Sustainable urban planning in Iran

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Sustainable designs as well as ecological and geographical considerations are issues of key importance in urban planning of old Iranian cities. In a wide country such as Iran, with different climatic zone, traditional urban designers and architects have presented a series of logical solutions for human comfort. This paper explores the influence of Persian culture on Iranian cities and concentrates on principles of sustainability as affected by climatic and geographical elements. The aim of this research is to investigate traditional urban settlements of Iran as examples of sustainable urban form and demonstrate how past successful experiences can inspire modern urban planners and designers. This paper will try to answer questions such as how many great cities were designed and erected in arid region like Iran and how these cities are able to function and live during history and by which ways previous urban designers have solved the climatic and geographical problems.

This sustainable design has been used in past urbanism experiences in Iran in many aspects but in this paper the most important ones will be introduced. The main aim is to mention the importance of climatic and geographical conditions on formation and design of Iranian cities.

1. Urban structure orientation

Settlement location was selected due to some specific qualities such as connection with major roads, commercial importance, regional centrality, soil conditions, absence of floods, earthquakes and other unexpected disasters and so on.

One of the most basic principles of traditional Iranian urbanism is orientation of the city according to a specific direction which was derived from wind direction, sun exposition, climatic and geographical factors. This specific orientation is called urban ROON in Iranian traditional urbanism vocabulary. There are three different orientations in Iranian cities and it caused these cities to answer all inhabitants' ecological needs and make urban form really sustainable.

2. Regard to water sources in urban planning

Water as a natural element in urban planning of Iranian cities is considered in many aspects and has always been an essential factor in Iranian towns.

Iran is a vast country with different geographical zones and water appears in different forms. Water source had an important role in urban design and land use of Iranian cities and I will explain it comprehensively. In this part I mention just some samples of its use and effect in traditional Iranian cities and I divide them into two major groups of man made water sources: Ghanat and Maddi and natural forms such as rivers and springs.

3.Garden cities

Some of old Iranian cities have been designed as a garden city and this plan was derived from their agricultural and economical role in the region. Consideration of this fact results in social and economical sustainability of traditional Iranian cities. As perfect examples of these garden cities I will introduce Isfahan as a designed garden city and Bam as an organic one.

Conclusion

With attention to the results that are achieved from this quest in urban design experiences of historical Iranian cities and with regard to this fact that old cities are still responding to functional and psychological needs in the best way, it is necessary to learn from these lessons and benefit from appropriate urban structure orientation, site circumstances and natural, regional potentials in designing new cities and also expanding existing cities to enrich urban space and make the cities worth living.

Keywords: Qanat, garden city, traditional Iranian cities, water management, sustainable design

Sustainable designs as well as ecological and geographical considerations are issues of key importance in urban planning of old Iranian cities. In a wide country such as Iran, with different climatic zone, traditional urban designers and architects have presented a series of logical solutions for human comfort.

Urban environment is defined as a place that covers all natural and man-made aspects which concentrated in the cities with its habitats. It is understood that the urban environment is shaped by these two factors; however, this paper shall only discuss the influence of natural aspects in urban environment such as climatic, geographic and other natural influences on the settlements.

This paper explores the influence of Persian culture on Iranian cities and concentrates on principles of sustainability as affected by climatic and geographical elements. The aim of this research is to investigate traditional urban settlements of Iran as examples of sustainable urban form and demonstrate how past successful experiences can inspire modern urban planners and designers.
This paper will try to answer questions such as how many great cities were designed and erected in arid region like Iran and how these cities are able to function and live during history and by which ways previous urban designers have solved the climatic and geographical problems.

This sustainable design has been used in past urbanism experiences in Iran in many aspects but in this paper the most important ones will be introduced.

1. Urban structure orientation

Settlement location was selected due to some specific qualities such as connection with major roads, commercial importance, regional centrality, soil conditions, absence of floods, earthquakes and other unexpected disasters and so on.

One of the most basic principles of traditional Iranian urbanism is orientation of the city according to a specific direction which was derived from wind direction, sun exposition, climatic and geographical factors. This specific orientation is called urban ROON in Iranian traditional urbanism vocabulary. There are three different orientations in Iranian cities and it caused these cities to answer all inhabitants' ecological needs and make urban form really sustainable.

In fact ROON is defined as the direction of major public spaces, bazaar and in fact open spaces in a city. For example in the city of Tehran the layout and orientation of houses is northeast-southwest. Urban ROON has been determined according to the direction of floods or favorable winds in the area. Indeed wind towers in Iranian cities were designed and erected faced to the appropriate wind and along the direction of urban ROON.

This direction in Iranian cities has been achieved by use of hexangular geometry. Iranian architects determined three major directions for the cities: Rasteh, Isfahan and Kerman. Cities like Tehran and Tabriz are placed at the direction of north eastern-south western. This direction is almost at the route of Qible.

The suitable direction in some other cities such as Isfahan, Estakhr, Perspolice is northwest-south east. Isfahan is located between Soffe and the Atashgaah mountains and this direction has solved many climatic problems for residents. This rule is still applied for constructing buildings. This direction is exactly shown in Naghshe jahan square. The most famous and well-known architect of Isfahan Ali Akbar solved the incoherent directions of the Qible and urban ROON very wisely (the square as a major public space should follow the urban ROON and also because of religious beliefs all mosques should be erected according to the Qible direction. This great architect has designed a joint between these two important directions and besides creating beautiful scenes in both interior and exterior view, has solved this problem functionally.)

The direction of Kerman ROON is west-east and Kerman, Hamadan and some other cities were constructed according to this direction. In Kerman, mountains extend in north and south. In Hamadan city, because of an unfavorable wind that blows from Abbas Abad valley, this direction is used. One of the most effective factors in selecting this urban ROON in designing cities was the location of them adjacent to one or more mountains. For example Yazd city, placed between two important mountains, is designed according to a mixture of Isfahan and Kerman Urban ROON, one direction follow the blowing of favorable wind from Isfahan and the other is faced the direction of winds that blows from Shirkooh Mountain. These two directions are perpendicular to each other and because of this wind towers look towards two sides. In Tabas city urban ROON is faced against unfavorable wind.

2. Regard to water sources in urban planning

Water as a natural element in urban planning of Iranian cities is considered in many aspects and has always been an essential factor in Iranian towns. Its rarity in an arid country made people respect and treasure it. Indeed Islam holds that water is holy. Iran is a vast country with different geographical zones and water appears in different forms. Water source had an important role in urban design and land use of Iranian cities and I will explain it comprehensively. In this part I mention just some samples of its use and effect in traditional Iranian cities and I divide them into two major groups of man made water sources: Ghanat and Maddi and natural forms such as rivers and springs.

2.1. MAADI

In addition to the Zayandeh River, Isfahan is fed by mountain water carried in canals which meander in profusion through the city. They are invariably lined with trees and provide routes of considerable scenic beauty and water make the environment cool even on the hottest summer days.

Zayandeh River is the most important and also largest river in central Iran. Many important constructions (major factories and power plants) and the second biggest city of Iran (Isfahan) are located along this river. They profited from this river in many different ways. Its water was distributed in different ways. The main traditional way was streamlining, which means that the water of Zayandeh River was distributed from different canals through the entire city and irrigate agricultural and urban fields through these routes. Shortage of water in Isfahan region and the right to use water was a struggling issue in those days. This led to finding new methods and distribution systems. To solve this problem in Isfahan, Sheikh Baha'i, an architect, scientist, philosopher and also a famous poet in the time of Safavid dynasty created a new water distribution system which was named MAADI. According to this watering system the river water is circulated through these canals on specific days, for limited periods.

Figure 1. Aerial photo of Niasarm MAADI and Zayandeh River

From this river five branches are separated to water gardens, palaces, buildings and also farms. These channels are called MAADI in Isfahan dialogue. These canals entered the city in this order:

1. Shah canal: which water was specified for royal palaces and its water volume was half of the Farshadi canal (see 3).

2. Niasarm canal (shown in figure 1): this MAADI is the biggest one in Isfahan and is detached from Zayandeh River next to Marnan bridge and flows to the east part of the city. (See figure 1)

3. Farshadi canal: this canal is detached from the river after Niasarm and its water is one quarter of Niasarm.

4. Fadan canal: the water of this canal is endowed by Safavid king to vow for his health condition. This canal led water towards the government gate after which it was divided into several minor canals.

5. Tiran (Tehran) canal: This canal directs the water to the western part of the city.

Totally, from the source of Zayandeh River to Gavkhooni Marsh 154 MAADIs branch off from this river and run through various villages and cities and irrigate many farms. The word MAADI is derived from Maad dynasty (3000 years ago). In that ancient civilization people would extract water from wells and Qanats and distribute it through canals. The Safavid rulers had noticed that endurance of any garden and green zone in the city depends on water supplies in advance. Regarding this fact and the identification of the concept of region and space and the assistance of Zayandeh River and the slope of the ground, they constructed canals which were detached from the main river and fed all the city buildings and farms through which they solved water shortage problem

Figure 2. Landscape design that occurred next to MAADIs

Apart from the functional role of MAADIs (watering farms, gardens and buildings) along their way through the city, they demonstrate a subtle, brilliant and beautiful scenery and inspire a special and specific typology of architecture around them. They penetrate into the entire city as natural veins. Regarding the traditional architecture and urbanism typology in cities located in desert situations, this natural circulation of MAADIs and green organic routes create

an eye catching scene of urbanism and enrich the city with a combination of nature and architecture (see figure 2).

Identification of site and penetration of nature inside it have been defined as two important concepts of relationship between nature and the meaning of space in sustainable design. By adopting these principles and relying on these rules the Government of Safavid dynasty and architects reached a unique urban design in Isfahan which acts as a perfect structure today. I should mention here that Isfahan is a protected World Heritage Site according to UNESCO.

2.2. Qanat

A Qanat or Kareez is a water management system used to provide a reliable supply of water for human settlements and irrigation in hot, arid and semi-arid climates. Qanats are slightly inclined tunnels, at the end of which the water level coincides with the water level at the base of a mountain or foothill. Water flows along the floor of the tunnel until it reaches the ground surface at a location of lower elevation (see fiqure 3).

Vertical shafts extend from the ceiling of the tunnel to the ground surface. These serve the dual purpose during construction of providing ventilation and as an exit for the excavated material. Qanats have been constructed in the Middle East for the past 2500 years. They may be several kilometers long and have been used both for irrigation and municipal water supply. Many are still in use in certain regions of Iran.

The oldest and largest known Qanat is in the Iranian city of Gonabad which after 2700 years still provides drinking and agricultural water to nearly 40,000 people. Its main water well depth is more than 360 meters and its length is 45 kilometers. Yazd, Khorasan and Kerman are zones known for their dependency to an extensive system of Qanat. Each city in these provinces has more than one Qanat.

Fields and gardens are located with a short distance of Qanats' outlet. Water from the Qanats defines both the residental regions and outlying district of the city.

The water is fresher, cleaner, and cooler in the upper parts and more prosperous people live immediately upstream to the outlet. When the Qanat is still below ground level, the water is drawn to the surface via water wells or animal driven wells. Private subterranean reservoirs could supply water for domestic use and garden irrigation as well. Further, airflow produces from Qanat used to cool an underground summer room found in many old houses and buildings.

Downstream of the outlet, the water runs through surface canals called Jubes which run downhill, with lateral branches to carry water to the neighborhoods, gardens and fields. The streets normally run parallel to the Jubes and their lateral branches. As a result, the cities and towns are oriented according to the gradient of the land, which is sometimes viewed as chaotic to the western eye while it was a practical solution for efficient water distribution in different regions.

The lower parts of the canals are less desirable for both residences and agriculture. The water becomes progressively more polluted as it runs downstream.

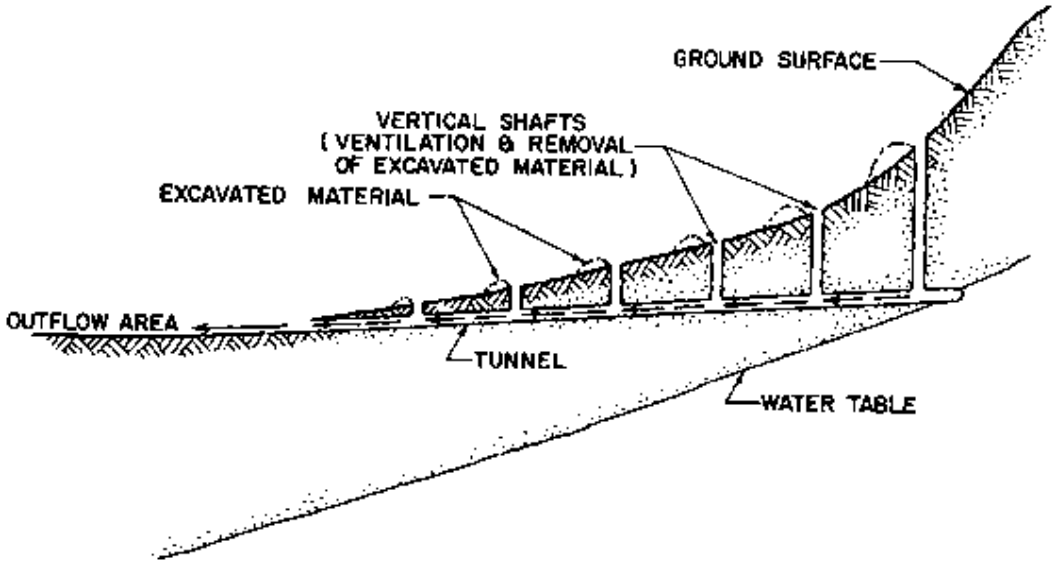

Figure 3. Qanat technology

Qanats were frequently split into an underground distribution network of smaller canals called Kareez when reaching a major city. Like Qanats, these smaller canals were constructed underground to avoid contamination.

The use of Qanat results in the construction of special spaces in cities. Because of the hot weather of desert cities and the absence of any permanent river (most rivers in Iran are seasonal and have traditionally not been able to supply the needs of urban settlements) water is a valuable element for living. That means that in this culture water and access to it is designed as an underground process. Water is delivered under the ground and in some specific spaces people got access to it.

Qanats used in conjunction with a wind tower can provide cooling as well as a water supply. A wind tower is a chimney-like structure positioned above the house to catch the prevailing wind. The tower catches the wind, driving a hot, dry breeze into the house; the flow of the incoming air is then directed across the vertical shaft from the Qanat. The airflow across the vertical shaft opening creates a lower pressure and draws up and mixes with the cool air from the

Qanat tunnel. In dry arid weather this can result in a greater than 15°C reduction in the air temperature coming from the Qanat; the mixed air still feels dry, so the basement is cool and only comfortably moist (not damp). Wind tower and Qanat cooling have been used in hot areas for over 1000 years.

An AB ANBAR is a traditional reservoir of drinking water in Persian antiquity. The Persian phrase literally translates as "water warehouse". AB ANBAR has a long history in Iran, and there are still some remaining today from the 13th century. These reservoirs would be subterranean spaces that were connected to the network of Kareez in the city. A typical residential AB ANBAR was located in the enclosed garden, having the capacity to hold 50 cubic meters. It was filled once every two weeks, and has its inside surfaces cleaned from sediments once a year (called LAYEH RUBI). In order to access the water, one would go through the entrance which would always be open, traverse a stairway and reach the bottom where there would be faucets to let the water in the storage.

Next to the faucet would be a built-in seat or platform, a water drain for disposing water from the faucet, and ventilation shafts. Depending on where the faucets are located, the water would be colder or warmer. Some storage would have multiple faucets located at intervals along the stairway.

Thus nobody had access to the body of water itself, hence minimizing possible contamination. The storage is completely isolated from the outside except for ventilation shafts or wind catchers. To further minimize contamination, the storage tank's interior was scattered with a salty compound that would form a surface on top of the water. The storage tank would then be monitored year round to ensure that the surface would not be disturbed. The water of course would be drawn from the bottom using the PASHIR (see figure 4).

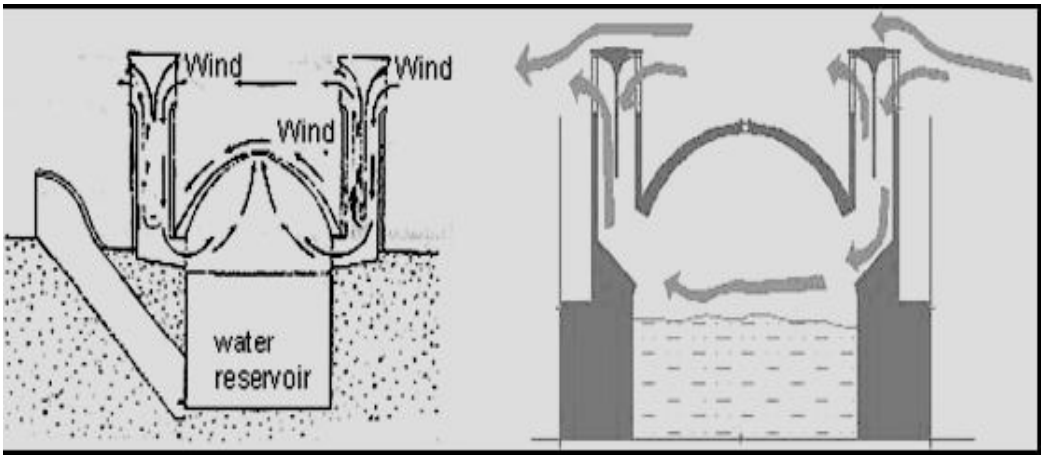

Figure 4.AB ANBAR (water storage) system

Public AB ANBAR was often built wherever demand dictated. But factors such as its accessibility to Qanats, ease of public accessibility, and a homogeneous density of it in each area determined the size and location of an AB ANBAR.

Each Qanat covered a specific neighborhood and often further branched into *sub-kareezes* as they went along serving private and public AB ANBARs. Yet most AB ANBARs were located in adjacent to commercial, religious, or other public places of interest. Many of them had been located at busy intersections. Unfortunately in early 20th century the urban structure of many traditional Iranian cities has changed dramatically. Hence AB ANBARs today seem to be situated out of place.

In Qazvin, which was nicknamed as the city of AB ANBRs, today less than 10 AB ANBARs remain intact from the destructive forces of hasty modern urban development. Of the other 100 that used to be scattered throughout Qazvin, only parts (such as the steps, the entrance, or the storage) remain. Most have been destroyed by housing projects and private developers. In Qazvin, none are functional anymore. However some continue to be used in some areas in rural Yazd and urban Nain.

Table1.Fully intact surviving AB ANBARs of Qazvin in order of capacity

Ab anbar name	Dimensions (m)	Capacity (m^3)
Sardar-e Bozorg	17 x 17 x 17	4900
Jame' Mosque	37.5 x 10 x 10	3750
Nabi Mosque	36 x 10 x 10	3600
Sardar-e Kuchak	20 x 19 x 5.5	2090
Haj Kazem	26 x 7.5 x 10	1950
Hakim	18 x 18 x 6	1944
Agha	11.5 x 10.25 x 5.5	648
Razavi Caravanserai	14.5 x 6.5 x 5	471
Zobideh Khatun	11.5 x 2.65 x 6.5	198

Explosive migratory trends in Iran in the past 30 years have led to a wave of hasty development inside the old quarters of old cities, destroying their original structure.

3. Garden cities

Some of old Iranian cities have been designed as a garden city and this plan was derived from their agricultural and economical role in the region. Consideration of this fact results in social and economical sustainability of traditional Iranian cities.

The main characteristic of these cities was the use of water; it was the ultimate luxury to desert dwellers, who appreciated it not only because it allowed plants to grow but also it cooled the air and pleased the ear with the sound of its movement. Water moves in the middle of main streets and passages and in a warm country like Iran this circulation helps a lot for cooling and decreases the hotness of summer technically and psychologically.

As perfect examples of these garden cities we can name Shiraz and Isfahan. Because of its unique beauty and historic ambiance, Isfahan is called "Half the World" as called for the first time by French poet Renier who visited this city in the 16th century. The most famous Persian description of the city of Isfahan is "*Esfahan Nesf-e Jahan*" which means Isfahan is half of the world and was coined in the 16th century to express the city's grandeur. The history of Isfahan can be traced back to the Paleolithic epoch. During their excavations, archaeologists have succeeded to discover enormous historical artifacts dating back to Paleolithic, Mesolithic, Neolithic, Bronze and Iron ages. Isfahan during Shah Abbas period was designed and erected as a city with various gardens and with full respect to its nature. Isfahan became the capital of Iran by Safavid dynasty from the time of Shah Abbas I (1587-1629), who built numerous fine buildings, some of which still survive. He also set up spacious gardens and avenues and extended the bazaar, for which workmen were forcibly imported from Armenia. The Armenian community has its own quarter across the river.

Shah Abbas selected a wide ground next to the old city and Zayandeh River to construct royal gardens and palaces for the king. Isfahan followed the pattern of Qazvin urban design. A garden city (Baghistan) was created south of the old city center. A large street was built in 1596 to connect the entrance at the Dawlat gate near Shah Abbas urban residence to his great suburban garden to the south. This garden that stood south of the Zayandeh River was known as the Hizarjarib (1000Jarib) garden. A canal dug from the river irrigated the garden and ran through the street that formed the main axis of the new garden city. The Georgian Allahvirdi Khan was commissioned to build a monumental bridge finished in 1602 that connected the two portions of the promenade.
Shah Abbas also drew up the street plan, the layout of the parks and gardens and the construction of royal pavilions scattered about in the greenery. An immense bridge was constructed over Zayandeh River and was considered an extension of the magnificent (1,750 yard) ceremonial avenue known as Chahar Bagh. Chahar Bagh Street (4 Gardens Street) starts from Naghshe Jahan square and ends in several gardens which cover more than ¾ of Isfahan urban area. A wide water canal would run along in the middle of this beautiful street. The water benefits from the natural slope of the region and passes Zayandeh River and reaches 1000 Jarib garden at the end.
This street and several gardens match with Zayandeh River beautifully and by use of this skillful design river becomes an inseparable part of the city and urban life. The combined historic-natural axis of Isfahan is with no doubt the most significant urban structure in Iran that was planned in seventeenth century - in continuation of the organic structure shaped in previous centuries

- and has influenced and guided the growth of the city during the past 400 years (see figure 4).

The historic axis consists of five sections:

1. The bazaar stretching about 2500 meters from Toghchi Gate to Naghsh-e-Jahan Square;
2. The Safavid Court Quarter 500 meters long from Naghsh-e-Jahan Square to the beginning of Chahar Bagh;
3. The Abbasid Chahar Bagh with an approximately 1500 meters length, from Dowlat Gate to the Zayandeh River;
4. Si-o-se-pol Bridge, 400 meter long (over the width of the river, along the axis);
5. Upper Chahar Bagh with 1500 meter length from Zayandeh River to Hezar Jarib Garden

Thus, the length of this man-made axis is totally 6400 meters.

The Second axis consists of the Zayandeh River between historic bridges of Marnan and Shahrestan with an approximate length of 8000 meters and width of 300 meters. For depicting the combined historic-natural axis of Isfahan an area of 340 hectares including 1320 parcels (registered plots) is allocated where over 220 historic buildings with excellent or distinguished values (such as mosques, caravanserais, schools, public baths) as well as several complexes with authentic historic composition are located.

Figure 5. City of Isfahan

The historic site (the result of the two historic and natural axes in perpendicular shape) is the only remaining work of an integrated planning and design scheme in the country's history that, in spite of negligence during the past three centuries, still possesses the potential of self-demonstration in the contemporary city.

Another good example of Iranian garden city is Bam city. Unlike Isfahan that was designed as a garden city by government, Bam is an organic garden city which was designed and shaped by people during a long time. Bam and its surroundings are inscribed as a world heritage sites. Bam is situated in a desert environment on the southern edge of the Iranian high plateau (see figure 5).

The origins of Bam can be traced back to the Achaemenid period (6th to 4th centuries BC). Its prosperity was from the 7th to 11th centuries, being at the crossroads of important trade routes and known for the production of silk and cotton garments. The existence of life in the oasis was based on the underground irrigation canals, the Qanats, of which Bam has preserved some of the earliest evidence in Iran. Arg-e Bam is the most representative example of a fortified medieval town built in vernacular technique using mud layers (*Chineh*).

The city of Bam and its surrounding cultural landscape represent an exceptional testimony to the development of a trading settlement in the desert environment of the Middle Eastern region. The cultural landscape of Bam is an outstanding representation of the interaction of man and nature in a desert environment, using the Qanats. The system is based on a strict social system with precise tasks and responsibilities, which have been maintained in use until the present, but have now become vulnerable to irreversible change.

Figure 6. Bam citadel and garden city

Conclusion:

Some Iranian traditional experiences in urban sustainability are described in this paper. The main aim is to mention the importance of climatic and geographical conditions on formation and design of Iranian cities.

In countries like Iran it is inevitable to establish cities in arid regions. Many new cities have been designed in the current century but most of them could not solve regional problems and respond to inhabitants need. The most important factor in designing a city is to plan it in such a way that it could function and develop during the history.

With attention to the results that are achieved from this quest in urban design experiences of historical Iranian cities and with regard to this fact that old cities are still responding to functional and psychological needs in the best way, it is necessary to learn from these lessons and benefit from appropriate urban structure orientation, site circumstances and natural, regional potentials in designing new cities and also expanding existing cities to enrich urban space and make the cities worth living.

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