

Rehabilitation strategies for Tehran University Qanat in the frame of sustainable development

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Abstract

Historically, access to water resources had always been a key issue in the formation and perpetuation of ancient cities, more importantly in the arid and semi-arid regions like the central plateau of Iran. Based on the environmental situations, Persian civilization considered ecological realities and social interaction of conservation and proper distribution of the water to sustain its availability to all the users. Thereupon, they succeeded in achieving a lasting solution to the problem of the shortage of water. To overcome the inevitable climate condition, Iranians developed unique water structures such as qanats.

However, as a consequence of modernisation in the 20th century, the traditional water structures underwent considerable damage and were replaced by deep wells. These changes affected the groundwater supplies in turn and intensified the water crisis in Iran.

Focusing on its importance in the sustainable development, this paper aims to study the qanat system. Introducing Tehran University Qanat as a vivid example, the role of qanats in a sustainable urban development is elaborated. Based on the analysis, suggestions are brought forward for the rehabilitation of this qanat. The findings of this research are believed to raise the awareness about the role of qanats in the sustainable development.

Keywords: Qanat; Rehabilitation; Sustainable Development; Tehran University Qanat.

Introduction

Adapting to the environmental and climate conditions and having access to water resources have always been among the largest human concerns for establishing and developing prosperous cities. The importance of access to the resources of water is more perceptible in the arid and semi-arid regions like Iran. Approximately, more than 90 per cent of the total area of Iran, situated in an arid and semi-arid climatic condition are deprived of having access to the surface water such as rivers. Up to 70 per cent of the precipitation is lost in the evaporation that intensifies the severity of water shortages. [1]

Considering the environmental condition, Persian civilization recognized both ecological realities and social imperatives of conservation and proper distribution of the water so as to ensure its availability to all. Thereupon, they succeeded in achieving a lasting solution to the problem of the shortage of water. They created various complex systems and structures such as qanat¹ to surmount the problem of access to water and irrigation of the agricultural lands.

The consequential role of this structure in enlivening the waterless lands and planting arid regions of Iran and other parts of the world is undeniable. Therefore, in 2016, under the title of 'Persian Qanat', this structure was registered on the World Heritage List. The inscription of the qanat is justified by criteria 3 and 4 for being a testimony of cultural traditions and an outstanding typology of technological ensembles. [3]

In recent years, however, drought and mismanagement of water resources have turned water into a crisis in Iran. The UN Development Program has predicted that compared to 1990 with 2,025m³, the level of Iran's per capita water resources will fall to as little as 816m³ in 2025.

¹ Qanat is a form of a subterranean aqueduct, which collects and directs groundwater to the surface canals through a gently sloping underground conduit. [2] Qanats are composed of different parts: mother well (the starting point of qanat), well shafts, tunnel and mazhar (the exit point of water).

[4] Iran's Institute for Forest and Pasture Research has reported that the level of groundwater has dropped two meters across 70 plains in the recent years affecting as large as 100 million hectares.

[5] In the light of these facts, the technologies used by Persians to overcome the unavoidable issue of access to water are of a great importance. Highlighting this problem, qanat can be an effective means towards shaping sustainable cities. Nevertheless, with the development of science and the advent of novel watering techniques in the 20th century, the traditional and sustainable water supply systems, deemed less productive in the ever-growing urban areas, were widely overlooked.

In Tehran, the capital of Iran, qanats were more affected by the changes of the modernisation so that a considerable part of the qanat network was severely damaged. To meet the growing demands for water in this metropolitan, the government and other investors took advantage of modern and less sustainable hydraulic systems such as deep wells and pumps, because they were more productive in a short-term. [6] This substitution speeded the pace of the water crisis through draining aquifers, changing the groundwater table and reducing the water supplies. It is plain to understand that, disturbing the balance in the environment will bring about further irrecoverable problems in future.

Tackling these problems, it is assumed that preservation and rehabilitation of qanats can help detract the inflicted harm upon the environment and preserve a balanced interconnection between elements of the sustainable development.

Based on the previous discussions, in order to better clarify the problem, a case study approach has been opted for. To this aim, Tehran University Qanat is reviewed in order to examine and analyse the role of qanat in the sustainable development. According to the historical records, Tehran University Qanat is one of the oldest qanat routes in Tehran. [7] The importance of this qanat lies in its capacity to be efficiently exploited. It also passes through important areas and universities in Tehran. Yet, because of the construction of four highways and two subway lines along the qanat route, it is damaged in multiple sections of its structure. These damages can be in turn at the expense of the new urban constructions and infrastructures that are connected to this qanat.

Qanat and sustainable development

"The 'environment' is where we all live, and "development" is what we all do in attempting to improve our lot within that abode. The two are inseparable. Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs." [8]

Development should provide modern needs of each society without imposing any harm on the environment or causing any sacrifice of the future generation's power for securing their needs. This kind of development is permanent and sustainable. Sustainability means consistency, coherence, and continuity. It is active and in movement and means "to save for the future".

Sustainability, in spite of its fundamental and spreading mottos that are universal and aim at the problem of environmental conservation, recommends a local attitude. It considers the global slogan of "think universally but act locally" in order to provide realistic and feasible solutions on one hand and protection of the diversity on the other hand. [9]

Sustainability is a complicated concept and is defined differently by different researchers and concerned groups. One of these definitions has been introduced by Cato. Diagram 1 shows the interrelation between the three elements of "economy", "society" and "environment" in sustainable development from Cato's perspective. In this diagram, the environment limits the economic and social factors, which means that compared to the other two factors, the environment has a higher priority in the sustainable development.

Diagram 1. The interrelation between the main elements of the sustainable development [10]

In other words, the tolerance capacity of the environment should have a priority importance in sustainable development plans. Interestingly, Persian architectural maxims comply with this definition. According to these maxims, 'any effect causing harm to the environment and

its component is forbidden'. [11] Taking this discussion further, qanat system will be analysed in relation to the sustainable development criteria.

The outstanding advantage of supplying water through this structure is its perfect compatibility with the surrounding natural and environmental condition. Using qanat, water is extracted according to the regular capacity of aquifers and the groundwater supplies. Since qanats concert with the balance between groundwater discharge and recharge, they maintain the quality of the soil and prevent soil salinization. In other words, qanat gains the required water from aquifers putting no pressure on nature and causing no change in the environmental balance. In short, these systems are eco-friendly.

Independence and self-sufficiency and no need for other external energies such as fuel or electricity are among other advantages of qanat system. Adding to these benefits, and considering the long course along which a qanat is stretched, a special social management system was required to ensure the integrity of the beneficiary communities. [Diagram 2] In this management system, some agents were in charge of managing and monitoring the qanat beneficiaries and supervising the distribution of water. Using this management system, the property right for the qanats and the amount of water that each user could benefit from were well defined and agreed upon. Local community and the supervisory board were responsible to protect qanats, dredge and repair them. Accordingly, contribution of and cooperation among the locals, owners, and supervisors were a key factor for protecting qanats and a guarantee for a sustainable use. This social system could also, in turn, strengthen cultural identity and the spirit of cooperation in the community.

Diagram 2. The traditional management system of Qanat. By authors; Data source: [12]

Considering the economic aspect of sustainability, qanats can have a prolonged and unlimited lifespan, if only they are regularly dredged and repaired. Compared to the wells that have a lifespan of about 20 years, the output water of a qanat within a given period is much more steady and reliable. [13] As remarked, the soil quality is enhanced where qanats are used. This advantage dispels the need for investment in improving the soil quality. Furthermore, the

economic prosperity can be regarded as an indirect impact of qanats since the constant presence of water in any region guarantees development of wide range sectors such as industry, agriculture and animal husbandry.

Tehran University Qanat

Introduction

For centuries, the city of Tehran, like any other cities in the central region of Iran, was taking advantage of qanat as its irrigation system. Qanats were among the most productive water systems in the world until the 1960s when the modern urban development, construction of deep wells, destruction of mother wells, and lack of dredging degraded qanats. From more than 500 qanats of Tehran, most are currently dry or are in danger because of discharging sewage into their body or over-extraction of groundwater using deep wells. [14]

Tehran University qanat, one of the most productive qanats in Tehran, was built before the establishment of Tehran University (1934). The original name of this qanat, “Jalalieh”, was changed after transferring its ownership to Tehran University. Later, the Regional Water Company of Tehran recorded this qanat as Tehran University Qanat with the registration number of 37O-11Q.

The length of Tehran University Qanat is about 6900m. According to the Urban Development Department of Tehran Municipality, this qanat has 176 well shafts. The current depth of the first and main well is 40 meters. [7]

Based on the field observation of the authors, some local residents of Eyvanak demand to have a share of the qanat water for irrigating their gardens. The Water and Wastewater Company in the intersection of Hemmat Highway, the Management Faculty of Tehran University and Tarbiat Modarres University are the next beneficiaries. Finally, Tehran University is the owner and major user of the qanat. In the present climate, the social system of water management of qanats is overlooked in the modern society of Iran. This situation, in turn, has brought about some problems and poses threats on the qanats. Tehran University Qanat, as an example, has

undergone a complicated situation in which owners and users improperly extract water and no one is responsible for the supervision of water use and safeguarding the qanat. [Figure 1]

Figure 1. Tehran University Qanat. By authors (Data source: Tehran Municipality, ESRI Basemap, OSM, DIVA-GIS and Earth Explorer)

Problem Analysis and Scenario Development

In the recent decades, due to the changes in the traditional management system, qanats have been ignored and not well monitored. Furthermore, Tehran University Qanat, akin to any other qanat route in Tehran, has not been mapped and identified accurately. For example, the precise coordinates of the well shafts on the qanat path are still unknown and therefore, not considered in the new construction projects.

In 2010, the tunnel of Tehran University Qanat was damaged due to the construction of a bridge in the South of Hemmat Highway and a huge amount of water was being wasted as a result of this event. Even though this part was later repaired, the qanat is still suffering from the illegal water extraction by some of the organisations that are located along the qanat path.

During the fieldwork, it was found that two well shafts on the interspace between the Management Faculty and Tarbiat Modarres University are still exploitable, but water is illegally extracted using pumps. As a result, the level of water has increased up to 5 meters in these shafts. The level of the tunnel in this part of the qanat route is 10 meters under the ground surface. Due to the unusual accumulation of water, this problem puts the tunnel under such pressure that can cause the destruction of the well shafts and the tunnel. The excessive water extraction with the construction of deep wells has also decreased the amount of water discharge at mazhar to zero. The amount of water discharge of Tehran University Qanat, according to the report of Tehran Regional Water Company and the observation of the authors, is as follows. [Diagram 3]

Diagram 3. The amount of water discharge at the mazhar of Tehran University Qanat, 1970-2016 (Data source: Authors' observation and [7])

Lack of an appropriate management and monitoring system, lack of dredging during the recent years, chemical contamination of the qanat water, and wastage of the qanat water are among other important problems of Tehran University Qanat.

Bearing this situation in mind and considering the similar cases, three risk scenarios can be developed for the purpose of the problem analysis and finally reducing the damages on the qanat.

Construction Risk

As mentioned, the absence of a precise map of the qanat and lack of awareness about the location of the well shafts poses a major risk on the new constructions as well as urban infrastructures. In most cases, when facing the well shafts, the builders fill and block those using impervious materials, such as cement and concrete. This disturbs the natural process of soil capacity for absorption of precipitation and the flow of water to the lower levels. Blocking the well shafts, in turn, changes the flow of groundwater so that water accumulate at some points of the route. This increases the risk of damage -such as cracks and even sinking foundation or collapse- to the new constructions.

The improper policy regarding qanat networks in Tehran is also discussable in the large-scale urban infrastructure projects, for example, the construction of highways and subway lines. Planning and structural and seismic calculation of these infrastructures are carried out having no regard for qanats. Since the tunnel and well shafts are timeworn and not reinforced, they are more vulnerable to the vibration and the pressure resulted from the new constructions and more prone to damage and collapse; this, in turn, jeopardizes the new structures built on or in the adjacency of the qanat route. Several examples of this problem have been reported in Tehran. In 2008, for instance, a seven-story building that had been constructed on a qanat route collapsed, in which 17 construction workers lost their lives. [15] In another event, a 5.4-meter deep sinkhole opened up in Tohid Tunnel that had been constructed on a qanat route. According to the records, before the

accident, large cracks and water leakage had appeared in this longest tunnel in Tehran. Lack of a proper mapping of the location of qanat shafts, the negligence of the planners in their structural calculations, and blocking the shafts without considering another route for the qanat is said to be the cause of this accident. [16]

Earthquake Risk

Considering the location of Tehran on several active faults [17], an earthquake is a serious threat to this metropolitan. Tehran is developed on the network of qanats that are currently suffering from a fragile structure due to the lack of a suitable policy and an efficient monitoring system. In the event of an earthquake, it is highly predictable that the well shafts and the tunnel of Tehran University Qanat will collapse. Since the new constructions and urban infrastructures such as highways and subway lines lack proper seismic analysis with regard to this qanat, next, these constructions will damage considerably.

Groundwater Risk

A potential land subsidence is one of the risks of the excessive extraction of a large volume of water and changes in the groundwater level. When the water is inordinately extracted by pumps, the groundwater level declines considerably and the subsurface of the soil loses its strength.

In the case of Tehran University Qanat, lack of balance in the extraction of water along the qanat course, in particular between the Management Faculty and Tarbiat Modarres University, might cause land subsidence. Furthermore, the accumulation of water in one point and pumping water from well shafts, as explained previously, will cause other well shafts in the lowlands and the main tunnel of qanat to lose their water and dry out. This will increase the probability of the collapse of the vulnerable shafts that have not been reinforced or dredged for a long time. [Diagram 4] Because four highways and subway lines number seven and six cut through the qanat tunnel, as a result of this event, an irreplaceable damage to the urban infrastructures can be predicted.

Diagram 4. Potential impacts of the excessive extraction of groundwater using pumping well: groundwater drawdown, land subsidence, earth fissures, drying of the qanat and the collapse of the shafts

Rehabilitation of Tehran University Qanat

Qanat rehabilitation aims to increase the water flow of qanats and revive the traditional knowledge about this technology in order to preserve it for and hand it over to future generations. [18] Taking this definition into account, and considering the socio-cultural roles of universities, rehabilitation of Tehran University Qanat that is intersecting with three important education centres can help achieve this purpose.

Safeguarding this qanat helps protect the local technology and the cultural identity of its social context. Moreover, it can be an inception for increasing the awareness about the importance of qanats, their impacts on the urban areas, and the significance of sustainable watering structures in the arid regions of the Iranian Plateau. Finally, if Tehran University as an active organisation in the culture and education arena tries to persuade state organisations to include the network of qanats in the Master Plan of Tehran, the path to having a sustainable city will be paved.

In what follows, based on the previously defined risk scenarios and the current state of this qanat, some suggestions for the rehabilitation of Tehran University Qanat are provided. According to the nature of these suggestions, they are classified into three categories of “managerial”, “structural/physical” and “cultural”.

Managerial Suggestions

- Reviving the traditional water management system, bringing it to an up-to-date state through integration of the present governmental and regional management bodies, defining new roles for the qanat beneficiaries, governing and controlling the distribution of water; hereupon, specifying the ownership and property rights of the qanat is of a great

importance for overcoming the existing problems and guaranteeing the sustainability of this system. [Diagram 5]

Diagram 5. Recommended management system for Tehran University Qanat

- Defining the rightful beneficiaries of the qanat, supervising them, and legislating regulations in order to prevent ill-usage of water and illegal exploitation.
- Considering the qanat structure in the urban planning in order to preserve the qanat networks, avoid further damage to this structure and future problems for the new urban infrastructures. This can be achieved by reconsidering the location of new constructions and/or defining alternative routes for the qanat tunnel.

Structural/ Physical Suggestions [Figure 2]

- Detailed documentation of the divisions of the qanat route that are yet unidentified. This includes the distance from the mother well to its intersection with Hemmat Highway (about 500 m) and the division where it will be affected by the construction of the new monorail line (about 200 m).
- Dredging the qanat tunnel and repairing the clogged shafts. Currently, about 600 meters long from mazhar to the north of the qanat route is in urgent need of dredging.
- Digging alternate well shafts and changing the tunnel course where collapsed in order to avoid water accumulation and a consequent landfall occasion.
- Structural calculation and analysis for identifying vulnerable points of the qanat, in particular in its intersection with highways and subway lines.
- Reinforcement of the qanat where the subway lines No. 6 and 7 cut through the tunnel leastways from the Management Faculty up to 500m to the north. The same measures should be taken for construction of the future monorail line.

- Taking advantage of new materials and modern construction technologies for retrofitting and consolidating the structure against natural events such as an earthquake.
- Forbidding discharging chemical wastes and sewage into the qanat tunnel in the Eyvanak neighbourhood.
- Solving the problem of blocked water and unusual water accumulation in the interspace between the Management Faculty and Tarbiat Modarres University.
- Cleaning the qanat tunnel from construction material and waste such as cement that had been discharged into the tunnel during the new construction works. Repairing the damages that these constructions inflicted upon the qanat and reinforcing the tunnel wall and well shafts using light materials (for instance breeze concrete) in order not to prevent the natural process of absorption and flow of water in the soil.

Figure 2. Proposed rehabilitation plan for Tehran University Qanat. By authors (Data source: Tehran Municipality, ESRI Basemap, OSM, DIVA-GIS and Earth Explorer)

Cultural Suggestions

- Holding an exhibition of the rehabilitation process and arranging workshops in the education centres of Tehran and Tarbiat Modarres universities to educate the citizens and beneficiaries about proper ways in dealing with qanat shafts if they located on their properties.

Conclusion

For a long time, the agricultural settlements on the Iranian plateau were being nourished by qanats. By their very nature, qanats as renewable water supply systems encouraged sustainable water use for millennia. [6] The flowing water in the qanat system can remain stable for centuries. If properly managed, qanats not only impose no harm on the environment but also can they be effectively used to avoid catastrophes like desertification. Briefly, taking advantage of qanat

system is completely in coordination with the sustainable development criteria since it increases the cooperation spirit, encourages efficient use of water resources, preserves resources for the future generations and delivers a long-term economic advantage.

Nevertheless, considering the population growth and their increasing demands, it is unrealistic and not feasible to supply the required water merely by qanats. ‘Rehabilitation of qanats can only succeed if married successfully to modern developments taking place in the enabling environment, a process of retro-modernisation if you like.’ [19] Accordingly, with a sensible perspective to this problem, qanats cannot respond to the urban populations unassisted, but they can reduce the improper extraction of water resources and therefore detract damages to the environment. Nevertheless, protection and exploitation of qanats need a concerted action plan with the cooperation among the state organisations and all the owners and beneficiaries.

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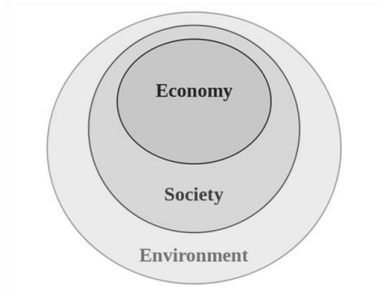


Diagram 1

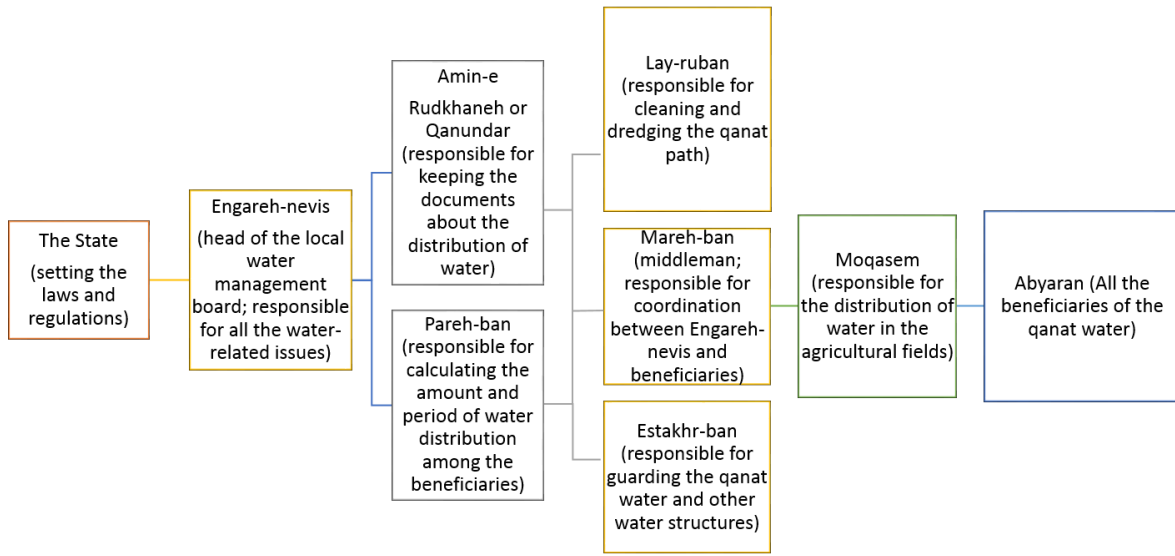


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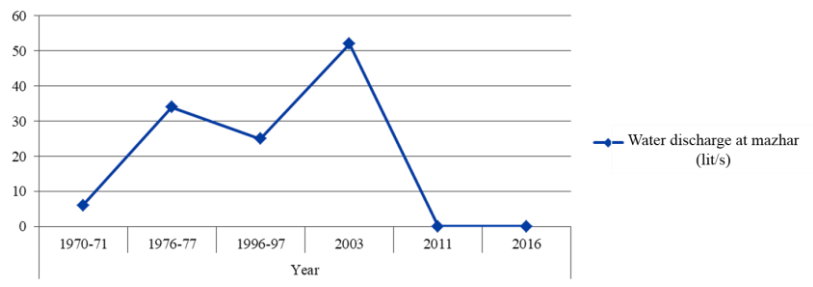


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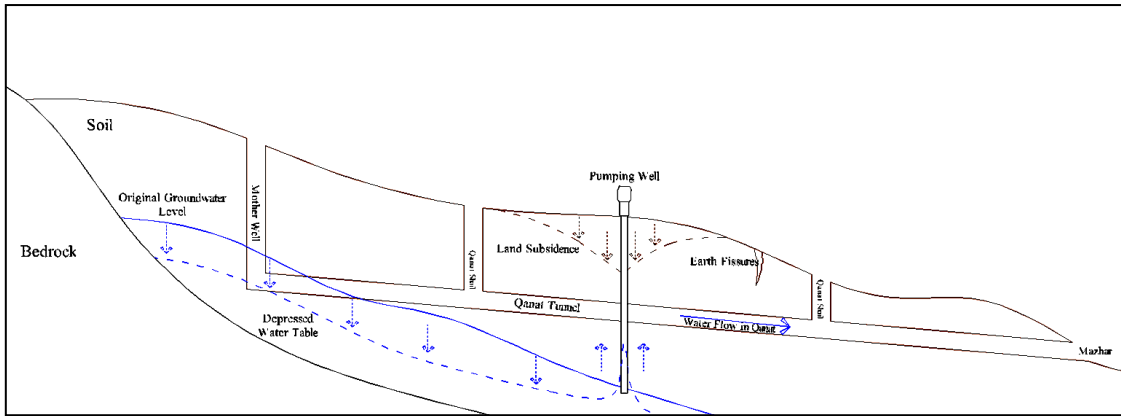


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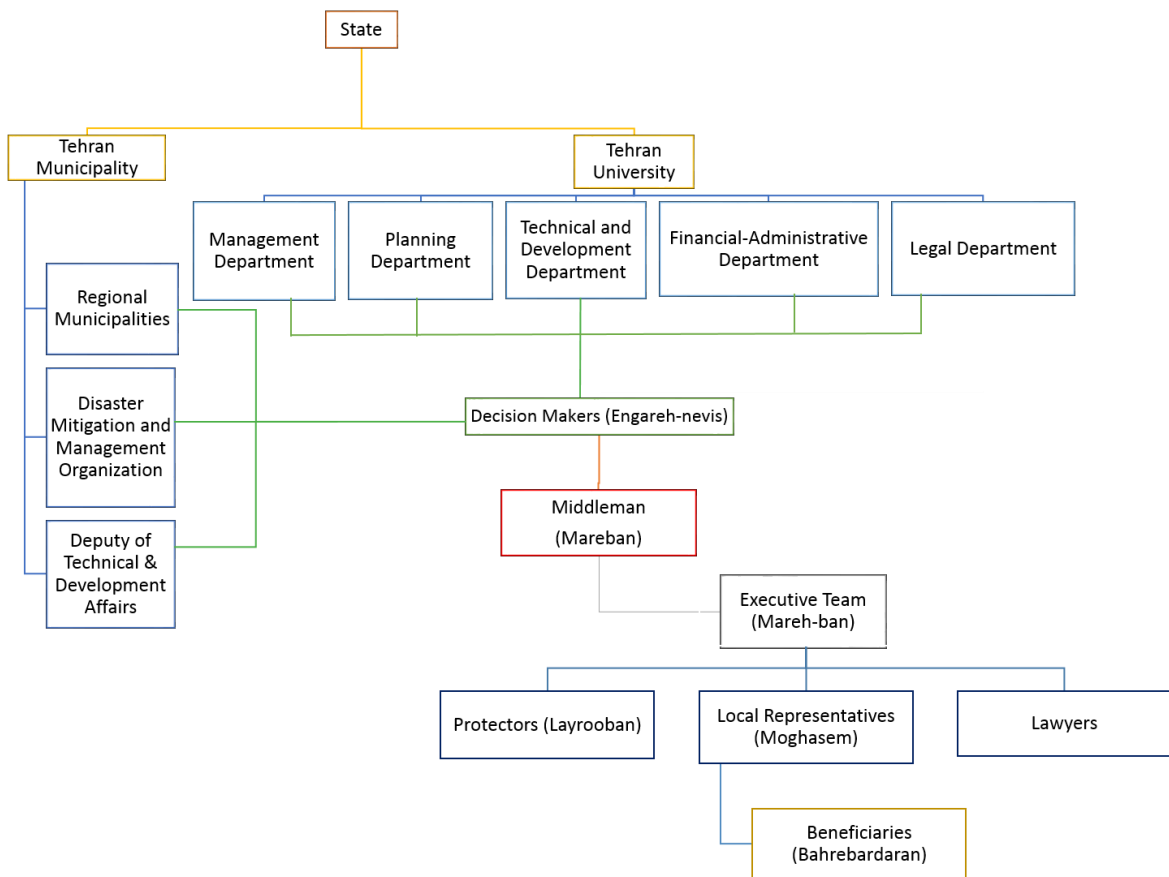
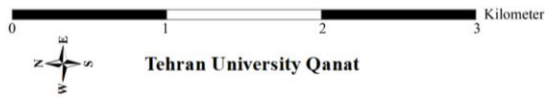
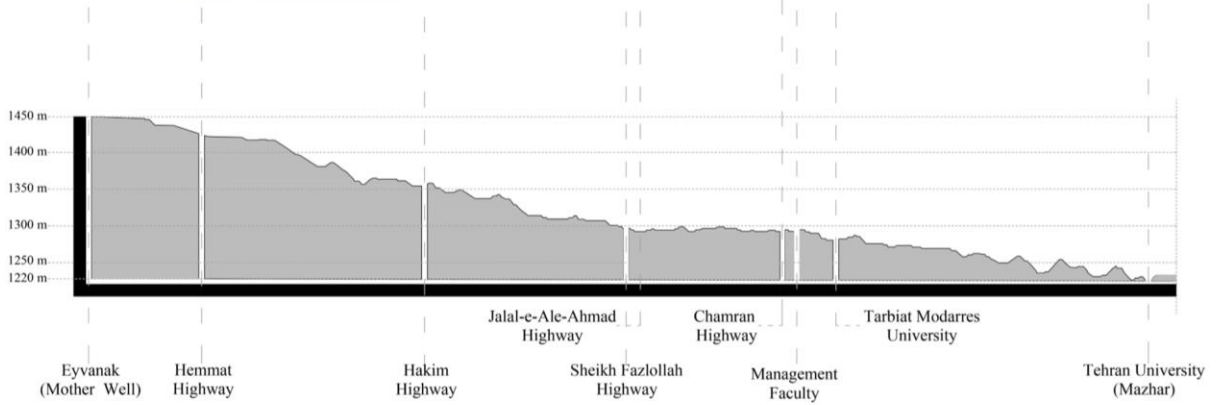


Diagram 5



- Tehran University Qanat**
- Mazhar
 - Mother Well
 - Shafts
 - Qanat Route
 - Highway
 - Subway Line
 - - - Monorail Line (Future Plan)
 - - - Other Qanats

Mother Well UTM Coordinates:
X: 532600; Y: 3957450; Z: 1430

Mazhar UTM Coordinates:
X: 535500; Y: 3951400; Z: 1220

Length:
6900 m

Owner of the Qanat:
Tehran University

Figure 1

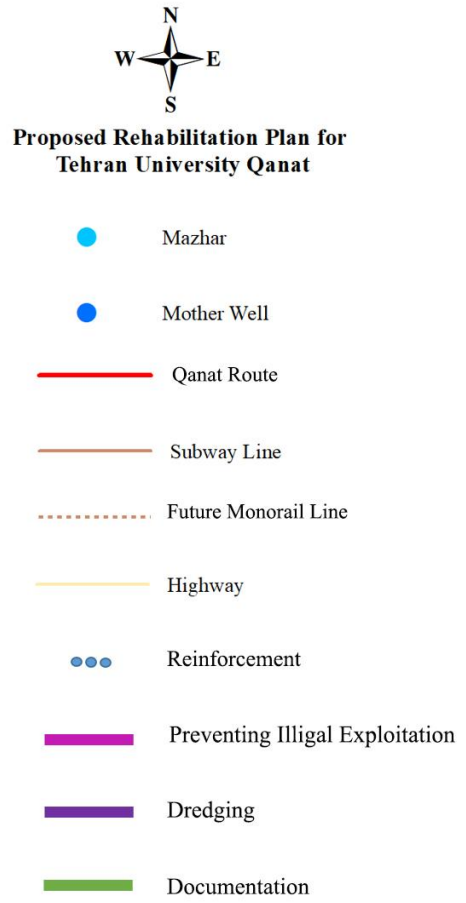
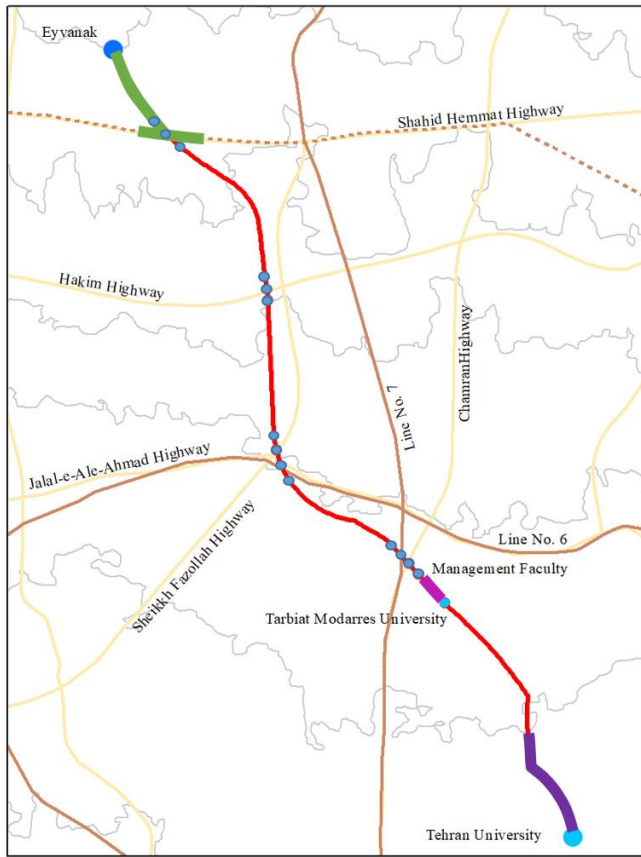


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