Participatory Management of Traditional Urban Water Infrastructures in Iran

The Case of Tehran Historic Qanats

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Abstract

Qanats have played a vital role in underground water extraction since ancient times based on the community-based water management schemes in Iran. Due to recent urban sprawl and development pressures, qanats are progressively abandoned and degraded in the cities and are considered as endangered assets. To be sustainable, in addition to physical maintenance, the ecological and social aspects of qanat management systems, as the main characteristic of Urban Water Infrastructures in Iran, also need to be taken into account. A review of the traditional participatory management systems in Iran, as well as the contemporary community-based interventions (CBI) in the context of qanats, demonstrates the significant role of public participation in this regard. This research aims to provide solutions and recommendations for enhancement of stakeholder engagement in contemporary qanat rehabilitation practices by adapting the traditional communal management techniques and multi-stakeholder approaches to qanat maintenance in Iran. For this purpose, the transformation of the key urban water stakeholders from past to present are studied and mapped based on their roles and influence on decision making process for the management of qanats. The resulting illustration of the stakeholders' networks and the comparative study of inter-relationships not only reveals today's institutional gaps and missing links in qanats' management procedures, but also highlights the former community-based coordination mechanisms that used to support the smooth functioning of this socio-technical infrastructure by promoting constructive interactions among conflicting parties. In order to tackle contemporary governance challenges, this research also provides a set of practical recommendations to adjust those traditional learnings to new conditions by addressing the physical, environmental, and socio-cultural aspects of qanats in Tehran.

Keywords traditional urban water infrastructures, stakeholders engagement, community-based partnership, qanat rehabilitation, qanat, participatory approach

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Introduction

The central plateau of Iran which is surrounded by Alborz and Zagros mountain ranges from north and west, has long been an arid region. Due to aridity and water scarcity of their land, ancient Iranians had to periodically switch their settlements between mountains and plains in search of seasonal water resources (Estaji & Karin, 2016). Lack of year-round water supplies like rivers made it hard for societies to adopt sedentism. However, around 3000 years ago, ancient Iranians could devise an innovative and sophisticated hydraulic structure, termed "qanat" or "kariz", which enabled them to access groundwater resources.

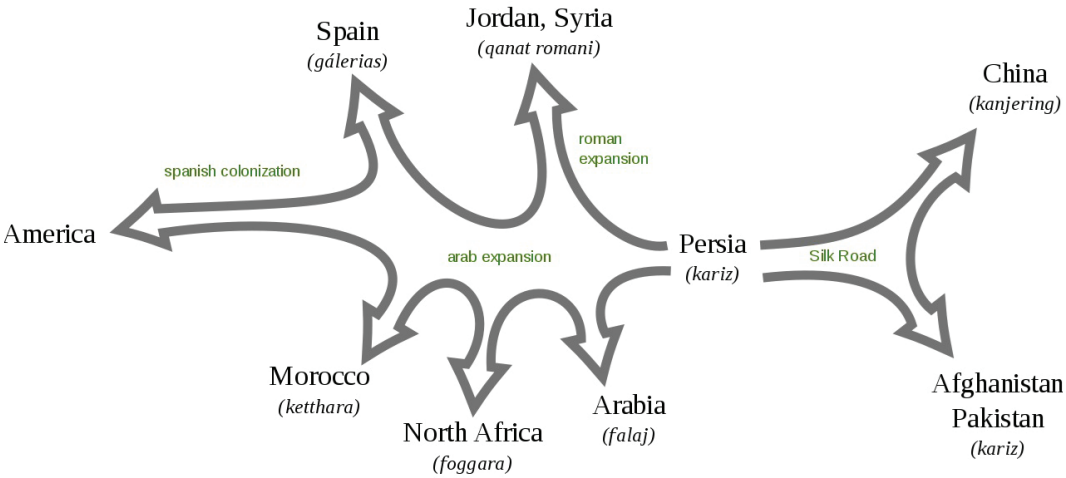

FIGURE 1 Probable diffusion of qanat technology ("Qanat," n.d.).

The idea of a qanat system was gradually exported to other areas of the world including Iraq, some African countries, parts of Europe, and China (Maleki & Khorsandi Aghaei, 2006) (Fig. 1). However, Iran, as the origin of the qanat, has possessed the greatest number of qanat systems throughout the history of civilisation. In its 40th session in July 2016, the World Heritage Committee of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) inscribed the "Persian Qanats" property on the World Heritage List. The World Heritage Committee recognised the Outstanding Universal Value (OUV) of the property notably because of its authenticity and integrity and the following criteria for OUV properties:

A The Persian Qanat system is an exceptional testimony to the tradition of providing water to arid regions to support settlements. The technological and communal achievements of the qanats play a vital role of qanat in the formation of various civilizations. Its crucial importance for the larger arid region is expressed in the name of the desert plateau of Iran which is called "Qanat Civilization".

B The Persian Qanat system is an outstanding example of a technological ensemble illustrating significant stages in the history of human occupation of arid and semi-arid regions. Based on complex calculations and exceptional architectural qualities, water was collected and transported by mere gravity over long distances and these transport systems were maintained over centuries and, at times, millennia.

A Qanat system (Fig. 2) mainly consists of an inclined underground tunnel connected to some shaft wells along its path which transfers groundwater from an aquifer to the earth surface. The place where the gallery and the ground surface eventually intersect is the qanat's outlet where the water appears. The vertical shafts sunken along the horizontal gallery are used for lifting up excavated material from the tunnel to the surface. They also provide access and ventilation for the tunnel. Water coming from qanats was used

for diverse purposes by means of different supplementary elements, including ditches and streams that transferred water to farmlands, water reservoirs that supplied water for domestic or public use, etc. (Semsar Yazdi & Labbaf Khaneiki, 2017).

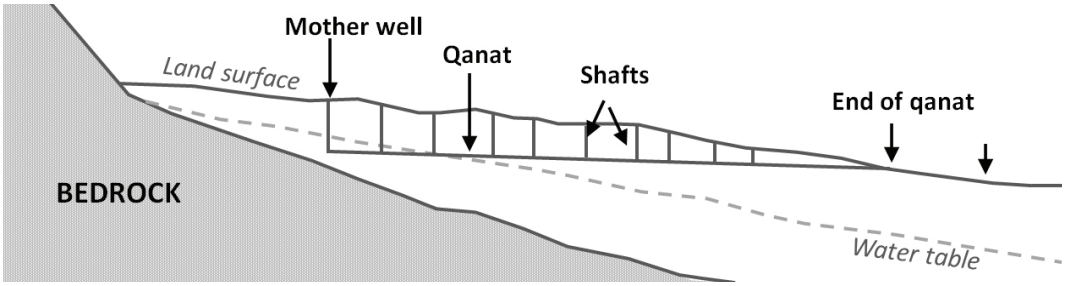

FIGURE 2 Schematic section of qanat (Manuel et al., 2017).

In addition to the qanat's role in the initial establishment of human settlements, cities' physical expansion and population growth were influenced by the amount of their qanats' water supply (Aghazadeh, 2013). Furthermore, qanats affected urban pattern; if they were close to each other the city became compact and dense. Additionally, the overall direction of farming lands and cities obeyed the qanat's direction, an attribute that helped the urban structure to better adapt to the arid climate of the region (Shiraazi, Milani, Sadeghi, Azami, & Azami, 2012) (Fig. 3).

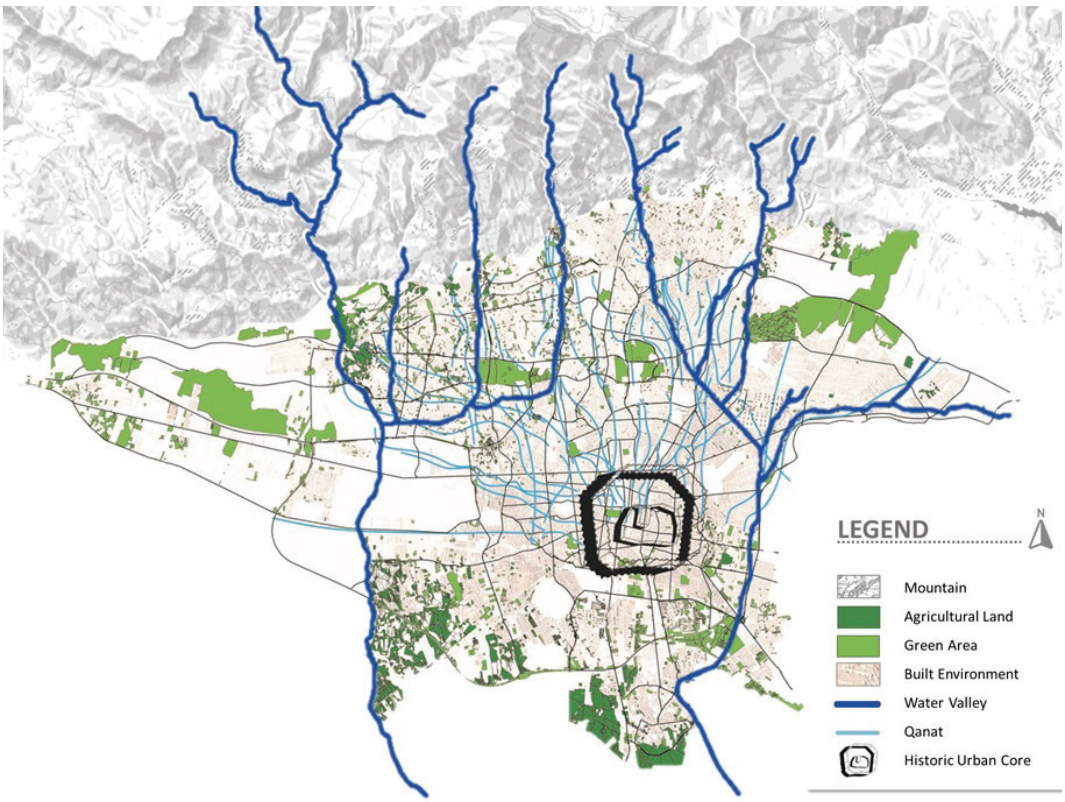

FIGURE 3 Schematic map of Tehran: location and green areas shaped by Qanat network.

Qanats continue to provide the essential resource water that sustains Iranian settlements and gardens, and remain maintained and managed through traditional communal management systems (ICHHTO, 2015). Currently, there are nearly 50,000 qanats in Iran, more than 200 of which, with a total length of 2,000 km, are located in the capital of Tehran (Zivdar & Karimian, 2019).

The existing literature on the qanat is quite extensive; it encompasses research from various perspectives, including the qanats' historical background and heritage value, the technical mechanism and engineering knowledge behind qanat construction and operation, qanats' ownership laws, and irrigation management traditions (Khaneiki, 2019, paras. 11–15). Yet, the greatest share of the available literature on the qanat has been produced in the technical realm. In their book *Qanat Knowledge*, Semsar Yazdi and Labbaf Khaneiki (2017) give a thorough description of the qanat's hydrological mechanisms and the technical mastery of qanat diggers. Several scholars have examined the impacts of modern water provision technologies, on qanats' deterioration and abandonment, and their replacement by deep wells over the past century (Bonine, 1996; English, 1968; Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008).

Apart from being an infrastructural element created by engineering knowledge, qanats have been of great importance from a socio-cultural perspective. In fact, the qanat was a socio-technical system whose ownership and management depended on a community-based partnership, rooted in collective practices of several shareholders. Despite the prevalent technical viewpoints in qanat literature, there are several research works conducted on the qanat with a focus on socio-cultural facets. Bonine (1996) investigates the social and cultural characteristics of qanat systems in Iranian rural areas. In his paper, he put an emphasis on the former common irrigation rules and qanat management practices (Bonine, 1996, pp. 195-201). hrough examining the available resources and case studies from four middle eastern countries Hussain et al. (2008) defined a qanat as "an established socio-cultural institution which involves shared expectations and pattern of cooperation and conflicts. It is a pivot around which different community activities take place" (p. 334). Therefore, social factors, which include "social cohesion in community, social participation, cultural values, and community leadership" go hand in hand with technical conditions and structure, to facilitate qanat's smooth functioning (Hussain, Abu-Rizaiza, Habib, & Ashfaq, 2008, p. 346).

In the regions where qanats are the cornerstone of the local economy, community cooperation is significant. This cooperation also spreads to the other realms of social life and comes to turn into a sort of cultural genetics (Semsar Yazdi & Labbaf Khaneiki, 2017, p. 2). Some scholars have made attempts to translate these traditions to management models and frameworks. Khaneiki (2019) explored the cooperation taking place between a number of territories using the same qanat, in achieving a participatory water management system which ensured fair water distribution. Based on the insights from a case study in arid regions of Iran, he formulated a territorial water cooperation model (Khaneiki, 2019). Building his work on the explanations given by Semsar Yazdi (2014) about Zarch qanat stakeholders and the traditional collective water management patterns, Salek (2019) generated a theoretical framework based on Actor-Network Theory, to guide the transition from a centralised water management regime towards a participatory, community-based water governance style.

The emergence of modern hydraulic structures like deep wells, dams, reservoirs, and piped water supply systems resulted in a decline of qanats. However, many places and local communities are still solely dependent on the qanat water supply. In such cases, besides water distribution, community cooperation takes place in the maintenance and repair of qanats. In the paper, "Renovation of Qanats in Syria", Wessels and Hoogeveen (2002) developed some feasibility criteria for qanat renovation in the Middle East. They included "strong social cohesion in community" and "willingness of water users to contribute" among the six renovation criteria they developed, which are essential in all community-based interventions (CBI) (Wessels & Hoogeveen, 2002). Wessels (2005) also described two CBI projects carried out within a wide development study on traditional water management in Syria. The study follows a Participatory Action Research (PAR)

approach in which a CBI is developed to investigate the social and physical possibilities of renovating a qanat at community level. These projects involved the strong commitment of external actors in the facilitation of the CBI (Wessels, 2005).

In a 2019 study, Zivdar and Karimian (2019) focused on Mehrgerd Qanat, a 700-year-old infrastructure running through a densely populated urban district of Tehran. Even though their work mainly concentrates on the analysis of the qanat's landscape based on the Heritage Impact Assessment (HIA) method, they criticise the negligence of community participation in current practices of qanat revitalisation (Zivdar & Karimian, 2019).

The fact that several remaining qanats, like Mehrgerd, are still draining groundwater without any maintenance for decades, added to the proven inefficiency of modern water provision systems to meet water demands in the face of the approaching water crisis, has motivated water sector and urban authorities to embark on qanat rehabilitation projects. However, these efforts are disappointingly doomed to failure when they put their main focus on the physical and technical restoration of qanats, overlooking the participatory conservation and sociocultural aspects of qanats.

In spite of the valuable contributions these researches have made to the sphere of knowledge on qanats, studies that address the challenges that qanat networks face under the pressure of modern-day urbanisation seem to be rare. The majority of available literature is centred around either qanats of rural areas or qanats utilised by the agricultural sector, while there are thousands of kilometres of qanat networks entangled in urban fabrics like Tehran. Many of these qanats are progressively abandoned and degraded because of recent urban developments.

Research Objectives, Method, and Framework

A review of the traditional participatory management systems in Iran, as well as the contemporary community-based interventions (CBI) in the context of qanats, demonstrates the significant role of public participation in this regard. This research aims to provide solutions and recommendations for the enhancement of stakeholder engagement in contemporary qanat rehabilitation practices in Tehran by adapting the traditional communal management techniques and multi-stakeholder approaches to qanat maintenance in Iran. This aim could be translated to the study's main question; How can the traditional community cooperation in qanat management practices be used as a pattern for engaging the present-day overlooked communities, who affect or are affected by qanats' presence, in the contemporary rehabilitation programmes?

To better address this question, we will try to answer the following sub questions:

- How and why have the status of qanats changed in the urban context of Tehran?
- How have these transformations influenced the qanat management practices and stakeholders involved in qanat-related matters?

To answer these questions, the transformation of the key urban water stakeholders from past to contemporary time (Fig. 4) are studied and mapped based on their roles and influence on decision making processes for qanats' management. Primarily, the relevant stakeholders who were typically engaged with qanats' management and exploitation process in the past were identified through a detailed review of available literature and historical accounts. Then, the current state of the management of qanats in the

contemporary institutional structure of Tehran's water sector is investigated, so that the present-day central and marginal stakeholders, from public sector, private sector, and civil society are derived based on a review of relevant literature including published articles, a number of unpublished materials, and official policy reports. Additionally, the roles, responsibilities, capacities, and impacts of each stakeholder on qanats' management are identified. The resulting illustration of the stakeholders' networks and the comparative study of the findings not only reveals today's institutional gaps and missing links in qanats' management procedures, but also highlights the former community-based coordination mechanisms that used to support the smooth functioning of qanats in the past.

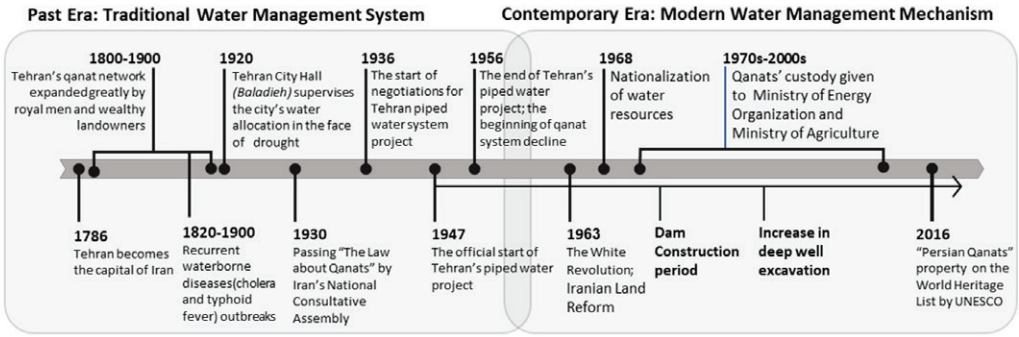

FIGURE 4 Framework of the research (the studied timeframe).

Participatory Management of Qanats in Tehran

The Traditional Qanat Stakeholders

Tehran was merely a small town when it was chosen as the capital of Iran by Agha Mohammad Khan, the king of Qajar dynasty in 1786. Owing to its new prominent position, the small town went through a noticeable population growth that influenced it in many aspects, including citizens' water demand. To meet the city's rising need for new water resources, the government embarked on constructing new qanats in lands that could potentially yield sufficient groundwater resources (Abbasi, 2008, p. 49). Apart from the central government, some wealthy landowners would construct qanats in their own properties, either for benevolent purposes or for making profit by selling extracted water (Ghaffari, 2012, p. 18, 19). Qanat construction was a technical expertise that was held by experienced masters, called *mughannis*, who were appointed by the owners to dredge the qanat galleries and canals from time to time, so that qanats could operate more efficiently.

After a qanat was established, the bigger challenge would arise: how to fairly distribute the water among those who had irrigation rights and lived or worked in the vicinity of qanat outlet. At that time, the only way to regulate water allocation was to implement a turn-based procedure; each group of water consumers, including farms, gardens, businesses, and houses situated in a particular section of the area would be given regular turns, during which water was led to ditches running into their water storage areas (Ghaffari, 2012, p. 44). According to this method, people's turns had to be determined and supervised by a trusted person called *mirab*. Although government once made an attempt to distribute water by means of a clay water pipe (*tambooshe*), the lengthy, serious quarrels over water shares among people, especially in dry seasons, proved

the advantages of seeking the help of *mirabs* for fair water division. *Mirabs* were usually trustworthy and active figures of a neighbourhood who were elected by locals. They would allocate qanat water according to a list containing the names of the residents with water rights and the amount of their water shares, as well as dealing with the qanats' financial affairs (Abbasi, 2008; Salek, 2019). Such a time-oriented water distribution mechanism could not impose any limitation on the water consumption rate, which would be an issue during times of water scarcity and drought. This drove Tehran's City Hall (*Baladieh*) to intervene actively and supervise the city's water allocation in 1920 (Abbasi, 2008, p.58-62).

Apart from households and reservoirs as the two major water consumers, there were several businesses that relied on water to operate. Farmers and gardeners, as one of the largest groups of shareholders in the qanats' water, consumed considerable amounts for irrigating their lands and gardens (Abbasi, 2008, p. 60,61). The other two water-dependent business groups were icehouse owners and barrel owners. Since it was common among barrel owners to deceive people into buying low quality ditch water as fresh water from the qanats' outlets, the City Hall took charge of them directly (Abbasi, 2008, p.83,119,120) (Fig. 5). Watermills and bathhouses also depended upon qanat water to provide their service (Semsar Yazdi & Labbaf Khaneiki, 2017, p.145). Water carriers were a fairly small group of people who carried containers in the street in order to sell or distribute water for free (Ghaffari, 2012, p. 39,40). In those decades, qanat water was transferred to houses and water reservoirs via open water channels like streams and ditches that ran through the streets, giving way to a gradual accumulation of pollutants in the water. This led to frequent outbreaks of waterborne diseases which made the Tehran municipality start covering ditches and paving the streets to prevent dust and pollutants from entering the water. Along with the municipality's actions, the government's health department appointed Pasteur Institute of Iran to assess qanats and domestic water quality (Abbasi, 2008, p. 112-117).

FIGURE 5 Queue of barrel owners at Shah Qanat outlet, Old Tehran, 1930s (Kheshtesarekhom, 2018).

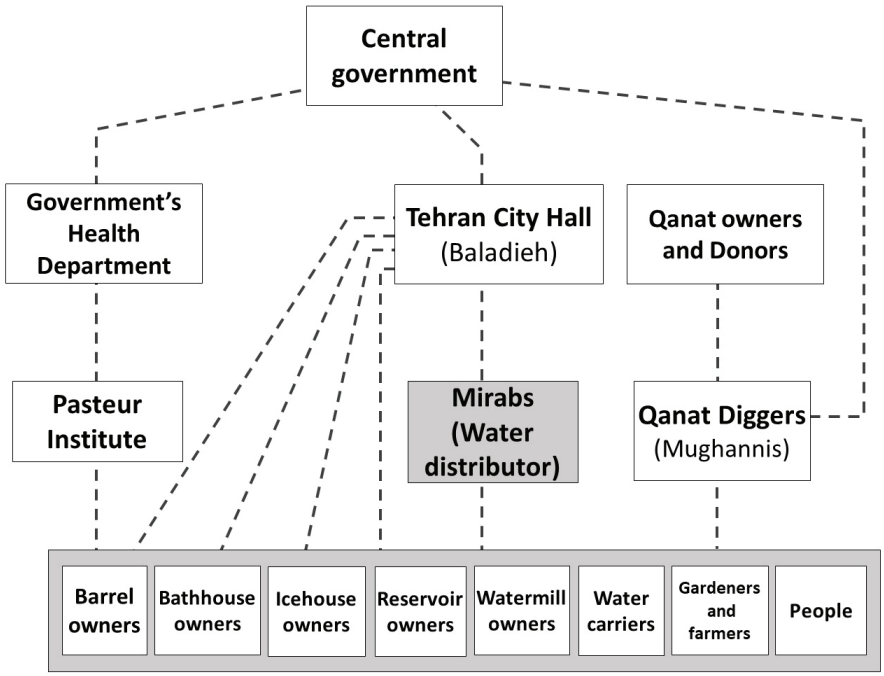

FIGURE 6 Traditional qanat exploitation and management regime.

How influential each of these stakeholders were in the management of qanat systems might have varied throughout city's qanat-dependent lifetime; still, the mechanism shown (Fig. 6 & Table 1) gives an overview of Tehran's traditional water management regime and the parties involved in the process, which functioned effectively for a relatively long period, until the modern time.

The Emergence of the Modern Water Systems

As Tehran was transforming into the flourishing capital of Iran, the modernism movement was thriving in the west, reshaping European cities in an unprecedented way. Witnessing some European governments' enthusiasm in modernising their big cities, Iranian kings and officials showed a tendency for pursuing the same path, and chose Tehran as the flagship of the government's modernisation schemes. At that time, in their memoirs or reports, some foreign travellers and representatives would mention Tehran's primitive infrastructure, especially the polluted, stinking, unsightly ditches (Abbasi, 2008, p.167,168; Ghaffari, 2012, p. 27-29). Such embarrassing accounts, which were damaging to the central government's international pride, became a strong motivation for initiating infrastructure-based developments in the country's water and energy sector during Pahlavi Dynasty (1930s). The transition from the traditional water provision system of qanat towards the piped water system was one of the most significant features of the intended modernisation process. An improvement that took almost two decades, from 1936 to 1956, to be realised, after being halted several times for various reasons, including World War II, economic issues, and political controversies (Abbasi, 2008, p. 142-157). The immediate, easy access to clean drinking water from tap, an age-old dream that had come true through the piped water system, gradually eliminated the past difficulties of supplying clean water for houses from people's memories; despite the fact that they were still living in a mostly arid country with high chances of facing water crises, wasting water became a common act, especially among younger generations.

TABLE 1 Qanat water exploitation and management stakeholders in the past, from late 18th to mid-20th century.

SECTOR	STAKEHOLDER	WAYS OF INVOLVEMENT	REFERENCE
Public sector	Central Government Tehran City Hall	Constructing qanats Supervising qanat water allocation, controlling urban water supply, quality assurance for drinking water, supervising barrel owners' activity	(Abbasi, 2008) (Abbasi, 2008)
	Government's Health Department	Dealing with the issue of water pollution	(Abbasi, 2008)
	Pasteur Institute	Assessing qanat water and domestic water quality	(Abbasi, 2008)
Private Sector	Barrell owners	Supplying and selling high quality qanats water (under city hall's supervision)	(Abbasi, 2008; Ghaffari, 2012)
	Bathhouse owners	Collecting water for providing public hygiene services (under city hall's supervision)	(Abbasi, 2008)
	Reservoir owners	Collecting water for public consumption	(Ghaffari, 2012)
	Icehouse owners	Collecting and use of water for producing ice (under city hall's supervision)	(Abbasi, 2008)
	Watermill owners	Using qanats' hydropower for grinding grains	(Semsar Yazdi & Labbaf Khaneiki, 2017)
	Gardeners and farmers	Using water for irrigating their lands and gardens	(Abbasi, 2008)
Civil Society	Mirabs	Allocating water shares to irrigation right owners	(Ghaffari, 2012)
	People	Using water for domestic purposes	(Ghaffari, 2012)
	Qanat owners and donors	Funding qanat construction	(Ghaffari, 2012)
	Water carriers	Selling or distributing water for free in their containers	(Ghaffari, 2012)

A similar transition occurred in the agricultural sector's water provision mechanism on a national scale. Before Iranian Land Reform in the '50s and '60s, landowners were the owners of qanats as well, so they were responsible for maintenance and repair of qanats if needed. But, with the implementation of the land reform programme and redistribution of lands from large landowners to smaller agricultural workers, the custody of qanats was given to multiple owners, a situation that resulted in the mismanagement or dereliction of qanats (Maleki & Khorsandi Aghaei, 2006, p. 47,48). The fact that qanats were extended over a vast geographical area beneath several lands with different owners, sometimes became a source of conflict among qanat owners and landowners. As a consequence, National Consultative Assembly of Iran passed a law on qanats, in an attempt to determine legal considerations and limits of construction, development, and exploitation of qanat systems. However, landowners preferred to dig deep wells in their own lands in order to avoid such controversies. Digging these deep wells without conducting previous hydrological assessments led to a gradual decrease in the groundwater level and the complete drying up of nearby qanats (Maleki & Khorsandi Aghaei, 2006, p. 44).

Along with these two fundamental changes, there were several other factors that more or less contributed to the gradual decline of qanats systems. Dams that were constructed across rivers from the 60's onwards reduced the supply of water that fed Tehran's peripheral plains, leading to a constant reduction in the amount of underground water, resulting in many qanats starting to dry up. Coupled with declining subsurface water levels, the uncontrolled process of urbanisation severely damaged qanat networks.

Many qanat channels and shaft wells got ruined while excavations were carried out for motorway or high-rise construction projects. Lack of attention to the paths of existing qanat networks and their buffer zones by the officials in Tehran's metro tunnels construction project destroyed many of them over the past three decades. To worsen the situation, the leakage of sewage from domestic wastewater collection wells into the qanat channels deteriorated many qanats' water quality (Maleki & Khorsandi Aghaei, 2006, p.47-49).
In terms of management and exploitation, the numerous laws and legislations concerning qanats and groundwater throughout the past century not only resulted in a heightened complexity of bureaucratic procedures, but also diminished people's role in the preservation and exploitation of qanats. This plurality in the management and ownership of qanats, and the multiple laws concerning this system, have given rise to bureaucratic complexity, inconsistency between different sets of laws, and conflict among key stakeholders in qanat exploitation and maintenance.
All these transformations that have taken place over the last 70 years have brought about several new forces and considerations that influence the qanat system's existence and function. As a consequence, the categories and interrelationships of stakeholders involved in contemporary qanat exploitation and management regimes dramatically differ from those of the past.

The Contemporary Water Governance System

Over the past decades, owing to the reliance of consumers on piped water systems, new qanats have been rarely constructed, and qanat-related activities have become limited to their exploitation, maintenance, and rehabilitation. As the country's water sector has gone through dramatic changes over the past decades, partly due to laws and legislations that introduced water resources as public assets, a considerable share of authorisation and responsibilities concerning qanat construction, maintenance, and rehabilitation was assigned to two major public organisations: Ministry of Energy and Ministry of Agriculture *Jihad* (Ministry of Agriculture (*Jihad*) Act, 2001; Ministry of Energy Organization Act, 1975; Nationalization of Water Resources Act, 1968). Nowadays, Ministry of Energy stands at the top of the hierarchy of power, occupying the most influential role in the decision-making processes relating to qanats. The ministry's mandates for qanat preservation and management include conducting benefit assessment and feasibility study for the construction of new qanats or dredging and rehabilitation of existing ones, issuing excavation permits, verification of competency for *mughannis*, resolving the conflicts among qanat beneficiaries and adjacent qanat owners, determining qanats' buffer zones, and delegating some of the aforementioned responsibilities to its subordinates. Furthermore, according to the law, Ministry of Energy has the authority to take the possession of qanats that have been abandoned for more than four years. The regional water company branches, as the main subordinates of Ministry of Energy, are entrusted with issuing excavation and dredging permits for qanats in their respective provinces. Alongside Ministry of Energy, and at the same time under its authorisation, the Ministry of Agriculture *Jihad* is responsible for qanats that are utilised for agricultural purposes. Because of the increasing complications arising from the arguments over ownership of qanats, Real Estate Registration Organisation is in charge of drafting ownership documents and determining the owners' property rights (Fair Water Distribution Act, 1983).
Currently, the most important beneficiary of the majority of active qanats in Tehran is the city's Gardens and Green Spaces Organisation, which, under the authorisation of Tehran Municipality, uses qanat water for irrigating urban green spaces (Shoaei, 2018). This puts Tehran municipality under the obligation to preserve and maintain qanats, not only as their current owner but also as a major organisation with a wide range of authorities. Ministry of Energy and Tehran's city council have put an emphasis on the municipality's obligations concerning qanats (Fair Water Distribution Act, 1983). In addition to its direct responsibilities for qanats, Tehran municipality influences qanats within the city indirectly through some subordinate organisations, such as Waterways and Qanats Department, Disaster Mitigation and Management Organisation, and Department of Environment and Sustainable Development. These organisations are assigned to do diverse tasks, including identification and mapping of existing qanats

networks, managing qanat water consumption, protecting qanats from pollution or destruction, and mitigating the threats of land subsidence due to the destruction of qanats ("Saze-haye Hayatbakhshe dar Hale Ehtezar [Vital Structures at Stake]," 2019; Shoaei, 2018; "Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018).

Apart from Tehran municipality, there are still some qanats that are owned by individuals. in such cases the owners are in charge of all the expenses and implementations needed for the repair, dredging, and rehabilitation of their qanats, although they have to obtain required permits for these practices (Fair Water Distribution Act, 1983).

FIGURE 7 Participants of World Heritage Volunteers Camp 2017 doing preservation activities for Hasanabad-e Moshir Qanat, Mehriz ("Bargozari-e dovomin camp-e davtalabane-ye UNESCO dar Iran [Holding the second UNESCO Volunteers Camp in Iran]", 2017).

Local qanat knowledge had a mostly empirical basis in the past, so qanat-related studies were rare and usually conducted by foreign scholars. However, nowadays, the qanat is regarded as a valuable feature of Iranian cultural heritage. Hence, many institutions and research centres encourage carrying out studies on qanats from various perspectives, from socio-cultural to technical (Fig. 7). Over the past a few decades many researchers and university students have conducted studies in order to achieve the best ideas and practical solutions for the efficient rehabilitation and protection of existing qanats. Together, this community of researchers and scholars form a new type of actor named "the academia". Alongside the Department of Environment and Sustainable Development of Tehran municipality, the academia supports the improvement of qanat knowledge.

The challenging coexistence of qanat systems and contemporary urban elements had generated overlapping responsibilities or conflicts of interests between the stakeholders of present qanat water management regimes (Ministry of Agriculture (*Jihad*) Act, 2001) (Fig. 8 & Table 2).

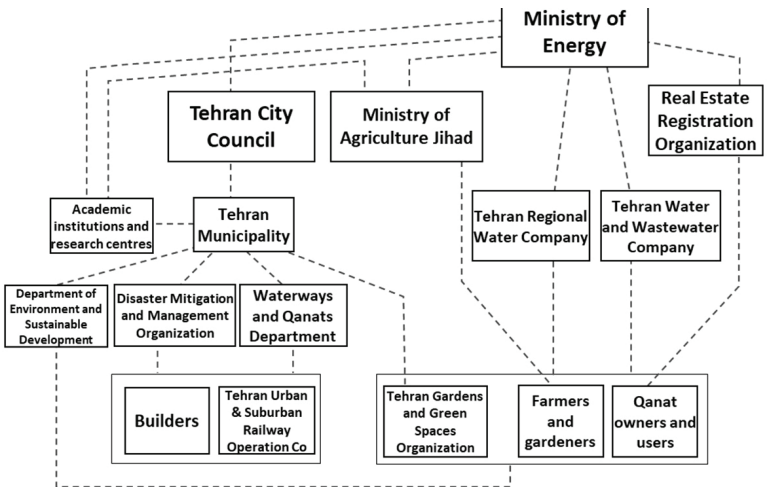

FIGURE 8 Contemporary qanat exploitation and management regime.

TABLE 2 Present qanat water exploitation and management stakeholders.

SECTOR	STAKEHOLDER	WAYS OF INVOLVEMENT	REFERENCE
Public sector	Ministry of Energy	Protecting and supervising qanats, issuing permits for construction of new qanats or dredging and rehabilitation of existing ones, issuing excavation permits, verification of competency for diggers, determining qanats buffer zones, requiring owners to dredge or rehabilitate qanats	(*Fair Water Distribution Act*, 1983; Ministry of Energy Organization Act, 1975; Nationalization of Water Resources Act, 1968)
	Ministry of Agriculture Jihad	Protecting and supervising qanats which are utilized for agricultural purposes, especially qanats situated outside city boundaries (alongside ministry of energy)	(*Fair Water Distribution Act*, 1983)
	Tehran Regional Water Company	Issuing qanats dredging and repair permit (under supervision of ministry of energy)	(*Fair Water Distribution Act*, 1983; Shoaei, 2018)
	Tehran Water and Wastewater Company	Preventing from leakage of urban sewage into qanat water	(*Fair Water Distribution Act*, 1983)
	Real Estate Registration Organization	Drafting qanat ownership documents and resolving controversies surrounding qanats (under the supervision of Ministry of energy and Judicial system of Iran)	(*Fair Water Distribution Act*, 1983; Nationalization of Water Resources Act, 1968)
	Tehran City Council	Pushing through legislation on protection of urban qanats, requiring the municipality to take needed actions	(*Fair Water Distribution Act*, 1983; Shoaei, 2018)
	Tehran Municipality	Protecting and maintaining qanats within the city boundaries (the main beneficiary of qanat water), Identifying qanat networks and obliging other organizations and private sector builders to respect their buffers	(*Fair Water Distribution Act*, 1983; "Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018; Shoaei, 2018)
	Tehran Gardens and Green Spaces Organization	Using qanat water for irrigating urban green spaces	(Shoaei, 2018)
	Waterways and Qanats Department	Protecting qanat networks against urban construction and excavation projects	("Saze-haye Hayatbakhshe dar Hale Ehtezar [Vital Structures at Stake]," 2019)
	Disaster Mitigation and Management Organization	Preparing qanat network maps for other organizations' inquiry	("Naghshe-ye Bi-khasiat az Qanavat-e Tehran [Useless Maps of Tehran's Qanats]," 2018)
	Department of Environment and Sustainable Development	Gathering information about qanats, using new methods and techniques of planning and managing activities and interrelationships concerning qanats, optimizing qanat water consumption, preventing qanat water pollution, supporting researches on qanat rehabilitation and protection	(Hashemi, 2007)
	Tehran Urban & Suburban Railway Operation Co	Considering qanat networks and paths in the design and construction of tunnels	("Vaghti Qanat-ha Zir-e Pa-ye Tehran ra Khali Mikonand [When Qanats Cause Land Subsidence in Tehran]," 2018)
Private Sector	Builders	Considering and respecting qanat paths and buffer zones in construction projects	(Shoaei, 2018)
	Farmers and gardeners	Using qanat water for irrigating their agricultural fields and gardens	-
Civil Society	Qanat owners and users	Dredging and repairing qanats	-
	Academic institutions and research centres	Conducting researches on qanats	-

Key Findings and Discussion

According to Hussain et al. (2008), the functioning of the qanat systems is dependent upon three types of factors: physical, environmental, and socio-cultural (p. 343). This classification was used as a basis for summarising challenges that Tehran's qanat networks deal with (Table 3 and Table 4). When compared, the two different time frames reveal a noticeable change in two main aspects of qanat life: first, the kind of challenges that the qanat network has faced over the past century, from common operational issues to the problems that stem from the inharmonious coexistence of qanats and urban development products; second, the number and socio-occupational status of the stakeholders involved in the process.

TABLE 3 Qanat challenges in the past and stakeholders who were involved in addressing the issues.

	PHYSICAL			ENVIRONMENTAL		SOCIO-CULTURAL		
	Repair and Dredging	Qanat network Damages and destructions due to urbanization	Land subsidence due to qanat tunnels destruction	Decrease in groundwater level	Water pollution due to wastewater seepage	Conflicts over ownership and water rights	Costs of repair and maintenance	Heritage preservation
Ministry of Energy	√	√		√	√			
Ministry of Agriculture Jihad	√	√		√	√	√	√	
Tehran Regional Water Company	√			√			√	
Tehran Water and Wastewater Company					√		√	
Real Estate Registration Organization								
Tehran City Council		√					√	√
Tehran Municipality		√					√	√
Tehran Gardens and Green Spaces Organization								
Waterways and Qanats Department	√	√	√		√		√	√
Disaster Mitigation and Management Organization		√	√					
Department of Environment and Sustainable Development			√	√	√			
Tehran Urban & Suburban Railway Operation Co		√	√					
Builders		√				√		
Farmers and gardeners					√			
Qanat owners and users	√				√			
Academic institutions and research centers	√	√	√	√	√			√

Evidently, the number and diversity of qanat users has decreased over time. This is partly due to the disappearance of several traditional businesses like icehouses. Replacement of qanats with piped water systems and deep wells is another reason for the limited numbers of remaining users. This shift has led to a decrease in the influence of civil society on decisions made in relation to qanats. According to Hussain et al. (2008), the proper functioning of the qanat relied on social factors of cohesion in community, participation, cultural values, and community leadership, combined with technical interventions. However, with the downturn in community presence and influence, qanat-related activities converted from a participatory action into a technical intervention on the part of the small groups of remaining users.

A comparison of the two qanat governance regimes indicates another important result: the challenges this traditional system encounters currently is predominantly addressed by governmental organisations, whereas in the old times it was the community who played a more effective part in solving the problems. As an example, *mirab* was one of the most influential players of the past who has totally disappeared over the years. With a multifaceted role, *mirabs* used to make a significant contribution to the smooth operation of qanats before the modern era. Apart from supervising the water share division and rational water consumption, they were held accountable for settling water-related disputes and administering the qanats' budgets. But, in their absence in the contemporary qanat management regime, those responsibilities seem to be distributed among the governmental bodies (Ministry of Energy, Ministry of Agriculture *Jihad*, Tehran City Council, and their subordinates). This change has brought about a big drawback: the omission of a facilitator of communication and a mediator between community members and formal institutions, which has become a vast gap between the qanat-related community and the authorities. Without such an actor, neither governors nor authorities would notice the real-life problems and conditions that qanats may experience or cause. In addition, the people who affect or are affected by the presence of qanats cannot properly express their demands.

TABLE 4 Contemporary qanat challenges and stakeholders who are involved in addressing the issue.

	PHYSICAL		ENVIRONMENTAL		SOCIO-CULTURAL		
	Construction	Repair and dredging	Decrease in water level	Water pollution	Distribution challenges	Disputes over water share	Costs of qanat maintenance and repair
Central Government	√						
Tehran City Hall			√	√	√	√	√
Government's Health Department				√			
Pasteur Institute				√			
Barrell owners		√		√			√
Bathhouse owners		√		√			√
Reservoir owners		√		√			√
Icehouse owners		√		√			√
Watermill owners		√					√
Gardeners and farmers		√					√
Mirabs		√	√		√	√	√
Households		√		√			√
Qanat owners and donors	√				√	√	
Water carriers		√		√			√
Qanat diggers	√	√	√				

The present-day highly bureaucratic qanat management system, which excludes stakeholders from civil society in the problem-solving processes and interventions, has not been particularly successful so far. As an example, over the past decades several organisations and institutions have been directly appointed by the central government to deal with the issue of qanat destruction during urban construction projects (namely Waterways and Qanats Department, Disaster Mitigation and Management Organisation, and Department of Environment and Sustainable Development), yet none of these bodies has been able to effectively tackle this problem. This is mainly because when multiple organisations are in charge of the same issue, instead of reaching a consensus over the actions and plans needed, they either come into conflicts, or pass that responsibility onto one another to avoid complications that might arise. Unfortunately, this ignorance has caused many qanat channels and galleries to get destroyed by excavation projects. Salek (2019) argues that

while a centralised water management regime turns out to be incapable of solving such conflicts effectively, a participatory, community-based water governance style will make way for more hands-on solutions.

However, as we can see, these transformations have not always ended up with eliminating the part of civil society actors. Among the multiple new governmental organisations that have been established or got involved in qanat's matters, there is a new party from civil society with a considerable influence in the realm of qanat knowledge. With its reliance on science and knowledge, "the academia" has an extensive capacity to take part in diverse qanat challenges. As qanats' status has shifted from the city's most fundamental water infrastructure to a technical legacy of past generations, some new types of qanat-related interventions have emerged, termed as preservation and rehabilitation activities. Even though most of the preservation activities are planned and performed by governmental bodies, the academia plays a role in this particular domain.

The academia has the potential to make remarkable contributions to almost all aspects of the qanat's life, through raising awareness about the heritage values of the qanat and its capabilities for mitigating the urban water crisis, and providing technical consultancy services and working out novel ideas to better adapt the qanat system to the modern-day urban context. Owing to their respected position among the public and their ability to effectively liaise with governmental organisations and authorities, this party is also the best group from which the missing valuable actors of the past could be recreated in the form of multidisciplinary committees.

Conclusion

The interconnection between the present-day Tehran's urban life and its existing qanat networks is really challenging on account of the threats they pose to each other. On the other hand, qanats can bring added value to their urban context not just because of their heritage value, but for their potential in mitigating the upcoming water crisis. Qanat rehabilitation programmes that have been implemented have so far proved ineffective, for they focus solely on the physical maintenance of qanats and neglect the vital role of community participation in the process. This confirms that qanats will not be revitalised unless there is a social mobilisation and willingness for its revival among the community.

The qanat's background in shaping particular cooperation among community members could be a useful starting point for recreating those participatory patterns. However, under the present circumstances and dramatic transformations that have occurred in Tehran's socio-environmental realm, those patterns are not applicable unless they are adapted the changing needs and uncertainties caused by urbanisation process, demographic growth, and climate change.

Therefore, through a comparison of the traditional qanat management practices and the involved key actors' interrelations, with the contemporary management regime, this research tried to discover the gaps that hinder the sustainable rehabilitation of qanat networks. Rather than the common limited focus on physical aspects, this study demonstrated the increasingly widespread and complex social, cultural, environmental, and political challenges in water regime of Tehran with an emphasis on a broader appreciation of community engagement processes in urban water management. The insights from this comparison provide a grounding for further research on how actors and institutions from the public sector, the private sectors, and particularly the civil societies and local communities interact in planning, governing, and inhabiting the built environment.

Further research into participatory qanat rehabilitation in Iran is still required—in particular in the area of stakeholder engagement and a coordination mechanism for the water management sector in Iran, including traditional water infrastructures. Moreover, a greater degree of integration between interrelated stakeholders from public and private sectors, as well as civil societies, is needed to effectively synthesise the socio-economic and environmental challenges within these endangered qanat systems. As such, this research is both an attempt to study participatory approaches to qanat rehabilitation in Iran from past to present and an invitation for future collaboration to put this knowledge into practice on the ground.

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