

THE IMPACT OF QANATS AS SUSTAINABLE URBAN INFRASTRUCTURES ON THE PROCESS OF FORMATION OF URBAN STRUCTURES AND ARCHITECTURE

***Nasim Ashrafi and Ghazal Safdarian**

Department of Architecture, Faculty Member of Islamic Azad University, Pardis Branch, Tehran, Iran

**Author for Correspondence*

ABSTRACT

Exacerbation of global climate change and current life style caused the earth environmental potential not to appropriately respond to pollutions and contaminations. Therefore methods and techniques consistent with ecological principles have been given more attention. An important part of these skills is experience and knowledge obtained by indigenous people after thousands of years of adaptation to the environment and their habitats. Many regions have a share in the local knowledge, but Kariz or Iranian Qanat has an important place in this regard. Qanats, as one of sustainable urban infrastructures in hot arid regions, play an important role in location of specific areas of cities (cisterns, icehouses, schools, mosques, markets, etc.). In addition, when climate change made countries to face water crisis, they are considered as an important sources of fresh water. By contamination and loss of most Qanats due to modern life and change of human needs, not only chain performance of architectural and urban spaces of old texture, an important factor in urban sustainability, distorted but also it has led to the loss or waste of one of important renewable resources. This research based on documents and library studies and by descriptive and analytical approach aims to identify impact of the Qanats on performance of urban and architectural elements of cities like Yazd and Kerman and consider Iranian Qanats from a new aspect as an indigenous technology in order to express this system's importance in the age of climate change and water crisis and discuss and review the need for restoration and rehabilitation of the remaining Qanats as an opportunity in the process of sustainable development.

Keywords: *Qanat, Water Crisis, Climate Change, Sustainable Urban Infrastructure, Sustainable Development*

INTRODUCTION

In the arid areas of Asia, especially in ancient Persia, water shortage forced people to pay attention to exploitation of groundwater. Sustainability in Iranian cities has originated from interaction of cultural, social, economic, environment and climatic structures over time. In addition to influence the form and function of urban texture during many years, Qanats have also had significant impact on cultural and social principles and relations of urban people (Haeri, 2006).

Only 2.75% of the world's water is fresh, 2.05 of which has been stored in the icehouses and 0.068 % of which has been stored as underground water and 0.011% of which flows as surface water like rivers and seas and this small amount of water is unevenly distributed on the earth (Soltani *et al.*, 2011). At present, 9 countries benefit from 60 percent of all freshwater resources of the world: Canada, China, Colombia, Peru, Brazil, Russia, USA, Indonesia and India. In contrast, 80 countries face water shortage (Jason *et al.*, 2009). Due to climate change and increasing population, access to adequate and suitable water in some countries has become a serious crisis and our country Iran is no exception. However Qanats, that the art of their extraction belongs to the Iranian, have supplied water of hot arid areas of the country for 2500 years (Ahmadi *et al.*, 2010). In recent years, these infrastructures are needed more than any other time due to the water crisis, unfortunately, due to the expansion of modernization goals and use of modern infrastructures and social and economic objectives in the historical towns of Iran, these valuable resources have been left abandoned. Abandonment is the first step of destruction of Qanats and considering that Qanats are extended almost throughout the planet between 20 and 45 degrees latitude (Salih, 2007) and on the other hand, areas that are facing a water crisis at present are located in the same geographical

Research Article

position, the need to restore and protect Qanats seems to be very important in order to meet the water shortage of hot and dry regions of the world somehow (Figure 1).

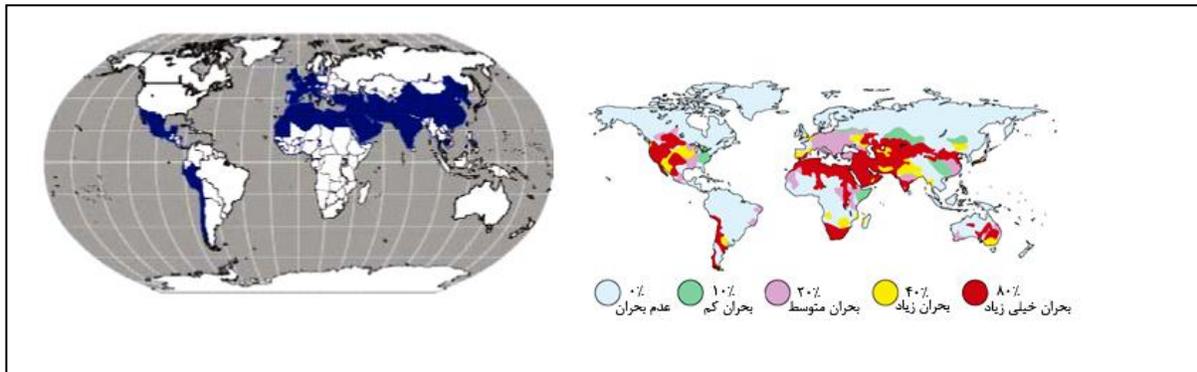


Figure 1: Existing Qanats in the World (left), Areas faced Water Shortage in the World (right)

MATERIALS AND METHODS

The present research is aimed at studying Qanats during the history and their contribution to economic, urban and architectural activities. Then, Qanats are introduced as sustainable urban infrastructures in hot and arid regions of the country, especially in two city of Kerman and Yazd and their urban and architectural structures are studied in order to explain location of main buildings and places of any city including mosques, markets, etc. on the direction of Qanats. By this way Qanats are introduced as a factor of sustainability in these cities that unfortunately with demolition of these structures, sustainability of cities has been threatened as well

RESULTS AND DISCUSSION

History of Qanats Evolution in Iran

Iran is origin of Qanats and during many years its technology was transferred from Iran to other countries and territories (Figure 2) and in proving this claim, Gablo (Expert of Water Science and Technology) writes in his book (1971 AD): "All evidences indicate that the first Qanats have appeared in the cultural limit of Iran."

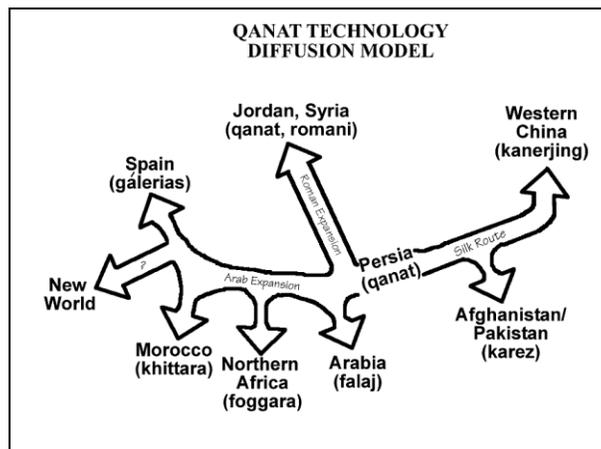


Figure 2: Expansion of Qanat from Iran to Different Parts of the World (Source: taken from Salih, 2007)

Invention of Qanats happened in northwestern Iran (Urartu), Turkey, and it was transferred to the adjacent areas of the Zagros Mountains (Abizadeh, 2011). Qanats' importance has been studied in different periods of time as follows:

Research Article

The Achaemenid Empire (330-550 BC):

People who dug Qanats and transferred underground water to surface did not pay tax to the government and this tax exemption continued up to 5 generations.

The Seleucid Empire (Seleucia) (250-312 BC):

Qanats seems to have been abandoned and some of them were destroyed after occupation of Iran by Alexander.

The Parthian Empire (Arsacid Empire) (150-250 BC):

Parthian kings ignored maintenance of Qanats contrary to the Persians.

The Sasanian Empire (226 BC -650 AD):

In this period of time, Qanats and agricultural lands were considered and the official rulings on construction of Qanats, dams, springs, etc. were passed. In addition, restoration of damaged Qanat was other governmental functions and cities were formed on the basis of these Qanats.

The Islamic Era

In the Abbasid Period until the Mongols invasion, people who were able to dig Qanats were exempted from tax and Qanats were considered more than any period but in the Mongol period many water systems were damaged and dried (Kardavani, 1997). Qanats were restored again in the Safavid period. Qanats carried the most amount of water in Qajar era. In 1840 AD, Hamedan had 50,000 Qanats, Isfahan had 200,000 Qanats, and Tehran had 130,000 Qanats. Construction and maintenance of Qanats continued in the First Pahlavi Regime but on the Second Pahlavi Regime much of Qanats were destructed due to modernization approaches and overuse of this energy source. In the Islamic Republic Era, realizing the qualitative value of Qanats in sustainability and energy, many international conferences were held on this subject and over the years a number of Qanats were restored (Semsar, 2006). Based on the review of Qanats in different historical periods of Iran, the issue is brought up that qualitative status of Qanats has had fluctuations in different years. According to the mentioned trend, wars were factors threatening Qanat in the past but in the last century, due to excessive use of fossil fuels, change in human lifestyle, and change in environmental performance are considered as main factors threatening Qanats that cannot be controlled easily (Figure 3).

Structure of the Qanats

Qanat consists of an open mouth, a qanat channel and several vertical wells that connect the underground duct or furnace at a distance of 20 to 30 meters to the surface. The wells that are called Access Shaft, in addition to act as ducts to transfer drilled materials out, ventilate the underground channels and they are considered as connection ways to dredge and visit Qanat. The mouth is origin of Qanat that is called Outlet of Qanat. Embankment is the interval between 2 access shafts of Qanat and the last access shaft of Qanat at the bottom of "Pishkar" is known as mother well (Figure 4). The longest Qanat and deepest mother well of the world is located in Gonabad City that the history of digging this Qanat goes back to the Achaemenid period or before it. This Qanat is 70 km in length and its mother well is 350 meters in depth (Ahmadi, 2005)

Qanats in Urban Texture

In general, infrastructures affecting urban structures in Iran include religion, economics, and environment and climate (Honari, 1989). Environmental and climate are considered as the most important and influencing components of urban spaces. Considering the traditional textures of Iran, these textures have a harmony and integrity that the contemporary cities lack it and this integrity is resulted from 3 above discussed factors that we should not be unaware of the impact of each factor on the other factors. Qanats, as critical sources and infrastructures of the desert cities like Yazd and Kerman, are flowing as networks under the city and towards topographic direction. Orientation of streets, urban roads, markets and cisterns has been always derived from Qanats' stream and this factor has provided development of cities towards topographic direction. According to Figure 5, the oldest core of Kerman city, i.e. market, already constructed in the north – south direction i.e. towards Qanat, expanded in the east - west direction in Pahlavi Era ignoring the urban infrastructure although this orientation is inconsistent with the sustainable urban principles.

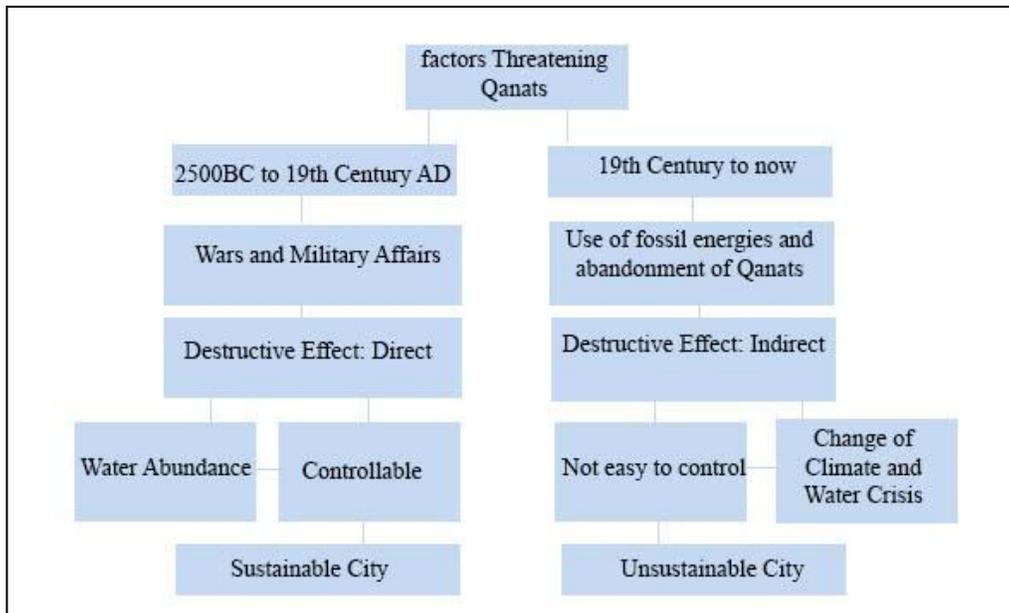


Figure 3: Factory Threatening Qanats

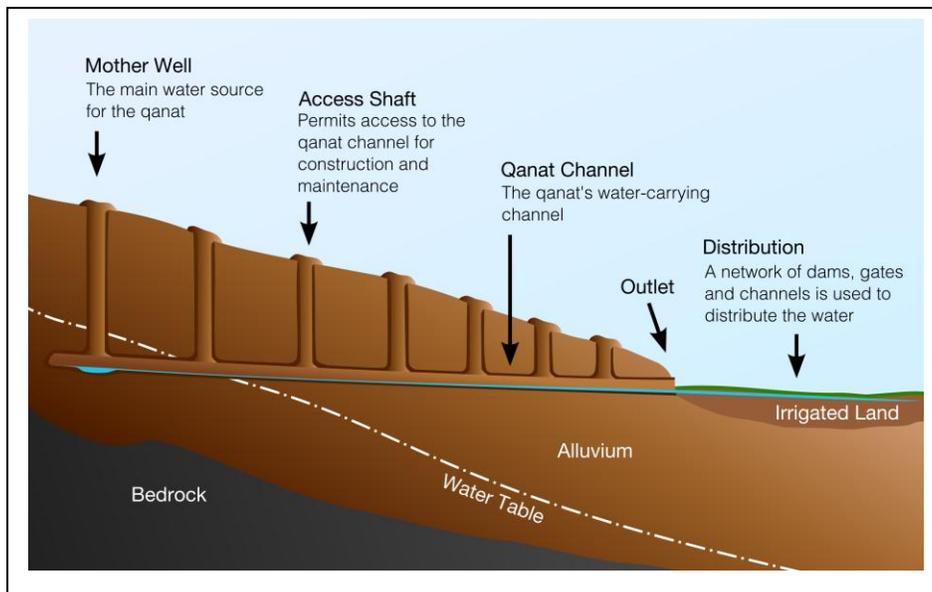


Figure 4: Structure of Qanats

Qanats are considered as factors of unity or discipline of traditional texture of cities like Yazd and Kerman. In Yazd, irrigation systems are patterns of arteries orientation so that the main arteries are located in the direction of the main qanat channels and side streets are designed according to tributaries of Qanats and a checkered network of Qanats route is created by continuing this trend. Houses and agricultural lands are located within each of these blocks. Qanats, according to a hierarchy, have passed under the houses and then enter into farmlands (Moradi *et al.*, 2011) and the houses have access to the spring water through a flight of stairs. In general, the study of elements of Yazd city like cisterns, gardens, icehouses, bathrooms, water mills and their connection to Qanats, this important issue is found out that Qanats are connected like a string and have played an important role in the location of main areas of the city so that their replacement will interfere with Qanats function (Beaumont *et al.*, 1989). Topography and

Research Article

stream of Qanats from Shirkooh Mountain (southeast) to the farmlands (northwest) have had a great impact on orientation and expansion of Yazd.

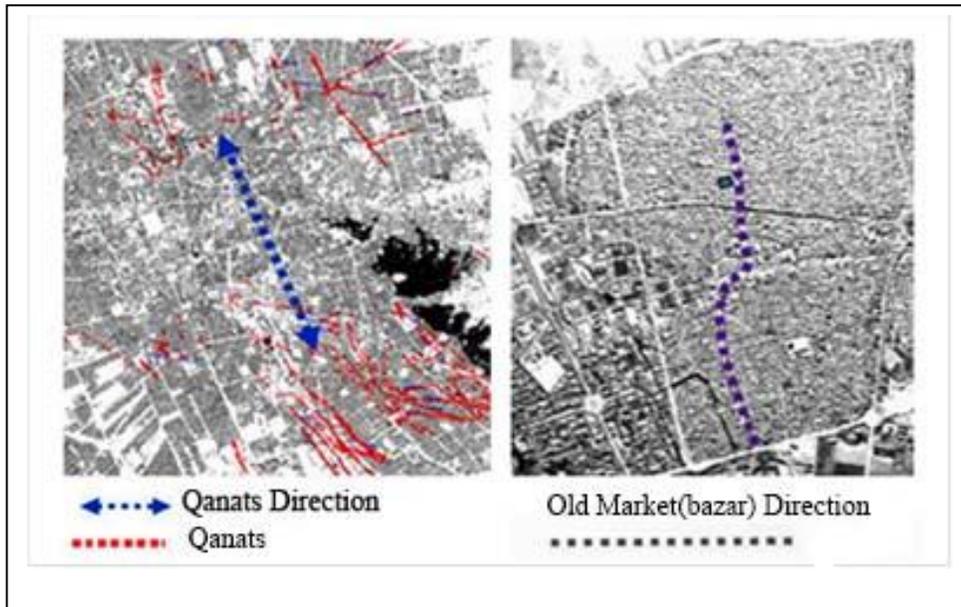


Figure 5: Qanats and Kerman’s Market Direction

It is worthy to note that 2 major and water full Qanats of Yazd named Zarch and Firoozabad pass through the old city and the most important historical monuments of Yazd are located in direction of these Qanats (Figure 6).

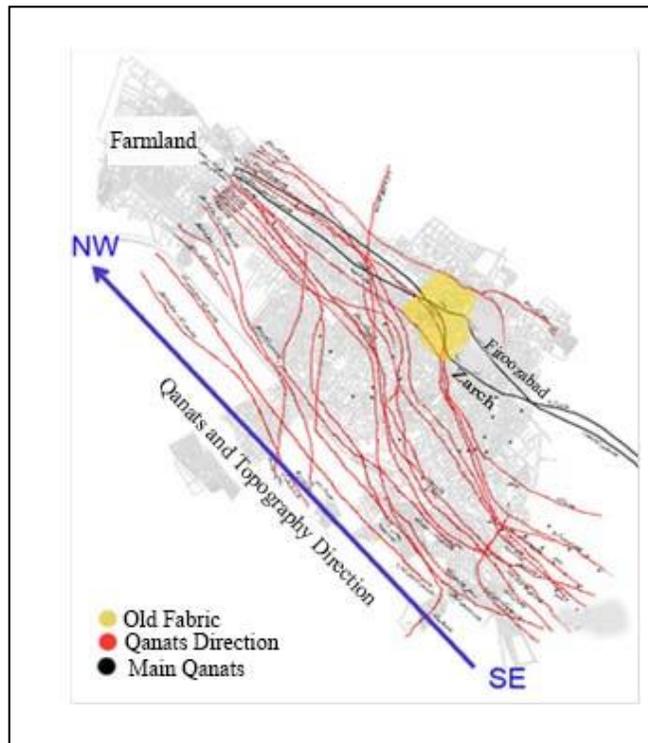


Figure 6: Direction of Qanats in Yazd City (Source: the Author and Water Museum of Yazd)

Research Article

Qanat in Architectural Structures of Hot and Dry Regions

Specific climate of some cities of Iran like Yazd has led to create advanced methods of architecture and urban planning in these places.

Qanats and wind catcher s are two key elements in the development of architecture and urban spaces of Yazd. Qanats, as an important source of energy and without any waste in operation, together with ventilation systems (wind catchers) have turned desert cities into paradises. Qanat has many advantages in improving the quality of life.

Prevention of water evaporation, access to water without pump and having water as a renewable energy source are 3 main advantage of Qanats. Human being changes ecosystem and the environment according to his needs. As a result, these changes over time will affect the lives of future generations. Qanat in addition to influencing the urban fabric, affects the internal structures of buildings and even the culture and economy of society.

One of the major advantages of Qanats is providing appropriate conditions for social solidarity and involvement in all affairs and promotion of group living culture and sustainability in the establishment of a community (Zarabadi *et al.*, 2011).

Cistern

Houses used to be constructed in the urban fabric where the Qanat's water was going down and when the water came to the surface, it would lead to agricultural land (Maleki *et al.*, 2005). This pattern has been observed in all urban areas. Access to Qanat's water took place in a hierarchy. In the first phase, water was stored in the cisterns through main Qanat. Therefore, the cisterns were often located at main streets and a few were on the alleys. It is noteworthy that these spaces had important role in organization of their surrounding spaces. Considering special architectural spaces of hot and dry region we find that construction and operation of all the places were related to the Qanat.

Persian Gardens

Persian gardens have a history of 2500 years and have been created coincided with the invention of Qanat and are totally dependent on the Qanats. The geometry of four gardens of Persian Gardens has been based on distribution of Qanats' water. The main axis of the garden is usually composed of main spring of Qanat that is called "Shahjo" and branches that are separated from the Shahjo turn the geometry of garden into a quadrate network.

Bathrooms

The bathrooms function was also associated with Qanat's water and one of the reasons why these buildings were built in the basement was access to water of Qanats.

Icehouses

Icehouses like cisterns were usually built in the direction of the main Qanats and their performance was so that water that entered the icehouses' pond froze in the cold winter nights and they were collected next days and placed at the bottom of the icehouses. These buildings like cisterns were important in organization of their surrounding buildings.

Main Spaces of the City (Mosques, Schools and Markets)

Spaces like mosques and markets that were considered as the core of city were usually located at mainstream of Qanats in order to access to water through "Payab". Water has played an important role in the mosques and so the mosques were located where it was easier to access to Qanats. In Figure 7, the location of a number of mosques, schools and cisterns considering Qanat position have been shown. Main spaces of city were constructed around main Qanats and mosques had the closest and easiest access to Qanat water. Outlet is where Qanat water reaches the surface and "Payab" is the square space in some buildings such as mosques that surrounds Qanat outlet. Yazd Mosque is located on the route of Zarch Qanat and 2 other Qanats named Mahmoud Abad and Vaghf Abad and it has 4 Payab (Figure 8). Usually the payab is located at intersection of main spaces like vestibules or landing (Roaf, 2009).

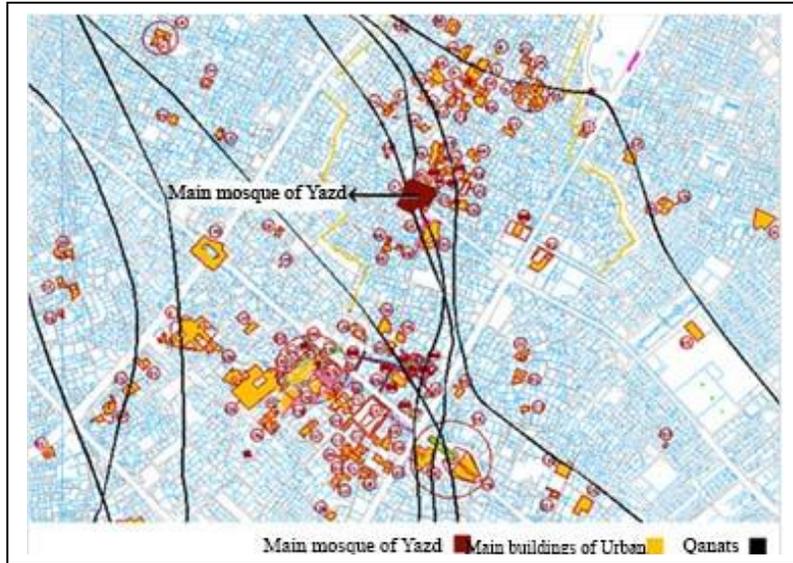


Figure 7: Form of Qanats and main buildings of Yazd (Source: the Author and Water Museum of Yazd)

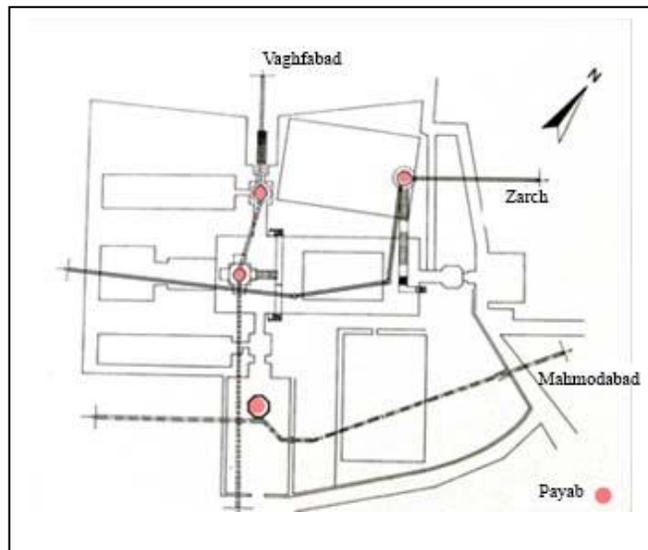


Figure 8: Location of Payab in the plan of Yazd Mosque (Source: Cultural Heritage Organization of Yazd Province)

Houses

Qanats have affected the space performance, form and structure of house more than anything (Roaf, 1989). Houses of the rich, like mosques and markets, were usually built where Qanats were close to the surface and had several payabs. In the rest of houses, the Qanats passed under the buildings and access to water was through a flight of stairs.

In some textures where a common Qanat was used, depending on the water quality, urban and rural areas were based on a hierarchy.

For example, spaces that stored pure and clean water like cisterns were usually in a position that received water from the basement and main Qanat and spaces that water pollution had no effect on their performance like water mills were located where water reached the surface and directed towards agricultural lands. In Figure 10, the hierarchy of water operation is shown in the rural texture of

Research Article

Kharanaq. This hierarchy of operation of water specified the location of urban spaces and on the other hand, Qanat water was used for different purposes without any wastage (Figure 9)

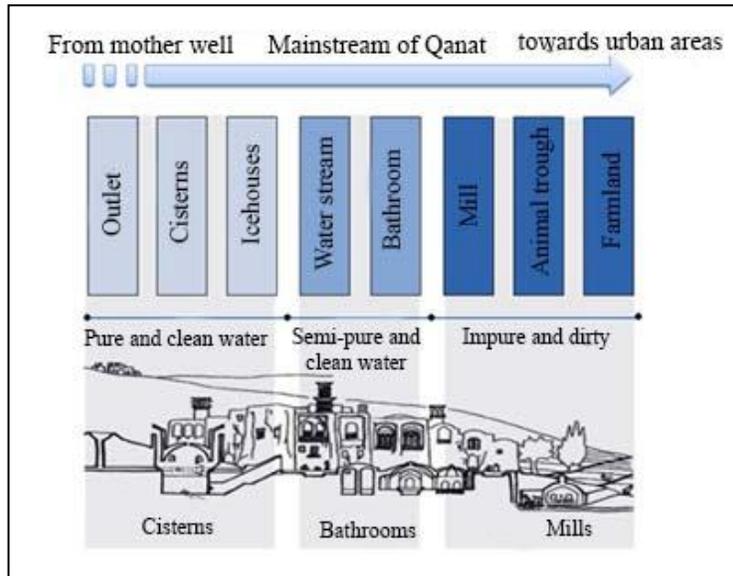


Figure 9: The Hierarchy of Operation of Qanat Water based on Quality of Water in Kharanaq Village, Yazd

In some spaces of Iranian traditional houses, simultaneous operation of Qanat and windcatcher perform evaporative cooling that has optimized function for cooling the house. Evaporation phenomenon in wind catcher occurs when water surface is exposed to the wind. The windcatcher and Qanat performance is so that at first air enters into the Qanat tunnel through vertical channel, which is outside of the building, then the air cooled in facing Qanat stream, enters to the basement space through another vertical channel that connects Qanat to the basement. On the other hand, the warm air entered into the house via windcatcher is cooled and flows out through suction of the windcatcher. The air flow through the intake and suction of windcatcher and entry and circulation of the cooled air in the space, without consumption and waste of energy, cool the basement space and other relevant areas. Another type of windcatcher works so that the air entering through the windcatcher, is cooled by directly encountering Qanat and entered the house space. This system requires that the windcatcher is at least 50 meters above the house (Roaf, 2009) (Figure 10).

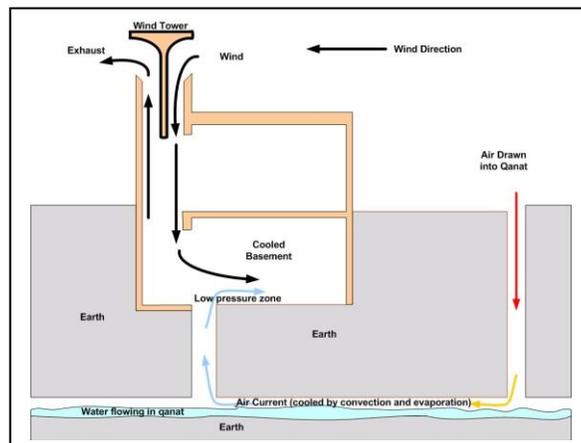


Figure 10: Cross-section of windcatcher and Qanat performance

Research Article

According to the above mentioned, the close relationship of Qanat with urban spaces and architecture in the historical texture of cities like Yazd is undeniable and herein what is important in the impact of this relationship in the contemporary urban sustainability. Therefore now that the two main structures of Qanat and windcatcher, considered as elements of urban sustainability, have been forgotten due to modern technology and modern living standards and change of needs, and this leads to the loss of these elements, it should be always considered that restoration of old and ancient elements not only plays an important role in the urban development but also it will have a profound impact on tourism and social norms.

Conclusion

Due to the rapid development of modern technology and the changing needs of people, the use of traditional elements and living in the old texture has been almost impossible and what drives people from the old to the new textures is the easy application of modern sources in the living space. In other words, lack of facilities in the old textures drives people towards living in the new textures. Therefore restoration of these textures, considering the modern facilities, will not only revive the dead textures but also it will have an effect on the performance of adjacent spaces. Consequently, the objectives of sustainable development and urban growth will be achieved. Qanats are one of these structures with heritage value that have been considered as a dynamic and evolving technology to appropriately supply water for hot and dry areas for 2000 years without any loss of energy. They influenced orientation of urban elements and architectural spaces so that their chain and dynamic performance led to sustainability of urban spaces. Therefore, in this modern world, need to restore Qanats as urban infrastructures and an important source of renewable energy, especially in hot and dry regions which face water crisis, arises as to resolve the issues resulted from climate changes and water shortage (Figure 11).

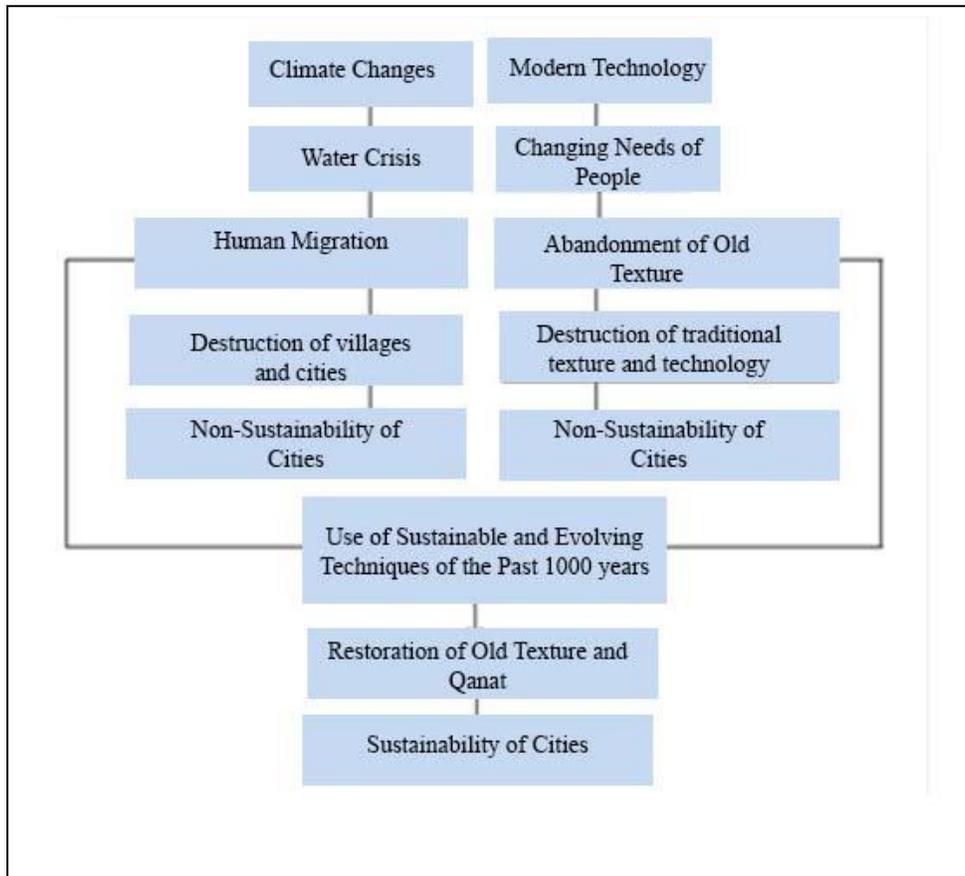


Figure 11: Chart of Non-Sustainability of Cities due to lack of Qanats

Research Article

REFERENCE

- Abizadeh E (2011).** Review of Qanat focusing on education and revival of cultural and indigenous technology. *Quarterly Journal of Armanshahr* **7** 40-45.
- Ahmadi R (2005).** The history, structure, position, role and importance of Qanat in Iran. *International Conference on Qanat, November 23rd and 24th, Kerman* 10-20.
- Soltani A and Namdarian AA (2011).** Analysis of the role of urban spaces in achievement of sustainable development of cities, explanation of the relationship paradigm. *Journal of Bagh-e-Nazar* **18** 3-12.
- Haeri MR (2006).** Qanat in Iran. *Cultural Research Bureau* 50-52.
- Maleki A and Khorsandi Aghaei A (2005).** *Qanat in Iran* (Publications of Urban Processing and Planning).
- Kardavani P (1997).** Iran, the Origin of Qanat and its Spread in the World. *Geographical Research* **35** 7-20.
- Ahmadi H, NazariSamani A and Malekian A (2010).** The Qanat: A Living History in Iran. In: *Water and Sustainability in Arid Regions*, edited by Schneier-Madanés and Courel MF (Springer) 125 -138.
- Beaumont P, Bonine M and McLachlan K (1989).** Qanat, Kariz, and Khattara: traditional water systems in the Middle East and North Africa. *London: School of Oriental and African Studies* 19.
- Honari M (1989).** *Qanats and Human Settlement in Iran*, edited by Beaumont, Bonine, and McLachlan 61-85.
- Jason M, Morikawa M, Murphy M and Schulte P (2009).** Water scarcity and climate change, *Ceres Report*.
- Moradi AM, MehdizadehSeradj F and Tajeddini S (2011).** The effect of sustainable urban infrastructures on the process of formation of historic cities in Iran. *5th Symposium on Advances in Science and Technology* 12-17.
- Salih A (2007).** Qanats a Unique Groundwater Management Tool in Arid Region. *UNESCO Cluster Office* 79-86.
- Semsaryazdi AA (2006).** A survey of the Historical Evolution of Qanats in Iran. *G-WADI Meeting on Water Harvesting, UNSCO, ICARDA, 20-22nd November, Aleppo, Syria*.
- Roaf S (1989).** Settlement form and Qanat routes in the Yazd Province. In: *Qanat, Kariz and Khattara*, edited by P. Beaumont, M. Bonine and K. McLachlan, (MENAS Press, Wishbech Cambridgeshire) 59-61.
- Roaf S (2009).** Resources Quality Cascades in Traditional Low Energy Technology: The Qanats and Badgirs of Yazd. *3rd International Conference on Smart and Sustainable Built Environments (SASBE 2009)*, 15-19.
- Zarabadi ZSS and Haeri N (2011).** Qanat as the Sustainable sign in During Time. *International Journal of Academic Research* **3(5)** 425-429.