	−3.9	−4.3	−6
2020	−4.9	−3.6	−6.5	−6.6
2021	−5.2	−5.3	−4.4	−4.3
2022	−5.5	−5.2	−5.2	−4.7
2023	−4.8	−5.5	−4	−4
2024	−4.4	−3.8	−7.6	−7.6
2025	−4.5	−5.5	−5.8	−4.4
2026	−4.3	−5.7	−6.2	−5.2
2027	−5	−4.9	−4.9	−5.8
2028	−4.8	−4.7	−4	−6.2

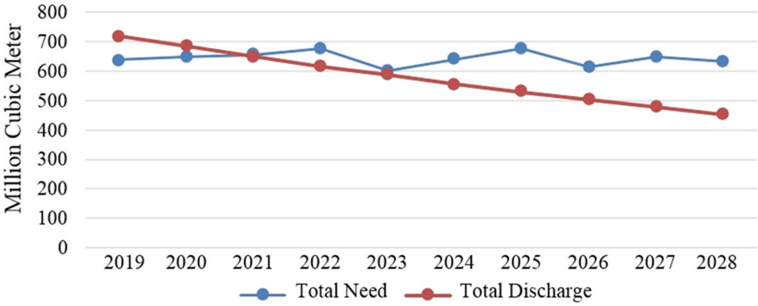


Fig. 4 The discharge and water needs from 2019 to 2028

The water table in Qom-Kahak, Salt Lake, Sharifaabad, and Masileh aquifer are the independent variables in the MATLAB code, which are calculated monthly for the ten years. In the model, the change in aquifer volume is calculated based on Eq. 11. Then, based on the relation between the aquifer volume changes and water table fluctuation (Eq. 12), the amount of water table changes is calculated for each aquifer. In this regard, the related input data were provided by Yekom consulting engineers (2016).

$$\Delta V = Q_{\mathrm{in}} + R_{\mathrm{p}} + R_{\mathrm{r}} + R_{\mathrm{w}} - \left(Q_{\mathrm{out}} + D + E + W\right) \tag{11}$$

$$\Delta h = \frac{\Delta V}{S \times A} \tag{12}$$

where Q_{in} and Q_{out}, R_{p} and R_{r}, R_{w}, D, E, W, Δh, S, and A are the amount of water entering and leaving the aquifer, rainfall and flood water infiltration to aquifer, irrigation return flow, aquifer drainage, groundwater evaporation, groundwater withdrawal, water table fluctuation, storage coefficient, and the area of aquifer.

Table 8 shows the trend of average water table changes in different aquifers of the province. The model results indicate the significant variation of about 4 to 8 m. At the end of the ten years, this level reaches about 4 to 6 m in different aquifers of the province. These values exceed the permitted range, signifying that due to the importance of supplying water needs, groundwater abstraction from wells increased over ten years, and there will be a need for groundwater recharge.

Figure 5 represents annual mean values of different water needs without considering water transfer. As can be seen, drinking water needs are much lower than total agricultural water needs, but they are more vital than other needs, and their variations are predominantly in lower range of others.

To achieve the project goals and more accurate results, a questionnaire was designed for the polling of the experts in a way to gain more precise information about the priorities of water uses in the region and that of plains for allocation of transfer water.

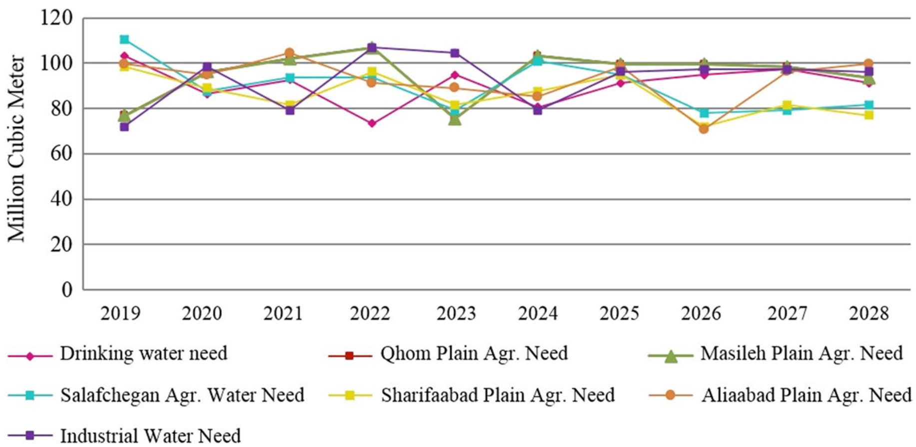


Fig. 5 Comparison of annual mean values of different water needs without considering water transfer

A questionnaire was designed for the polling of the experts to gain more precise information about the priorities of water uses in the region and plains for the allocation of transfer water.

Measures of central tendencies (mean, median, and mode) were used to analyze polling results. Figures 6 and 7 represent the results. Weights were assigned to variables based on the results obtained from statistical analyses, and the model was performed again using these weights. Results show that maximum weights in both perspectives are for drinking use. Aquifer recharge has minimum weight in the water value perspective, but agricultural water use has minimum weight in the strategic perspective. Qom plain has maximum priority among plains.

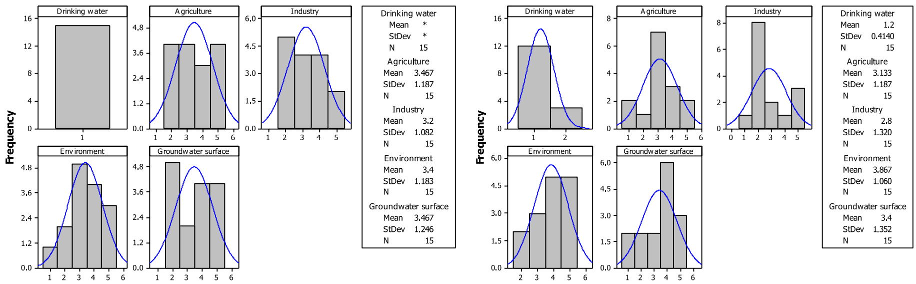


Fig. 6 The results of polling about priorities of water uses from water value (right) and strategic perspectives (left)

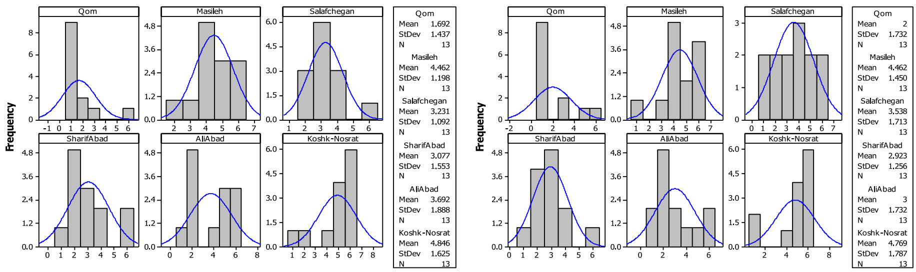


Fig. 7 The results of polling about priorities of Qom province plains from water value (left) and strategic (right) perspectives

Table 9 Normalized weights of priorities of uses

Water use	Weights	
	Water value perspective	Strategic perspective
Drinking	0.43	0.38
Agricultural	0.14	0.11
Industrial	0.21	0.19
Environmental	0.11	0.13
Aquifer Recharge	0.11	0.19

Table 10 Normalized weights of priorities of plains

Plain	Weights	
Water value perspective	Strategic perspective	
Qom	0.36	0.4
Masileh	0.09	0.1
Salafchegan	0.12	0.1
Sharifaabad	0.18	0.133
Aliaabad	0.18	0.2
Kooshk	0.06	0.067

The reciprocal of numbers obtained from statistical analysis of questionnaires were considered as the weight of variables in the optimization model (weight of the highest priority is taken equal to one). Tables 9 and 10 represent the normalized values.

5.3 Mathematical structure of allocation model considering water transfer, weights and scenarios

Allocation of water from Dez river branches is made according to statistical analysis results in the previous section and calculation of the main variables in the allocation model. In addition to constraints and conditions of the previous section, transfer water is allocated from strategic management and water value perspectives and three scenarios of discharge variation, population growth, and increased areas of plains under cultivation. In the new model, in the first two perspectives, water transfer and calculated weights are applied to the objective function and constraints. Results of the model are represented in six combinations of the perspectives and scenarios.

5.3.1 Strategic management perspective

Strategic management is defined as the science and art of formulating, performing and evaluating multi-criteria decisions- with focusing on integrating management, marketing, and financial elements production and services, research and development, information systems and etc. to achieve organizational objectives. Also, in this perspective, water use has a major priority in allocation, for example, in general, the production of wheat (as a strategic crop for food supply) could be a strategic goal, thus without considering any economic issue, water should be allocated for producing food. Basically, the drinking water supply should be prioritized by decision-makers due to the social and political aspects of this goal. So, as can be seen in Table 8, the drinking sector has a high rank in comparison with other sectors. However, the determination of the strategic goal among the other sectors (e.g., industrial and agricultural) could vary from a study area to another one depending on national policy and local water authority's perspective. In this case, the related experts prioritized industrial production (e.g., animal husbandry production) in comparison with agricultural production.

5.3.2 Water value perspective

In this study, a model for water allocation was prepared and performed based on water value using experts' opinions presented in the previous section. In the water value perspective, the authorities and stakeholders select weights based on the total benefit and costs, and the value of water. Considered scenarios are as following:

5.3.3 First scenario: discharge variation

Discharge variation is one of the main concerns in recent decades, and its impacts on nature and the environment being critical in some regions have been extensively studied. One of these impacts could be reduced precipitation and drought that influences water discharge across the province. To see this effect on the model, according to the long-term 6 percent reduction in amount of precipitation, it is assumed in this scenario that surface water discharge decreases by 6 percent each year.

5.3.4 Second scenario: population growth

The population is one of the main decision-making criteria in countries' main issues. It also has great importance in water resource management. It is necessary to consider population growth into account in water allocation models to reach more realistic results. According to the latest census reporting average rate of population growth in the province to be 1.93 percent (the statistical center of Iran). This value is considered the Annual Population Growth Factor.

5.3.5 Third scenario: increased area under cultivation

Since agriculture in the case study has the largest share of water resources and there is an increasing need for domestic production of crops, it is necessary to pay great attention to this parameter. According to water shortage, the need for improving the efficiency of water use and agriculture in the province, the rate of increase of area under cultivation is assumed one percent yearly.

5.3.6 The results of scenarios

The model was performed considering weights and water transfer. The value of water needs supplied by existing water resources in the province and water transferred from Dez branches are calculated separately. In the first, second, and third scenarios of strategic management perspective, the results of total annual water demand and discharge with and without water transfer are illustrated in Fig. 8i–iii, respectively. The diagrams show that considering constraints and the objective function of the model, water needs will be met within the first four, five, and six years for the first, second, and third scenarios, respectively. However, since 2022, 2023, and 2024, the amount of water needs has been more than expected for the mentioned scenarios. Similarly, the related results for the first, second, and third scenarios of water value perspective are shown in Figs. 8iv–vi, respectively.

Moreover, based on Eq. 11 and Eq. 12, the effects of each scenario on the input data were evaluated. Also, the aquifer volume changes and water table fluctuation were

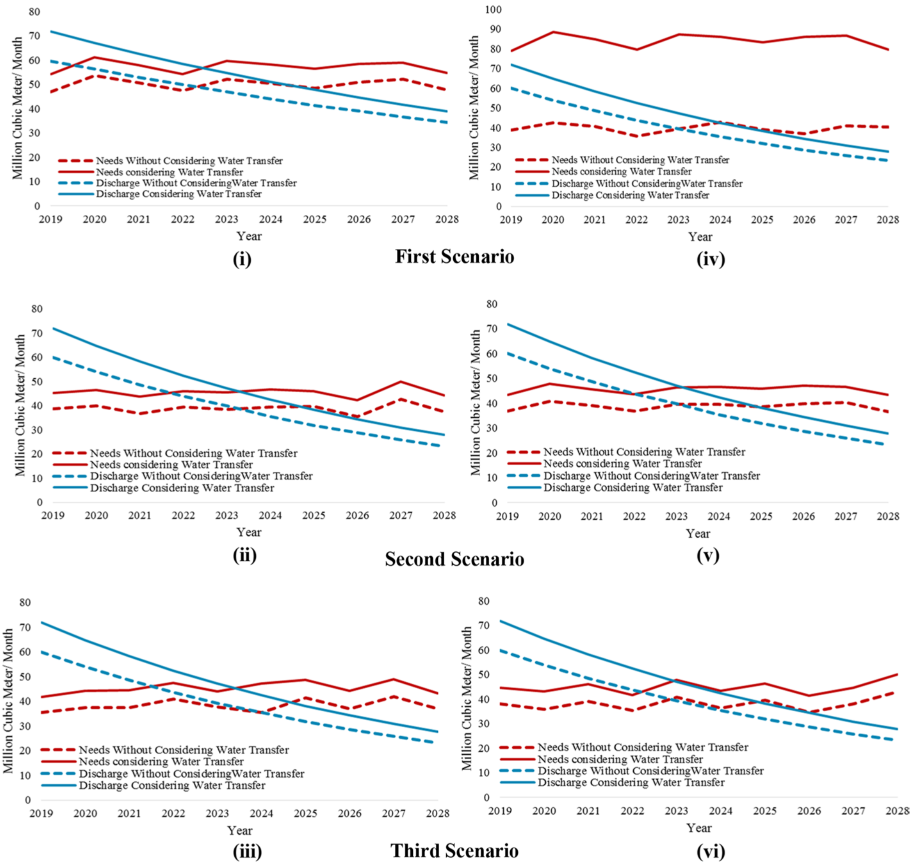


Fig. 8 Comparison of needs and discharge with and without considering water transfer during 10 years from strategic management perspective (left) and water value perspective (right) (2019–2028)

calculated. In the first, second, and third scenarios of strategic management perspective, Fig. 9i–iii represent the average water table fluctuation of different aquifers in the study area, respectively. The water table at Namak lake aquifer has not changed significantly in ten years, but the Qom-Kahak aquifer in 2021 and 2027, Sharifaabad aquifer in 2026, 2028, and 2022, and Masileh aquifer in 2026, 2022, and 2025 have the lowest water level for the first, second, and third scenarios, respectively. Also, Fig. 9iv–vi illustrate the similar results for the first, second, and third scenarios of water value perspective, respectively. In addition, Fig. 10 represents the sum of average monthly allocations which vary approximately in a range.

5.4 Conflict modeling and analysis using GMCR+

The process of conflict analysis in GMCR II and earlier game theory models consists of defining possible modes of play by identifying the decision-makers and their scenarios and then determining the equilibrium points of the game by identifying priorities for each player. The new conflict analysis model, GMCR+, introduced in 2015 by Kinsara et al.,

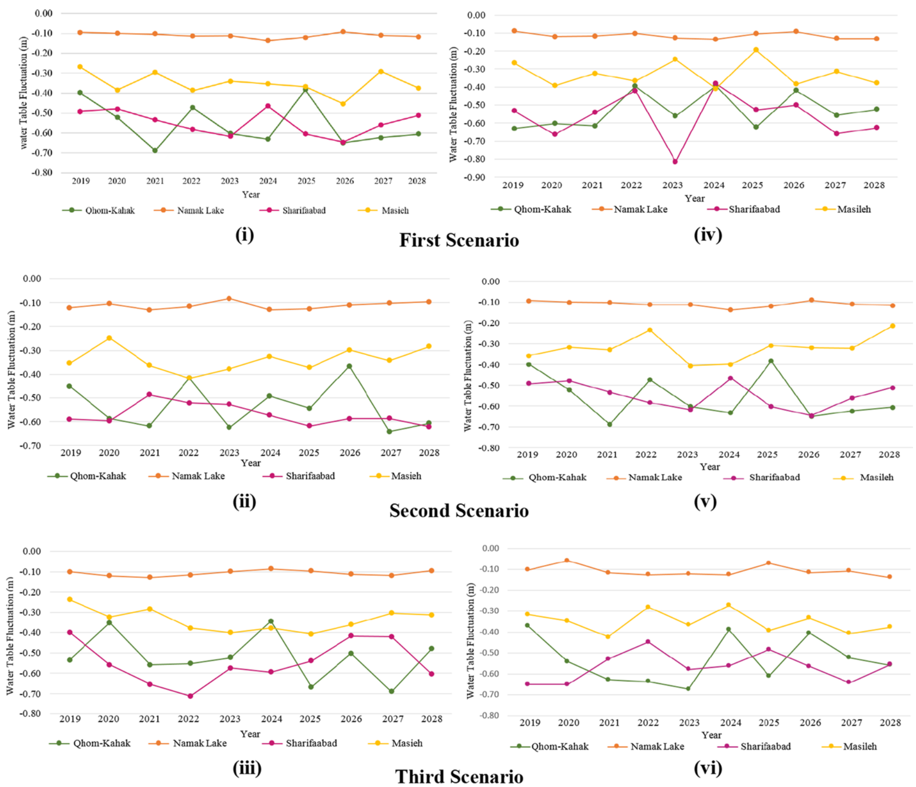


Fig. 9 Average water table fluctuation of different aquifers from strategic management (left) and water value (right) perspective (2019–2028)

has a new tool called Inverse GMCR. In addition to its ability for analysis of a conflict and determination of equilibrium points, it is also able to specify players' preferences for reaching the desired balance point by identifying players and their scenarios and by introducing the equilibrium point of the game. Since it is complex to determine players' preferences to reach the equilibrium point, and if we do not know the players' preferences, we cannot rely on the obtained equilibrium points; this method is reliable because having little information about the players' choices and only by identifying the desired equilibrium point can be used (Kinsara et al., 2015).

5.4.1 Conflict modeling

Water needs exist in the urban water section, agriculture section (Qom, Masilah, Salafchegan, Sharifaabad), agriculture and the industry section (Aliabad), and six scenarios are defined for water allocation in these sectors. But conflict modeling is limited by the number of players and their preferences (the number of players and their scenarios is directly related to the total number of conflict states, and increasing them does not yield tangible results from conflict analysis). Therefore, conflict modeling has to be done according to the players and their preferences.

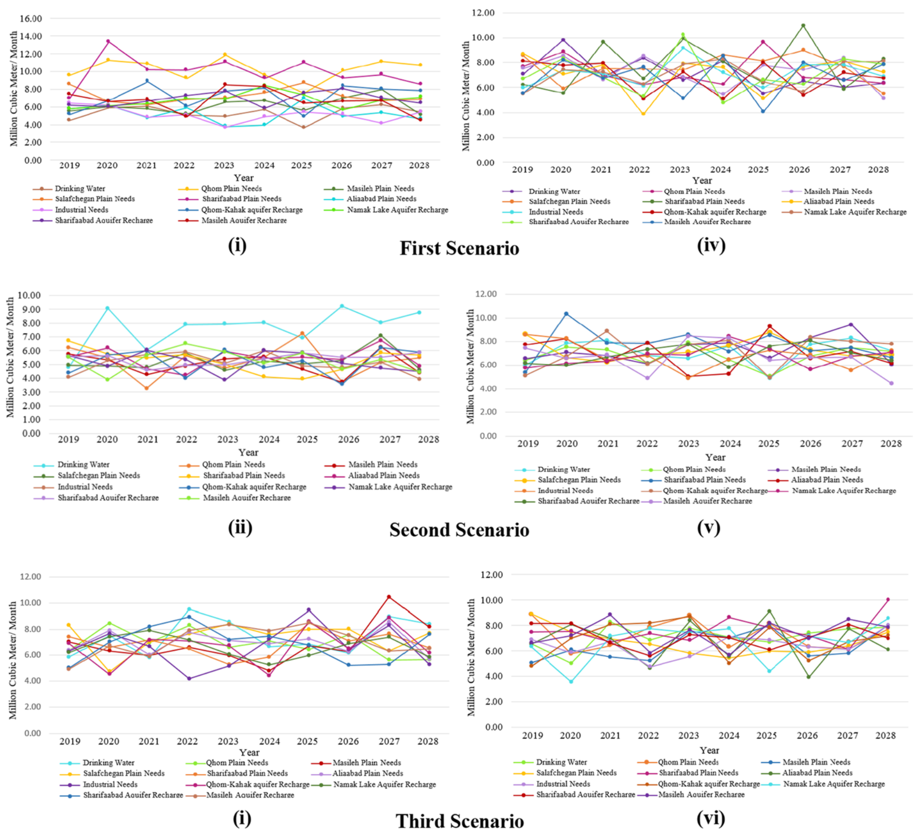


Fig. 10 Sum of average monthly allocations for each needs during 10 years from strategic management (left) and water value (right) perspective (2019–2028)

Since in the water value perspective-first scenario, in the agricultural sector, the Masilah, Salafchegan, Sharifaabad, and Aliaabad plains are the priorities, we consider all of them as one player. There are also players' preferences and the status quo of the conflict for each of them in the strategic management perspective-first scenario (S1), water value perspective-first scenario (S2), and strategic management perspective-second scenario (S3). Therefore, possible equilibrium can be reached while eliminating the other three scenarios in the conflict modeling.

After defining the players and their scenarios, infeasible states are eliminated. In this conflict, each player must respond positively to one scenario. In other words, it cannot answer negatively to all scenarios. Therefore, states in which these conditions do not occur are eliminated. At the final step of the conflict modeling, the players' preferences are identified. Here, it is assumed that players prioritize cooperative solutions in which all players choose a scenario, and in non-cooperative situations, they prioritize alternatives that have more allocation (in the average for the next 10 years) to their sector and less allocation to other sectors.

Table 11 Results of the conflict analysis and stability states

State Equilibrium	1	39	41	81
Nash	Y	Y	Y	Y
GMR	Y	Y	Y	Y
SEQ	Y	Y	Y	Y
SMR	Y	Y	Y	Y

Table 12 The situation of the equilibrium points

Player	State Scenario	1	39	41	81
Urban water section	S1	Y	N	N	N
	S2	N	N	Y	N
	S3	N	Y	N	Y
Agriculture section- Qom	S1	Y	Y	N	N
	S2	N	N	Y	N
	S3	N	N	N	Y
Agriculture section	S1	Y	N	N	N
	S2	N	Y	Y	N
	S3	N	N	N	Y
Industry section	S1	Y	N	N	N
	S2	N	Y	Y	N
	S3	N	N	N	Y

5.4.2 Conflict analysis

The conflict is analyzed after modeling. At this stage, based on the 4 players with 3 scenarios for each one, among 81 (3*3*3*3) feasible states, the equilibrium states are found using GMCR+(Table 11). Afterward, the probable equilibrium is obtained according to the status quo of the conflict.

As shown in Table 12, in the states 1, 41, and 81, all players choose the same scenarios which are S1, S2, and S3, respectively (cooperative solution), but in the state 39, each player goes for the scenario with the highest priority (non-cooperative solution). Under these circumstances, it is necessary to achieve a probable equilibrium through equilibrium states with the help of a status quo of the conflict. It is clear by a bit of trial and error that the status quo of the conflict in the drinking sector and agricultural sector of Qom and other plains, as well as industrial sectors, are in strategic management-second scenario and water value- first scenario, respectively, and the status quo of the conflict is in state number 42.

Figure 11 shows the unilateral movements of the players in the conflict graph, using which it is possible to examine the role of each of the decision-makers during the conflict. As shown in this graph, the nodes represent conflict states (red nodes represent equilibrium states and the green node represents the status quo of the conflict), and the edges represent unilateral player movements. Unilateral movement means that the player is willing to move from one state to another if and only if his/her benefit increases. In this case, given the

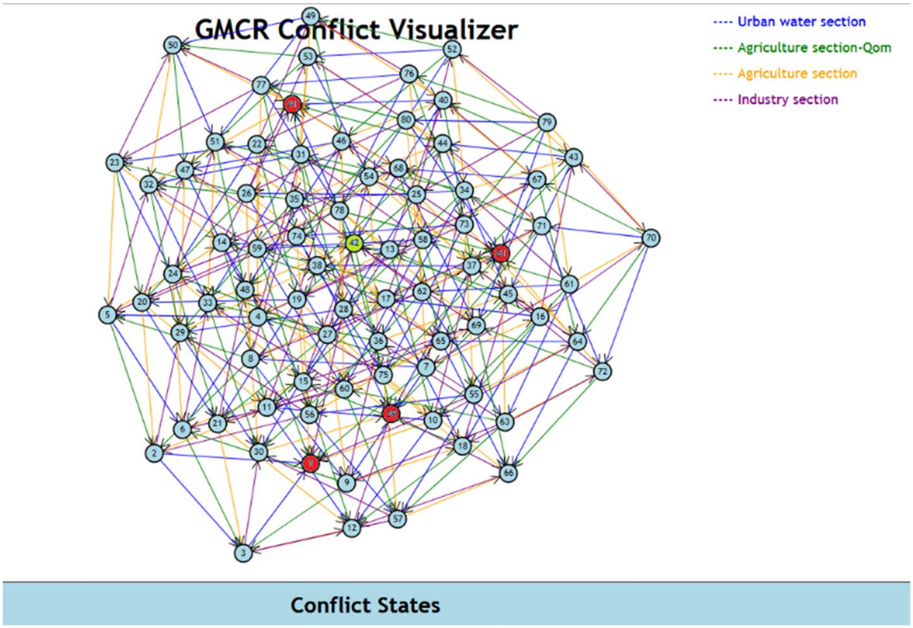


Fig. 11 The unilateral movements of DMs in the graph model

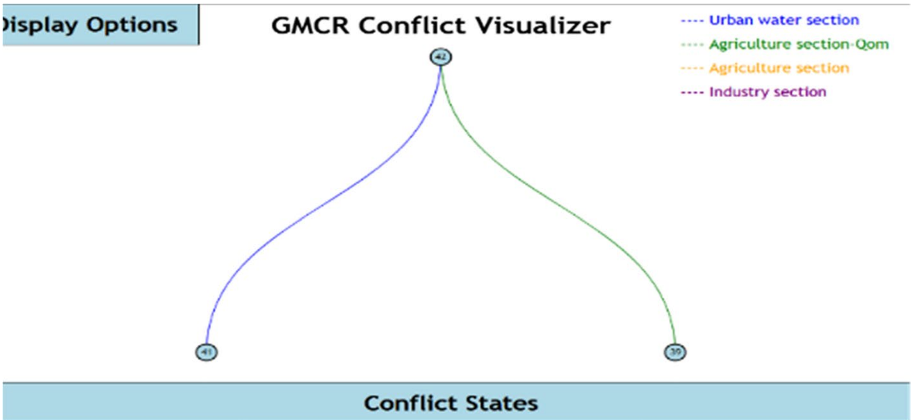


Fig. 12 The Conflict tree from the start at the status quo

equilibrium definitions, one can get the nodes, which have the most input and no output in this graph, which are the same equilibrium points of the conflict. In addition, according to the definition of the equilibrium point in the game, it is expected that no player will be able to move unilaterally when the conflict reaches equilibrium.

It is necessary to draw the conflict tree to achieve an equilibrium from the status quo of the conflict. Figure 12 represents the conflict tree from the start of the conflict in the status quo.

As shown in Figs. 11 and 12, the conflict starts from the status quo (state 42), by change of the scenario in the drinking sector, it reaches status 41, and by change of the scenario in Qom plain's agricultural sector, it reaches status 39. These two are the most likely equilibrium states. Since this research requires a scenario for all of these sectors (co-operative solution), it is clear from the results of the conflict analysis that the state 41 is a possible equilibrium point for this conflict. In this state, as can be seen in Table 12, all sectors choose the water value perspective—first scenario (S2). Significant allocation will be made to the agricultural and industrial sectors (approximately 96% and 94%, respectively) and 94.6% to the drinking sector by performing this scenario. It should be noted that the drinking sector plays an important role compared to other sectors, and its needs have to be met completely. It is achieved by using solutions such as water loss reduction by investing in improving water transmission and distribution networks.

As shown in Table 13, the percentage in each scenario is calculated based on the water allocated per initial water needs (the average water needs in Table 7). In the strategic management-first scenario, the highest monthly allocation belongs to the Qom plain's agricultural water need with 10.2 MCM, and the lowest is for the Aliaabad Plain Agriculture with 5.23 MCM. In the water value- first scenario, Sharifaabad plain's agricultural need has the highest monthly average allocation of 7.93 MCM, and the lowest belongs to the Qom-Kahak Aquifer Recharge with 6.73 MCM.

Similarly, in the strategic management perspective-second scenario, the highest monthly allocation belongs to the drinking water need with 7.67 MCM, and the lowest is for the Masileh plain's agricultural water needs equal to 5.02 MCM. In the water value perspective-second scenario, Sharifaabad plain's agricultural water need has the highest monthly average allocation of 7.71 MCM, and the lowest belongs to the Masileh aquifer with 6.68 MCM. In the strategic management perspective-third scenario, the highest monthly allocation belongs to the drinking water need with 7.43 MCM, and the lowest is for Namak Lake aquifer, with 6.63 MCM. In the water value perspective-third scenario, Sharifaabad plain's agricultural water need has the highest monthly average allocation of 7.58 MCM, and the lowest belongs to the Masileh plain's agricultural water needs with 6.4 MCM (Fig. 13).

As shown in Table 14, since there is no preference for any need over the others, their transfer water allocation is approximately the same. There is a water shortage for the optimal water allocation in all scenarios by assuming 173 MCM of water transfer per year (including treated wastewater from other uses) and total annual discharge (720 MCM). This shortage is 58.23 MCM for the water value perspective-first scenario being the best scenario for which different suggestions can be made.

5.5 Policy and managerial implications

Based on the final outputs of the proposed methodology, allocated water to each stakeholder in various approaches has been determined. Since in the allocated water to demands, preference of stakeholders or players in the problem, has been considered, results have minimum conflict and maximum acceptable level among them. Thus, the authority of water resources planning and management could accept the outputs as a policy. This policy is more sustainable and has optimum criteria compare with the current allocation.

Table 13 Comparison of average monthly allocations by scenarios and type of needs (MCM)

Needs	Initial water needs	Strategic management-first scenario	Percent	Water value-first scenario	Percent	Strategic management-second Scenario	Percent	Water value-second scenario	Percent	Strategic management-third scenario	Percent	Water value-third scenario	Percent
Drinking	7.54	5.34	70.8	7.13	94.6	7.67	101.7	7.11	94.3	7.43	98.5	7.12	94.4
Qom Plain Agriculture	7.93	10.2	128.6	7.18	90.5	5.25	66.2	6.83	86.1	6.92	87.3	7.24	91.3
Masileh Plain Agriculture	7.93	6.14	77.4	7.2	90.8	5.02	63.3	7.27	91.7	6.84	86.3	6.4	80.7
Salafchegan Plain Agriculture	7.49	7.23	96.5	7.48	99.9	5.22	69.7	7.29	97.3	7.38	98.5	6.7	89.5
Sharifaabad Plain Agriculture	7.16	9.95	139	7.93	110.8	5.29	73.9	7.71	107.7	6.87	95.9	7.58	105.9
Aliaabad Plain Agriculture	7.74	5.23	67.6	6.95	89.8	5.46	70.5	6.97	90.1	7	90.4	6.71	86.7
Industrial	7.72	5.14	66.6	7.27	94.2	5.08	65.8	6.85	88.7	6.68	86.5	6.42	83.2
Qom-Kahak Aquifer Recharge	–	7.19	–	6.73	–	5.18	–	7.19	–	6.71	–	6.88	–
Namak Lake Aquifer Recharge	–	6.74	–	7.27	–	5.19	–	6.74	–	6.63	–	6.68	–
Sharifaabad Aquifer Recharge	–	6.89	–	7.17	–	5.38	–	6.89	–	6.87	–	7.1	–

Table 13 (continued)

Needs	Initial water needs	Strategic management-first scenario	Percent	Water value-first scenario	Percent	Strategic management-second Scenario	Percent	Water value-second scenario	Percent	Strategic management-third scenario	Percent	Water value-third scenario	Percent
Masileh Aquifer Recharge	–	6.68	–	6.98	–	5.29	–	6.68	–	7.06	–	7.33	–
Annual Sum	642.1	920.7	–	951.2	–	900.3	–	930.4	–	916.6	–	914	–
Subtracted from 893 MCM discharge	–	−27.7	–	−58.2	–	−7.29	–	−37.4	–	−23.6	–	−21	–

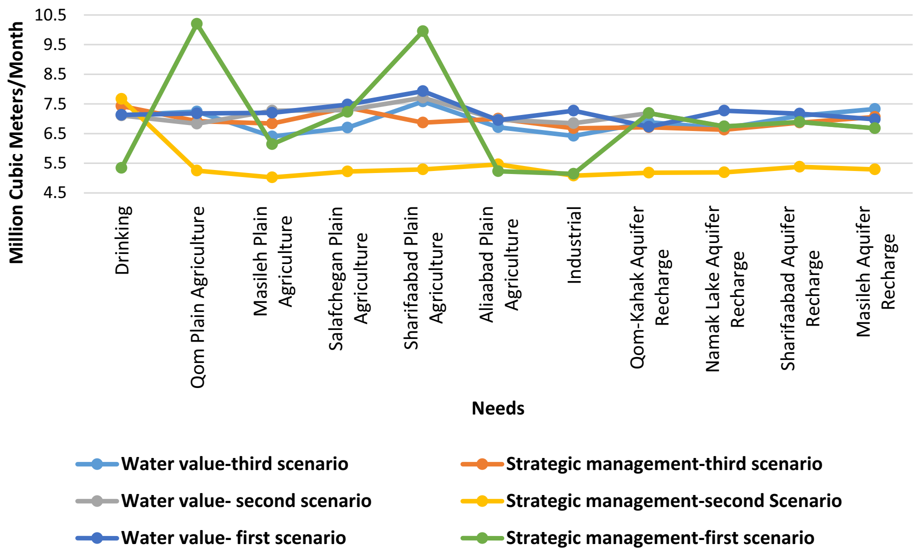


Fig. 13 Comparison of scenarios according to needs

6 Conclusion

According to the high costs of fulfilling the water needs of the province and transferring water from the Dez branch to this province, the purpose of this study was to optimize the allocation of water resources to different sectors to maximize the profit from water allocation. The optimization model performed with and without considering the water transfer and taking into account the priority of users from the strategic management and water value perspectives. Without considering water transfer due to fewer constraints and non-prioritization of uses, the overall amount of water is higher, but in the other two states having more constraints and allocating some water to the aquifer recharge, its value has reduced to half.

The amount of water allocated to the plains other than Sharifaabad plain has decreased by assigning weights to the model. Water allocated to the drinking and industrial sectors has increased due to water transfer. It is clear from the results of the conflict analysis that according to the conditions, all sectors choose the water value-first scenario. By implementing this scenario a significant allocation has been made to industry and agriculture, and 94.6% to the drinking sector. It should be noted that the drinking sector plays a more important role than other sectors, and it is necessary to satisfy drinking water needs. Finally, to compare the results of this study with the real situation of the study area in 2021, statistical data show that total precipitation is less than in the past years and total discharge has been decreased. So, based on the slope of the total discharge line in Fig. 4, it could comply with the estimation.

Table 14 Percentage increase or decrease of scenarios compared to the initial water needs

Needs	Strategic management-first scenario	Water value- first scenario	Strategic management-second Scenario	Water value- second scenario	Strategic management-third scenario	Water value-third scenario
Drinking	−29.2	−5.4	1.7	−5.7	−1.5	−5.6
Qom Plain Agriculture	28.6	−9.5	−33.8	−13.9	−12.7	−8.7
Masileh Plain Agriculture	−22.6	−9.2	−36.7	−8.3	−13.7	−19.3
Salafchegan Plain Agriculture	−3.5	−0.1	−30.3	−2.7	−1.5	−10.5
Sharifaabad Plain Agriculture	39.0	10.8	−26.1	7.7	−4.1	5.9
Aliaabad Plain Agriculture	−32.4	−10.2	−29.5	−9.9	−9.6	−13.3
Industrial	−33.4	−5.8	−34.2	−11.3	−13.5	−16.8

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