Reinterpreting sustainable design of traditional Iranian cities

A thesis submitted for the degree of Master of Philosophy

Nima Dibazar

Welsh School of Architecture

Cardiff University

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Abstract:

In our constant attempts to reduce the negative impact of urbanisation on natural environment and to improve quality of urban life, we must be inventive with new technologies but also to re-learn and re-use effective local solutions which have been used for centuries in vernacular cities before the industrialisation and widespread use of fossil fuels. The study focuses on vernacular Iranian cities in order to highlight architectural and urban solutions adopted in response to harsh climate of Iranian plateau.

Throughout the study climatic adaptations in vernacular Iranian cities have been investigated in response to four elements of sun, wind, water and green spaces. The main research approach adopted in this research involved urban structure analysis through aerial photos, historic maps, existing literature in Farsi and English as well as on site observation by the author.

Native builders informed by accumulated knowledge of their ancestors, constructed dense urban environments with available local materials. These compact cities were efficient but also diverse in land use. Dense urban fabric protected building from cold winter winds and harsh summer sunlight. Water was transported from foothill of mountains via network of underground channels to supply water to buildings and also to moderate temperature by surface evaporation. Local knowledge of regional winds enabled native people to build houses and streets with appropriate orientation and benefit from favourable winds for ventilation and to avoid harsh unpleasant winds.

The study examines the pleasant microclimate of courtyard houses and possibilities of internal seasonal migration in order to locate to sun-catching warmer areas during cold season and occupy the cooler shady parts of the building in summer.

The study demonstrates various methods utilised for climatic adaptation in vernacular cities. It recommends that further research to be undertaken to expand our understanding of vernacular built environment in order to interpret and use lessons from the past in contemporary cities.

Acknowledgment

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List of contents:

Chapter 1: Introduction and research context

Chapter 2: Urban development in Iranian cities and dimensions of urban sustainability

Chapter 3: Environmental sustainability in the vernacular built environment

Chapter 4: Summary and conclusion

List of Figures

Chapter 1 Introduction

خانه ای ساز که پهنایش به بستر خورد و افرازش به بالای تو

Build a house to fit your bed size and your head height

1.1 Research Context

Life in a country with an arid and dry climate has always been challenging for Iranian people but it also inspired and motivated them to devise ingenious methods to create not only pleasant environments to inhabit but also paradise like gardens and courtyards for recreation and meditation. Traditions of vernacular architecture have developed over millennia in response to the Iranian plateau's arid climate, scarcity of building materials and extremes of temperature (Tavassoli 2005). Private houses, public buildings and urban neighbourhoods were developed to respond to local climate, topographic conditions and availability of construction materials. The art of building pleasant human habitat transferred from one generation to another and improved through many years of trial and error.

In contrast to modern Iranian cities, which are simple copies of contemporary European and American cities, the traditional urban texture is dense, combining diverse land uses with tight relationships among buildings. Urban spaces are enclosed and buildings are closely built sharing walls and roofs to minimise exposed surfaces to direct sunlight. Urban direction or *roon* is defined as the direction of major public spaces, bazaars and open spaces according to main wind direction, solar path and geographic conditions. Alleys are narrow with many turns, surrounded by tall walls where there is always a shadow side (Kheirabadi 1991).

Analysis of housing patterns in different climates shows how morphology of vernacular buildings evolved through centuries to respond to local climate. Courtyard houses in cold and dry climates contain their main living spaces in the northern part of the building to maximise direct daylight reaching rooms through the courtyard space during cold winter days. Inside these houses the eastern and western parts of the building are only used for service rooms such as bathrooms, kitchen and storage. This pattern changes significantly in other climatic regions such as hot and dry climate where southern parts of buildings are favoured to contain main living rooms to protect people from unpleasant summer heat.

The bazaar is one of the main elements of traditional Iranian cities. While the centrality of the bazaar within the city emphasises its economic and cultural importance, its form and appearance reflects the climatic considerations. The linear

bazaar is covered by a series of brick domes to protect visitors and shop owners from the heat of summer and harsh cold winters. The morphology of bazaar structure has changed and adapted to regional climate. *Raste* or passages were built with higher ceilings and more openings on roof in regions with hot climate to improve ventilation within internal spaces whereas smaller spaces and fewer openings were used in cold climate.

The availability of water was crucial to the formation of the cities and its rarity in a dry country made people respect and treasure it. Water channels or *jubs* running along streets and shallow pools with fountains are evident features of traditional cities. Their function is not only to distribute water within the city, but also to create a micro climate in urban scale. Evaporation from the pool increased the humidity and lowered the temperature in its immediate vicinity (Beazley 1982). This principle was widely used in courtyard houses and one could notice small pools constructed at basement level inside larger dwellings. In addition to its climatic role, water had an aesthetic function and brought peace and stillness and pleased the ear with the sound of its movement.

Cisterns and icehouses exemplify effective building solutions to preserve water and ice under optimum conditions (Porter 2003). *Ab-anbar* was a traditional reservoir of drinking water which was a subterranean space connected to the network of underground water channels or *kareez* in the city. The main part of water reservoirs was built underground to prevent temperature penetration and utilise soils as the natural insulation around the reservoirs. Ice-houses are another type of traditional buildings which were built to produce and store ice which was used in drinks in summer. The challenge of producing ice in the hot and dry climate of the central plateau of Iran was overcome by utilising temperature fluctuation over night during short winter seasons. Ice-houses were in common use until the introduction of modern refrigeration and road transport after World War II (Kazemi and Shirvani 2011).

Utilising the wind in passive cooling was very advanced in traditional cities. Wind catchers were built for courtyard houses and water cisterns facing cooler breezes, and shielded from the unpleasant dusty winds. They functioned by catching wind at high level and drawing air through the building at low level due to different air pressure.

Pigeon tower or dovecote is a good example of utilising available natural materials for human needs. The largest dovecotes were made of unbaked mud bricks and

could house 14,000 pigeons, accommodating an annual harvest of dung for field manure and for the softening of leather in tanneries (Hensel 2012).

In modern Iranian cities, traditional bazaars have been replaced by shopping centres and urban commute in most parts is only possible by private cars. Modern technologies enabled people to control and adjust their living environment independent from outdoor conditions. However, air-conditioning systems are heavily dependent on electricity and fossil fuels to provide a habitable space for their users. Without the need to adapt to outdoor weather condition, these modern buildings are poorly designed, senselessly oriented and highly wasteful.

In urban scale, the introduction of cars proved to be the most significant factor in transforming the shape of the traditional built environment into a modern city. New streets and boulevards were designed and built cutting through old fabric of the city without careful consideration of hidden boundaries of existing neighbourhoods. Segregated neighbourhoods are no longer accessible on foot and a greater car-dependency is required for transport of people and goods. Apart from constant pressure on old fabric of the city, car-oriented developments created new neighbourhoods in the suburb. The dominance of cars in new developments means urban areas are no longer suitable for walking or cycling and everyday journeys to work, school and shopping depend on private cars or other motorised vehicles.

Contemporary Iranian cities are facing major challenges such as excessive air pollution, noise pollution, lengthy traffic jams, high consumption of fossil fuels and electricity for heating and cooling and shortage of water (WHO 2013). In response to current challenges, there have been very few attempts to investigate and understand relevance of vernacular built environment to urban life in Iranian cities. Traditional buildings are mostly appreciated and preserved for their historic significance and few recent studies published in connection to effective climatic adaptation of vernacular buildings, have only been limited to analysis of individual building elements such as wind towers or courtyards.

This study finds that vernacular approaches to construction of building and cities have been abandoned and almost lost from people's collective memory. It argues that there are many lessons to be learned from vernacular architecture. However, given the limited scope of this dissertation, the analysis presented will focus on the climatic characteristics of traditional cities. It will also investigate how these cities have satisfied the need of their inhabitants in terms of climatic factors, architectural quality and urban design objectives.

1.2 Reasons to study and significance

Little has been done to reveal the importance of the vernacular built environment in Iranian cities and strong attempts are needed to rediscover their significant role in providing a comfortable habitat for people. The body of knowledge is particularly limited when we examine the environmental aspects of vernacular buildings in urban scale. This study argues that an understanding of the main design principles and the context in which they were used will make it possible to accept the relevance of such ideas and use them in contemporary cities.

Building on the works of others – both in Persian and English languages – and embarking on unexplored concepts, this study will search for the rationale behind the physical morphology of vernacular cities from an environmental point of view. Among the numerous studies dealing with Iranian art and architecture, there are very few texts focusing on Iranian cities. Studies done in this context are mostly limited to the historical background and physical development of cities without any significant discussion regarding their successful built environment.

The spatial pattern and physical environment of Iranian cities have been studied by Heinz Gaube (1979) and Masoud Kheirabadi (1991). Although they discuss the historical development and morphology of cities, they do not give insight into the environmental characteristics and technical features of cities and their energy-efficient concepts and designs. Elizabeth Beazley's book "Living with the desert" (1982) contains a good discussion of the vernacular architecture and indicates the building materials, water supply and water management systems in Iranian settlements. Other relevant studies on Iranian cities such as the widely known book by Arthur Pope "Persian Architecture" (1976) have been conducted with an archaeological approach.

Throughout the study the term 'vernacular' has been used to describe a construction period before the twentieth century modernisation and the establishment of modern universities in Iran when the profession of architect and urban planner had not been recognised with their modern definition.

There are two books written in Persian which will be referred to in this study. *Eglim ve Memari* (Climate and architecture) by Morteza Kasmaei (1993) and *Sakht-i Shahr va Memari dar Eqlim-i Garm va Khushk-i Iran* (Urban structure and architecture in the hot and arid zone of Iran) by Mahmood Tavassoli are among the few sources that provide information about environmental aspect of Iranian cities. However, none

of these studies highlight the environmental response in dry and cold climate and urban formation in this region.

The proposed study is significant because it will:

a. Produce an introductory study of Iranian cities from an environmental point of view
b. Raise awareness and help to understand the inherent value of traditional urban form
c. Generate greater awareness about the vernacular architecture of the two Iranian cities of Tabriz and Shiraz

1.3 Research question

What can we learn from traditional cities and vernacular architecture in terms of environmental sustainability and how can this knowledge be used in contemporary cities to enhance urban environment and reduce negative environmental impact of populated contemporary cities.

1.4 Aims and objectives

This study aims to investigate the spatial patterns and urban morphology of traditional Iranian cities in order to identify the historic knowledge and techniques behind the environmentally sustainable built environment of traditional cities. This main aim leads to a number of objectives which can be framed as the following questions:

- Can vernacular architecture and urban design be considered environmentally sustainable?
- How did vernacular Iranian cities respond to local climatic conditions to create environmentally sustainable habitat?

A counterargument to this study would be that vernacular solution is only appropriate to traditional cities where population was low and demand for energy and water resources was limited and large contemporary cities require new solutions to house human activities and provide comfort. This is correct in many cases and daily life in large cities with millions of habitants is vastly different from small town qualities. However, human needs for shelter, security and comfort remained unchanged for many centuries. In absence of abundant energy resources to heat and cool buildings, vernacular builders devised various methods to reduce

climatic stress imposed on built environment and efficiently manage scares water, food and energy resources.

1.5 Scope of study

This study will focus on the spatial analysis of Iranian cities from the Safavid Empire (1502-1722) to present day with primary focus on the cities of Tabriz and Shiraz. The study will examine the internal structure of the cities in an urban neighbourhood scale and search for ways in which public squares, street and housing patterns have reflected a rational response to the natural environment. These particular cases have been selected for their similarities in urban structure and differences in climatic conditions.

Tabriz is located in the Northwest of Iran and has a dry and cold climate. The bazaar of Tabriz is listed as a UNESCO world heritage site. However, the city has been subject to very few studies when it comes to its traditional buildings. In contrast, the city of Shiraz with its hot and dry climate is an important southern city. Both cities have an organic structure with the bazaar at the heart of the old town. Other major elements of the city such as the Friday Mosque, the citadel and city squares complete the city structure by joining to the bazaar complex. The urban structure of both cities was established from the 15th century and their shape until the 20th century indicates a fair representation of a typical traditional Iranian city before modernisation which it happened mainly during the 20st century.

1.6 Research Methods

The study is mainly a qualitative research. It attempts to analyse the key elements of environmental consideration and their impact in design and construction of traditional cities. These factors are examined within the scale of an urban neighbourhood, public buildings and individual dwellings and include several elements such as urban pattern, land use and access network.

The nature of the study and the broad scope of research require a multiplicity of research methods. The study requires both theoretical research and practical investigation. The theoretical research is mainly accomplished through the review of recent relevant literature. The practical investigation benefits from personal observation on site by the author. The main methods that this analysis will employ are:

- Library research
    - A literature review including both quantitative and qualitative methods of research from relevant publications, drawings, maps to observe definitions, principles and interpretations of vernacular architecture
- Practical research
    - Direct in-situ observations in regard to passive cooling, natural lighting and solar gain within existing buildings and public spaces
    - Production of visual materials such as sketches and visuals to communicate design consideration and construction principles

1.7 The research structure

The organisation of the study is planned as shown below:

- Chapter 1: Introduction to research context and aim and objectives
- Chapter 2: Urban development in Iranian cities and dimensions of urban sustainability
- Chapter 3: Environmental sustainability in the vernacular built environment
- Chapter 4: Summary and conclusion

Chapter 2: Urban development in Iranian cities and dimensions of urban sustainability

2.1 Introduction

In order to provide an introduction to morphological development of Iranian cities, chapter two focuses on the historic development of the two cities of Tabriz and Shiraz. As mentioned in chapter one, to make the study feasible and manageable, this study only analyses the period from the 16th century to the present day, and an historic overview of two cities is presented in this section. The focus on this historic period is due to availability of historic maps and accounts of travellers and visitors to these cities, which is very limited for earlier periods. The first part of chapter two concentrates on general information about geographical and climatic condition of vernacular cities of Iran.

The historic background for both cities that is presented in this study is significant due to limited available literature in English. Also, research and publications in English as well as Farsi addressing the environmental benefits of vernacular cities are unusually rare. Throughout chapter two, the historic background provided for cities of Tabriz and Shiraz demonstrates how a small market town on trade routes of caravans developed inside city gates and later expanded to establish itself as a commercial and political centre for various ruling dynasties in Iran.

In addition to information presented about vernacular cities in Iran, chapter two seeks to provide a very brief summary of recent discussions and urban policies forming our understanding of environmental sustainability in contemporary cities around the world. This information has been included in advance of chapter three to pave the way to make easier connections between the principals of urban sustainability and similar approaches observed in vernacular cities.

2.2 Iranian cities, climate and development

Vernacular cultures in different parts of the world have developed within their natural environment and their existence depends on their environmental context. The diversity of these vernacular cultures and their ability to cope with different physical conditions of their surrounding resulted in distinctive architectural responses to local weather conditions.

Patterns of vernacular settlements are mainly influenced by topography, availability of water, and land, building materials, defence reasons and trade opportunities

(Kheirabadi 1991). Among the environmental factors, local climate has a powerful impact on human life. Climate is the pattern of weather or atmospheric conditions over a period of years. The Greek word *klima* and Latin *clima* ('slope') suggest how local environmental conditions are dictated by the angle of solar radiation (Oliver 1997). The need for a specific type of shelter and the building material locally available are predominantly influenced by the climate. The climatic zones around the earth can be categorised into humid and arid regions, semi-humid and semi-arid regions (Oliver 1997). The climatic diversity considering its direct impact on built environment can be subdivided into nine categories:

1. Arctic and sub-arctic, with extreme cold and frozen ground
2. Continental, with warm summers and cold and windy winters
3. Desert or arid, with clear skies and substantial daily and seasonal temperature fluctuation
4. Maritime or temperate, with changeable weather, from the effect of oceans
5. Mediterranean, with warm stable summer and short wet winters
6. Monsoon, with a lengthy hot dry period disrupted by a hot rainy season
7. Montane, effected by altitude and terrain but also controlled by rainfall
8. Subtropical, with constant humidity through extended warm summers and short winters
9. Tropical, with lasting year-round warmth and humidity

The location and urban structure of Iranian cities have been strongly influenced by environmental and cultural factors. Apart from physical aspects such as a hostile climate and shortage of water, Iran's location at a crossroad of ancient trade routes such as Silk Road from the Far East to the western world has greatly influenced its culture and the development of towns and cities.

In the process of formation and development of Iranian cities, three factors are the most influential:

- The physical environment
- Trade and historical events
- Socio-political structure of the country

These closely interrelated factors have dominated the process of the formation of cities and further progress of their urban form and spatial patterns (Kheirabadi 1991).

This study focuses on the physical environment of traditional or pre-industrial cities in Iran. This refers to urban settlements before the overall modernisation of Iranian society that began after the World War I.

Iranian cities have appeared and spread in areas where water and relatively arable land were available. In most regions, cities are located at the foothills of mountains or intermountain basins where water is collected from man-made underground channels or *qanat*s. Overall, the distribution patterns of cities have been influenced by the physical geography of the Iranian plateau and availability of water.

Fig. 2.1: Shazdeh Garden (Bagh-e Shazdeh) Mahan, Iran. The qanat system direct water from the mountains to the garden (source: Architectural Design 2012).

Iran expands between latitude 25 and 40 degrees north and longitude 44 and 63 degrees east, with an area of 1,648,000 sq km. A mountainous country with an average height of 915 metres above the sea level, it is stretched from the Caspian Sea in the north to the Persian Gulf in the south. Two systems of mountain ranges

enclose the interior basin and stand in the way of rain-bearing western winds. The Zagros Mountains stretch from the northwest to the southeast and similarly, the Alborz Mountains expanding from the northwest to the northeast stretching along the southern coast of the Caspian Sea, block the northern winds from penetrating further south into central part of the country. The two major mountain chains have created a bowl-shaped physical geography and general dryness. The amount of precipitation varies remarkably from over 1250 mm on the Caspian Sea to less than 55 mm in the desert areas (Kheirabadi 1991).

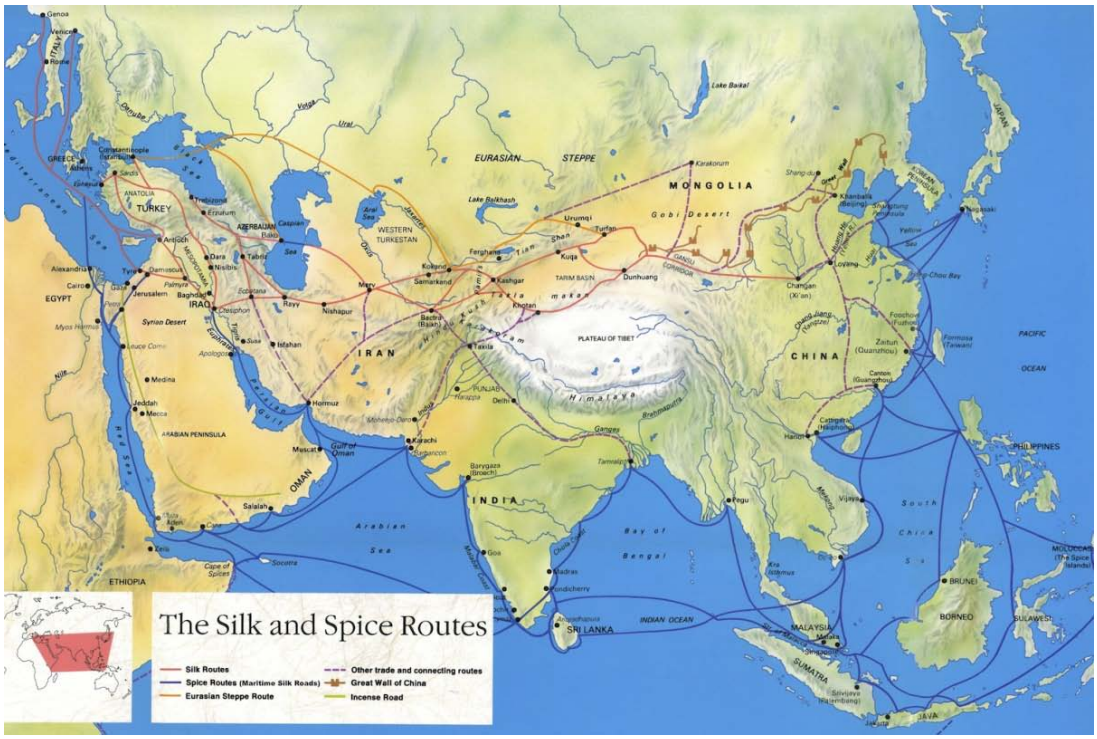


Fig. 2.2: The Silk and Spice routes linking East and West (source: UNESCO 2016)

Figure 2.2 displays silk and spice routes from the Far East to the European countries and the prominent location of Iranian cities on major trails. Due to the general dryness of the country, the distribution of human settlements and the intensity of human activity has always been defined by the presence of water (Ghobadian 1998). The western slopes of Zagros Mountains have been capable of supporting substantial urban population thanks to the humid western winds from the Mediterranean climate. Some other cities such as Tabriz, Hamadan, Kirmanshah and Shiraz located in intermountain basins have also benefited from the surface water powered by the rain carried by these westerly winds (Habibi 1999). Rivers originating from these mountains bring life into dry lands and irrigate the towns and fields. A great example of this relationship between the city and the river is the city of Isfahan and its river called the Zayandeh-rud or the Life-giving River. Apart from

these naturally flowing rivers, man-made Qanats provided water for traditional towns. Qanats are subterranean aqueducts that carry the collected water through gently sloped tunnels from the foot of the mountain to town and cities located in the basin.

Through the millennia, the physical morphology of the traditional built environment changed and adopted as a cultural-historical response to its severe climate. The extreme climatic conditions are distinguished by a shortage of water, higher evaporation than precipitation, intense solar radiation and destructive dust and sandstorms. To cope with such a hostile climate, traditional urban planners learned how to minimise the impact of solar radiation in hot summer, to alleviate the impact of unpleasant winds and to optimise the use of shade, breeze and water around houses and public areas.

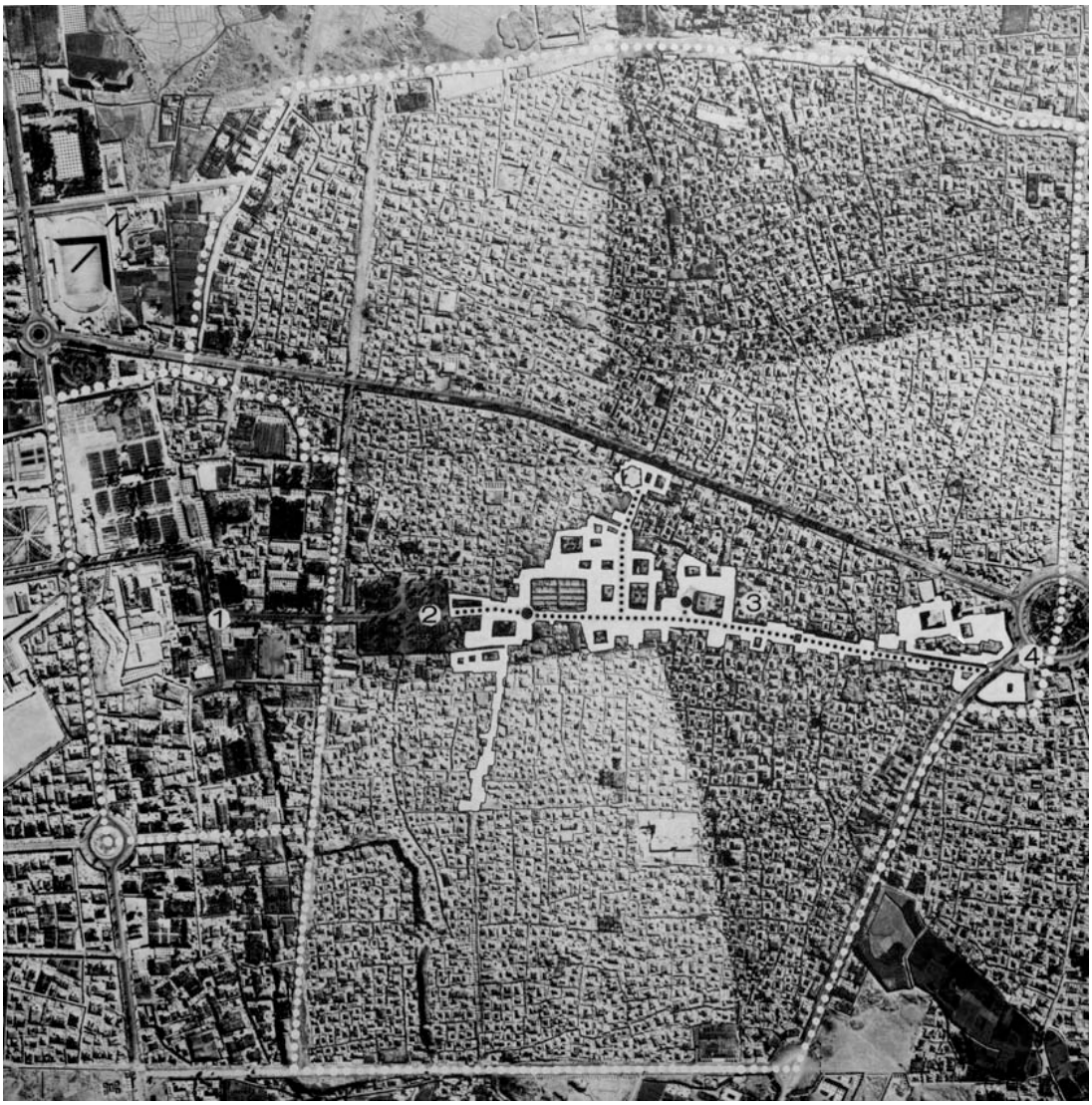


Fig. 2.3: The Bazaar of Kashan indicated in white at the heart of the old city (source: Ardalan and Bakhtiar 1973)

A clear example of the multiplicity of influences in the formation of Iranian cities can be observed in traditional markets or bazaars (Kheirabadi 1991). The bazaar, mainly located at the heart of the city, has always been an important part of economic and social life of the city and its structure and architecture reflects the climatic characteristic of the region. The bazaar is usually covered to protect its users from the heat of summer and frosty winter winds. Although bazaar's main structure and its morphology remains relatively similar but it is not difficult to recognise contrasts in size and shapes in various regions. In a dry and cold climate smaller shops and passages are more common and quicker to heat up by small wood burners and people's activity and traffic. Figure 2.3 shows a well integrated bazaar structure within a dense urban structure in Kashan.

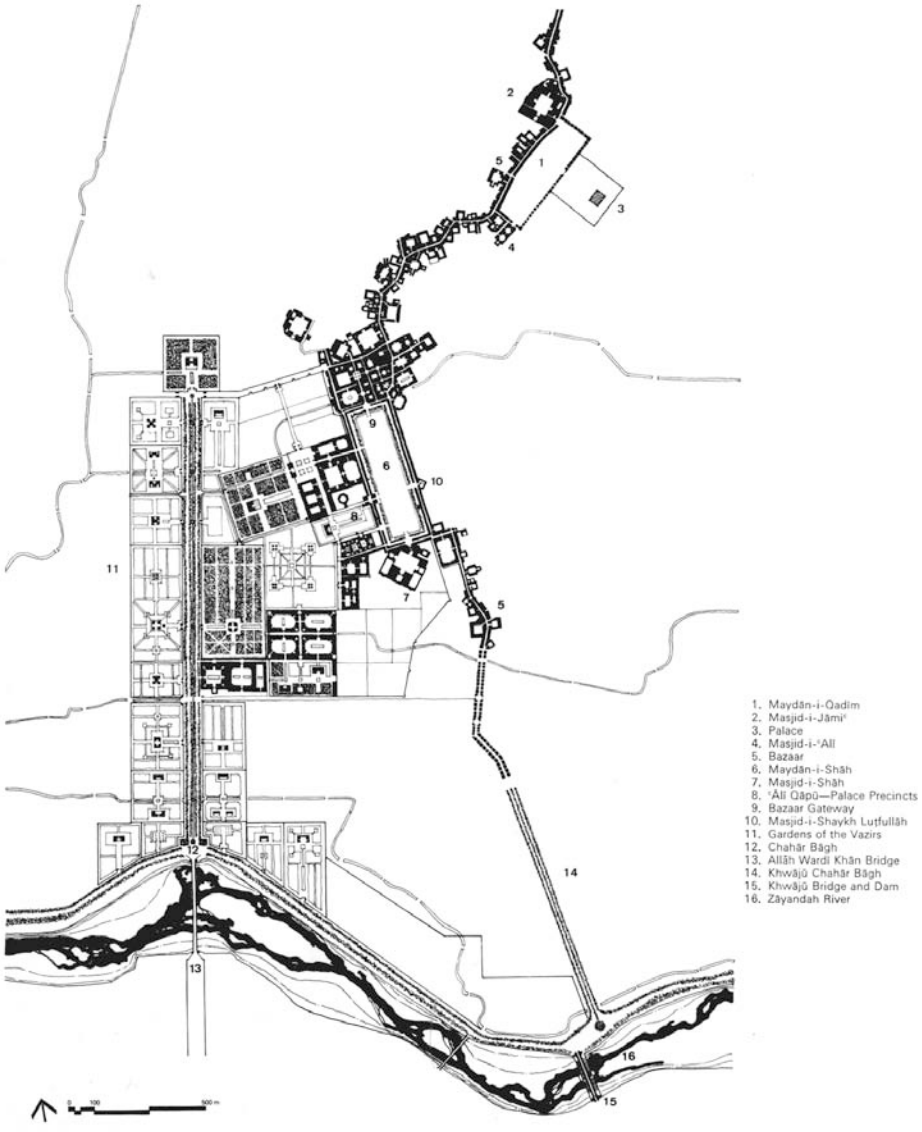


Fig. 2.4: Map of Isfahan & Zayande-rud River located in south of the city with Bazaar and formal gardens connecting the city to the river (source: Ardalan and Bakhtiar 1973)

2.3 Outline of the urban design of Tabriz

ساربانا بار بگشا ز اشتران
شهر تبریز است و کوی دلبران

Oh Sārbān, have camels' cargo unloaded,
For Tabriz is neighbourhood of the beloved.
—Rumi

The city of Tabriz, the capital of province of East Azerbaijan, is considered to be one of Iran's oldest cities. Located in the northwest corner of Iran where Turkey, Iraq, Azerbaijan, Armenia (and previously Russia) meet, the city of the Silk Road has been demolished and rebuilt after numerous earthquakes and devastating battles. The capital city of the Ilkhanid, Kara Koyunlu Turkomans and Safavid dynasties, and home of the prominent school of Persian miniature painting of the great artist Behzad, remains one of Iran's significant urban centres (Dumper and Stanley 2007). Recent archaeological excavations around the Blue Mosque revealed some remains from Bronze Age occupation extending the history of Tabriz to 1500 B.C. (UNESCO 2009).

Fig. 2.5: Map of Iran and its major cities (source: © 2013 Autonavi, Google)

Tabriz is located at 38˚ 8' latitude north and 46˚ 15' longitude east with an average altitude of approximately 1350 metres above sea level. The city is surrounded in three directions by mountains and it reaches Lake Urmiya in its western edge. In describing the geography of the city, Vladimir Minorsky, the Russian orientalist, stated: "Tabriz lies in the eastern corner of a level plain with an approximate area of 30km x 50km and slopes gently towards the north eastern coat of Lake Urmiya. The city is watered by several rivers which *Aji chay* or *Talkh-e rud* (literal translation is Bitter River) is the most important of them all with a length of 160km. The *Aji chay* originates from Mount *Sabalan* in the east of the city and cuts through the plain and brushes the northwest of the city after passing through Mount *Qaraje* in northern

part of the city and drains into Lake Urmiya. The *Mehran* River (*Meidan chay*) which passes through the middle of the city joins *Aji Chay* in the west. A mountain known as *Eynali-Zeynali* lies to the northeast of the city, has a height of 1800 metres and is a part of a chain that connects the *Gharaje Dagh* mountain range in north-northeast to the foothills of Mount *Sahand,* which is Tabriz's highest peak with an altitude of 3547 metres" (Iranian Cultural Heritage, Handicrafts and Tourism Organization 2009).

Fig. 2.6: Map of Tabriz in the Northwest of Iran (source: © 2013 Basarsoft, Google)

A large number of mines exist around Tabriz and large portions of materials are exported to neighbouring countries. With a population of 1,600,000 Tabriz has become the most significant industrial centre in the northwest of the country.

The Tabriz Bazaar, named a UNESCO listed world heritage site in 2010, is the largest covered brick structure in the world. Buildings in the bazaar of Tabriz are built with local materials and structural techniques appropriate to the climate and geography of the city. Due to its location along the Silk Road, it has always been considered one of the important commercial centres of the West and East. The Silk Road was a vital connection between Mesopotamia and China throughout ancient world and connected eastern and western countries for over 4000 years. It was a way of cultural and technological transmission while exchanging goods by linking traders, pilgrims, soldiers, nomads and urban dwellers from China to the Mediterranean Sea (Iranian Cultural Heritage, Handicrafts and Tourism Organization 2009).

The historic documents refer to several gates of old Tabriz. Ibn-e-Batoute described Tabriz market as full of goods, prosperous and one of the best markets of the world as he wrote: 'The next day we entered Tabriz city through the *Baghdad* gate and we arrived in a big market called "*Ghazan* Bazaar". That was the best bazaar I had ever seen in all cities of the world. Each of craftsmen had a special place. I entered into Jewellery Bazaar; I was dazzled by seeing so much jewellery. Nice servants with sumptuous dress, and silk shawls worn around their waist. They stood nearby their master and showed jewellery to the Turkish woman' (Omrani and Sangari 2006).

Various gates connected the city to other large neighbouring cities such as Istanbul and Baghdad.

1. *Istanbul* gate to Istanbul and then European countries
2. *Davachi (Shotorban)* gate to Caucasia
3. *Sorkhab* gate
4. *Baghmishe* gate to Ardabil
5. *Khiaaban* gate to Rey (Tehran)
6. *Nobbar* gate
7. *Mahad-mahin* gate
8. *Gajil* gate to Baghdad, Arabia and Africa

The commercial relationship of Tabriz with other main cities of the world led to enormous growth and prosperity of the city. Tourists were amazed at the multiplicity of the caravanserais inside bazaar complex and its profitable economy. It has also had global popularity for trading the unique goods such as Tabriz carpets, silk textile, clothing and dried fruits as travellers say the followings in this regards.

Marco Polo describes the city and its products in detail. "Tabriz inhabitants provide their expenses through trading various goods. Products include all kind of silk, some *simbaft* (Silver tread) and some gold cloths. You can find all sorts of precious stone in this city and businessmen who are trading here will gain remarkable profit" (Omrani and Sangari 2006). It is intriguing to see how the bazaar preserved its unique identity by containing most of these functions after centuries and turned into a cultural heritage for the city.

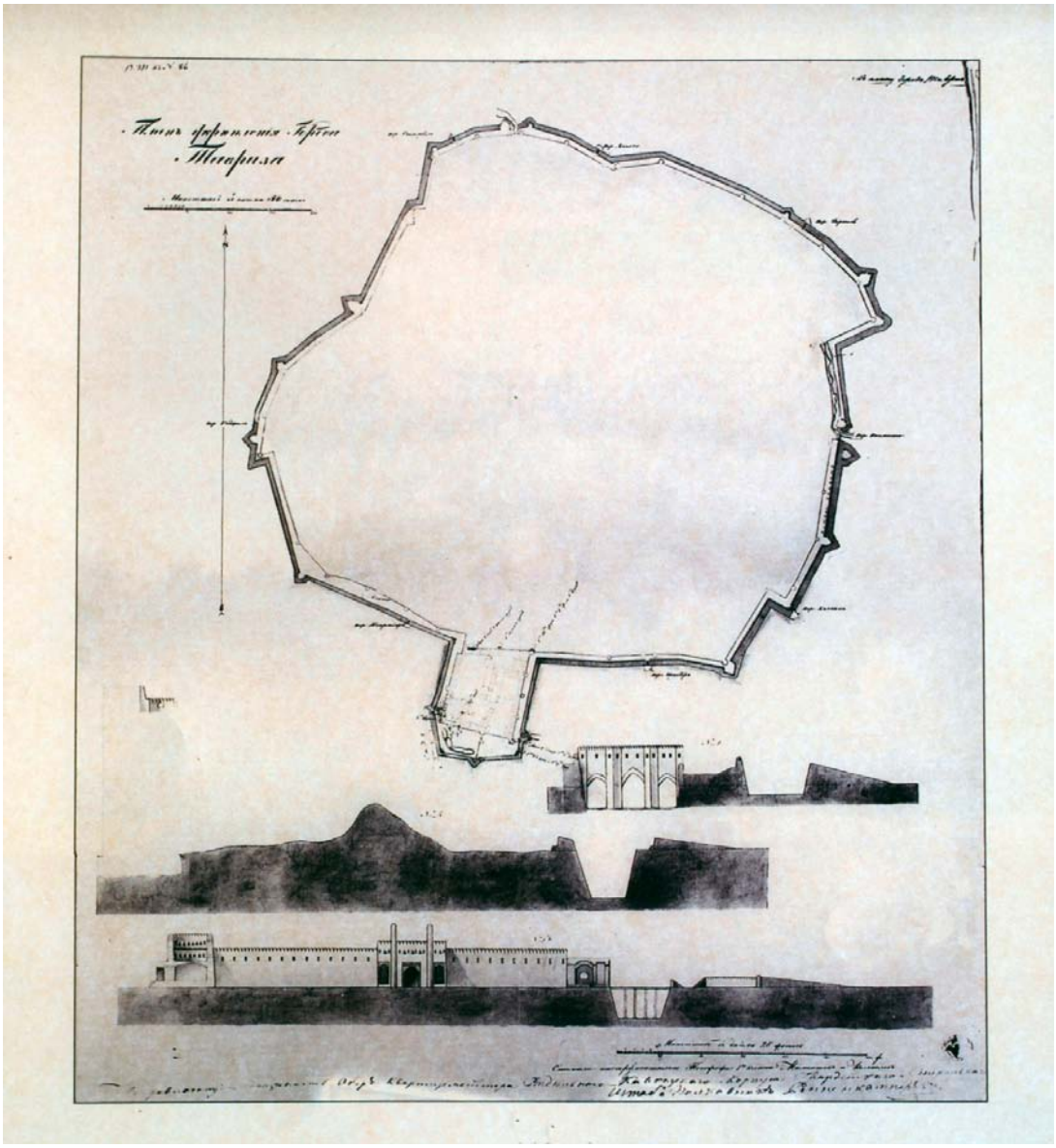


Fig. 2.7: Fortress map of Tabriz drafted by Mamontov and Kolokolov in 1827 AD (source: Bani Mas'ud et al. 2005)

Climate and Geology

Iran is divided into four climatic regions:

1. Mild and moist area of the southern coast of Caspian Sea
2. Cold and dry area of the western mountainous region
3. Hot and arid area of the inner Iranian plateau
4. Hot and humid area of the northern coast of Persian Gulf

Tabriz lies in the northwest in mountainous and cold area of Iran. The western mountain range blocks the flow of moist Mediterranean winds to reach Iranian plateau creating harsh winters and hot summers in valleys due to the intensity of the

sunlight. Long winters are usually cold and dry and snow stays on the ground for several weeks. Precipitation is generally low in summer and higher during the winter months in the form of snow. Regular snowfall whitens the top of mountains and on the heights above 3,000 meters, white summits are visible all year round (Omrani and Sangari 2006). Other major cities in this climatic region are Urmia, Sanandaj, Hamedan and Ardebil.

Tabriz has a cold semi-arid climate with regular seasons (Köppen BSk). The annual precipitation is around 380 millimetres which mainly falls as snow during the winter months and rain in spring and autumn. The average annual temperature is around 12°C with an average highest temperature of 32.9°C in July and average lowest of -6.6°C in January (NOAA 2012).

Due to its location on a major fault line, the city has been destroyed by earthquakes many times and because of its commercial importance, after each earthquake the city and its bazaar were reconstructed in the same location as before. Large masses of buildings and open spaces are closely interrelated in the bazaar structure. The open spaces act as lungs supplying fresh air into largely covered bazaar and also provide safe courtyards to escape in the case of earthquakes (Sultanzadeh 1997).

Major Historical Periods:

Safavid Dynasty

The Safavid dynasty is considered to be the most influential and powerful empire after the Muslim conquest of Persia. They established the Shia Islam as the official religion in the country and ruled from 1501 to 1722 AD. At their peak, they controlled all of modern Iran, Azerbaijan, Armenia, most of Iraq, Georgia, Afghanistan and the Caucasia, as well as Pakistan and Turkmenistan. The Safavid dynasty was found by *Shah Ismail* who invaded Shirvan in 1500 and captured Tabriz in July 1501 where he declared himself the Shah of Azerbaijan. The city itself did not experience major development under his rule due to continuous battles to conquer rest of Persia and also because of several attacks from Ottomans in this region. The city was invaded by Ottomans' troop after defeat at the battle of Chaldiran in 1514. After Shah Ismail, *Shah Tahmasb* succeeded his father and moved Safavid capital from Tabriz to Qazvin, a city further away from Ottomans reach, and finally made peace treaty with Ottomans in 1555 (Newman 2006).

Fig. 2.8: Miniature map of Tabriz drafted by a Turkish traveller in 1537 AD (source: Bani Mas'ud et al. 2005)

Jean-Baptiste Tavernier, the French merchant and traveller, who explored Iran many times in 1632 - 1668 AD and passed though Tabriz, describes the economic growth and the wealth of the tradesman, "Here, wine and water of life and in fact all kind of goods accessible to customers inexpensively are present. In Tabriz, money is exchanged more than anywhere else in the world. Many Armenian families have been affluent through trading there. Most of buildings are built from sun-baked bricks and wealthy people live in two-storey buildings... Tabriz has numerous and glossy bazaars which are always full of exquisite goods. Local craftsmen are generally blacksmith who often make tools such as handsaw, axe and some are locksmiths. There are few jewellery makers which do not make anything rather than clumsy silver rings. However, numerous skilled workmen are employed to produce handmade silk fabric of high quality and numbers of these people are much higher than any other craftsmen in the Bazaar".

Sir John Chardin, who travelled to Tabriz during Safavid period in 1673 AD, describes the city in full detail; "The town is immense and is the second populous city in Iran. It is built in an organic shape and does not follow any geometric order. It has no walls, barriers or fortifications... Tabriz has nine neighbourhood and fifteen thousand shops. In Iran shops are built along wide and covered passages, theses

streets which are usually built within the town centre are called Bazaar. Houses are built outside the Bazaar and almost all of them have courtyards. Three hundred caravanserais stand within the city and some of them are so enormous they could contain three hundred people. Coffee houses where people drink tea and smoke hookah and many public buildings such as mosques and baths built to harmonize with other splendid buildings. Two hundred and fifty mosques lie within this town... I tried hard to find out the number of inhabitants but it is conceivable that it is no less than five hundred fifty thousand people" (Iranian Cultural Heritage, Handicrafts and Tourism Organization 2009). Figure 2.9 is one of the most referenced sketches of the city during Safavid period which is referenced from Chardin's travelogue.

Fig. 2.9: A sketch by Chardin showing city's elements during Safavid period (source: Sultanzadeh 1997)

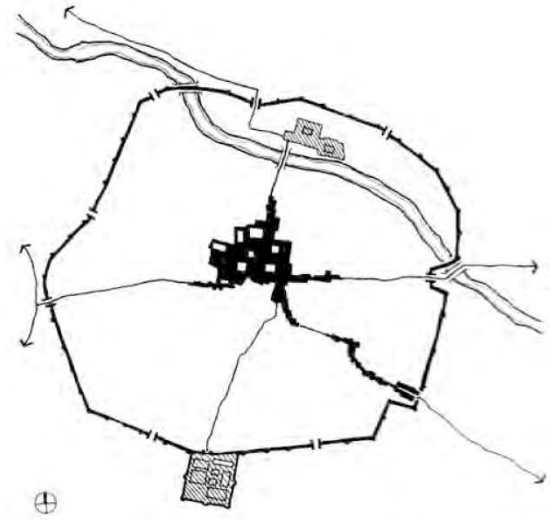
Qajar Dynasty

The Qajar family first settled in the vicinity of Azerbaijan during the Mongol period and were among the seven Qizilbash tribes that supported the Safavid. The family took full control of the country in 1794 after defeating Loft Ali Khan, the last king of Zand dynasty, and reclaimed parts of Caucasia. In 1796 Mohammad Khan Qajar was formally crowned as shah and the royal family ruled Persia (Iran) from 1785 to 1925. *Agha Mohammad Khan*, was known as one of the cruellest kings of Iran, who in one occasion blinded 20,000 men in the city of Kerman because the local people

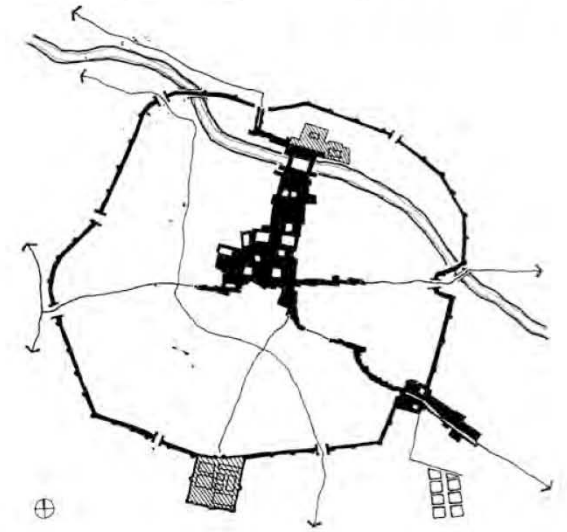
had chosen to defend the city and not to surrender. After the assassination of *Agha Mohammad Khan*, his nephew *Fath Ali Shah Qajar* succeeded him.

Fath Ali Shah embarked on a war against Russian Empire due to concerns about Russian expansion into Caucasia. The battle was known as Russo-Persian war of 1804 – 1813 but Qajar army suffered a major defeat and signed a treaty called as the Gulistan treaty in 1813 when it recognized the Russian control of Georgia and most of the Caucasian region. The second Russo-Persian war of the late 1820s, ceased with more devastating results for Qajars and temporary occupation of Tabriz. By signing the treaty of Turkmenchay in 1828, the king accepted complete Russian control of entire South Caucasia and area north of the Aras River (Ghani 1998).

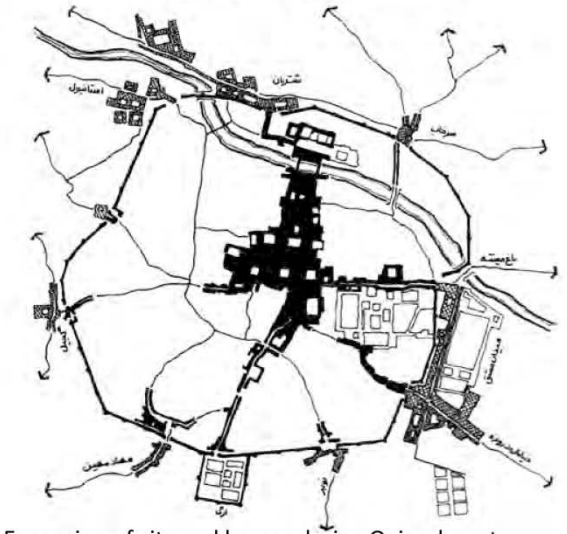
During Qajar period, western science, technology and educational methods were introduced into Iran and modernization of the country began. Due to political and economical significance of Tabriz, *Fath Ali Shah* authorised *Abbas Mirza*, the crown prince, to rule the city. *Abbas Mirza* started the redevelopment of the city with its army and used French and English military advisors to consolidate the army. Apart from expansion and reinforcement of the army, he also undertook and supported cultural projects and urban development. For instance, he supported the purchase of a printing machine and the establishment of printing workshop in Tabriz and publication of the earliest book in Iran. During his time, the French ambassador visited the city in 1839 and described the bazaar and surrounding buildings: “Tabriz looks like a grand and glamorous city from far. With its surrounding wall it appears to be a solid city but like many new buildings in Iran, the wall is built of mud bricks which are easily washed away in floods. Alleys are tight and grimy. In fact tall walls have been built along narrow passages and only a small hole in the wall allows one person to enter the house. It is sad to see local people built their houses in this way to protect their lives. But once you enter pass this tight and low entry, you discover green courtyards and pleasant gardens which are embellished with trees and flowers. This is the custom in most of Muslim Asian countries. Quiet alleys are in great contrast with lively and chaotic Bazaars. Outside the Bazaar everything is silent and deathlike” (Sultanzadeh 1997).



Bazaar complex and city wall during Saljuk



Expansion of bazaar towards northern and eastern gates during Safavid period - 16th century



Expansion of city and bazaar during Qajar dynasty - 19th century

Fig. 2.10a: Expansion of bazaar complex within city walls in Tabriz from 12th to 19th centuries (source: Sultanzadeh 1997)

Map of Tabriz presented in figure 2.10 clearly displays the organic form of the city in 1910 as it expanded beyond city walls. The grand bazaar constitutes the main part of the city centre with extensive network of streets and alleys expanding into residential districts. Various neighbourhoods have been marked on the map with oversized alphabets. However a clear physical divide between adjacent neighbourhoods is not noticeable. In contrast, in modern cities, wide road and highways indicate the border line between rich and poor areas.

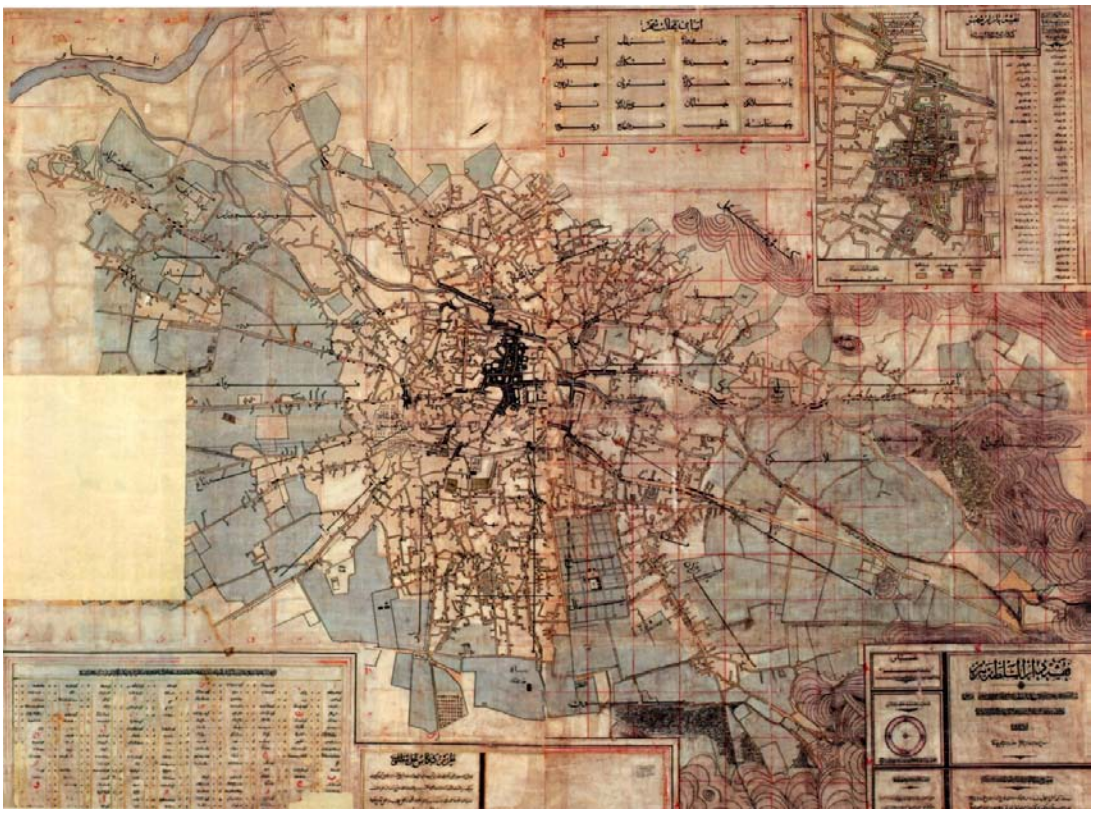


Fig. 2.10b: Map of Tabriz in 1910 showing bazaar structure highlighted in black and surrounding neighbourhoods (source: Tehrani et al. 2005)

Fig. 2.11: Behnam House was built during the early years of Qajar dynasty. The main building is a two-story structure standing on a basement (source: Author 2013)

Pahlavi Tabriz

The Pahlavi dynasty consisted of two Persian Monarchs, *Reza Shah Pahlavi* (ruled 1925-1941) and his son *Mohammad Reza Shah Pahlavi* (ruled 1941-1979). The Pahlavis came to power after Ahmad shah Qajar, the last ruler of Qajar dynasty who was overthrown in a military coup and exiled to France. The National assembly, known as the *Majlis,* on 25th Dec 1925, deposed *Ahmad Shah Qajar* and officially declared *Reza Shah* as the new monarch of the Imperial State of Persia. In 1935 *Reza Shah* commanded foreign embassies to address Persia by its ancient name Iran (Ghani 1998).

Economic and social reform during Reza Shah Pahlavi deeply affected Iranian architecture and urban life. Reza Shah's vision was to reconstruct and modernise the country based on western values. In city scale, wide and straight avenues were main features of Pahlavi architecture and they were built to achieve a modern and organized pattern for cities. Furthermore, wide avenues were perfect places for soldiers to march and demonstrate government's power. Construction of perpendicular network of roads resulted in destruction of old parts of cities and many traditional buildings. The avenues mostly stretched from one corner of the city to

another cutting through the organic fabric and making room for new modern buildings (Bani Mao'ud 2011). Old neighbourhoods were segregated by wide streets and appeared isolated and divided by new streets. The earliest road in Tabriz was named Pahlavi Street and it was built between 1921 and 1926 by the order of the Commander of Azerbaijani Army. This road separated Alishah Mosque (built in 1320 AD, historically the most significant building still standing in Tabriz) from the bazaar and historic core of the city (Sultanzadeh 1997). Pahlavi Street in Tabriz could be seen in figure 2.12 with a new typology of extraverted buildings along the street which was uncommon in traditional urban form. Figure 2.13 displays a more recent image of the city where monumental modern buildings such as banks, local government building could be seen adjacent to the old bazaar complex.

Fig. 2.12: General view from top of the Arg (source: Lockhart 1939)

Historic fabric of the city

Tabriz like many other traditional Iranian cities developed into several residential district or neighbourhoods called *mahalleh* where people from similar ethnic and religious background gathered together (Sharifi & Murayama, 2012). These areas would vary in size and population but each quarter was considered as a socio-urban unit which played an important role in arrangement of social and cultural relations within the city. Depending on its size, each *mahale* contained one or several hubs or *markaz-e mahale. These hubs were outdoor spaces* and meeting points of several

streets and gathering place for people. *Markaz-e mahalle* would generally contain few small shops, a mosque and a public bath called *hammam* in walking distance from houses.

Preserving the commercial centre at the heart of the city, the historic structure of the city was consisted of interconnected streets and introverted building forms and its organic urban pattern was an expression of city's historic, geographic and social background. Main roads which at time stretched from one city gate to another were built relatively wide and spacious but passages and blind alleys were built tall and narrow, sometimes so narrow that only one person could pass through (Sultanzadeh 1997).

Fig. 2.13: View from Northern part of Tabriz with new modern building visible near historic bazaar complex (source: Dibaj & Karang 1963)

Inside traditional city of Tabriz, buildings were built densely sharing external walls with neighbours exposing only one side of the building along passages. The exterior faces of buildings for the most parts were barely decorated with only an entrance portal noticeable from outside. This approach is also apparent for public building such as *hamam* or bathhouses, schools and smaller mosques.

The materials used in construction were limited due to generally dry climate and they were only sourced locally for practical reasons. Construction materials mainly consisted of stone used for foundation, brick and mud for walls, arches and domes

and timber for columns and roofs. Baked brick was also extensively used to decorate walls and window reveals in various shapes of geometric and curved patterns (Sultanzadeh 1997).

The most common types of residential building were the courtyard houses which were designed and constructed to achieve introvert buildings with very few openings towards alleyways. Internal courtyards were shaped to provide daylight, ventilation and pleasant views for internal rooms. In larger family houses, the building was divided within two parts of *Biruni* (semi private part) and *Andaruni* (private part) to create separate rooms for family members and visitors to further enhance privacy for inhabitants.

Fig. 2.14: Aerial view of old city of Tabriz with dense neighbourhoods and highlighted primary streets [no date cited, estimated 1920] (source: Sultanzadeh 1997)

The house layout was arranged to accommodate main rooms in northern side of the courtyards to maximise the solar gain during cold winters and less important rooms were located in westerns and eastern edges of the courtyard. Most buildings consisted of two storeys at ground and lower ground level but and large houses would be built on three or four levels. The basement rooms would raise nearly one

meter above the courtyard level to attain daylight and circulate fresh air. Basement spaces provided inhabitants with cooler spaces in summer and slightly warmer places in winter and some contained a small pool and would be used for storage of food as well as a pleasant living room for visitors.

Fig. 2.15: Aerial view showing an urban hub in Tabriz where small streets connect into a public square. Small alleys are highlighted in blue [no date cited, estimated 1920] (source: Sultanzadeh 1997)

Figures 2.14 and 2.15 are historically important images of city of Tabriz as they display the organic urban structure in early twentieth century. The urban structure in residential districts could be observed right before the modernisation. A *markaz-e-mahalle* or neighbourhood centre could be seen in figure 2.15 were few alleys meet to create a relatively small open square. Although it looks unplanned and accidental at first sight, dense urban pattern is the result of a formal response to physical shape of land and local climate. Courtyard houses were constructed sharing external walls with their neighbour and although varying in shape and size but they all enjoy some form of a green courtyard.

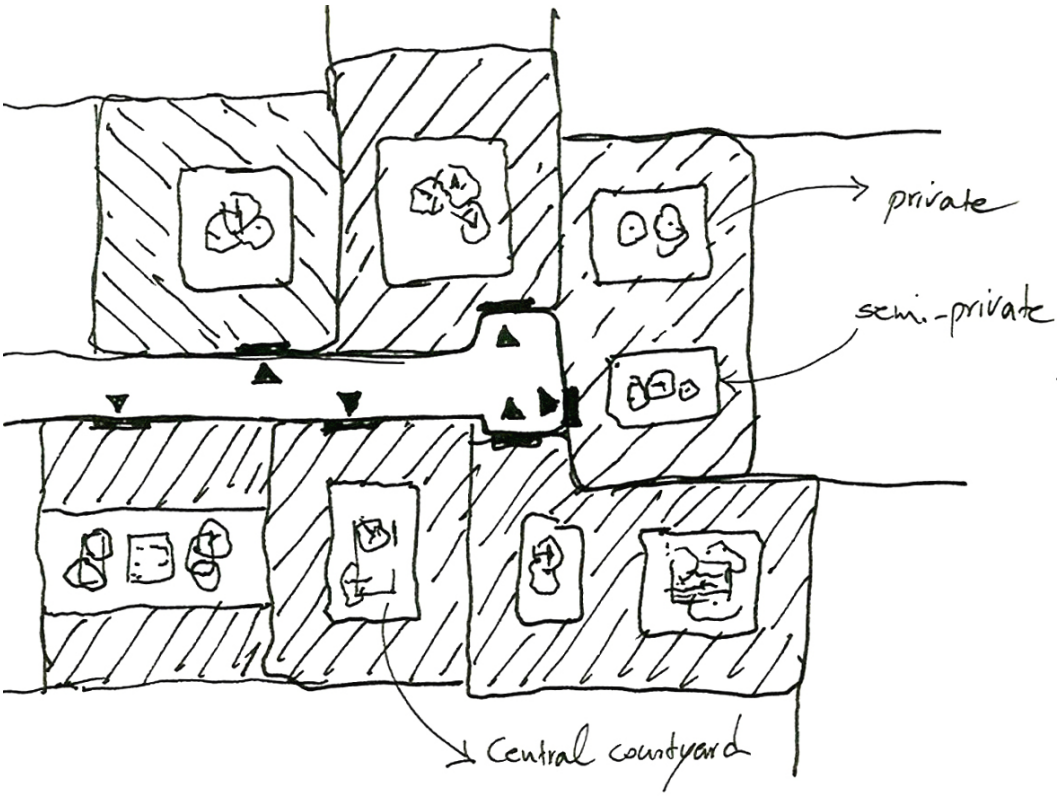


Fig. 2.16: Sketch of a small scale housing layout organised around a bon-bast or cul-de-sac in vernacular city. The layout of larger houses was divided into two parts with a semi-private courtyard near the entrance door and a private courtyard deeper inside away from the entrance (source: Author 2013).

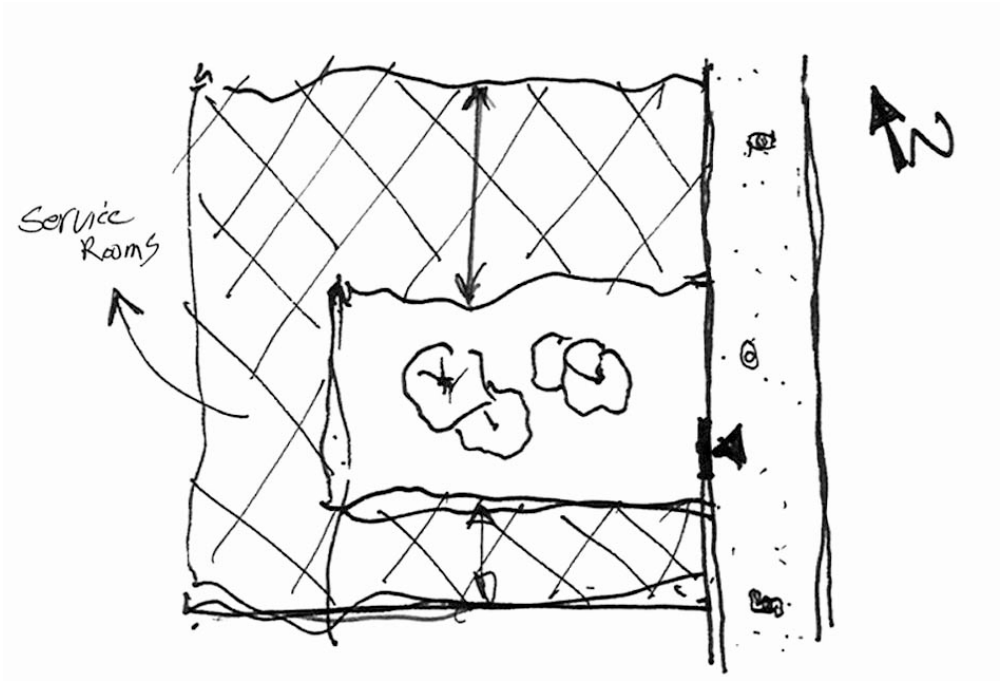


Fig. 2.17: Sketch of a typical courtyard house in Tabriz where larger main rooms are located in northern part of the house to benefit from direct sunlight during long winters (Source: Author 2013).

The contemporary city

In 1930s, Tabriz with a population of 260,000 developed rapidly to become once again an important commercial city in Iran (Sultanzadeh 1997). Major industries including high quality leather for domestic market and European export, cotton yards, woollen goods and production of soap, dried fruits and nuts attracted people from surrounding towns and villages. After the revival of the carpet industry in the second part of the nineteenth century in Iran, Tabriz established itself as a centre for European export. Developments included numerous factories, expansion of street network, public gardens and a town hall designed by German architects. The railway which was initially built by Russians to connect Tabriz to Jolfa-Tiflis railway extended further west to link Tabriz to Turkey and eastwards to the capital Tehran.

The image of the city has changed dramatically during last decades. Rapid development and expansion of the city was caused because of trade links with Turkey and Azerbaijan, large expansion of industries related to food and agriculture and construction boom. Rapid urbanisation and migration from villages to the city increased population and demand for housing and urban transport. New commercial developments continue to threaten the old fabric of the city as they expand into older parts of the city. Urban development policies in recent years favoured use of private cars as the main means of transport together with extended road network. New roads, bridges and car parks are being built as solutions for growing traffic and congestion in the city. Heavy traffic, air and noise pollution and invasion of public space by motor vehicles are only some of current challenges facing city dwellers (Parsipour 2010). Century-old solutions of vernacular architecture seem to be forgotten or at least considered not to be fit for a modern and fast moving city. Following the footsteps of modern European and American cities, newly developed districts in Tabriz and most modern Iranian cities follow a grid patterns for road network with blocks of buildings in between. The rectangular plots between roads create regular land sizes to build on. However, these divisions at many occasions fail to achieve appropriate orientation for the buildings and inhabitants. In most apartment houses while the building footprint is stretched from south to north each floor is divided into two or four units where one unit is south facing leaving other units facing north, east and west, receiving few hours of direct sunlight throughout the year.

Fig. 2.18: Satellite view shows the grid system of roads in recent developments (source: © 2013 DigitalGlobe, Google)

Fig. 2.19: View from top of the tallest building in the city showing Pahlavi Street on the left hand side and Mehran Rud River on the right (source: Author 2013)

The following two images demonstrate typical forms of residential buildings in modern Iranian cities. Dependency on private cars for daily commute also forces planner and developers to spare ground floor area including the courtyard for parking space for residents on upper floors.

Fig. 2.20: Apartment blocks raised from urban plots are the most common type of residential developments in recent years (source: Author 2013)

Fig. 2.21: Rising house prices and high demand for housing in recent decades encouraged the demolition of many low-rise buildings and construction of mid-rise apartment blocks (source: Author 2015)

2.4 Outline of the urban design of Shiraz

Shiraz is the largest city in Fars province in south of Iran and it was the political capital during Zand dynasty (AD 1747-79). It is located in south western Iran, in the inland around 200 km from the Persian Gulf. It is generally believed that the name Pars comes from early Aryan settlers in this region (1500 to 1400 B.C.). The name Persia is driven from Fars or Pars into Greek as Persis and the Arabic form of Fars (Memarian 1998).

Shiraz is located at 29° 33' latitude north and 52° 36' longitude east with an average altitude of approximately 1491m above sea level. Shiraz has a hot semi arid-climate (Köppen: BSh) with noticeable four seasons and the annual precipitation is around 305 millimetres. The average annual temperature is around 17.6 ˚C with an average highest temperature of 37.8 ˚C in July and average lowest of -0.4 ˚C in January (NOAA 2015).

Fig. 2.22: Map of southern part of Iran and Shiraz located in the Southwest of the country (source: © 2016 Map data, Google)

The city is surrounded by mountains and hills from north, south and west. The *Khorram Dareh* River flows from the northwest to the southeast of the city and drains into *Maharloo* Lake. The river and mountains surrounding the city have provided great security for the city but also limited its development in certain directions. The most extensive development in the city happened during the Zand dynasty when *Karim Khan Zand*, the founder of the Zand dynasty, chose Shiraz as the capital city. Numerous public buildings such as bathhouses, *madrassa* or schools, public gardens and underground cisterns were built developing the city on the north and northwest sides. The *Bazaar-i Vakil* together with *Toopkhane* square were another major development in this period. These large public developments in

the city diminished when the capital moved from Shiraz to Tehran during the Qajar dynasty.

Major Historical Periods

During Safavid and Zand periods in Iran a central dominant government was revived and longer periods of peace and economic stability created the context for cultural and artistic innovations to flourish. The cultural and economic connections with European countries developed and supported the rise in industrial and agricultural production. The expansion of small industries in cities to produce goods like carpets, spices and silk fabrics led to increase in urban population and development of cities like Shiraz and Isfahan. In fact the Safavid and Zand periods could be named the pinnacle of urban development in Iran (Ardeshiri and Memarian 2011). Safavid rulers in particular were keen to employ scholars and scientists to renew and develop their capital cities and their holistic and structured approach helped to utilise historic architectural knowledge in order to build new prosperous cities.

Large-scale urban developments in Shiraz during Safavid period were numerous and could be listed as construction of *dar-ol-shafa* or clinics, bridges, *Khan madrasa*, *Khan* Bazaar and *Chahar Bagh* or four-gardens along the main axes of the city from one city gate to another. Throughout Zand dynasty once again the city was imagined as the centre of government, administration and commerce where impressive infrastructure and large scale public buildings were on display for wealth and prosperity of the city. With declaration of Shiraz as the capital city of the Zand dynasty by Karin Khan Zand in 1750 (Burke and Elliot 2008) urban development projects accelerated. Karim Khan Zand proved to be a popular ruler with humanistic ideas and he concentrated his efforts to improve economic conditions of people by encouraging agriculture and establish trade links with British East India Company (Britannica 2016). In the course of three decades of Karim Khan's benevolent rule in Shiraz the city gates and ramparts were rebuilt for defence purposes and roads connecting the capital to other cities, mainly to port cities along Persian Gulf, were expended and improved. Inside the city, the citadel, Vakil Bazaar, Valik Bathhouse, caravanserais, water cistern and mosques were built and tomb buildings for two prominent poets, Sa'di and hafez, were erected (Ardeshiri and Memarian 2011). Paving streets and public open spaces with cobblestone and flagstone improved the quality of street network and it is argued that for the first time in Iran a system for management of surface water on streets was created by construction of a series of wells with net-like covers.

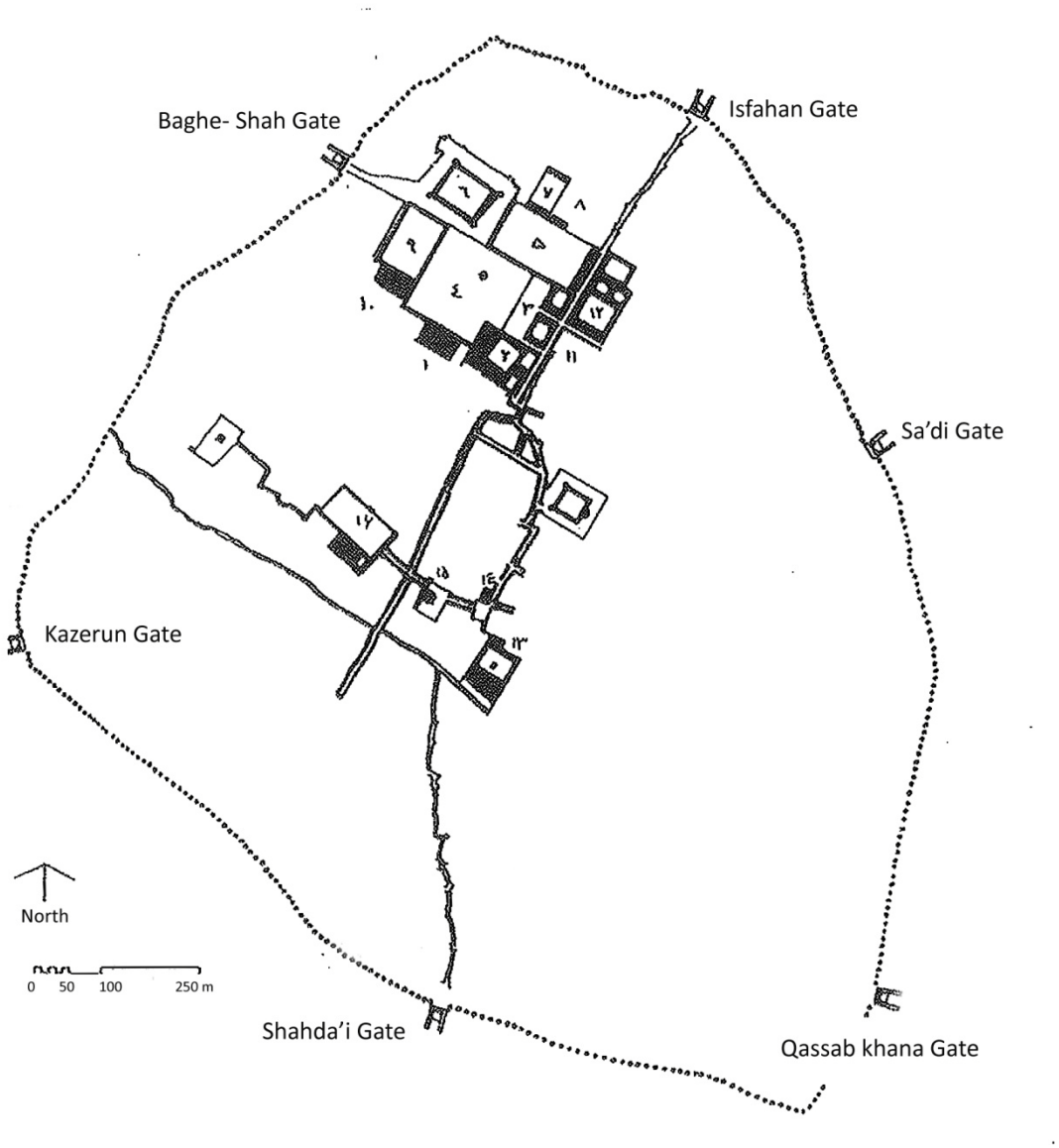


Fig. 2.23: Map of Shiraz and main public buildings within the city walls with reconstructed city gates during Zand period (source: Ardeshiri and Memarian 2011)

Qajar Dynasty (1794 - 1925)

After the death of Karim Khan Zand in 1779, Agha Mohammd Khan, a leader of the Turkmen Qajar tribe, managed to defeat his rivals including Loft Ali Khan the last ruler of Zand dynasty and regain control of the former Persian territories in Georgia and the Caucasus (Encyclopaedia Britannica 2016). The capital moved from Shiraz to Tehran and once again the rate of economic growth and urban development slowed down in Shiraz. In early nineteen century, three strong earthquakes hit Shiraz within less than three decades and caused extensive damage to houses and public buildings. But due to economic activities and good connection with southern port cities, Shiraz maintained its position as a commercial hub in south of Iran and

even few more caravanserais were added inside historic core of the city. During this period improvement works to passageways and building of water cisterns or *Ab-anbar*, bathhouses and small-scale additions to Bazaar structure was funded by local donors. A map of the city produced by the Russian army in 1850 displays a clear urban structure consisted of nine neighbourhoods or *Mahalle* contained within the borders of the city wall with six gates in different directions.

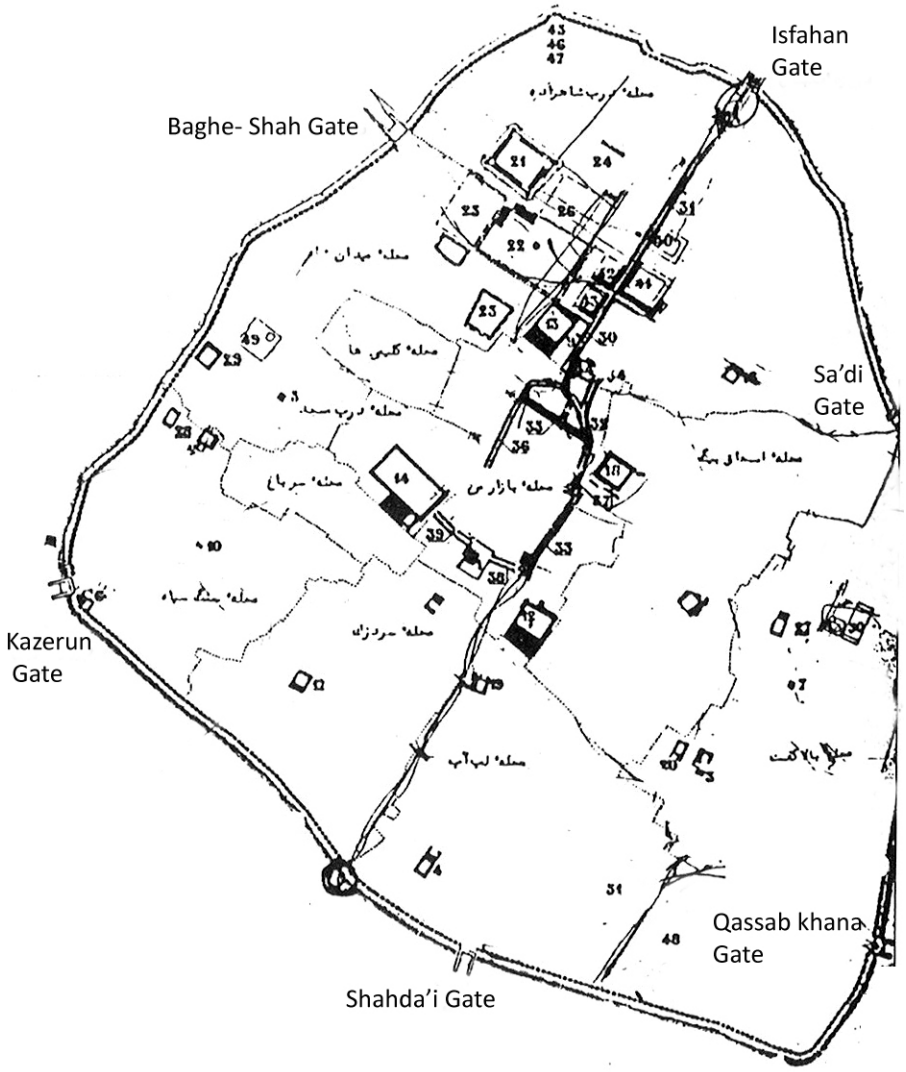


Fig. 2.24: Map of Shiraz with main public buildings and nine neighbourhood districts inside the city wall during Qajar period (source: Ardeshiri and Memarian 2011)

Similar to other large cities in Iran, during the Pahlavi period, the shape of the city transformed substantially by introduction of cars, wide straight roads and western style monumental buildings (Tabrizian 2010). The historic core of Shiraz was divided into northern and southern parts when wide streets stretching from east to west, cut though the Bazaar segregating it from the *Vakil* mosque. In absence of solid

conservation rules, many traditional houses and public areas such as *Toopkhane* square were demolished and replaced by new building along the streets.

For many years Shiraz remained within its limited boundaries and contained most of its economical, production and cultural affairs. A group of few residential districts shaped the main body of the city. These regions were expanded out from the main axis of the city formed by large public buildings such as bazaar, Friday Mosque, New Mosque, public gardens. These residential neighbourhoods maintained their organic forms and their connection with each other even after Safavid period (AD1502-1722). The main changes to shape of the city happened during Zand period and most recently modern interventions during the twentieth century.

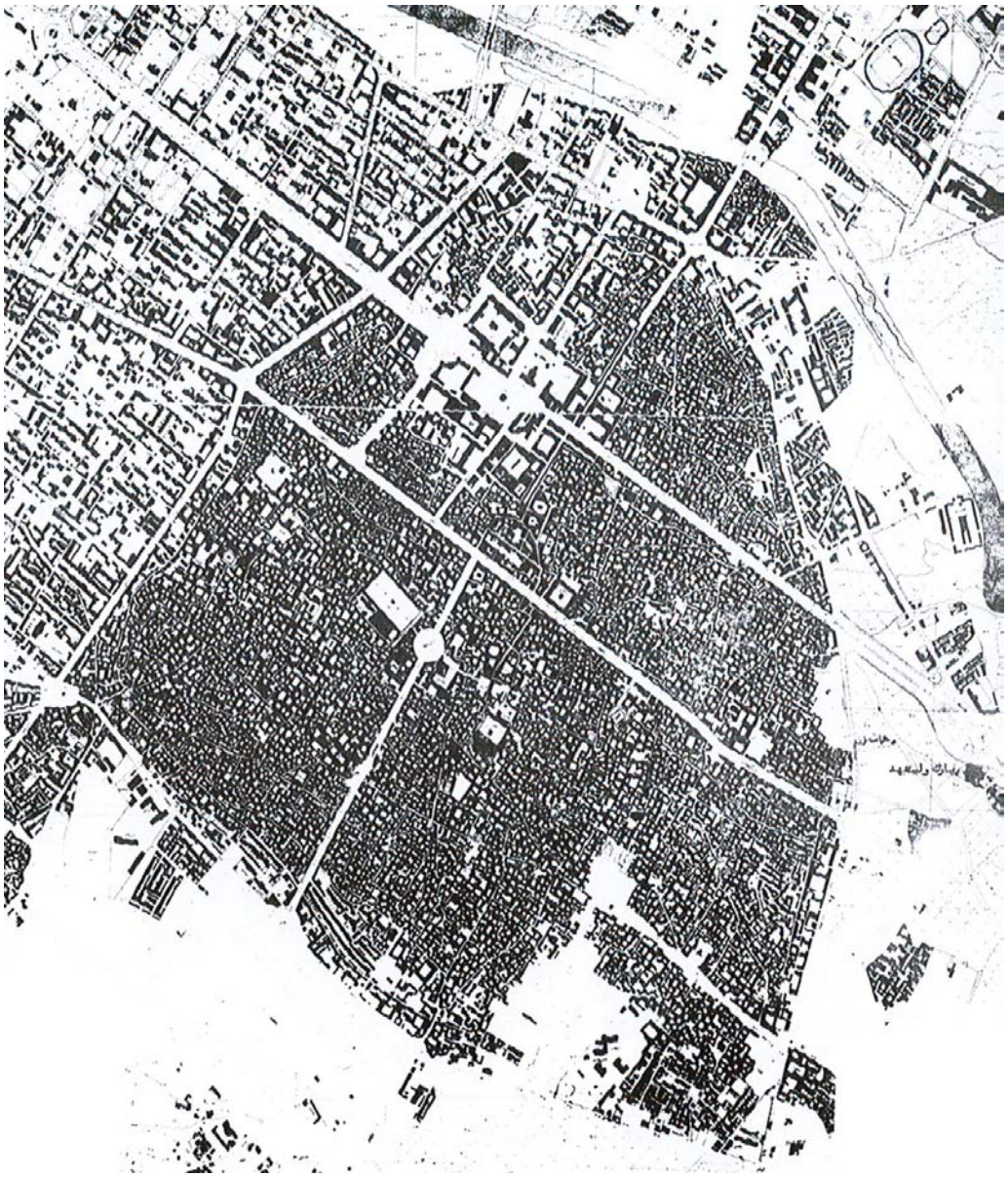


Fig. 2.25: The long-established core of the city is readily recognisable from its modern parts in north of the city (source: Falamaki 1977)

Shiraz Bazaar constitutes the economical backbone of the city and likewise, its structural growth and developments reflects the formal transformation of the city. As the city developed and expanded, necessary public buildings such as bathhouses, schools, teahouses and urban caravanserais were added to the main structure of bazaar beside residential quarters (Falamaki 1977).

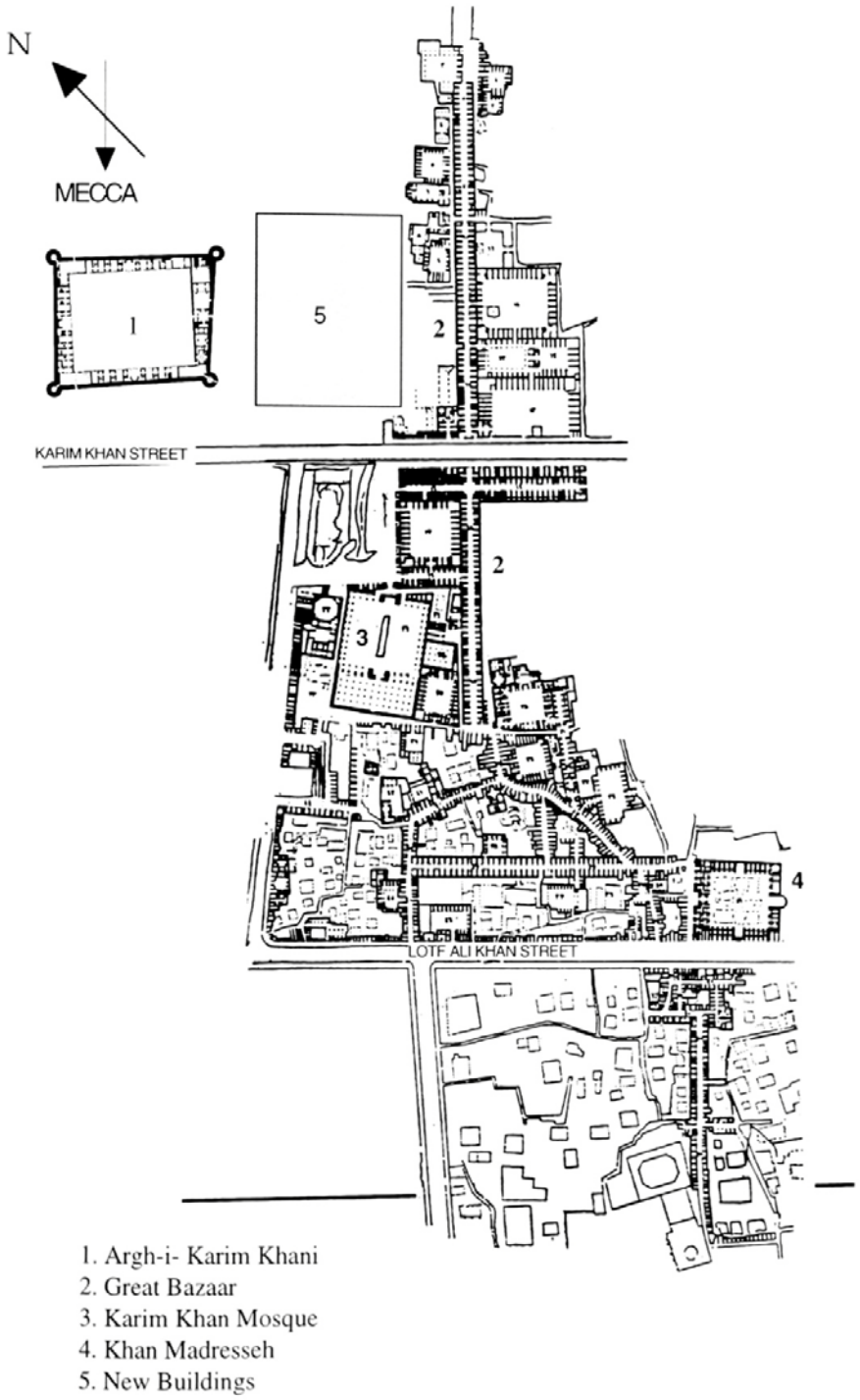


Fig. 2.26: The historic Shiraz Bazaar complex has been divided into three separate parts due to construction of new roads (source: Memarian 1998)

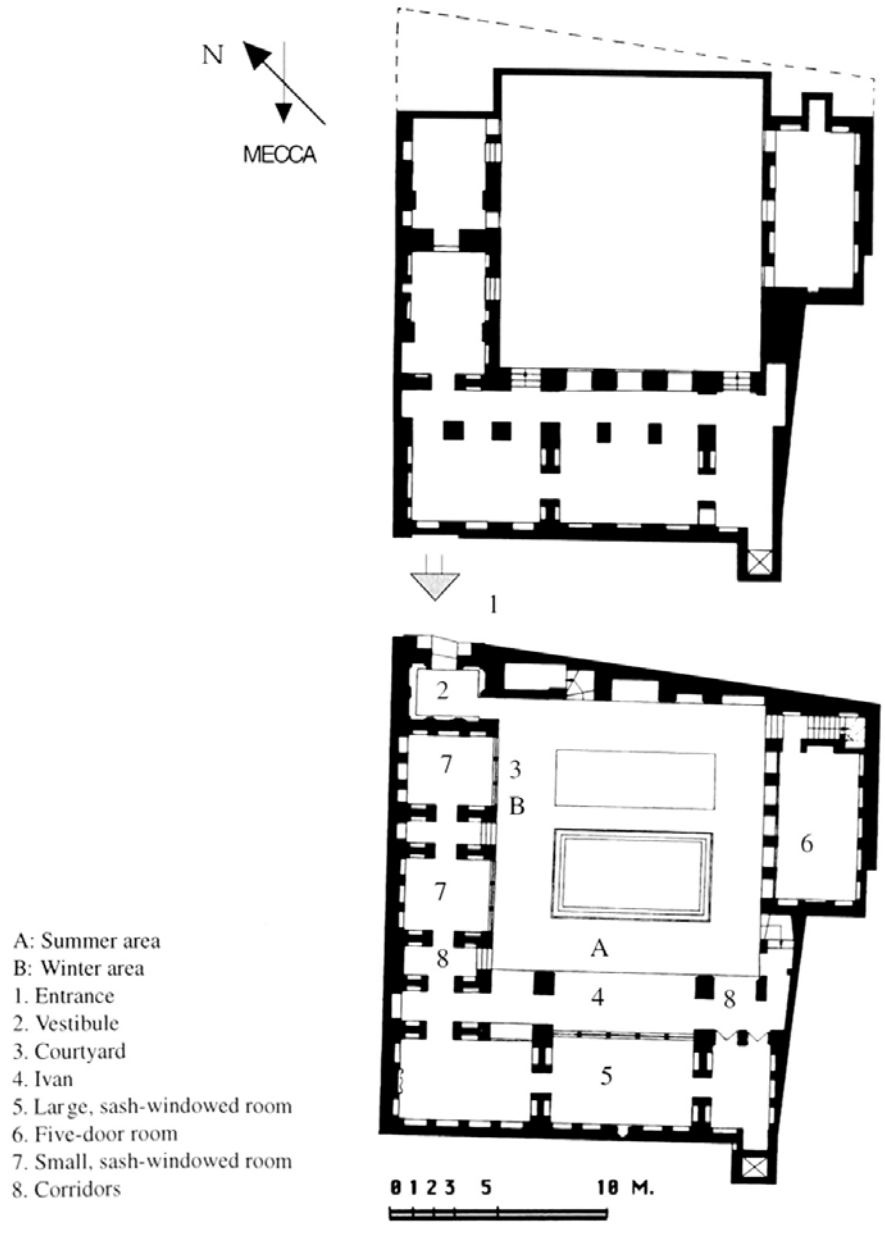


Fig. 2.27a: Mantegi Nejad House with basement plan on top and ground floor layout below. Larger living areas aare located in southern part of the city to avoid direct sunlight in hot season (source: Memarian 1998)

Among Iranian cities, Shiraz is famous for its numerous urban gardens. Smaller gardens are located inside houses and courtyards and larger public gardens. Evergreen trees and vegetations and shallow pools constitute the main features of the courtyard. Most usual types of trees and vegetation include tangerine, oranges, lemons, red roses and Damascus Rose. Inside courtyards pools are generally located central to the main room or *Shahneshin* and their sizes vary according to

courtyard sizes. In hot summer nights people spend most of their time in their courtyards. Apart from being a circulation space, courtyard with its small garden and pool provided a gathering place for family to meet visitors.

Urban gardens in Shiraz have numerous environmental, social and cultural impacts. Once preserved as private gardens for wealthy families, urban gardens such as Bagh-e Delgosha and Bagh-e Eram are now open to public and accessible to everyone. These urban gardens have turn to social places for locals and visitors to meet and celebrate urban life in the city (Alidoost 2013). The gardens are regularly used for cultural programmes such as music festival and art exhibitions. Cooler temperatures and pleasant surroundings attract many people to these gardens especially in hot summer nights. Surface evaporations from water channels and fruit trees, increases humidity helps to create a pleasant microclimate inside gardens and also to moderate temperatures by natural ventilations in surrounding buildings and open urban areas.

Fig. 2.27b: Begh-e Eram in Shiraz. Pavilion building with shallow pool located centrally to the building connecting the pavilion with the garden in front (source: Porter 2003)

2.5 Material type

Architectural response to local climate can be recognized in three categories within vernacular buildings:

- Construction material
- Building structure
- Spatial organization.

Comparable to other examples of vernacular built environment around the world, traditional builders in cities of Tabriz and Shiraz worked with available local materials. The availability of local material, their durability in climatic conditions and resistance to natural disasters such as floods, earthquakes and sandstorms had significant impact on building types, structural elements and urban pattern of vernacular cities.

Available materials such as abode, stone, brick and dried straw were adopted as building material for walls, roof and flooring (Zaimi 2010). For instance brick was used to construct load bearing walls, domes, paving, vaulted structure as well as facade ornaments. In absence of modern technology to cut and shape natural stone for flooring, brick was used for paving corridors and passages in bazaar.

Fig. 2.28: Brick is the main material used in Mozaffarrieh Bazaar in Tabriz to form paving, walls and roof structure (source: Author 2013)

Mud and adobe were made in situ and widely used in external walls as insulating material to reduce heat transfer between internal rooms and outdoor environment. Wide external walls could be built to a depth of 800 to 1000mm thickness. Stone was mainly used at ground level for foundation and lower part of walls to support lead bearing walls and importantly to stop rising damp from ground. Stone situated at the base of walls were built up to 1.0 or 1.5 meter height (Memarian 1998).

Timber was extensively used in traditional buildings for columns, posts, doors, windows and *orsi* or sash windows. Wherever timber was available for construction, light weight structures built from timber beams and columns were favoured to avoid heavy damages after earthquakes. The timber beams could also be reused to repair the roof after the earthquake. Timber canopies shown in figure 2.29 provide extra shading for shops in Tabriz bazaar.

Fig. 2.29: Timber used in public buildings for posts, roof structure, doors and windows. Tabriz, Iran (source: Author 2013)

Another common material in vernacular Iranian cities is mud-straw mix. The mud-straw mix consisted of earth and dried straw and was used to cover brick wall and roof structure from heavy rainfall. Structural techniques such as building double roof, semi-open balconies and semi-buried building were among effective solutions devised to control climatic stress. The spatial arrangements according to solar

pattern enabled inhabitants to migrate from one part to another side of the buildings and respond to seasonal changes (Memarian 1998). This concept is further presented in chapter three.

2.6 Dimensions of urban sustainability in contemporary cities

Urban sustainability is a widely used term and to help to refine and define the term in the context of this study, one can refer to the basic principles which are widely known from the 1987 Brundtland report; “Humanity has the ability to make development sustainable – to ensure that it meets the need of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development 1987). In simple word sustainability means a good life for us and future generations.

Rapid economic growth and accumulation of wealth in urban areas create enormous opportunities for urban dwellers but the notion of sustainability extends much further than purely economic growth in one country and it expands to other areas such as social, cultural and environmental aspects. A society could get richer and become more affluent but at the same time create a large negative impact on environment and therefore endanger the lives of future generations.

As cities expand and accommodate more people and activities, they demand more energy for heating and cooling of buildings, urban transport for public and domestic use. They consume large resources of non-renewable fossil fuels, increase pollution and contamination and threaten the ecosystem. It has been estimated that cities consume three quarter of world’s energy and produce three-quarters of global pollutions (Rogers 1997). No city can be named a 100% clean city and all cities increase pollution but their impact varies in different countries. In developing countries poverty is a great threat in maintaining good environment. Poor people are more likely to cut trees and use non-renewable resources in order to survive. Due to lack of financial resources and technical knowledge, sewage and untreated water is more likely to enter surface water and ground water and then eventually return to water cycle in poorest part of cities. However poor people consume less and therefore produce less waste and they tend to be more cautious with available resources and recycle more efficiently on small scale (Hall and Pfeiffer 2000).

In the middle income cities of developing world, people experience rapid economic growth and fast changes to urban fabric of cities. Rapid pace of urban development in these countries require low-cost building materials such as steel and concrete and

synthetic products which are difficult to recycle and contribute further to overall carbon emission. Lifestyle changes in larger cities such as car ownership could be seen as major source of pollution. As people become wealthier they could afford more space and move to suburban areas making longer journeys in their car between home and work. The pattern of car-based urban sprawl, started in New York in the early 20th century, has since been adopted in numerous growing cities. This grid pattern with low-rise and low density neighbourhood is mostly obvious in mega cities like Hong Kong, Sao Paulo, and Jakarta where forests and farmlands have been replaced by residential areas.

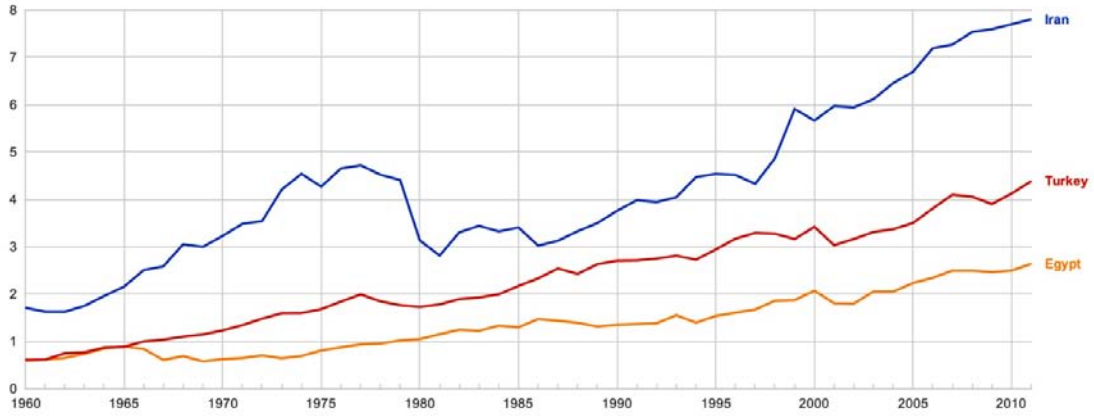


Fig. 2.30: Carbon dioxide emissions in metric tons per capita in three developing countries from 1960 to 2010 (source: The World Bank 2015)

More recently, increasing pollution and congestion caused by cars prompted citizens and policy makers to develop solutions which would help to transport people and goods within the city but at the same time reduce vehicular traffic. Effective urban strategies included developing polycentric cities where daily commute is reduced and city dwellers travel shorter distances between home, work and leisure. Extensive development of public transport and cycling networks together with reduction in car traffic and promotion of compact urban forms in cities like Freiburg, Zurich and Copenhagen served to create more liveable cities (Gehl 2010).

One of the main challenges in growing cities is to provide effective alternatives to private cars. The low-cost urban transport solutions are buses, bicycle and light train or tramway network and it is crucial to make these transport systems affordable, efficient and convenient for everybody (Hall and Pfeiffer 2000).

Liveable urban environment

Although good quality urban planning and design is difficult to measure, there are several aspects that could be considered. The traditional urbanists identify the

quality of city with density and diversity. Dynamic and yet peaceful urban areas in many European cities provide great examples for good urban design. In particular in residential areas a good balance of quiet, safe and secure streets combined with easy access to shops and services and public transport are desirable. A few examples to mention would be New York's Greenwich Village, San Francisco's Pacific Heights or La Zona Rosa in Mexico City (Hall and Pfeiffer 2000). The urban model in these areas is very similar to what Jane Jacobs presented in her influential book 'The death and life of American cities'. A good mix of medium density low-rise houses with high-density apartment blocks in close proximity to shops and local services where efficient public transport is supported by local residents (Jacobs 1962).

In fast growing middle-income cities rapidly rising land values reduces the building cycle. Recent developments from two or three decades earlier could be easily replaced by new buildings and at the same time the traditional built environment of cities is always under threat of demolition and replacement with brand new more expensive buildings. In modern Iran, most historic parts of cities have been neglected for such long time that they have become very costly to be refurbished and reused. It is also unfortunate to see the public opinion supports this type of aggressive modernism and the preservation of traditional buildings and urban quarters are secondary and unimportant compared to extensive development of roads and modern buildings. Fast development of commercial buildings and destruction of long-established urban areas results in formation of mundane cities without quality, elegance and memory (Hall and Pfeiffer 2000).

This pattern of accelerated modernisation is very much noticeable in Iranian cities where one could observe the signs of economic growth in cities but simultaneously the widening gap between rich and poor due to unfair distribution of wealth. The wealth gap contributes to social division and urban seclusion which further challenges the social cohesion in a society.

Cities and natural environment

Cities are man-made structures where people, buildings, production, consumption and transport are collected and they have a complex relationship with their natural surroundings. Cities need energy, natural resources and physical space to survive and function and as they grow larger they demand more space and more resources. It is essential to create well-balanced cities where natural environment is in harmony with urban development and people could still feel connected to natural landscape.

Although cities are mostly efficient in land use and concentration of people and activities, their constant growth and increasing demand for natural resources present a great challenge in contemporary cities. Figure 2.31 shows sharp rise in population growth in Iran within last fifty years. In rich countries people occupy bigger land, have several cars and consume more energy and produce greater waste. Data published by the US Energy Information Administration indicates carbon footprint of US in 2010 was around 18 tonnes per person compared to 3.4 tonnes in Turkey and 2.3 tonnes per person in Brazil (Rogers 2012). In poorer countries, the immediate need for food and housing overshadows the long-term planning for environment issues. Global warming, frequent flooding risks, lack of clean drinking water and energy resources are more likely to affect poor people around the world. But in all types of cities people are often far detached from environmental consequences of their immediate actions and lack of awareness and sensitiveness makes it more difficult to promote environmentally sustainable urban developments.

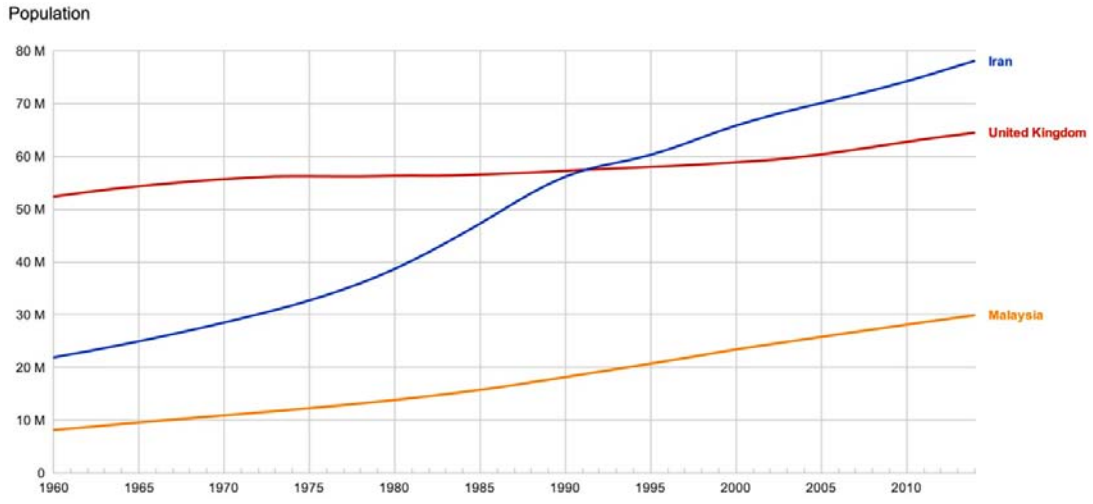


Fig. 2.31: Population rise in three countries from 1960 to 2010 (source: The World Bank 2015)

No city can be claimed to be 100% environmentally sustainable. They all pollute air by releasing toxic gasses, pollute water and soil and emit large amounts of green house gasses. Marine degradation, vast amount of deforestation and climate change are consequences of urban consumption and production of waste. Mexico City is the industrial centre of Mexico and its population in 1900 was only 340,000 but at the moment it contains 20 million people and 4 million cars. Air pollution in this mega city is above six times more toxic than acceptable levels set by World Health Organisation (Rogers 1997). Such environmental issues are caused locally with

global impact and therefore create shared responsibilities for mankind without borders.

Cities as problem and solution

Cities are problems because they function by consuming energy and water and producing concentrated pollutions. In large cities like London and Tehran it is not difficult to feel the fresh air getting thinner as you approach the city centre. As the urban sprawl expands to make space for new roads and buildings, the surrounding natural environment and its biodiversity diminishes every day.

Cities are also potential solution to environmental issues. Dense cities make it possible to insulate buildings better and effectively use scare environmental resources. A large percentage of energy in cities is used for heating and cooling of buildings and achieving successful energy saving targets could be possible in compact cities (Hall and Pfeiffer 2000). The high concentration of production and consumption make it feasible to develop circular systems of use and reuse instead of linear systems where resources are used and consumed and turned into waste. As argued by the urban ecologist Herbert Girardet, environmentally successful cities could be developed as a circular metabolism where efficient systems could minimise consumption and maximise recycle of resources. In this circular system, food and energy is generated from renewable resources not fossil fuels and organic and inorganic waste is recycled and fed back into the system to minimise new inputs.

In compact cities to increase the efficiency of power plants, the Combined Heat and Power plants (CHPs) can be used to generate electricity and at the same time heat water pipes to be distributed to local buildings. Instead of sending city rubbish to land fill sites, recycled waste could be burned in local CHP plans. Due to proximity of different activities in a compact city, heat generated from offices during the day can be transferred and used to heat houses, schools and other public buildings. Human waste collected from buildings can be recycled into fertilisers and filtered through natural systems, grey water can be used to irrigate urban landscape and also restore local water tables (Rogers 1997).

A great environmental challenge in fast growing cities is the reduction in ownership and use of private cars. Apart from being used as means of transport, private cars are also conceived as status symbol for many people. A great example of successful urban policies in dealing with private car ownership and reduction in number of cars on streets could be observed in Copenhagen in Denmark. Transit-

oriented urban form together with additional proposals helped to change the behavioural pattern, reduce traffic and create more attractive public realm. In a time frame of twenty years, additional measures were introduced and maintained to make the city centre more attractive and people friendly. These measures include urban infill projects to increase density, reduction in parking spaces, pedestrianisation of streets and solutions to make street life more active and lively (UNCHS 1996).

Car-free cities for people

The sharp rise in car ownership in cities transformed urban transport and mobility but also changed the physical shape of cities extensively. According to a report published by Wards Auto, the global number of cars on roads exceeded 1 billion in 2010. And according to a report jointly published by World Health Organisation and World Bank in 2004, an estimated 1.2 million people are killed at road accident each year and 50 million people are injured (WHO 2004).

Cars are the most space intensive means of transport and they require wide roads and parking spaces. A single car takes up to 20 square metre in an effectively design car park. Cars divide neighbourhoods and occupy urban spaces as their number increase. Cars are affordable for many people due to mass production and they also seem practical to many people because most cities have not been designed to include efficient public transport. Private cars are also highly popular because they are cultural icons and a symbol of social status. The impact of car traffic in urban neighbourhood and social interaction of locals was studied in a research in San Francisco. Three streets in a neighbourhood with different levels of traffic were compared and the results showed social interaction between neighbours and sense of community reduced as road traffic increased (Rogers 1997). Figure 2.32 demonstrates the results of this study with simple diagrams showing the intensity of human interactions affected by traffic levels.

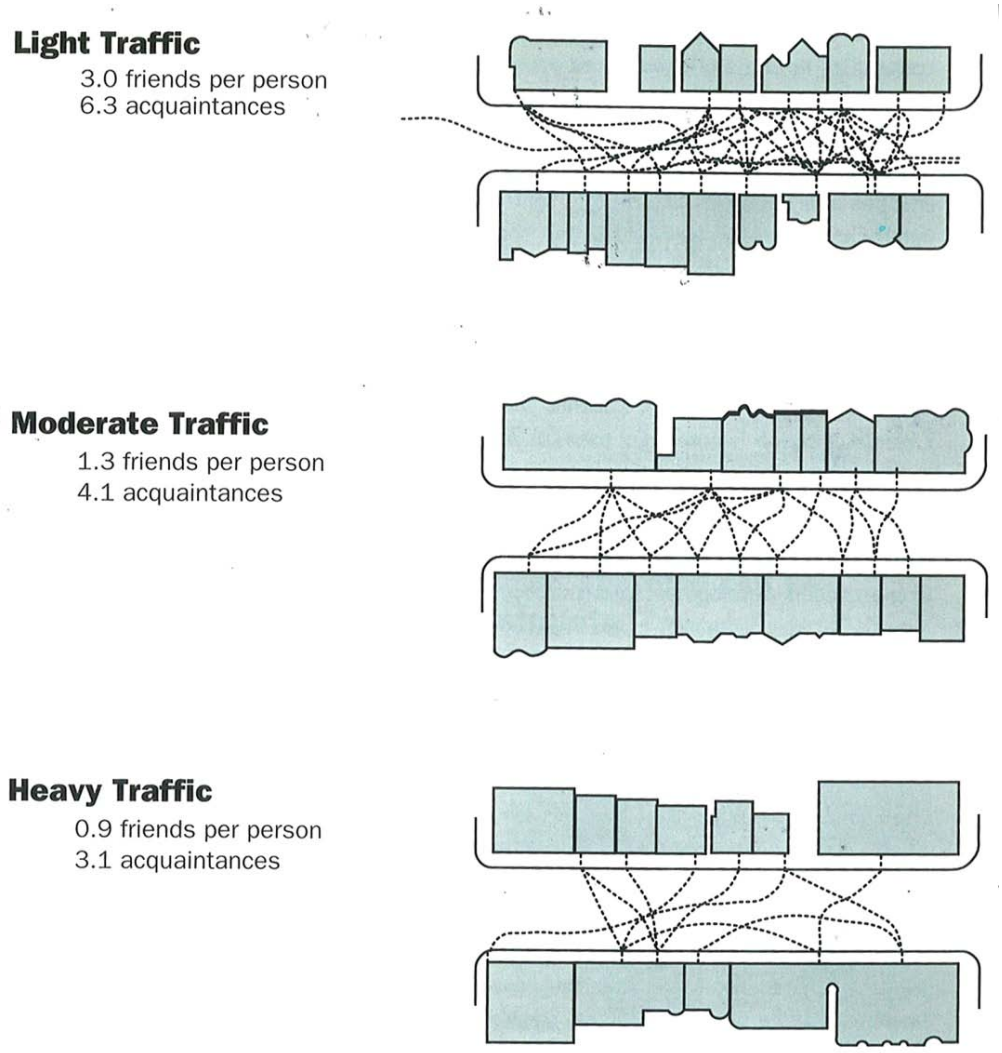


Fig. 2.32: Research in San Francisco demonstrates how road traffic between neighboured effect social interactions between neighbours (source: Rogers 1997)

Over the past decades, urban policies in favour of car ownership have caused numerous issues for cities. Directing the public funding towards the expansions of road networks, street widening and construction of ring roads around the city centres disconnected urban areas and disintegrated the harmonious structure of cities. In particular in historic towns and cities expansions of roads caused further isolation of historic city centre from the rest of the city (Urban Task Force 1999). The pattern of demolition of houses, public buildings and historic structure of the city are still very much present in many developing countries such as Iran where old buildings are being demolished to make space for wide straight roads for better and faster vehicular connection. Multi-storey car parks are ever more present to cope with growing number of cars and demand for parking space.

In successful cities, urban spaces are planned to provide safe and peaceful space for social interaction and they help to sustain community life. Streets and squares have been shaped as places where kids can play and neighbours could reach shops, services and public transport within walking distances (Bahrainy and Khosravi 2013). However, it is important to mention that these types of social encounters are not always pleasant but they teach people to learn how to accept others and tolerate them. In large rapidly growing cities some communities are socially isolated to a degree that they feel they do not hold any power and have no space in society. On the other hand as people become wealthier their tendency to own and use private cars for daily commutes increases. In some developing countries as the gap between rich and poor expands, wealthy people prefer to avoid using public transport and the richest people live in isolation inside gated communities with minimum interaction with outside world. They travel with their private cars to members-only venue where they meet and socialise with similar people who are already rich, highly-educated and well-connected. This model of social isolation of rich and poor communities could only result in a divided and unequal society. Many rulers also travel by cars and they rarely meet ordinary people on streets and lose sensitivity and social connection to daily life of citizen (Crawford 2000).

In recent years car-free developments in many European cities have provided good examples for successful and vibrant communities. On urban scale, recent improvements included urban densification, promotion of mixed-use developments, pedestrianisation of streets, reduction in car traffic, widening of pavements and improvements in affordability and efficiency of public transport (LSE Cities 2013). Densely built urban areas encourage a better use of available lands in cities and make it feasible to invest and improve public transport by solutions such as light rail and bus rapid transport systems. By removing cars and trucks from cities, streets and surface car parks become available for communities to build parks, playground and markets to serve local people. In a compact city with diverse activities daily commute is reduced and with few cars around walking and cycling to destinations is more pleasant. Better air quality in residential areas also encourages people to open windows for natural ventilation rather than relying on filtered air from air-conditioning.

To promote active transport such as walking and cycling in cities around the world the World Health Organisation recently developed an online tool called the Health Economic Assessment Tool (HEAT) to be able to quantify the economical benefits

of cycling and walking. The online tool is intended to assist planner for cost-benefit analysis of transport interventions or infrastructure projects in cities (WHO 2016).

2.7 Conclusion

Vernacular built environment in Iran is mostly associated with traditional towns and cities before industrialisation. The pattern of vernacular settlements and their distribution around Iranian plateau have been defined by availability of water, topographic conditions, defence reasons and trade opportunities throughout centuries.

A large part of the country could be considered to have desert or arid climate but due to presence of two large mountain ranges stretching from south to north and west to east, many cities have been formed at valleys and foothill of these mountains with continental climate. Two cities of Tabriz and Shiraz which are used as case studies in this research also fall under the category of continental climate. Apart from physical environment and socio-political factors, one major contributor to survival and development of Iranian cities is the location of these settlements on trade routes from the Far East to the western world or what has been known as the Silk Road. This in fact explains the formation and constant development and growth of cities like Tabriz, Shiraz and Isfahan with their bazaar as a fundamental and inseparable part of the city.

City of Tabriz located in the Northwest of Iran has been chosen as one of the case studies in this research due to its climate and consistent urban development from 15th century onwards. The contemporary city has a population of near 1.6 million and contains the largest brick structure covered bazaar in the world. The historic bazaar complex was added to the World Heritage Site by UNESCO in 2010. On the other hand, city of Shiraz in southwest of Iran with hot and dry climate also contains historic town centre and large bazaar structure.

Throughout the chapter two urban developments in Tabriz and Shiraz has been studied during major historical periods when both cities were chosen as political capital at different times. This historical background has been included to provide an understanding of the historic reasons behind urban pattern and formation of cities.

City of Tabriz is located on one of the major routes Silk Road with the bazaar at its heart as a prominent economical and cultural structure. The bazaar complex evolved from few narrow streets with shops on both sides into a large complex

structure stretching from one city gate to another with public buildings such as bathhouses, restaurants, large storages spaces and several caravanserais to serve local people and visitors. Major urban improvements and construction of cultural buildings occurred during the Qajar rule when the crown prince was appointed the ruler of Tabriz.

When the traditional city grew larger it expanded into several residential neighbourhoods called *mahelle* where people from similar ethnic and religious background lived. Almost self-sufficient, larger neighbourhoods contained few activity hubs or *markaz-e mahalle.* A square or *meidan* was an open-air gathering space where narrow streets met and grocery shops, a bakery, a bathhouse and a mosque were located and local people could reach these facilities within walking distance. Tightly built courtyard houses in traditional urban context share external walls with their neighbours to create an insulation layer around the building to minimise heat loss in winter and be protected from excessive solar gain in summer. Internal rooms organised around the green courtyard would benefit from reduced heat and increased humidity as well as a direct connection with a small piece of nature into daily life of people.

A brief introduction into contemporary cities in chapter two displays how contemporary urban growth in cities like Tabriz and Shiraz has changed the shape of cities in dramatic ways and how modern buildings, apartment blocks and commercial developments appear to be in sharp contrast to the existing old fabric of cities. Over the years, the integrity and importance of traditional built environment in cities has been ignored and urban policies in favour of private car ownership, street widening and development of wide European style boulevards altered the urban structure of historic cities deeply. Very often straight wide roads cut through the organic structure of the city and isolated central part from surrounding residential neighbourhoods. In both cities of Tabriz and Shiraz, parts of the historic bazaar structure have been demolished to make space for roads and bus stations and new shopping centres. In particular large-scale new districts have been designed based on a grid pattern of roads with residential and commercial plots just divided between roads.

Located in valley of Khorram Darreh River, Shiraz is the largest city in Fars province in southeast of Iran. The city has survived and flourished due to its relatively moderate weather and commerce links with the Silk Road and the Persian Gulf. Shiraz was chosen as political capital of Zand Dynasty in 18th century when city

walls were rebuilt and numerous public and administration buildings were built and infrastructure projects were completed. Similar to other Iranian cities with hot and dry climate, the historic city built inside city walls evolved into a compact and connected pattern. Introvert courtyard houses sharing external walls with their neighbours, expanded into residential neighbourhoods. Access network hierarchy from bazaar structure and public squares into residential district and narrow passageway is indeed noticeable in Shiraz like other vernacular Iranian cities.

Main changes to the structure of the city occurred during the twentieth century with expansion of road network and construction of urban regions beyond the boundaries of the old city. However, despite changes to urban structure of the city, Shiraz Bazaar remains a functional and vibrant part of citizens' life.

In order to find relevant connections between the sustainable impact of vernacular cities and contemporary notions of environmentally successful cities, a brief review of environmental aspects of sustainability cities has been included in chapter two. The basic principles include the followings:

- Liveable urban environment
- Compact city structure
- Urban relationship with nature
- Cities as problems and solutions
- Car-free city

The following chapter will expand on urban development and climatic adaptation in vernacular Iranian cities. By focusing on environmental adaptation in vernacular cities, chapter three aims to bring together and reveal the construction knowledge and local intelligence behind the environmentally successful traditional built environment in Iran.

Chapter 3: Environmental sustainability in vernacular built environment

3.1 Introduction

In order to construct a meaningful connection between the environmental benefits of vernacular Iranian cities and principles of successful contemporary cities, chapter three seeks to observe the formation and climatic adaptation of vernacular cities and discover the ways private dwellings and public buildings were built with rigorous attention to local climate and human needs.

Further to study of historic development of two cities of Tabriz and Shiraz and a brief discussion about principles of sustainable contemporary cities in previous chapter, chapter three focuses on recent publications, exhibitions and projects where researchers and designers recognised and promoted the relevance of vernacular knowledge and skills in modern times. Urban forms inspired from past, understanding of comfort in traditional built environment and compact settlements are discussed to uncover the relevance of vernacular methods and diverse solutions of climatic adaptations.

Chapter three has been structured to contain the main content and findings of this study and in addition to relevant contemporary discussion on the subject, this part of the study aims to reveal environmental consideration and construction techniques used in vernacular Iranian cities. The impact of main environmental elements such as water, wind, solar gain and green spaces on urban structure have been studied and various construction methods used in response to these elements have been presented with photos, maps and sketches produced by the author.

3.2 Vernacular architecture in contemporary city

In a fast moving modern city with extensive urban developments, the principles of vernacular architecture and urban planning seem to be forgotten. Vernacular architecture is associated with the past, tradition and underdevelopment. This pattern appears to be stronger in developing countries such as Iran where city planners and policy makers are keen to follow the path of modern architecture and urban planning in developed countries for “modernisation” rather than learning from local knowledge of building vernacular cities and their appropriate environmental qualities and consequently implementing well-informed concepts and solutions to contemporary cities.

More often vernacular houses and long-standing parts of cities are regarded as obstacles on the road to progress and new developments. This unfortunate reality becomes more tragic when the unfamiliar new buildings try to imitate the historic context only in shapes and facades without any relevance to local material, climate and ever changing culture.

Rapid population rise and ever growing demand for energy resources in cities have given rise to major challenges facing global community. At a very basic level the challenge is to provide appropriate shelter for the billions of people around the world in environmentally sustainable ways. Understanding and defining the suitability of vernacular architecture will help to raise academic, professional and public awareness and highlight the significance and relevance of vernacular skills and knowledge in present day (Hensel 2012). In order to achieve this aim, further research is needed with more focus on understanding development process, environmental principles, facts and evidence of remaining urban structure of vernacular cities. In doing so, it is essential to have a critical view on findings and constantly interacting with the realities of present time instead of concentrating on the nostalgic past (Asquith and Vellinga 2006).

Traditions and customs can be examined as creative processes through which people interpret past knowledge and experience and prepare to encounter challenges and demands of the present. The study of vernacular towns and buildings can provide a window on the lives of native people and help us to understand the origins of contemporary buildings and also why such buildings fail to meet our basic human needs. Indigenous expertise and wisdom about the ecosystem has evolved in an adaptive way over centuries and it is not difficult to see how some of new buildings and cities failed to response to their local environment and culture just by overlooking this fundamental knowledge (May 2006).

In 1987, the world Commission in Environment and Development (WCED) provided the most commonly referenced definition of sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their need’. The word sustainable is acquired from the Latin *sustenere* meaning to uphold or being able to maintain a certain state or condition. Traditional cities composed of vernacular buildings are great examples of sustainable developments that evolved and progressed gradually from one generation to other.

Modern architecture as it became the most widespread architectural movement throughout the twentieth century followed the aesthetics of industry and mass production. It was mainly summarised in two statements: one by Adolf Loos, ‘Ornament is crime’ and another by Louis Sullivan: ‘Form follows function’. But as modern movement in architecture and urbanism was used and to some extent abused by profit driven firms, it was widely criticised for lacking respect for cultural identity, historical reference and climatic response. Although modern architecture became the dominant discourse in academic education and professional practice, it has diversified and developed from its origin. These developments could be categorised in seven groups.

The first category could be recognised as the minimalist architects who are vigorous followers of modern principles of Mies van der Rohe and Walter Gropius. Claimed to be appropriate for any climatic and cultural context, international minimalism was criticised for its insensitiveness to geographical context.

The second group are mainly associated with followers of Le Corbusier who were more concerned with appropriateness of Modernism with diverse cultural and climatic context. The most influential figure in this group could be named as Alvar Aalto and his specific response to Finnish architecture based on principles of Modernism. Rafael Muneo, Tadao Ando, Alvaro Siza, Charles Correa and many others could be associated with this branch of Modernism which was referred as ‘modern regionalism’.

A third group of modern architects adhere to most ideas of Modernism but deemphasise the notion of ‘form follows function’ and take advantage of contemporary design and built technologies for expressive and liberated forms. One can refer to Frank Gehry, Zaha Hadid, Peter Eisenman, Daniel Liebeskind and Santiago Calatrava.

The forth group are admirers of Archigram Group and its concepts. Architects such as Jean Nouvel, Norman Foster and Richard Rogers designed and built some of the most significant modern buildings with the use of contemporary technologies.

Another group of architects refused to follow the fundamental concepts of Modernism and did not accept any limitation on creative expression. Designers like Anthony Gaudi, Paolo Soleri and Bruce Geoff remained in opposition to the mainstream modern architecture.

The sixth group of architects were Post-modernist who opposed the formalism of international modernism and attempted to bring back wit, ornament and reference to architecture. Pioneered by Robert Venturi, Charles Moore, Aldo Rossi, postmodernism in architecture was a short lived movement from the 1970s to the 1990s.

The seventh group are conservative architects who believe whatever was produced in the past is good enough for modern day and would be appropriate in an urbanised world. With the royal support of Prince Charles, classicists like Quinlan Terry and Leon Krier believe in the wisdom and accomplishments of the past. Another group of conservatives could be named as traditionalists. Traditionalists like the Egyptian Architect, Hasan Fathy, shared many aims with classists but generally were more focused on the rural environments and the adaptation of suitable technologies (Asquith and Vellinga 2006).

As an architect and activist, Hassan Fathy strongly opposed modern architecture and waves of Internationalism in his home country and in general. Although his buildings did not get a wide recognitions in his life but his vision proved to be very influential among other architects. One of his followers was John Norton, who established the Development Workshop (DW) together with Alain Cain and Farokh Afshar. The Development Workshop started in 1970s in Iran and aimed to combine global awareness with local needs and know-how in construction industry. DW became involved in several projects in Angola, Vietnam, Mali and Mauritania and developed inventive solutions benefiting from regionally available materials and trained local builders. A notable project was ‘Woodless Construction’ which was supported by United Nations and aimed at building without the valuable timber in Sub-Saharan Africa.

Another prominent name in traditionalism and vernacular architecture was Bernard Rudofsky. In 1964 Rudofsky put together an exhibition for New York’s Museum of Modern Art with the title of ‘Architecture without Architects’ featuring settlements and buildings forms developed by communities around the world. The exhibition generated a wider interest and debate in traditional architecture. But remarkably the most influential name in this field was a music researcher named Paul Oliver. He started his career as a music researcher and encountered a vast body of knowledge related to indigenous architecture around the world. He borrowed the term ‘vernacular’ from linguistics and his first book (Shelter and Society) was published in 1969 and it initiated a vast field of architectural research and explorations. His most

comprehensive research was published in 1997 named, The Encyclopedia of Vernacular Architecture of the World (Oliver 1997) where diversity and intelligence of vernacular buildings around the world was further revealed in his study.

Urban form inspired by learning from the past

Neo-traditionalism in urbanism could be traced back to European planner such as Ebenezer Howard and Leon Krier. Howard's idea of self-sufficient towns surrounded by green belts was very influential in Garden City movement and the building of the first garden city in 1903. Another influential academic was Jane Jacob who criticised modernist planning in her well-known book, 'The death and life of American cities' (Jacobs 1961). New Urbanism could be considered the most recognised urban design movement which initiated in United Sates in the early 1980s and the Congress for New Urbanism was established in 1993. New Urbanists advocated concepts of compact and mixed use neighbourhoods, consideration of historic patterns, urban infill development, reduced automobile dependency, people friendly cities and extended public transport (Sharifi & Murayama 2012).

Inspired by qualities of traditional Japanese towns and in similar ways to New Urbanism a new movement evolved in post-war Japan called *machizukuri*. The term Machizukuri is widely used to describe many types of activities but one definition is encouragement to focus on characteristics of traditional small towns. Based on this notion, planners and architects were inspired to build communities which were socially diverse with schools, shopping streets and public transport in walking distances from houses. They were motivated to create urban neighbourhoods with smaller and narrower roads to support limited or slower car traffic and to create safe urban spaces for local people to socialise and watch their children play.

A special study of vernacular settlements is Netting's study of Törbel (1981), a Swiss Alpine village. Törbel is located in the valley of the River Visp, south of the River Rhone, at an altitude of 1500 metres. The village is an old settlement of timber houses, barns and granaries with slate slab roofs. The natural setting of the village contains meadows, cultivated gardens, sloping vineyards and forests. Netting's study shows that this beautiful natural landscape contains cultural elements of inhabitants. The available local land and resources have been allocated and used for common good for many generations. The study examines the village as a small-scale ecosystem. This ecosystem is based on subsistence economy which reflects human culture in terms of social conventions, rules and regulations on local resources. The buildings have been built from locally available timber and stone by

local craftsman assisted by inhabitants. But the study also refers to sensible use of timber for construction and heating of domestic buildings in order to ensure the long-term conservation of the forest which is crucial for subsistence. Trees are not only recognised as building materials and heating resources but also to avoid landslides and avalanches (Jones 2009).

Comfort in vernacular built environment

In modern homes and work places comfort levels are perceived with indoor air temperature. Modern houses, schools and work places heavily rely on cooling and heating systems to maintain a constant temperature throughout the year in most parts of the building without paying much attention to outdoor environment and seasonal changes. It appears that the availability of air-conditioning systems and constant source of energy to run these systems at any given time reduces sensitivity to climatic conditions imposed on the built environment. In the absence of mechanical heating and cooling systems in traditional cities, people devised many other solutions to adapt to environmental conditions. These solutions could be studied as what Humphreys (1995) argues as adoptive comfort. The study of human comfort in the built environment is commonly referred as the analysis of heat exchange between human body and environment, and discomfort is realised as an imbalance between heat gain and heat loss in human body. The standardisation of comfort levels leads to a single solution for design purposes to reach a comfort temperature such as air-conditioned rooms to ventilate and maintain a constant temperature.

Due to constraints imposed on traditional and vernacular buildings maintaining an indoor fixed temperature was not feasible throughout the year. The main constraints included scarce energy resources, limited choice of building material and lack of technology for mechanical cooling and heating (Fernandes et al. 2014). Understanding and accepting these restrictions lead to diverse solutions invented by designers, builders as well as dwellers to achieve comfort via climatic adaptation. Internal migration to cooler parts of buildings during hot season, passive cooling, effective shading to protect indoor and outdoor spaces from excessive heating, reduction of human activity during hot hours of the day and appropriate clothing were some of few solutions devised by people in vernacular Iranian cities to maintain comfort levels.

Building envelope played a significant role in providing a suitable environment inside the building. Wide external walls with large masses of mud brick, stone and mud-

straw mix reduced heat exchange between inside and outside space with very high temperature. This strategy was also effective during cold season when heat loss would be minimised through external envelope. In vernacular architecture it is not uncommon to see buildings partially or completely built underground to benefit from geothermal mass (Pirnia 2006).

In recent years, private finances and technological capabilities in developing countries like Iran made it possible to design and built large complex buildings such as shopping centres. These large buildings attract people by offering air-conditioned indoor environment throughout the year regardless of outdoor climate. They compete with outdoor urban places such as traditional shopping streets, public squares and playgrounds to draw people in when temperatures outside is soaring hot or frosty cold. However, the environmental impact of these large complexes is immense due to excessive energy consumption for lighting and air-conditioning systems.

Different cultures in many parts of the world survived and sustained within their natural environment and learned to cope with their regional climate. A great deal could be learned from good examples of vernacular buildings and morphology of traditional towns. And to further the discussion in this context, some basic principles of vernacular built environment will be discussed in this chapter.

Compact human settlements

Human settlements around the world have developed into different layout including linear, nodal, dense and dispersed (Oliver 1997). The concentration of human activities and settlement has many benefits not only for a small village in Alpine regions of Switzerland but also in a very different climate such as desert houses in Iran. Compact urban forms create more available land for farming and work more efficiently in terms of services and infrastructure required such as roads, water network and sewage systems.

Another important principle in vernacular built environment is the idea of functional adaptability. Vernacular buildings were rarely abandoned by their inhabitants but instead they were constantly modified and re-used for different purposes. This functional adaptability and change of purpose motivated people to regularly maintain and renovate their buildings. In contrast to this practical approach, new developments in most parts of the world during the twentieth century were easily associated with demolition of existing buildings to make space for new ones. It is

particularly intriguing to see how difficult and challenging is to adopt and repurpose large buildings such as multi storey car parks or shopping centres. Therefore, in contemporary cities, it is common to see modern buildings, constructed only few decades ago, are being torn down to make space for new developments.

Patterns and principles from history

The existing vernacular built environment in town and cities provide numerous opportunities for designers and planner to study and analyse and learn from fundamental ideas shaping traditional cities. This knowledge would be most useful in understanding and application of energy efficient buildings and more pleasant and functioning public spaces. Some examples of environmentally efficient solutions in vernacular towns could be noted as below:

- Compact and multi-use urban districts with facilities available at walking distance from houses
- Extensive use of natural ventilation and solar heating instead of mechanical systems inside buildings and urban spaces
- Common use of local and reusable materials such as timber, local stone and bricks instead of synthetic materials
- Rainwater collection for domestic use and recycle of grey water

Lessons learned from native solutions can contribute to better understanding of connection between built environment and natural world and pave the road for protection and conservation of natural environment and cultural heritage of human settlements (Asquith and Vellinga 2006).

Mass production and rapid transport of modern materials such as steel and glass and global transfer of construction methods have replaced the traditional knowledge of local materials and building techniques. Furthermore, rapid development and consumption of industrial materials leads to significant rise in energy use and excessive use of synthetic and non-recyclable materials.

The research in the field of vernacular architecture and urbanism aims to understand the historical roots together with cultural and environmental aspects of traditional built environment. Within last few decades many people recognised the importance of traditional heritage in cities and its impact on architectural quality of cities. However conservation efforts were limited to physical shape of few buildings and cultural and environmental values of traditional cities have not been addressed.

Therefore what remained from the historical context are refurbished facades of old buildings and a dysfunctional silhouette of the old city.

3.3 Traditional architecture and urban form in Iranian cities

It is generally accepted that fast-paced modernisation in Iranian society started in Pahlavi era with substantial structural changes in cities in early 1920s. The founder of Pahlavi dynasty in Iran, Reza Shah, had ambitious plans for economical, political, social and cultural modernisation of Iran and his plans affected wide aspects of public and private lives of people in cities, towns and villages. In urban scale, foreign architects and planners were employed to modernise cities through building wide streets and boulevards making space for newly imported automobiles in the country. Following the street widening act of 1933, the network of roads and streets were built rapidly cutting through the old fabric of cities (Habibi 1999). These rapid changes first started in capital city of Tehran and thereafter were applied throughout the country from north to south without much consideration to local climate, culture or historic evolution of cities.

Wide boulevards, cutting through the existing urban structure, divided and segregated main elements of traditional cities such as bazaar from residential areas. New types of shops and houses appeared along the wide streets and introduction of Passage (shopping centre) with better vehicles access encouraged retailers to abandon their shops in old bazaar and move to new shops near modern roads. City square or *meidan* was also redefined as roundabout to ease car traffic and no longer to function as a public gathering place (Sharifi & Murayama, 2012). Figure 3.0 shows physical interventions in urban structure of Tabriz during early twentieth century. Wide boulevards, streets and roundabout cutting through organic urban fabric, have been built around bazaar to provide access for cars and ease of transport. Apart from these new roads, some existing streets were also widened to accommodate cars and provide vehicular access to residential quarters.

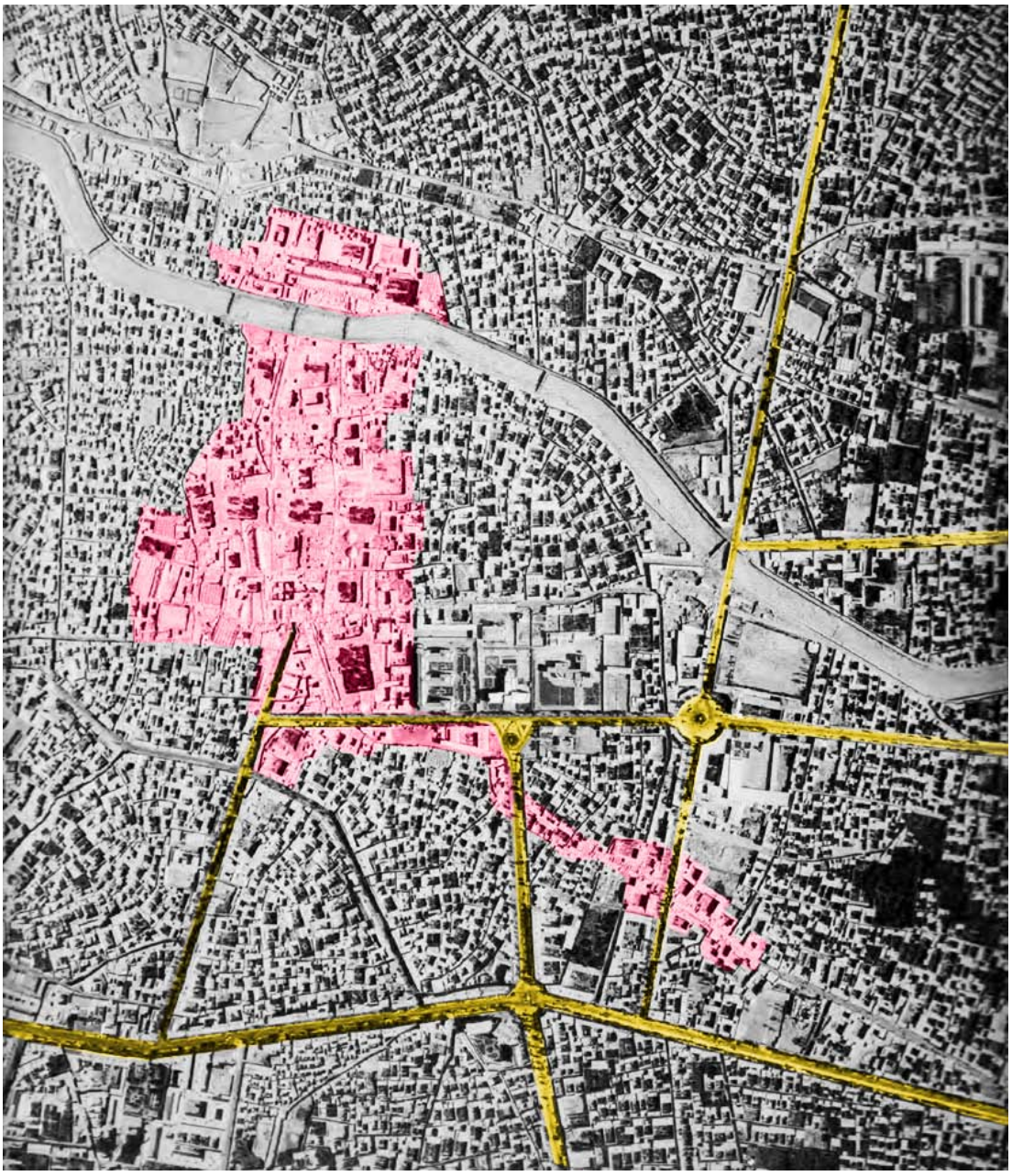


Fig. 3.0: Aerial photo of Tabriz with bazaar structure highlighted in red and new boulevards, streets and roundabouts built during early twentieth century in yellow [no date cited, estimated 1950] (source: Sultanzadeh 1997, edited by the author 2016)

With rapid expansions of traditional city and construction of new roads and large commercial building, monuments of the historic city are being neglected and eventually forgotten. Figure 3.1a shows a ground floor plan of historic core of Tabriz with bazaar structure in middle surrounded by courtyard houses in close proximity. Large open rectangular courtyards named caravanserai are recognisable inside bazaar structure with smaller shops and offices organised in all sides.

Fig. 3.1a: Bazaar structure sits fully integrated with neighbouring courtyards houses in central part of Tabriz [no date cited, estimated 1950] (source: Sultanzadeh 1997)

Figure 3.1b shows a recent photo of one of the surviving city gates in Tabriz called *darb-e baghmishe* which has been neglected for many years as road and bridges were built around the historic gate.

Fig. 3.1b: Part of historic city wall and *Baghmishe* gate in Tabriz seen at its current condition. The historic gate is a metal-clad timber gate which is currently buried under road surface (source: Author 2015)

Prior to establishment of modern universities in Iran and formal architectural education, masters of builders called *me'mar*s, had the responsibility to design and build houses and larger public buildings such as bathhouses, mosques and caravanserais. Most widely recognized person among them would be appointed by local governor to design larger public buildings and develop plans for new parts of the city (Pirnia 2006). In a similar fashion to other arts and crafts professions, the practical knowledge of design and construction transferred from masters to their pupils. Therefore, the practice of buildings towns and cities has improved and evolved through centuries of construction with local materials in suitable sites around Iranian plateau.

Working with harsh climate, traditional architects soon recognised the importance of dealing with absorbed solar heat in hot seasons and advantages of solar gain in colder seasons. On an urban scale, their main objective was to reduce exposure of habitable surfaces to direct sunlight. This simple solution worked effectively in small and large buildings. From densely-built family houses to main shopping straight of bazaar, sharing external walls and covered roof surfaces was a common practice to protect external surfaces from overheating during the day. This compact fabric also helped to create narrow alleys and shadowed passages between buildings (Monshizade 2008). The compact fabric extended from family houses to more public

areas of town and included local shops, teahouses and public bathhouses near *meidan* or the public square in each neighbourhood.

Most widely used principles of architecture and urban planning of modern Iranian cities seem to be an inaccurate and superficial copy of modern European and American cities (Tabrizian 2010). For example, the imposed grid network of roads is in great contrast to dense urban pattern of traditional cities and their irregular street pattern. The modernisation of historic cities and introduction of cars as dominant means of urban transport have immensely altered the form and function of traditional cities.

Vernacular cities evolved to live and adapt to their local climate and utilise limited resources available to inhabitants. The traditional dwelling is attached to its neighbours from three or four sides and most pedestrian spaces between buildings are sheltered from direct sunlight and unpleasant winds. Dense urban patterns also contribute to efficient land use with larger population. Density and diversity of land use in forms of residential, educational, religious and public areas, increased diversity and retained more land for agriculture (Kheirabadi 1991).

It could be argued that while social and economic advantages of vernacular cities were significant, however, effective climatic adaptation of compact cities in a country with hot and dry climate must have been the main reason for human survival within these communities. The climatic advantages of a dense urban pattern could be analysed as follows.

A compact urban fabric:

- Reduces direct solar gain on building surfaces over summer period
- Minimises the heat loss during cold winter days
- Maintains humidity within buildings and reduces evaporation
- Provides shadowed passages and cooler access routes between buildings
- Protects people and building surfaces from hot and sandy winds in summer and cold winter winds by creating taller and narrower streets

Traditional cities contained very few empty areas and the only necessary open spaces such as squares were formed in modest sizes and proportions. These open spaces were surrounded on all sides by neighbouring buildings and were further protected by tall shadow casting trees and presence of water in forms of water channels and shallow pools.

Access hierarchy from public to private in traditional cities was another important social and environmental factor in lives of citizen. In recent years, new towns and cities in Iran have been planned and built with access priority to cars in mind and recent master plans for expansion of new urban areas with residential and commercial developments are mostly traffic-oriented. Dwellings and apartment blocks have been oriented according to street network with front doors and windows open directly to wide roads with heavy traffic and high levels of noise and air pollution.

Fig. 3.2: The traditional city of Shiraz with its compact urban pattern appears to be different from recently developed areas in northwest of the city, aerial photograph 1967 (source: Kheirabadi 1991)

In contrast to these allegedly “modern cities”, vernacular houses were expanded following street hierarchy and gradual approach from private residential areas to more public parts of town such as bazaar and main square. This contrast in urban pattern could be seen in figure 3.2 in city of Shiraz where organic pattern of historic core is easily distinguishable from recent developments. Front door of a traditional house mostly opened to a small, narrow alleyway called *kuche*. *Kuche* in traditional city is the first point of contact between public and private spaces. It stretched along tightly-built houses with their external walls made of bricks or mud and straw. Walking around historic parts of Iranian cities, it is easy to notice that most houses were built with very limited openings to *kucheh* and only few moderate-sized doors with intricate brick details connected *kucheh* or the outside world to the private lives of people living inside buildings. Apart from their practical response to climatic conditions, narrow twisting alleys provided additional security and privacy for dwellers (Kheirabadi 1991). The closer you get to a front door of a house, the fewer strangers you encounter on your way, only neighbours and their visitors.

Fig. 3.3: Long and narrow alleyways with very few openings from houses (source: Kheirabadi 1991)

Security measures were another important aspect in social life of these narrow alleys. For instance, city of Tabriz due to its geographic location had always been vulnerable to frequent attacks and invasions by the Ottoman and Russian troops. Here in this city, narrow alleyways built with similar materials, colours and shapes disorientated strangers and made it impossible to be accessed by cavalry (Sultanzadeh 1997). In some parts of Tabriz, entrance to a blind alley is just wide enough for one person to enter and only neighbours use this small passage as the main access to their not so small houses.

A complex network of *kuche*s connected residential areas to bazaar, Friday mosque and administration buildings. Some of these alleyways were built wider named *guzer* which literally translates into passage. Wide and straight *guzer* were called *raste* meaning straight lane. In large cities like Isfahan, Tabriz and Shiraz *raste and guzer* functioned more as modern streets accommodating some public buildings such as bathhouses, teahouses and schools on their route to bazaar. Similar to some public buildings, *guzer*s and *raste*s were named after an influential person or generous donor who lived locally. Smaller alleys branched off from *kuche* were built in form of blind alleys named *bonbast* in Farsi (Kheirabadi 1991).

The access network as described above could be observed in small or large towns and cities. This spatial hierarchy is summarised in a simple diagram in figure 3.4. *Guzer and raste*s were defined as primary access routes to residential areas. In general, these routes ended in neighbourhood centres where few local shops and bathhouses were arranged around a square called *Meidan*. A new visitor to the city would normally arrive through city gates to the linear stretches of bazaar *called raste-bazaar* and willing to meet someone at his house, would be guided from a *raste* to *guzer* then reaching in neighbourhood centre. Arriving in a neighbourhood centre, one could immediately meet locals who would be socializing in teahouses or just sitting around the square in small groups. At this point, finding someone's house would be possible by speaking to locals and giving a name and person's profession.

This smooth transition from residential quarters to town centre or bazaar created an access network with street hierarchy expanding from private parts of the city to public areas. A group of houses accessed by a blind alley or *bonbast* created a semi-private outdoor space for neighbours where children could play and casual encounters of neighbour was possible (Sharifi & Murayama, 2012). This sense of place in vernacular town encouraged residents to share responsibilities in maintaining parts of their neighbourhood from protecting trees and greenery to

maintaining social relationship with neighbours. Not long ago in city of Tabriz with long and cold winters, it was common to see younger neighbours help their older neighbours to clean ice and snow from their front door and shared alleyway.

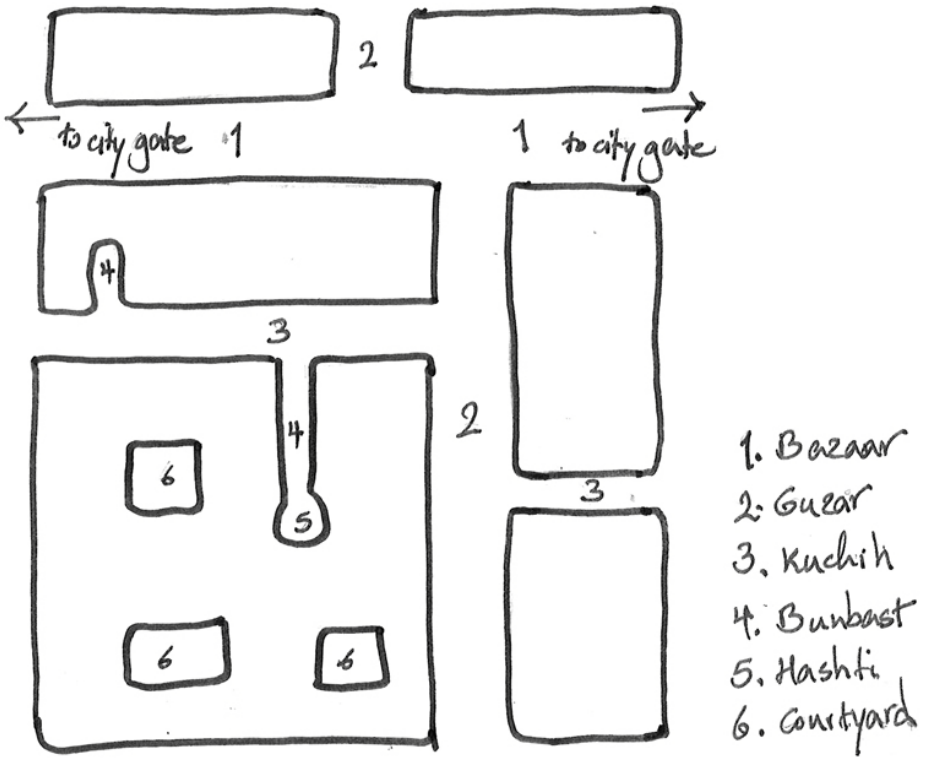


Fig. 3.4: Model of street access and hierarchy from private houses to public areas (source: Kheirabadi 1991)

The primary form of traditional housing in Iranian cities is courtyard houses. Open courtyard called *hayat* is surrounded by rooms in two sides or more. Enclosed by neighbouring houses and sharing common walls, access from *kuche* or alley to courtyard is only provided from one side of the building. This compact arrangement of cell-like houses creates an organic and highly dense urban pattern which benefits dwellers in many ways. Outside appearance of these houses are very similar. Built from available local material such as mud bricks and timber, few openings and windows are visible from outside. Entrance doors from alleys are heavy timber doors but rather small in size and scale and they seem to be in great contrast to sometime magnificent large family houses they contain. Houses in general are built lower than street level to help direct water from street level to inside the house and consequently the entrance door, sets into a niche located at a lower level than *kuche.* Another reason behind lower level entrance to courtyard is to provide easy access and daylight to partially buried lower ground floor (Sultanzadeh 1997).

Fig. 3.5: A sunken front door from alleyway on left and stepped entrance to the courtyard on right from two houses in Tabriz (source: Author 2013)

In a sharp contrast to monotone and repetitive appearance of *kuche*, living rooms and courtyard spaces are designed and decorated with imaginative colours and materials. Organised in two or three floors, painted internal walls with coloured windows and pleasantly cool green courtyards with small shallow pool, vernacular houses were designed to create a functioning and yet pleasant living environment. Living rooms and service rooms like kitchen and bathroom are arranged around the courtyard or *hayat.* Larger family houses accommodate two separate courtyards. The first courtyard with access from the main entrance door is called *birun* and the second closer to private family room is called *an'daron.* All courtyards even smaller ones contain a shallow pool which is surrounded by a small garden of fruit trees, flowers and vegetables (Sultanzadeh 1997). This pleasant microclimate is produced by evaporative cooling from the pool and trees and protection from direct sunlight provided by tall evergreen and deciduous trees. In a typical layout, the courtyard is located in the middle with major rooms in southern and northern side of the house. This typology of rooms and habitable spaces changes from region to region according to different climate. For instance in Tabriz where people cope with long and cold winters, rooms in northern side of the courtyard provide primary living space for residents due to more effective solar gain during cold season. These rooms are built larger with generous windows and elaborate details on walls and

doors but ancillary rooms such as bathroom and storage spaces located in southern parts within smaller spaces and openings. In hot and arid regions, however, major living rooms and semi-open terraces are built in southern side of the courtyard facing north protected from harsh summer daylight, sparing the northern side for winter rooms. South-facing winter room are called *aftab-ru* (facing sun) or *aftab-gir* (sun catcher) in Farsi.

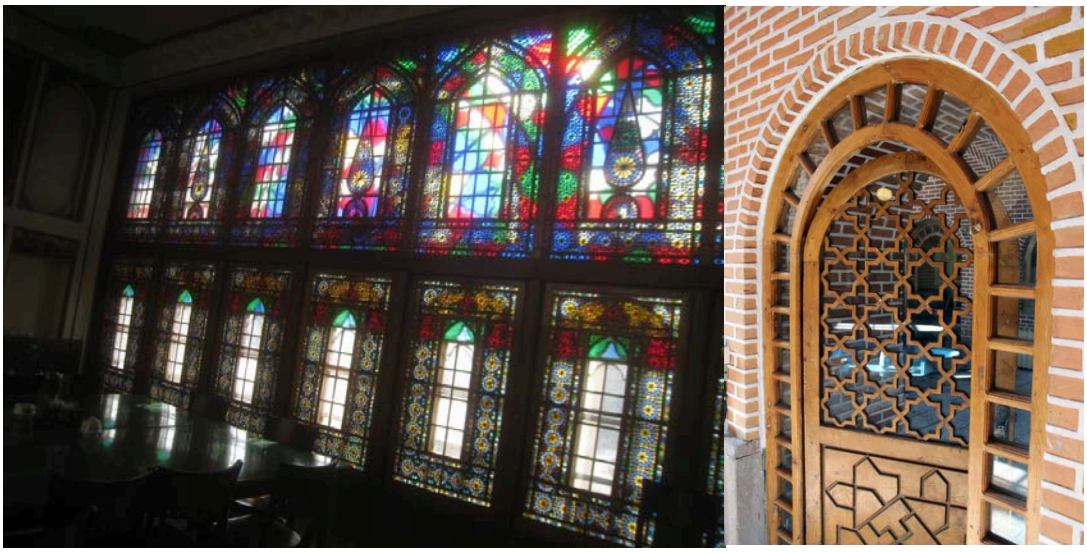


Fig. 3.6: Behnam House in Tabriz, interior view of the main reception room on ground level and basement door details (source: Author 2013)

In arid regions, a typical family house with its shady cooler side usually contains the following elements: *eyvan* is a balcony open from one-side, built with an archway above facing the courtyard; *badghir* or wind catcher and *panj-dari,* literally meaning a room with five doors. *Panj-dari,* located in summer section, is the largest room with higher ceiling used as family living room. Built at lower level than courtyard, *zir-zamin* is a partially-buried lower ground floor space used as living room during summer and a cooler space to store food (Kheirabadi 1991).

Roof construction in vernacular Iranian buildings varies significantly from domed brick roofs to flat timber and mud roofs. In hot and dry climate, brick dome has a great advantage in cooling the space below. In comparison to a flat roof, brick dome roof contains larger surface area and therefore is easier to cool down by passing wind. Dome shape creates a shadow side at any given time which absorbs heat from the warmer side and then radiates it outside. Flat roofs were more common for smaller houses due to their simple and economical construction methods. Flat roofs also provided a pleasant sleeping area for inhabitants over summer night. Sleeping

under clear night sky with family and friends seems to be one of the most delightful memories of every child in Iran.

Inside traditional cities, the principle of sharing external surfaces of buildings is even more apparent inside dense bazaar structure which could be considered the largest public structure in vernacular city. In smaller towns, bazaar was only limited to a narrow street with retail shops organised on both sides. But in larger cities such as Tabriz, Isfahan and Shiraz where trade routes were established over centuries, bazaar structure was considered the economic hearts of the city and was protected inside the city walls and in some points stretched from one city gate to another. Shops for smaller retailers were usually organised along *raste* or straight stretches of covered streets where visitors could freely move around and take their time to compare products from one shop to another. Wholesalers were located in smaller offices or *hojre* and were organised around the courtyard or caravanserais. While *raste* is generally covered by a continuous line of brick domes to protect occupants and visitors from environmental elements, open courtyard or *saray* helped to ventilate long stretches of bazaar. These large open courtyards named caravanserai or *saray* functioned as meeting place for travellers to rest and present their goods to potential buyers (Sultanzadeh 1997). Raste bazaar and rectangular caravanserais could be seen in a map of Tabriz Bazaar in figure 3.7 in this page.

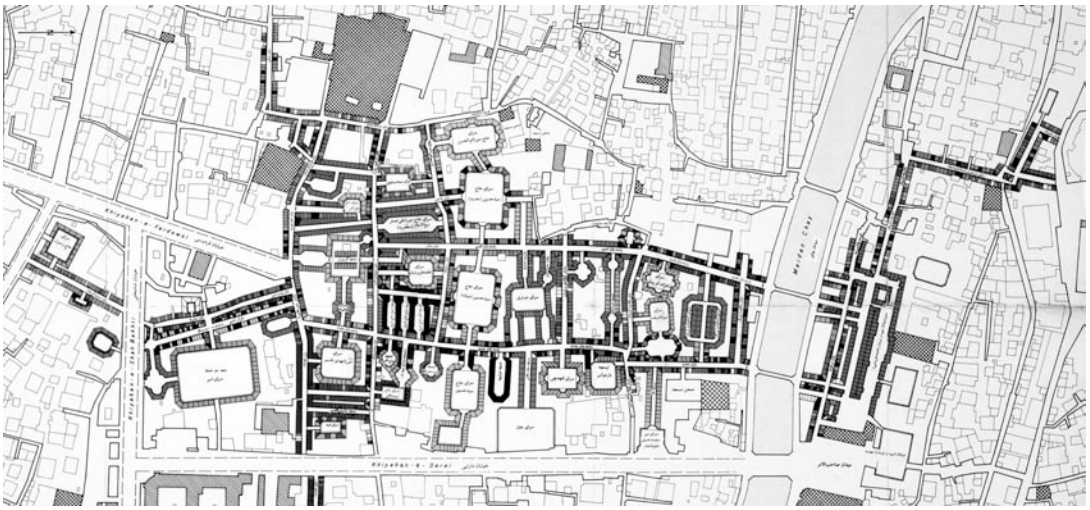


Fig.3.7: Plan of Tabriz bazaar structure with *raste bazaar* & open courtyards (source: Tehrani 2005)

Due to their economic and social significance of bazaar structure, major public buildings such as administrative buildings, schools, libraries and mosques were built either inside or immediately next to it creating a diverse and vibrant town centre.

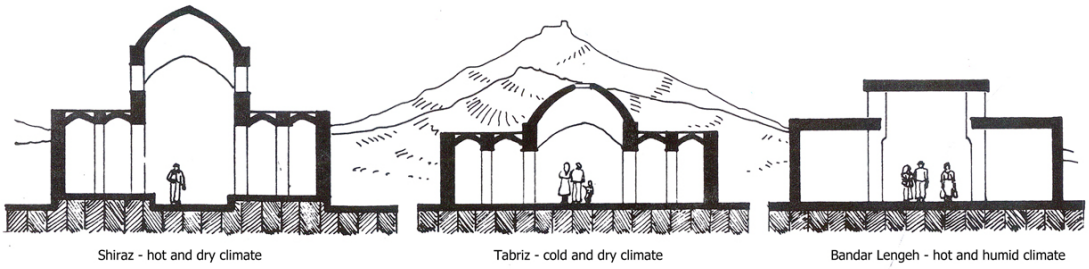


Fig. 3.8: Cross section of bazaar structure in three cities with different climate (source: Ghobadian 1998)

Although environmental characteristics of different regions had significant impact on formation and urban development of Iranian cities, other important factors such as social, economical and cultural aspects should not be overlooked. In consideration of sustainable development of traditional cities, one should also acknowledge the significance of other aspects such as economic trade routes, defence consideration and religious culture. However, to make this study feasible, the urban development in traditional Iranian cities and its response to environmental elements such as wind, water, solar gain and green spaces are the main focus of the study.

3.4 Wind

Through centuries of construction experience and knowledge transfer, traditional builders realised the significant impact of solar gain and local wind on buildings. It appears that they recognised two fundamental design principles in construction of human habitat. Number one was to study and understand regional climate and number two was to embrace and adapt to it. Appropriate use of local wind was particularly important as it could be observed in vernacular cities located in central part of Iranian plateau. Urban spaces such as public squares and market streets were oriented in specific direction to benefit from pleasant local winds for natural ventilation and shelter buildings and inhabitants from unfavourable winds. Due to high density of buildings in cities, the wind speed reduces significantly flowing from countryside to urban regions. Streets parallel to favourable wind promote higher velocity of wind in urban areas, whereas streets and alleys built perpendicular to wind direction, allow wind to pass above the street level (Brown & Dekay 2001).

It appears that, adaptation to local wind direction including both favoured winds and unpleasant wind, played an important role in choosing city location and also orientation of buildings and streets. Most traditional Iranian cities have been designed and built based on three main directions or *roon*. The orientation of streets

and public buildings was defined by attention to three factors. These decisive factors were:

- Land shape and topography
- Solar orientation
- Wind direction

The main orientation of traditional Iranian towns and villages could be conceived as a honeycomb or hexagonal shape with three lines connecting all six corners where each line represents a *roon* or direction. *Roon Raste* or Straight Order stretches from north-east to south-west and cities of Tabriz, Tehran and Yazd follow this direction. *Isfahan Roon* or Isfahan Order was considered for cities of Isfahan, Estakhr and Persepolis extending from north-west to south east. *Kerman Roon* or Kerman Order used for cities stretching from west to east. Cities of Kerman, Hamadan and smaller towns in East Azerbaijan province were built based on this orientation (Pirnia 2006). Three main urban directions are shown in figure 3.9 together with north direction for visual explanation.

Town planners and traditional builders of vernacular houses adopted an urban pattern of tightly-built buildings with tall and windings passages as an effective way to avoid dry and hot winds at summer and unpleasant cold winter winds. In a dense urban pattern, uniform height of buildings and their proximity helps to avoid unpleasant winds and unwanted turbulences at street level. Strong seasonal winds move freely above buildings and narrow passages between them with less contact with external surfaces of buildings.

In contrast to vernacular understanding of urban direction and street orientation, modern expansions of cities in Iran are usually associated with development of wider roads set in geometrical pattern to provide access for ever growing car traffic. High-rise buildings are hit by frequent strong winds and create persistent problems of turbulence at street level. Another issue with wide modern boulevards is their function as wind channels for rapid wind movement within the city. In cities like Isfahan located inside hot and arid regions of the country, wide streets channel hot and dusty air during the day and cold unpleasant wind of night. Wide open surfaces of road and boulevards also absorb more solar heat and raise the temperature above their immediate surface. This heated air rises in funnel-shaped dust currents and blows around the city roads and wide squares. This contrast is very clear while

you move away from compact historic parts to recently developed modern zones.

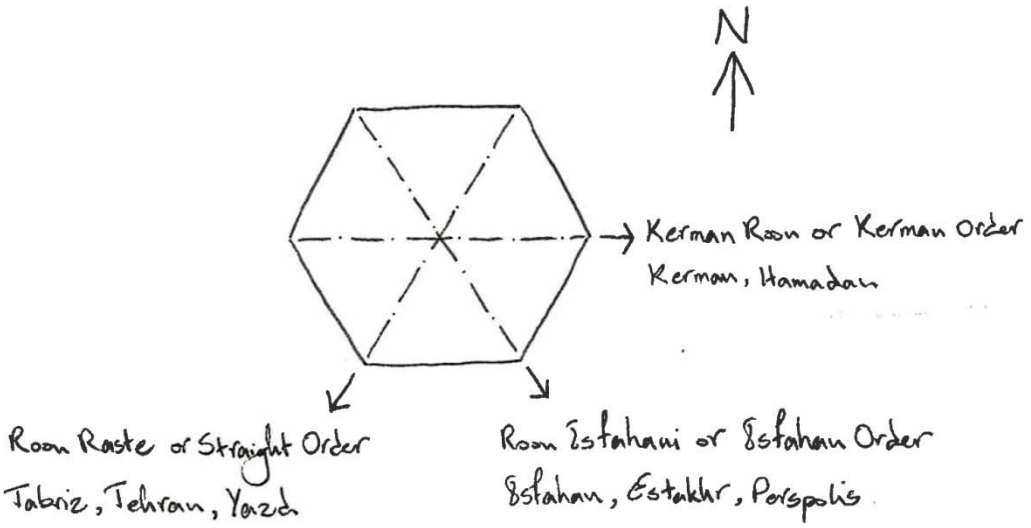


Fig. 3.9: Hexagonal shape used to demonstrate the main directions of which traditional cities were designed to adapt to local climate and solar radiation (source: Pirnia 2006)

Planning and building cities with correct orientation or *roon* meant narrow roads and alleys could effectively shelter people and houses from undesirable winds and only invite pleasant winds to further reduce temperatures (Kermani and Luiten 2009). Very similar rules were applied in local construction in regions with dry and cold climate. Local knowledge of climatic conditions and seasonal changes helped to build streets and dwellings with correct orientations and to protect people and houses from cold and frosty winter winds. A good example of modern wide roads build in historic context of Iranian cities could be seen in figure 3.10.

Fig. 3.10: Modern roads in Tabriz built into historic part of the city (source: Dibaj and Karang 1963)

Traditional covered bazaars are still major part of Iranian cities and they could be observed and studied as living examples of adaptable vernacular architecture to their surrounding climate. Traditional bazaars in larger cities such as Tabriz and Shiraz have developed from a single narrow market street into a complex network of linear roads containing several open courtyards. The linear parts of bazaar called *raste* are mainly covered by a series of brick domes. Sun-dried or baked bricks are sourced locally sometimes as close as excavated earth from bazaar's courtyards. The series of tightly built domes create semi-open spaces which are protected from harsh winter weather and hot summer. Floor levels at courtyards are lower than its surrounding area to create a flow of dense cool air into open areas to form a pleasant environment for visitors and business owners. On the other hand, open courtyards function as breathing organs for semi-closed areas (Soltanzadeh 1997). Figure 3.11 shows a small part of Tabriz Bazaar covered with brick dome roof structure with ventilation and lighting holes at top.

In absence of modern cooling equipment, natural ventilation was widely used inside family houses and larger public buildings. *Badghir* or wind catcher is a chimney-like vertical structure which is built to catch pleasant wind at a higher level above the building and direct it inside to lower level. The ancient city of Yazd is one of the largest cities in the world built almost entirely out of adobe. It is famous for its

elaborate wind catchers with tallest of them rising 34 metre above Dolat Abad Garden (2010 May).

In order to maximise natural ventilation inside building and benefit from local winds, the wind catchers are built to function either as convection system or convection plus evaporation system. Wind catchers in convection system are built mainly to relocate warmer air inside the building and replace it with fresh cooler air. However evaporative wind catchers such as the one in Bagh-e Dolat Abad in Yazd, use available water in their vicinity to increase humidity. The wind caught at high level enters the wind catcher and insert the building at basement level where a small shallow pool with fountain located. This room with pool and fountain is called *hashti* which refers to its hexagonal plan with doors on each side to different room. Whenever required the open door between *hashti* and the occupied room would enable cooler and humid wind to be directed from the bottom of *badghir* over the pool and into the room. This simple strategy was very effective in courtyard houses where most rooms have all their windows on one side facing the courtyard and cross ventilation is not possible due to their layout.

Fig. 3.11: *Raste Bazaar* covered with brick domes, Tabriz, Iran (source: Author 2013)

Another good example of evaporative wind catchers are found in city of Yazd where wind catchers are built few metres away from the building and the connection between two structures are made using an underground channel. The channel is covered with smaller garden and irrigation from this garden sinks down to reach the

channel and dampen its walls. The evaporated water then mixes with wind travelling through the channel entering the building on the other side. The evaporative wind catchers are used widely in cities with dry and hot climate in central Iran where additional humidity in desirable. In contrast, convection only wind catcher perform very well in southern parts of Iran near the Persian Gulf where climate is hot and humid. Due to high levels of humidity in this region, usually above human comfort zone, additional humidity from *badghir* would only increase discomfort and therefore wind catchers with convection system and slightly modified shape and sizes have been assembled near buildings (Ghobadian 1998). Figure 3.12 displays an elegant underground water reservoir with five wind catchers in Kish Island in south of Iran.

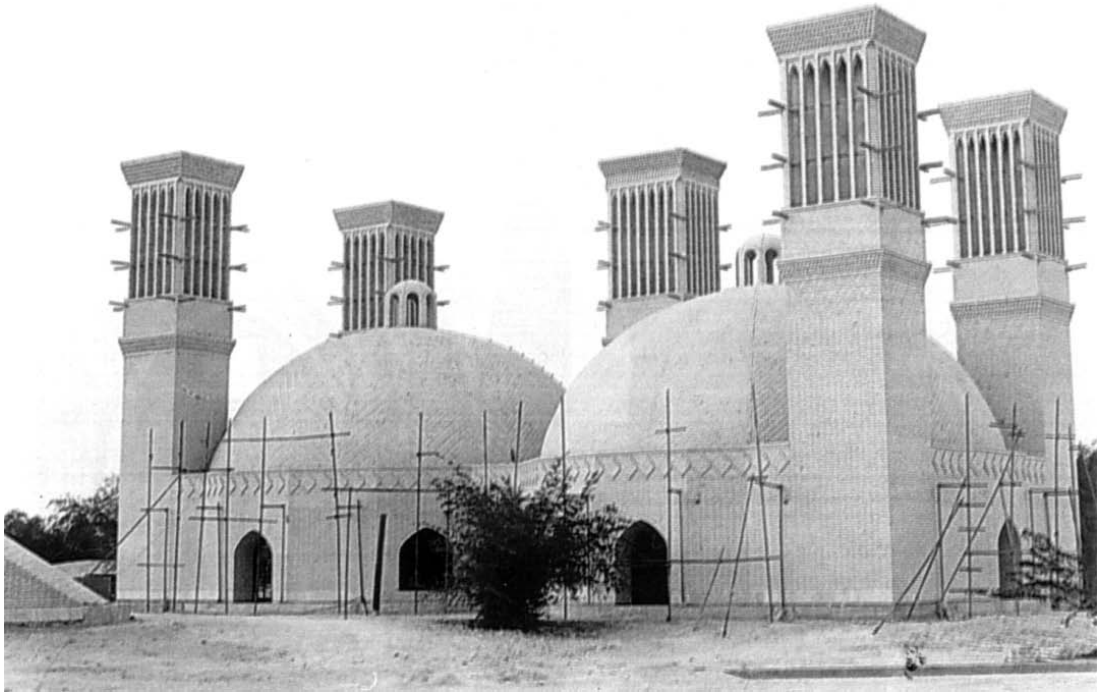


Fig. 3.12: Water cistern with five wind catchers in Kish Island (source: Ghobadian 1998)

Badghir structures differ in height and type according to local climate. For instance, wind catchers in Yazd are built using rectangular or hexagonal plan and are open to all sides to draw in wind from every direction. But this typology changes dramatically in Meybod, a city located only fifty kilometres away from Yazd. B*adghir* structures in Maybod are built with their head facing one direction only to catch favourable wind and avoid hot and sandy winds blown from the desert. These one-sided wind catchers have shorter tower to avoid catching sandy winds from the wrong direction. A simple diagram in figure 3.13 displays natural ventilation created inside a building by a wind catcher during the hot day, cool night and facing cool summer breeze.

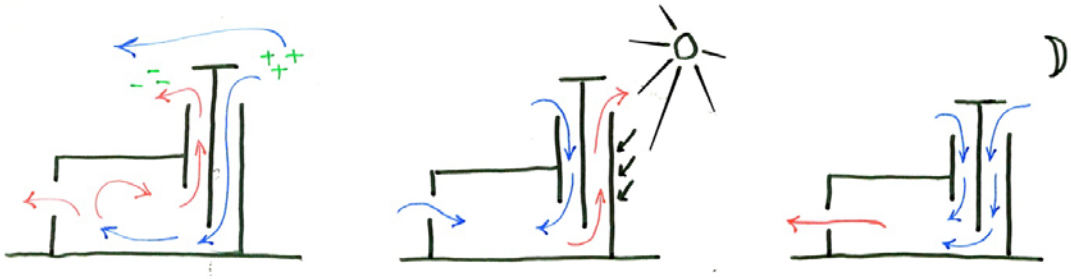


Fig. 3.13: At night cooler wind sinks into the air shaft forcing the warmer air out of windows and during the day, southern face of the wind catcher gets warmer, increasing the air temperature inside the airshaft to rise and the cooler air from green courtyard on the opposite side of wind catcher to enter the room. Built facing the local pleasant wind, in windy days, cooler wind flows down the air shaft from one side to ventilate and replace the warm air inside (source: Krautheim 2014).

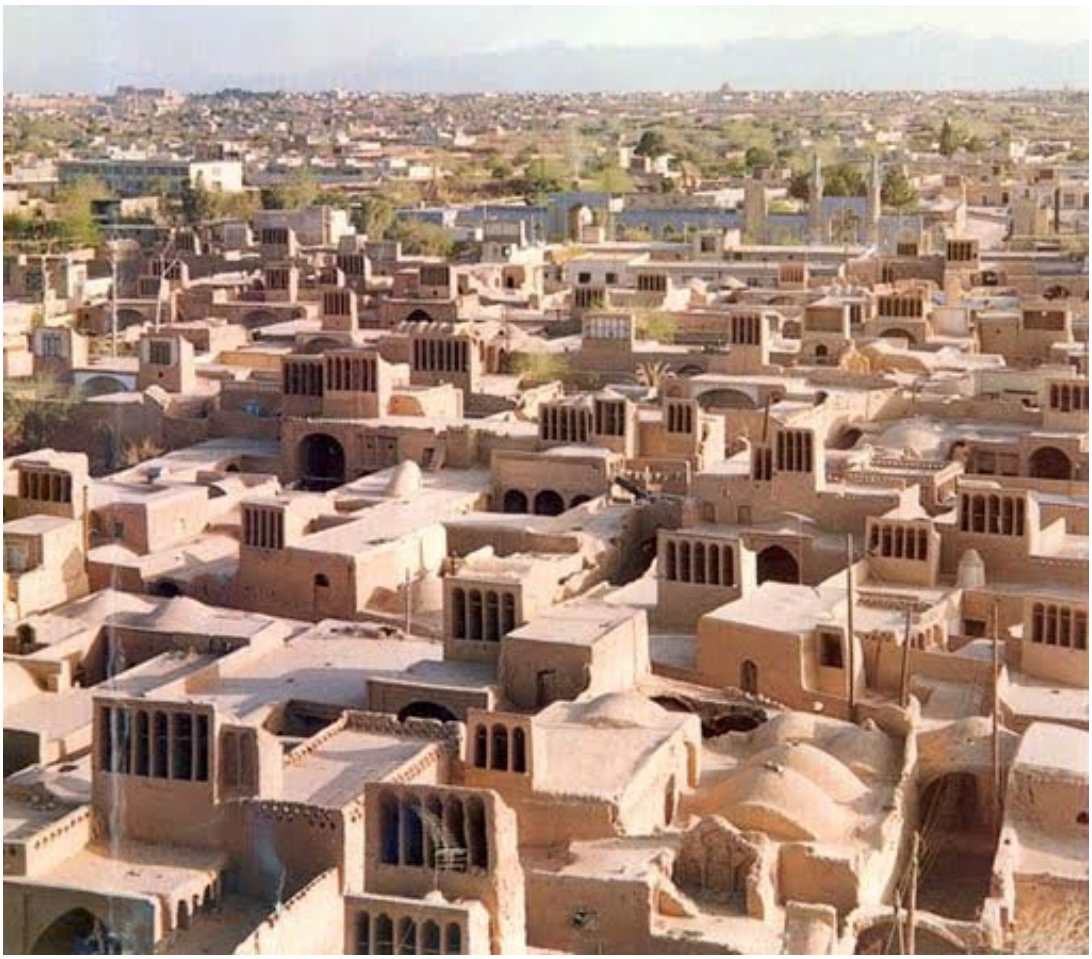


Fig. 3.14: Wind catchers in *Meybod* are shorter than other cities and only facing one direction (source: Ghobadian 1998)

In contrast, larger and taller *badghir*s designed with octagonal plans to be structurally more resistant against strong wings. This division of inlet opening at the top of the tower also helps to reduce incoming wind speed inside the building. In southern cities near Persian Gulf, local pleasant sea breeze is much lighter and

therefore *badghir*s are built in bigger sizes with wide opening to catch enough wind for internal rooms. In some occasions, these wind catchers are as large as the roof itself and even cover an area of eight square metres (Ghobadian 1998).

Wind catchers could also help natural ventilation inside the building with chimney effect only. When there is no air movement outside the building, hot air inside the building rises from the tower to outside and cooler, moist wind from the courtyard enters the room to refresh internal areas. Traditional wind catchers have few disadvantages which make them less effective in modern buildings. The frequency of incoming wind and its humidity level and temperature is not fully adjustable and throughout the year, ventilation inside the building is dependent on local winds. Recently there has been some improvement in functionality and durability of wind catchers by well-known Egyptian architect Hassan Fathy. Fathy added water tray and water sprays inside the tower to increase humidity and improve incoming dusty wind. Effectively designed wind catchers can be incorporated into modern buildings as a complementary system for natural ventilation together with mechanical air conditioning (Foruzanmehr and Nicol 2008).

3.5 Water

Water is an essential element to human life and for centuries human settlements have been formed and survived where water resources were available and accessible. Due to general dryness of Iranian plateau, early settlements only appeared where it was likely to have access to water. Developing from these early settlements, most Iranian cities exist within large alluvial fans in the foothills of mountains. Cities of Tehran, Qazvin and Kirman are good examples of this type of landscape. A large number of these towns did not receive enough water from annual precipitation for agricultural uses and water from *qanat*s was the only reliable source of water to sustain human activity thorough the year.

*Qanat*s are man-made subterranean aqueduct system where ground water is collected at the foot of mountain and directed by gravity to the town or farmlands through gently sloped subterranean channels. Qanats have been constructed by skilled men called *mugannis* with simple tools such as hatchet, short-handed shovel and oil lamps. The longest qanat recorded is nearly seventy kilometres long near Kerman but *q*anats usually do not stretch for more than five kilometres. The deepest well were called *madar-chah* or mother well dug at the foot of the mountain and the shallowest well near the edge of the desert. After passing through the town and

providing water for domestic use, qanat would stretch to agricultural fields. However, qanats system could not be used in all places around the Iranian plateau and they could only sustain consistent water where the mother well was dug either in a sufficiently watered mountain or a land which is watered by rivers and streams from highlands (Kheirabadi 1991). This is considered to be one of the main reasons for the lack of settlements in the central deserts or *kavir*s of Iran. Cross section and plan view of a typical qanat system is shown in figure 3.15.

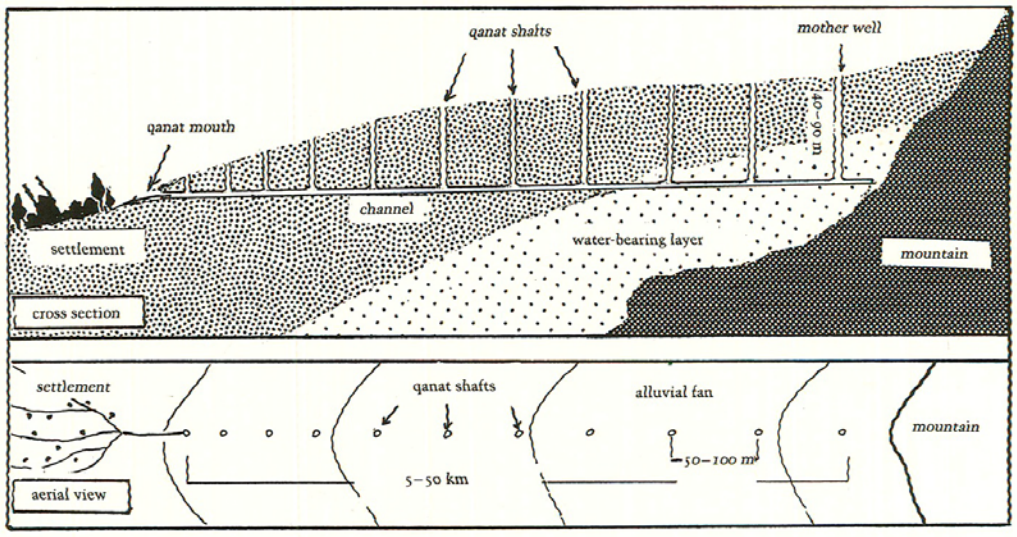


Fig. 3.15: Diagram of a typical *qanat* construction seen in plan and section (source: Kheirabadi 1991)

Fig. 3.16: Several *qanats* in Kirman seen as series of shafts stretching from mother well to the city (source: Kheirabadi 1991)

In many traditional Iranian cities it is possible to identify the direction of urban development by following water courses in the region. A clear example of a smaller settlement developed around watercourses could be seen in Iranian village of Muhiabad near Kerman. The buildings inside the village have been formed around the water streams arriving at the village through *qanats*. The surface water then flows into the village and branches into smaller surface and subsurface channels to enter houses and irrigate agricultural fields located near houses. The courtyard level of houses follows the water levels to make it easier for running water to enter the building. This change of level from street to the internal courtyard of the building could be as high as 6 metres in elevation creating what is known as *godal bakhche* or sunken garden inside private dwellings or public buildings such as traditional schools or *madrase*.

Fig.3.17: Satellite view of Muhyabad village near Kirman, Iran. The tree line along the water path in the middle of the village shows the main structural spine of the settlement. (Source: Google Maps 2015)

Apart from irrigation and household use, available surface water was widely used for climatic adaptations as well as aesthetic reasons. In hot and dry climate, air temperature can be reduced via availability of surface water for radiant cooling and increased humidity from surface evaporation. In a semi-enclosed open space such as courtyards, the evaporation rate changes following differences in the water temperate, the relative air humidity and the surface area of water (Brown and DeKay 2001).

Fig. 3.18: Shallow pools and open channels are present in every garden. Image taken in Fin Garden near Kashan (source: Rainer 1977)

At city scale, water was directed from streams and qanats into surface channels. The channels were constructed along streets and main passages to reach buildings and gardens. These wide open gutters called *juys or jubs* running at surface level, surrounded by walls to block sandy winds, increased humidity in their surrounding and provided plenty of waters for planted local trees. Water also appeared in form of shallow pools inside courtyard houses to create, together with planted trees and plants, a microclimate for inhabitants during hot season or cold and dry winters. Shallow pools in geometric forms were commonly built in every courtyard and they could be seen in larger royal gardens as well as smaller dwellings. Figure 3.18 display how presence of surface water and planted tall trees created a more pleasant microclimate for pedestrian in traditional city.

Unlike cities of central Iran, in coastal towns near Persian Gulf in the south or near larger lakes such as the Caspian Sea in the north, temperature fluctuation is small from day to night and weather in general is milder. In these regions, temperature rise on land is much faster than water temperature during the hot summer day but at the same time the land cools down very quickly after the sun set due to radiated heat from the earth to the sky. The heated earth under the scorching sun could reach a degree where walking on bare foot becomes impossible. In comparison, water temperature rises gradually during the day and falls slowly during the night. This is due to high heat capacity of water to other substances such as soil and air. In

addition, water evaporated from the sea increases humidity level in its surrounding and water particles in the air could absorb more heat during the day and also preserve their temperature during the night.

However, in parts of the country with hot and dry climate, this simple impact of airborne humidity in moderating surrounding temperature is greatly reduced and to some extent non-existent. In central regions of Iran, far from Persian Gulf in South and the Caspian Sea in North, where annual precipitation and airborne humidity is low and therefore the surface area of land covered by vegetation is very limited. This is where *qanat* and interlinked water channel systems were effectively used to direct water away from steep slopes of mountain to reach human habitat. Increase humidity caused by evaporation from water channels and pools produced milder temperatures in their immediate surrounding environment. Another common and a very simple method of moderating internal room temperature during hot and dry summer days and nights was to splash water inside courtyard area to temporarily increase humidity.

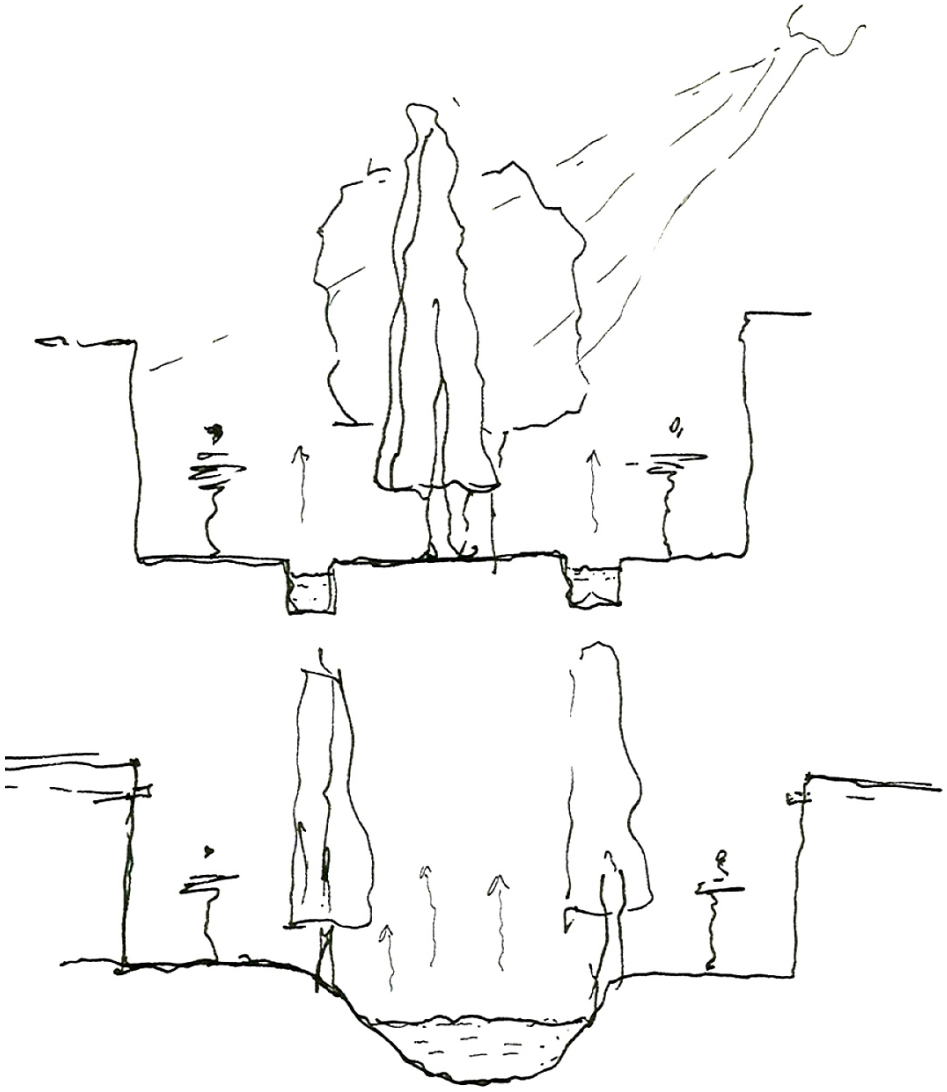


Fig. 3.19: Sketch of tree-lined alleys and narrow streets with *juy*s or open gutters (source: Author 2013)

Distribution of water in many cities has been so important that many recent scholars argue that the main structure of urban plan in traditional cities, which mostly contains *raste bazaar* and connecting streets, has developed following existing water courses of *qanats* and *juys*. This pattern could be conveniently observed in many open water channels along streets and inside dwellings with subterranean structures called sard'ab. *Sard'ab* literally translates to cool water. Sard'ab is a purpose-built subterranean structure in larger buildings with direct access from inner courtyard, where fresh water could be collected for household use (Kheirabadi 1991). Figure 3.20 displays a cross section of a large family house with *sard'ab* located under the courtyard.

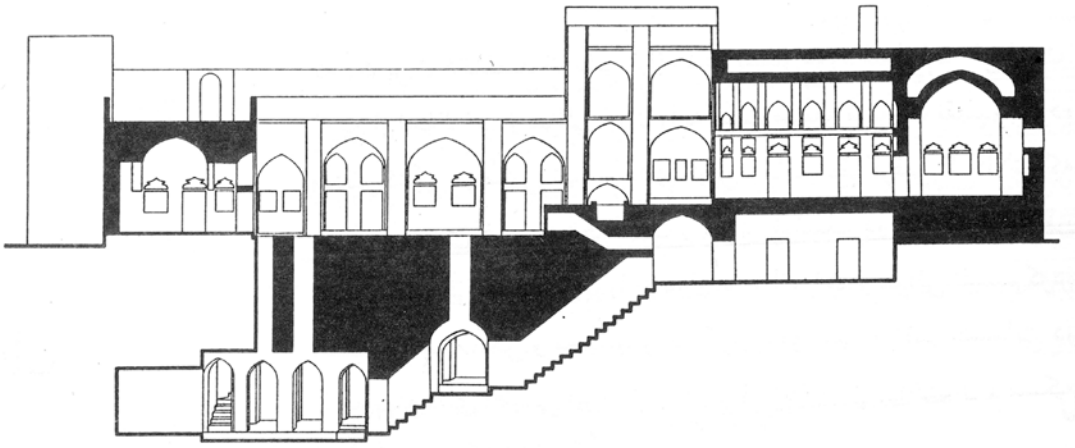


Fig. 3.20: In large family houses, fresh water was collected from Sard'ab, a subterranean room connected to underground water channels (source: Pirnia 2006)

In cities like Tabriz with a dry and cold climate, in addition to external shallow pool in the courtyard, some larger houses contained a smaller pool inside the house at basement level to be used during frozen winter days. These pools with small fountains significantly improved low levels of humidity and provided pleasant living environment in sharp contrast to bitter cold weather outside. An image of basement room inside Behnam House in Tabriz is displayed in figure 3.21.

In his book, Yazd and Its Hinterland, Michael Bonine recognizes topography and irrigation systems as two main reasons behind street pattern in traditional cities and pre-industrial economies. He refers to a pattern of major streets being established in line with water channels used to irrigate agricultural land and therefore, main streets and smaller alleys existed within this pattern before population growth and construction of houses within fields. Based on these observations, he concludes that the sizes and shapes of new suburban houses were defined by the pre-existing passages and therefore water courses.

3.6 Solar factor

In hot and dry climate the sun and radiated daytime heat is very much present in every aspect of people's life and designing comfortable buildings and efficient cities could only be possible with rigorous attention to solar gain during lengthy hot seasons. Intense solar radiation and reflected heat from building and street surfaces lead to extreme conditions in open spaces outside as well as inside the buildings. Therefore, daytime protection from direct solar radiation has been the number one concern of traditional designers in this region. In temperate climate, although protection from direct sunlight in summer is very important, however, efficient winter

heating is also very much dependent on solar heat. As a result, adequate exposure on south-facing facade of buildings is vital. In larger city scale, wider east-west streets provide enough space between buildings to benefit from solar access during cold seasons.

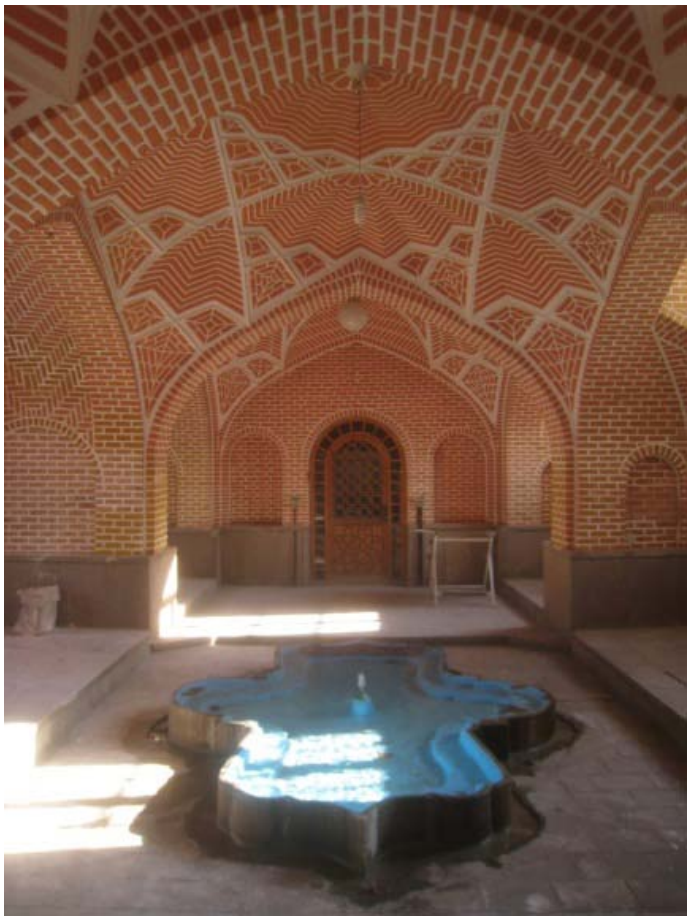


Fig. 3.21: Behnam House in Tabriz, interior view of the main basement room with pool (source: Author 2013)

Starting from a single dwelling unit such as a courtyard house, traditional towns in hot climates were developed into large group of tightly linked buildings. By sharing external walls, this compact group of buildings minimise direct exposure to daylight and the only exposed surfaces were the roof surfaces plus one external wall facing street. This solution works very effectively in reducing absorbed solar heat during the day and thus lower heat conduction through external walls to internal areas. This dense urban pattern could be observed throughout the Middle East and North African where narrow streets with tall buildings have been built together to cast shadows on neighbouring buildings and protect them from excessive solar radiation. Due to high altitude angle of midday sun, it is not practical to only rely on shading provided by adjacent buildings and various solutions such as semi-open balconies, pergolas or tree canopies have been employed to achieve more efficient shading.

Learning from native architecture of his home country, the Egyptian architect, Hassan Fathy, designed a compact urban structure for New Bariz in Egypt. By creating smaller open spaces and narrow streets, Fathy intended to maximise morning and afternoon shade within a dense pattern.

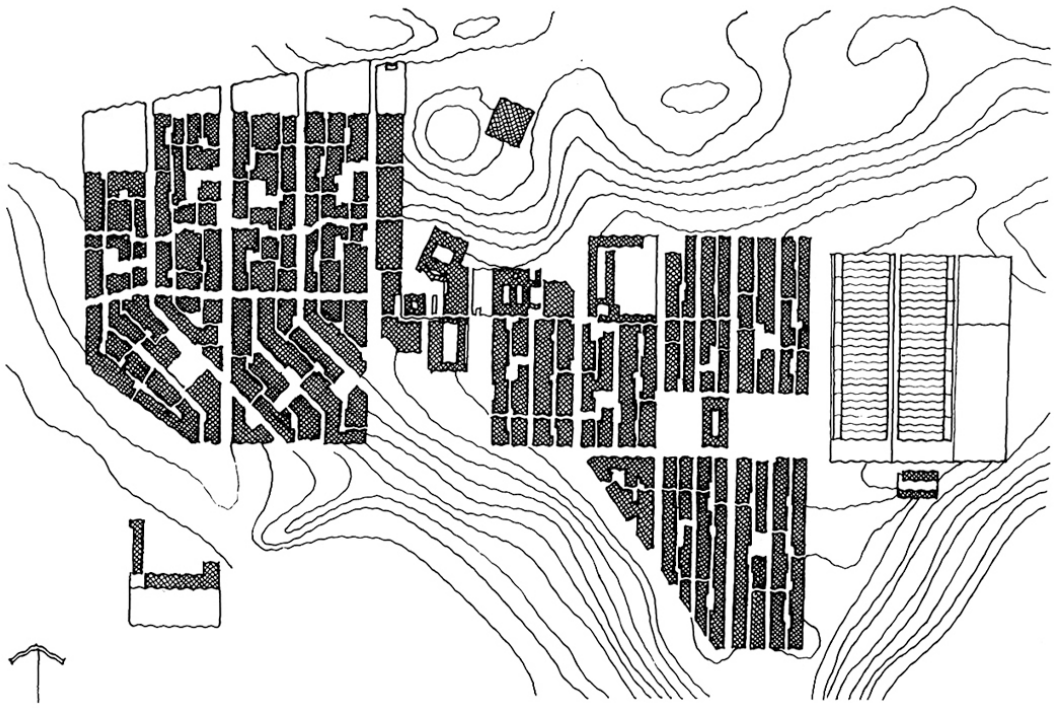


Fig. 3.22: Site plan for New Bariz, Egypt, 1967, Hassan Fathy (source: Brown and DeKay 2001)

Planning narrow streets within a dense urban layout is another effective solution to block direct daytime sunlight reaching external surfaces and therefore, reducing temperature variation between day and night. Exposed roof surfaces of buildings heat rapidly because of direct solar radiation and lose their absorbed heat rapidly during the night due to radiated heat back to clear sky. However, down at street level, visible clear sky is limited and therefore, streets cool down slowly. In hot climate, narrow streets stretching from east to west maintain shaded surfaces for longer hours during the days and therefore are most suitably affective for pedestrian movement and outdoor activities (Brown and DeKay 2001). To further protect outdoor environment, in vernacular Iranian cities, in a very similar way to the Middle Eastern and North African cities, shading of exterior building facades have been achieved through partially covered streets and corridors. It is very comment to see brick arches stretching from one side of the alley to another creating a bridge between two buildings standing opposite each other. Apart from shadow casting over pedestrian walking area, this technique helped to stabilise external walls which were mainly built of locally available mud brick or only rammed earth.

Inside a dense neighbourhood which was built partially due to limited available land and topographical restrictions, aligning the entire building in the right direction may have not been practical, however, arranging living areas and service rooms around a large open courtyard enabled vernacular designers to create summer and winter rooms according to the position of the sun in different seasons. Rooms located in southern part of the courtyard house have the least exposure to direct sunlight and the openings in this side of the building only receive direct sunlight in the early and late hours of the day. Following this shading pattern, most domestic buildings in hot and dry climate, developed in a way to accommodate their larger main living areas in southern part of the courtyard where cooler temperature could be maintained during summer. Floor plan of a single courtyard house in Shiraz in figure 3.23 displays how larger rooms are located in southern part of the courtyard. This pattern is significantly different in other cities such as Tabriz in the northwest. Long and cold winters required northern part of the courtyard to accommodate larger living rooms and benefit from increased solar gain through facade openings and heat conduction via external walls facing the courtyard.

Although windows and opening facing the south could be protected by smaller overhang for shading purposes, a big disadvantage of these windows is the fact that they receive minimum wind during summer since despite local variations the prevailing cool wind usually blows from the north in the Northern Hemisphere. Facade opening to the west, receive the most solar gain during the day due to the heat gain of the surrounding environment and angle of altitude but the eastern facade is only exposed to direct sunlight from sunrise to noon making it most suitable for bedrooms (Brown and DeKay 2001).

Another important aspect of domestic life inside traditional houses was the functional flexibility of habitable rooms. Until recently, instead of fixed furniture such as beds and sofas, sleeping mattresses and sitting cushions were used. Spread on the floor, these lightweight sleeping and sitting mats made it possible to use one single room as living and guest room and later at night to transform it into a sleeping area. This functional flexibility inside the house enabled residents to use different part of the house throughout the year. This seasonal migration and adaptation inside a building is a reminder of nomadic tribes and their seasonal migration in search of pasture for livestock around the Iranian plateau (Diba 1981).

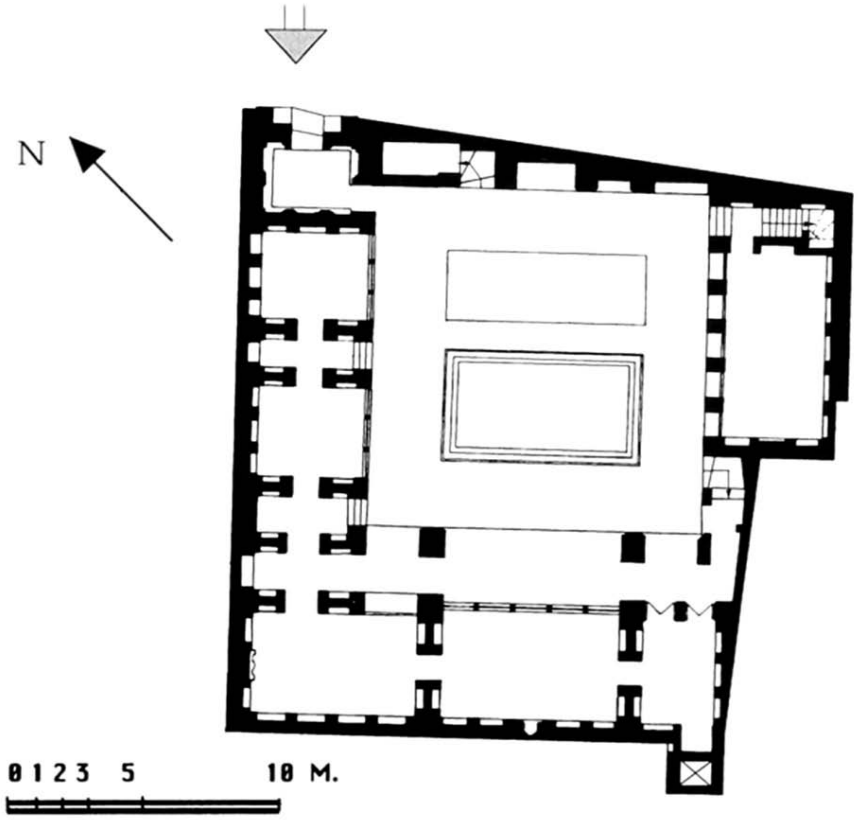


Figure 3.23: Ground floor plan of a traditional courtyard house in Shiraz with main living areas in south and west side of the courtyard to avoid direct exposure to daylight in summer (source: Memarian 1998)

The roof is the most exposed surface of a building to the sun and it is constantly heated during the day. This absorbed heat is transferred to internal surfaces leading to temperature rise inside the building. Flat roofs in particular, absorb heat from direct sunlight throughout the day. One effective way of reducing this unwanted solar gain in hot climate is construction of pitched or arching roof above large areas.

Traditional buildings in Iranian cities are easily recognised with their dynamic roofscape consisted of brick domes in various sizes. Due to hemispherical form, a domed roof maintains a shadow side for the most of the day. The obtained heat from the exposed part of the dome is absorbed and conducted to the cooler part of the dome and then transmitted to the cooler outside air. The domed roof also creates extra space inside the room above the usual head height for the hot air to rise and then to be conducted to the outside of the roof. Another advantage of brick dome roof is the increased surface area of the roof in comparison to the flat roof. The absorbed solar heat spreads over larger roof surface and therefore the average temperature of the roof and heat transmitted to the interior side is reduced (Fathy

1986). In larger houses or public buildings such as schools or mosques, where funds were available for more sophisticated building techniques, larger brick domes were designed and built of two separate brick layers to reduce heat loss from the internal surface of the roof during cold season and also avoid heat conduction from the outer surface to inner areas during hot seasons. Figure 3.25 shows a typical cross section of a double skin brick dome.

Fig. 3.24: View over the Friday Mosque and bazaar in Isfahan shows how connected brick domes and surrounding dense structure protects it from intense summer heat (source: Rainer 1977)

Despite common misconception of achieving a fixed temperature to maintain comfort levels, an outdoor space could be pleasant for a person with reasonably warm clothing in temperatures as low as 4° C if the space is accessed by direct sunlight and it is sheltered from wind (Brown and DeKay 2001). This principle was thoroughly used in vernacular Iranian architecture. Ivan is an external semi-open recessed balcony space which is only open from one side facing the internal courtyard.

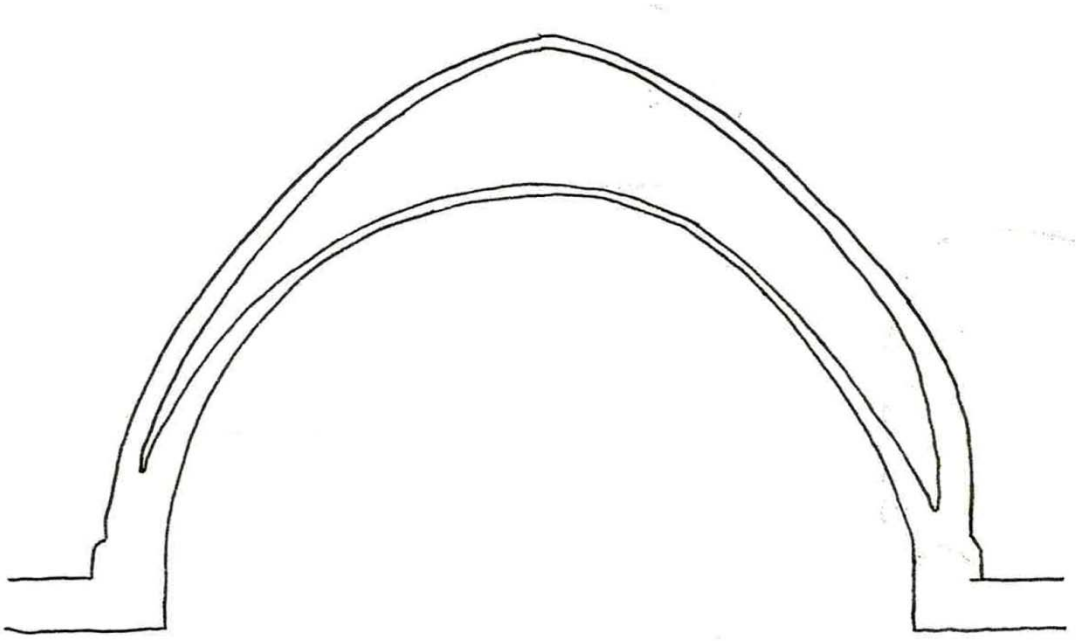


Fig. 3.25: Sketch of a double layered brick dome, (source: Author 2013)

Openings and windows in vernacular buildings have three main functions; to let the daylight in, to ventilate and to create a view for internal rooms (Fathi 1986). Inside traditional courtyard houses, main windows to living rooms and bedroom are mostly open to the courtyard where cool air from the courtyard enters the room from one side and escapes from opening on opposite side. In larger houses with two courtyards it is very common to see a double height reception area or guest room located between courtyards with large windows on both sides. The large windows on opposite side let the bright daylight to enter the room and provide ample light for internal activities. Cross ventilation for the reception room is easily achieved by opening two windows on opposite sides to draw air in from one courtyard through the room to the second courtyard. To avoid extra heating in summer, these large windows are mostly decorated with coloured glass to reduce the intensity of daylight entering the room and also create fanciful pattern of light inside (Zaimi 2010). Coloured windows are shown inside a domestic building and a large mosque building in figure 3.26.

Fig. 3.26: Coloured glass windows used in domestic scale on left and large scale public building (source: Author 2014)

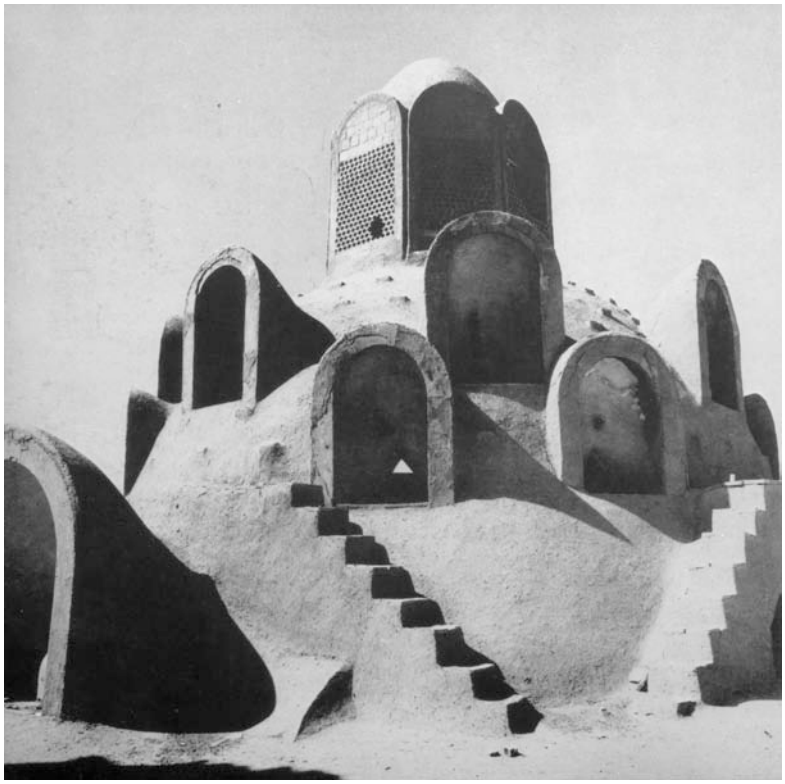


Fig. 3.27: Dynamic roofscape of Boroujerdi's House in Kashan provides self-shading over the roof as well as ventilation and light vents (source: Rainer 1977)

3.7 Green spaces

In urban areas temperature is generally several degrees higher than surrounding countryside due to heat generated from human activities, buildings and reduced wind speed. On the contrary, green spaces and densely planted areas are often cooler that the rest of the city by 6-8℃. This temperature difference comes from a mix of shading, solar reflection and evaporation from plants and trees. Green

spaces created in the vicinity of tightly developed urban areas create local air patterns as the heated air rising above the urban blocks is replaces by cooler air from green areas. Although the cooling effect of green spaces is more apparent in their immediate surroundings but studies show that desirable local winds could stretch this cooling effect to urban areas in a distance of 200-400 metres. In hot and dry climates, a combination of shading and evaporation from trees and vegetations helps to reduce temperature, however, in all climates, this effect creates saving in cooling close to 17-57% for a 25% increase in tree cover (Brown and DeKay 2001). Considering the fact that trees use less water than turf, in hot and dry climate where water resources are limited, it is more practical to cover green space with dense trees rather than shorter plants and grass.

Living with arid climate of Iranian plateau and scares resources throughout many centuries, Iranians appreciated and honoured the importance of maintaining green spaces in their immediate surroundings. The significance of creating and protecting green spaces in their living environment, lead to accurate and sophisticated techniques in planning and construction of elaborated gardens. The most celebrated form of these gardens is known as Persian garden and it has become part of the national identity of the nation. It is intriguing to observe how those who could build on large lands usually prefer to build bigger gardens rather than larger buildings. So it is not surprising to walk around a grand garden with extensive plantation and come across a fairly small pavilion or *kushk.* Purpose-built pleasure gardens and wide green courtyards constitute large areas of traditional Iranian cities. In smaller towns and villages, public places and neighbourhood centres are usually marked by century-old trees. One particular neighbourhood in old part of Tabriz has been recognised and named by its trees called *gere agaj* meaning dark tree in local language. In general the type of plantation indentified the type of garden: the *golestan* is a rose garden; *sarvestan* a garden of cypress; *narenjestan,* an orange grove*; bustan;* an orchard (Porter 2003).

As discussed earlier in chapter three, in traditional Iranian cities, an affective technique for irrigation of gardens and agricultural fields was realised to be construction of *qanat* or subterranean water channel network. Fresh water deposited in mountain foothill was directed into qanats and then into subterranean water channel network called *Kariz* to reach occupied land. Water channels reaching town and villages and branching into streets, provided constant source of water for trees such as poplar, willow or plane trees. This dense arrangement of trees together with open surface water channels created pleasant green corridors for pedestrians

approaching from public squares to residential areas. An example of a new modern street inspired by green corridors of vernacular city could be seen in capital city of Tehran along Vali'asr Street with its famous plane trees and open water channels on either side. The presence of water and green spaces in different parts of traditional cities not only helped to moderate extreme temperatures but also created public spaces where people felt comfortable to stop on their way and interact and socialise with others. This way of integrating green spaces into open public areas is very much needed in contemporary cities where most parts of urban environment are designed and used as passing points for people and vehicles (Reiner 1977). By prioritising vehicle access on wide roads and large roundabouts, modern cities in present day Iran severely lack the intimate and welcoming public realm for their citizen to stop, interact and appreciate their surroundings.

The connection between the human habitant and the natural environment is not a recent phenomenon and the idea of living your life in peace and tranquillity and spending free time in gardens under fruit trees and listening to the sound of running water and singing birds, has always been present in collective memory of the nation. The notion of living a balanced life in harmony with natural world and the importance of local trees, green spaces and biodiversity in human living environment could be observed in traditional Persian literature and poetry throughout centuries. Therefore, creating green spaces inside and around the living environment seemed to be natural and essential in planning and building of cities. Places without trees and plants are considered dead and lifeless and not very suitable for a happy and harmonious life.

In a smaller urban scale, domestic gardens were created inside courtyard houses with deciduous trees, plants and flower beds. Taller fruit trees with wide leaves planted inside courtyard helped to reduce daylight reaching living rooms. These deciduous fruit trees such as oranges, berries and cherry trees helped to block intense solar radiation in summer and moderate temperatures. Planted trees along small alleys and streets were integrated well into urban structure of vernacular towns. Apart from forming a visual sign for people to help them navigate through complex network of passages, large trees created shaded spots for urban traveller and protected the external wall of the building from unwanted heat in summer. Deciduous trees were also an appropriate choice for cold season as they dropped their leaves and allowed solar heat to reach internal living areas and semi-opened balconies. As shown in figure 3.28, it was important to understand suitable location and type of planted tree adjacent to the building (Faghih and Sadeghy 2012).

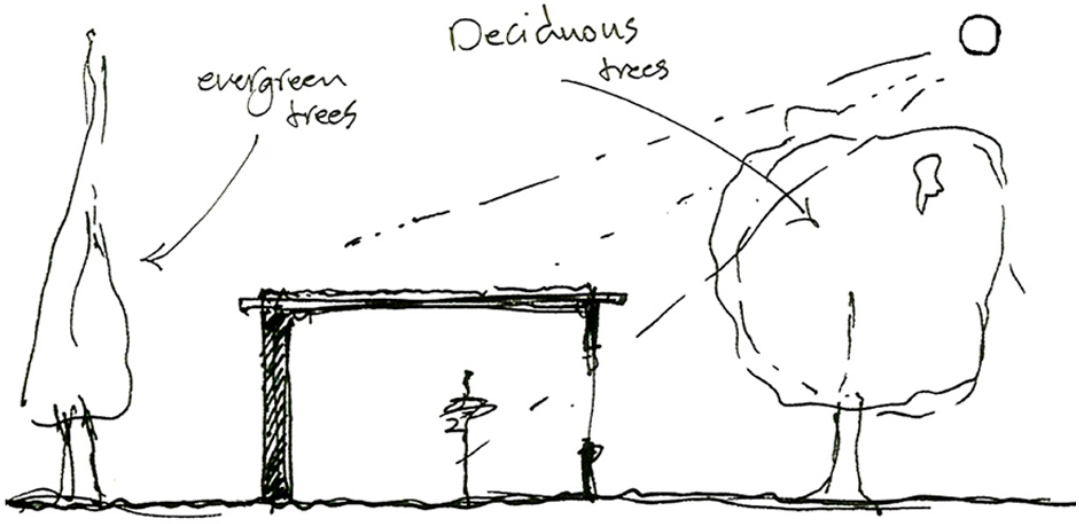


Fig. 3.28: While evergreen trees provide continuous barrier from the undesirable winds, deciduous trees shelter buildings and urban areas from intense solar radiation during summer (source: Author 2014)

Such courtyard gardens inside dwellings could be seen as the smallest units of green areas in traditional cities. Garden trees inside houses were mainly preferred from local fruit tree species and they enhanced living environment of inhabitants in many ways. Planted next to a shallow pool inside the courtyard, they increased humidity and help to create a milder and cooler micro-climate. Large areas of planted flowers and vegetable near windows reduced reflected solar heat from paved areas. These private gardens inside courtyards expanded outward to passages, public squares and larger public gardens with great impact in moderating surrounding temperature. Finding a shaded spot under green umbrella of a tree always promised a resting corner for a traveller walking from one point to another. Outside the residential districts in the fields, tall trees such as poplar were planted to mark borders between two neighbouring lands and block winds in open fields.

Due to a combination of shading, evaporation and reflection, planted areas could be approximately 5.5 to 8.3℃ cooler than other urban areas. In arid climate, a single tree can transpire up to 380 litres of water in a single day (Brown and DeKay 2001). This additional humidity from trees and plants is highly effective in creating a pleasant microclimate in small urban areas and internal courtyard spaces. Due to minimal annual rainfall in most parts of Iran, regular irrigation of trees and planted areas is very crucial. In general larger trees could only be found along the surface water channels or near town square where surface water is collected and distributed in an open pond. Water channels extended from qanats and *kariz* provided

necessary irrigation to fruit gardens surrounding the town and green courtyards (Ghobadian 1998).

Fig. 3.29: *Narenjestan-i Qavam*, a nineteenth century house and garden built for the influential Qavam family in Shiraz (source: Porter 2003)

Trees are also commonly used as windbreak in open urban spaces and rural areas. A row of evergreen trees or densely planted deciduous were used as a buffer zone to stop undesirable frosty winter wind or hot summer wind to reach buildings and farmlands. Density and height of the planted trees had a great impact on their function as wind barrier. In cold climate, the windbreaks significantly reduced thermal loss in buildings during cold seasons. A view towards a green courtyard inside a large family house is shown in figure 3.29. It appears that the picture was taken from inside the *Ivan* or semi-open balcony area to present what is known as a typical rectangular courtyard with a central shallow pool and planted trees facing main living rooms and a wind catcher erected behind the building.

Fig. 3.30: A large house in Kashan with a common type of rectangular courtyard with shallow pool, fruit trees and flower beds (source: Rainer 1977)

A surprising fact about vernacular Iranian cities with courtyard houses is the significant proportion of overall urban areas covered with green courtyards and fruit gardens. A visual analysis in figure 3.30 reveals that although green spaces were divided into numerous small courtyards inside buildings but total area covered by these green spaces adds up to 30% to 40% of the land covered by entire city. This large proportion of green urban zones becomes more significant when one acknowledges the fact that most traditional Iranian cities evolved in dry areas with low precipitation and low humidity.

Fig. 3.31: Aerial photograph of outskirt of Kerman with highlighted green courtyards (source: Rainer 1977, edited by the author).

3.8 Precedent

Designed by Kamran Diba Architects and Completed in 1977, Shushtar New Town in Iran could be seen as the only example of a modern development in Iran which was built with attention to regional vernacular architecture. This residential community was designed to for a population of 25-30,000 people. It was planned and built near the ancient city of Shushtar in Khuzastan, southern Iran. Although the city was designed to accommodate families from different income groups, but the main purpose was to house employees of a specific company.

The main spine of the city is an east-west pedestrian boulevard consisted of gardens, fountains and shaded areas. Diverse activities such as bakeries, schools and bazaars are built around this central boulevard to further encourage pedestrian

movement and activity along the boulevard. Narrow streets connecting residential neighbourhood are designed particularly for pedestrian use and to serve only few houses where people could stop and interact with their neighbours. In a similar way to urban structure of traditional Iranian cities, the internal part of city life were designed and developed for pedestrian movement and only limited automobile access was permitted at certain points leading to car parks.

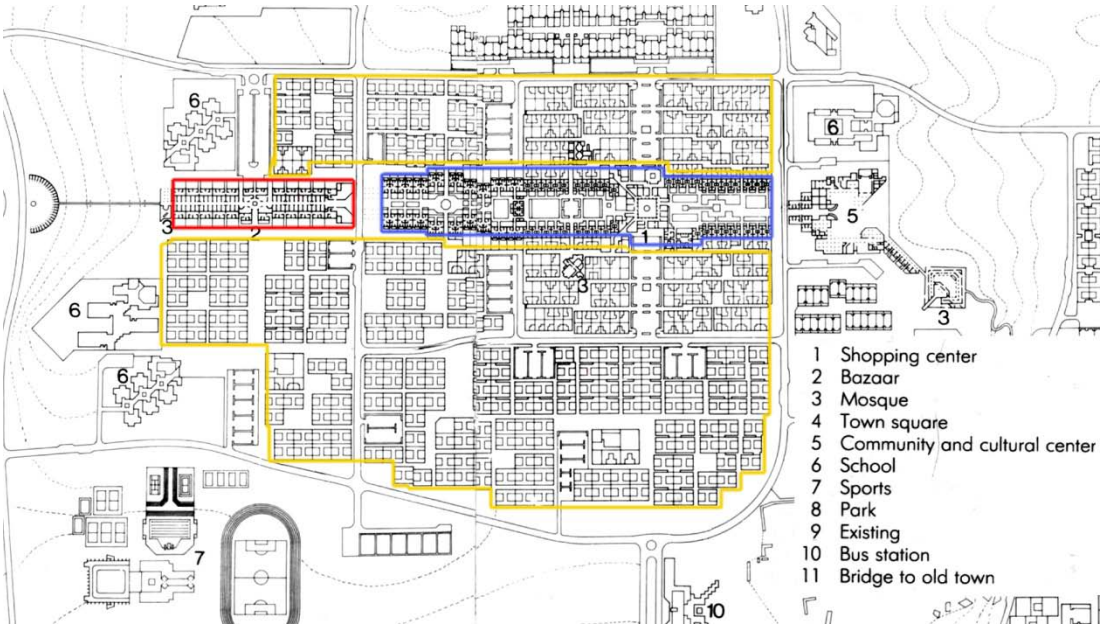


Fig. 3.32: Plan of Shushtar New Town city showing integrated retail and bazaar structure in blue and red with surrounding residential area highlighted in yellow. Other buildings such as schools, cultural centre and religious buildings were planned in close proximity to the town centre and residential areas (source: Diba 1981)

Housing units in Shushtar New Town were designed to contain two to three rooms. The internal rooms were designed with flexible functions to enable residents to use them for different activities throughout the year and not be restricted to a single function such as living room or bedroom. This adaptable and multifunctional use of space is very much related to seasonal migration pattern in traditional courtyard houses. All housing units were provided with a private garden inside the building (Diba 1981). Figure 3.32 show master plan of New Shushtar Town with a pedestrian boulevard and bazaar structure creating the town centre.

The planning concept of Shushtar New town reflects careful attention to climatic conditions and environmental solutions borrowed from traditional Iranian cities. Some of these solutions include:

- Dense urban fabric to increase shading provided by buildings

- Narrow and deep streets with insulating brick used for paving
- Street orientation in direction of prevailing breeze to increase cooling effect
- Use of surface water in public areas for cooling
- Courtyard houses with thick insulating walls and flat roof for evening sleep
- Use of local materials and available construction technology

Image 3.33 demonstrates early study sketches by the architect used for study of traditional architecture of Iranian cities and their environmental benefits such as solar shading, passive cooling and surface water evaporation in courtyard houses and narrow streets. Despite successful environmental considerations utilised in construction of Shushtar New town, the social aspects were not as successful as planned. Overcrowding in residential areas created problems with supply of water, electricity and drainage and lack of regular maintenance and cleaning of streets were apparent. These might have been caused due to top-down approach in construction and housing of people from various social groups. The first phase of the project started in 1976 and completed in 1978 but the political unrest in 1979 in Iran disrupted the projects and only another small part of the project was constructed between 1980 and 1985.

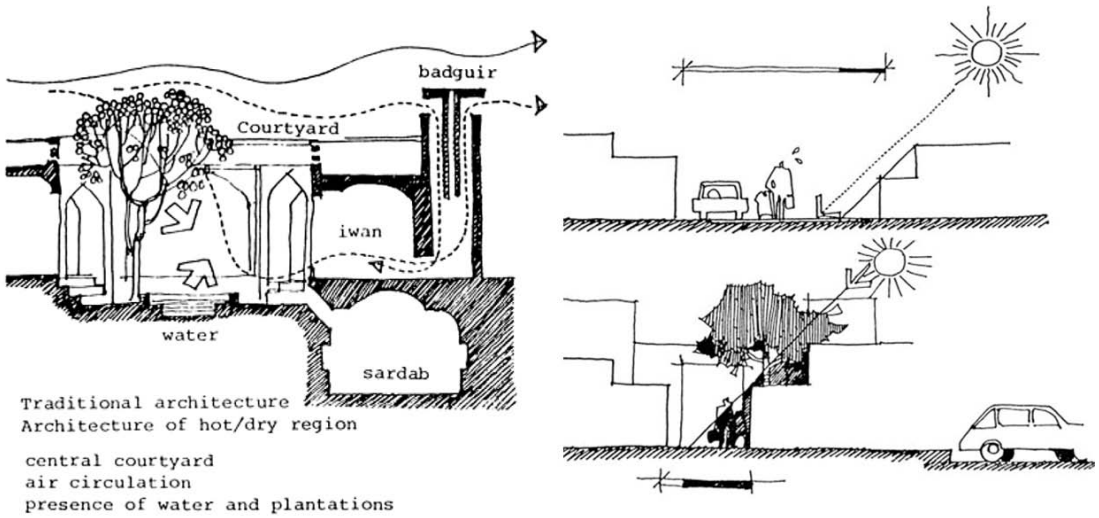


Fig. 3.33: Design sketches for Shushtar New town showing environmental advantages of traditional architecture in public and private areas (source: Diba 1981)

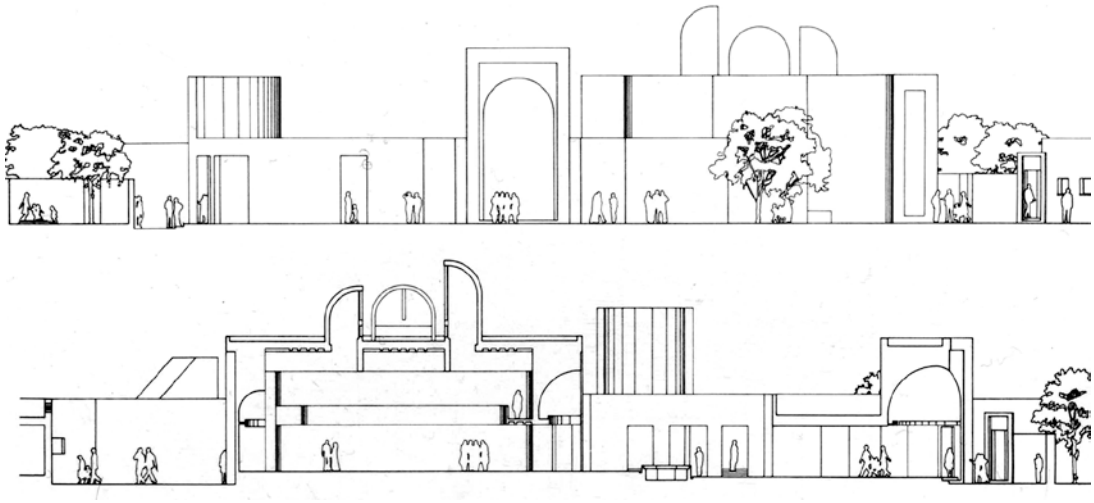


Fig. 3.34: Section drawing and street elevations of Shushtar New Town with recognisable elements of traditional Iranian architecture such as framed entrance, wind tower and domed roof (source: Diba 1981)

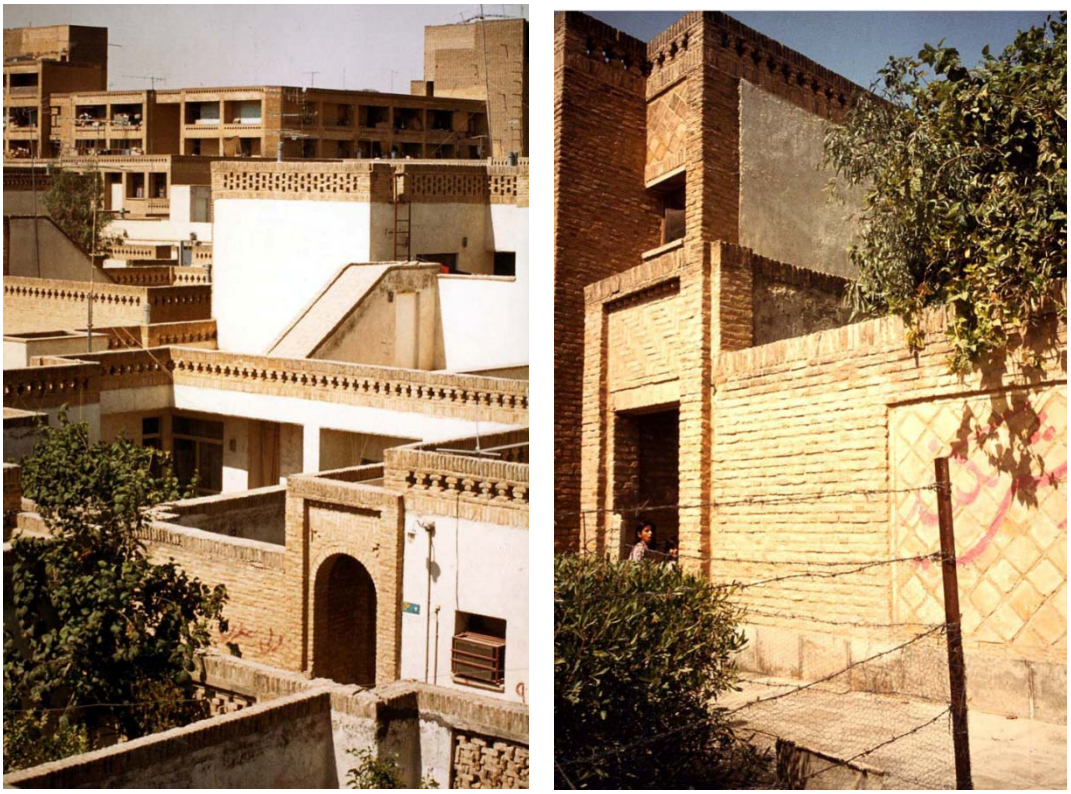


Fig. 3.35: Images of residential quarters in Shsuhtar New town showing dense building relationship, small courtyard gardens and local materials used in construction (source: AKDN 1986)

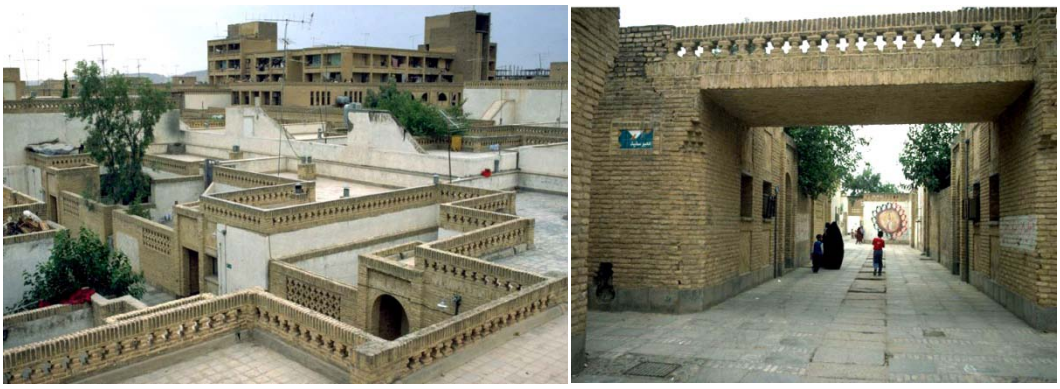


Fig. 3.36: Images of Shushtar New Town with narrow streets and roof level view of houses (source: AKDN 1986)

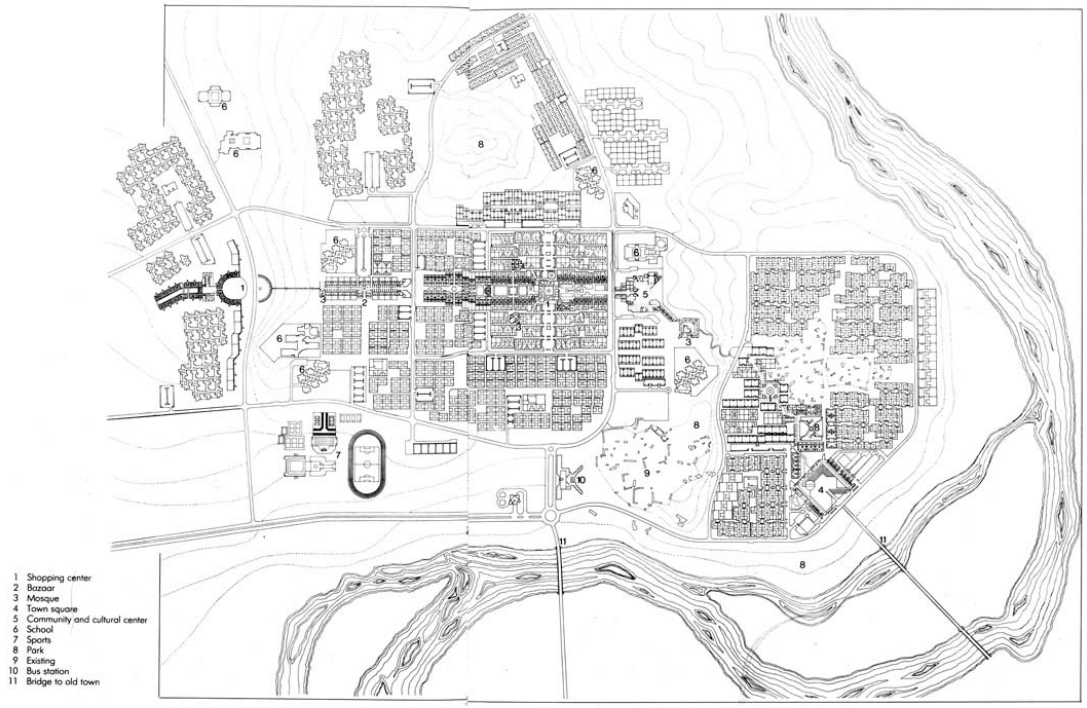


Fig. 3.37: Mater plan of Shushtar New Town city by Kamran Diba Architects (source: Diba 1981)

3.9 Conclusion

The recent discussions and attempts by designers and urban planners to understand and employ the environmental benefits of vernacular cities have been discussed in first part of chapter three. For long vernacular architecture around has been associated with the past, underdevelopment and not fit for modern life in contemporary cities. In rapidly developing modern cities with ever increasing number of people and increasing demand for public buildings, transport, health and leisure facilities, there was little space for traditional buildings and outdated old fabric of cities.

In recent years modern architecture and urban planning has been widely criticised for lacking sensitivity to local culture, climatic adaptation and historic relevance. On the other hand, growing environmental concerns about high energy use in cities and alarming levels of CO2 emission and climate change have challenged architects and city designers to seek alternative and improved ways of living in cities and to reduce dependence on polluting fossil fuels to build and manage human habitats around the world.

One well-known architect who opposed mainstream modern architecture and internationalism in his home country Egypt was Hassan Fathy. Fathy and his followers turned their attention to local materials and vernacular buildings techniques where they believed architecture and urban form were shaped in harmony with surrounding natural environment and cultural needs of inhabitants. Publications and exhibitions by other prominent researchers such as Bernard Rudofsky and Paul Oliver also led to wide interest and further explorations into construction knowledge behind vernacular buildings developed by communities around the world. Recent movements such as New Urbanism in North America proved to be very influential in turning planners and policy-makers attention from principles of modern planning to traditional qualities of human settlements.

Chapter three also demonstrated that how various solutions for adoptive comfort in vernacular built environment helped native people to adjust to their local climate. Common understanding of comfort in modern buildings is mostly defined as reaching and maintaining a constant indoor temperature throughout the year. Without much attention to outdoor temperature and climate, this constant temperature is maintained by mechanical heating and cooling and available energy resources such as natural gas or electricity. In absence of mechanical cooling and heating and lack of immediate energy resources, local communities devised multiple solutions to maintain comfort in vernacular built environment. Wide external walls to reduce heat exchange, migration from cooler parts of the house to sunny catching rooms during cold season, creating passive cooling and natural ventilation and reducing human activity throughout hot hours of the day constitute some of these effective solutions to create comfort levels.

This chapter has provided the evidence for organic growth of vernacular cities in Iran. In response to dry climate of Iranian Plateau, vernacular cities in most parts of Iran developed with a dense and compact pattern. In traditional societies construction skills and knowledge have expanded and evolved through centuries of

direct experience of building with local material and experience of living within natural environment. And in absence of modern universities and formal education, this knowledge was handed to the next generation, constantly changing and developing through time. Vernacular towns in Iran are associated with a compact pattern of buildings with introverted houses. Through time, traditional master builders called *me'mar* realized the efficiency of compact settlements in protection from excessive heat in summer and cold frosty winds in winter.

Climatic advantages of compact urban structure can be briefly listed as:

- Reduced solar gain in summer due to tightly built buildings and limited exposure of external envelope of buildings to direct sunlight
- Reduced heat loss from external walls and roof during cold season
- Reduction in water evaporation and humidity loss in a dry climate
- Protection of streets and urban spaces from direct contact with sunlight
- Protection of buildings and dwellers from hot and sandy winds in summer and cold winds in winter

In contrast to modern cities where street network has been developed to provide easy access for cars, vernacular cities have developed with access hierarchy from private residential neighbourhood to public areas. This hierarchy of access meant neighbours could enjoy peaceful and familiar local environment outside their houses where narrow alleyways or *kuche* lead to a fairly small square with local shops. Small-scale intimate passages created opportunities for people to meet and socialise. This would also create a safe and secure environment because of indirect observations by locals. *Gozer* and *raste* were built as wider passageways giving access to bazaar and other public parts of the city.

This chapter has provided evidence for the primary form of housing in vernacular Iranian cities. The courtyard house is an introverted building with a courtyard in centre and surrounding rooms in two, three or four sides of the courtyard. Due to its climatic advantages, the internal courtyard arrangement was also commonly used in public buildings such as schools, mosques and smaller caravanserais inside bazaar. The courtyard pattern could be repeatedly observed in various cities but shape and layout varies due to climatic differences. In a city with dry and cold climate like Tabriz in northwest of Iran, main living rooms are located in northern side of the courtyard to benefit from direct sunlight during extended cold season whereas in southern and central regions, large living rooms are located in southern side of the

courtyard to be protected from harsh summer sunlight. Plans and photographs presented in chapter three suggest the courtyards were built in geometric shapes mostly as a rectangular space. Larger family houses could accommodate two courtyards to provide private and semi private gardens with surrounding numerous rooms. Planted trees and flower beds inside the courtyard together with a shallow pool increased humidity and reduced direct sunlight penetration into living areas.

In order to expand on this subject and uncover evidence of environmental adaptation in vernacular cities, chapter three includes construction and urban solutions employed in response to environmental elements such as wind, water, solar heat gain and green spaces.

Acquired local knowledge through centuries informed local designers to consider three main factors in construction of houses, public buildings, urban streets and public squares. The three dominant factors are:

- Topography
- Solar orientation
- Wind direction

With comprehensive attention and understanding of these three aspects, traditional vernacular town in Iran were developed in three main orientations or *roon*s. *Roon Raste* or Straight Order, *Isfahan Roon* or Isfahan Order and *Kerman Roon* or Kerman Order, were common orientations used to build and expand cities in specific direction to benefit from favourable winds and cope with unwanted winds. The impact of unfavourable winds is very significant in central and southern parts of Iran where hot and sandy summer winds blown from the desert could bring outdoor life to a standstill. On the other hand, in mountainous regions where cities like Tabriz are located harsh cold winter winds are the main concern in orienting buildings, streets and larger open areas. Dense cities with uniform building height and smaller open urban spaces were effective solutions to direct the undesirable winds above the buildings and avoid unwanted turbulences at street level.

The evidence presented in chapter three as diagrams and photos shows extensive use of wind towers or *badgir* for passive ventilation in cities with hot and dry climate. In particular vernacular city of Yazd is famous for its numerous symbolic wind towers facing towards the pleasant cooling summer wind.

The importance of water in a country with hot and dry climate is undeniable and availability of water was most essential reason for sustenance and development of traditional cities in any part of the country. The study examines water distribution techniques used by locals in dry regions of the country to transport water via underground channels from mountain foothills to rural and urban areas and to irrigate fields and fruits gardens. Surface water in open channels inside gardens and along streets also helped to increase humidity and reduce temperature in immediate surroundings.

The section 3.6 in this chapter focuses on adaptation strategies in response to intense solar radiation in vernacular Iranian cities. Dense urban pattern protected external building surfaces and open squares from overheating during the day. Partially or fully covered streets are also noted as affective solutions to protect outdoor spaces from unwanted solar gain. This simple shading solution has been widely used in traditional bazaars where *raste bazaar* is generally covered by a connected structure of brick domes and flat timber roofs. In private dwellings open courtyard with living room arrangements around it, enabled inhabitants to make seasonal migration from warmer sun-catching parts of the building to cooler shadowed side of the courtyard.

The evidence provided in section 3.7 illustrates the cooling effect of green spaces in urban areas. The impact of green spaces in vernacular built environment is critical both in small and large urban scale. Developed from smaller towns surrounded by fields, vernacular cities managed to maintain their connection with natural environment throughout centuries. Maps and photos presented in this part of the study demonstrate presence of local trees in public and private spaces. Tree-lined passages created a micro climate with lower temperature. An inseparable part of traditional courtyard house is the green courtyard with planted fruit trees, vegetation and flower beds. This moderate green space inside each building moderated indoor temperatures of surrounding rooms and provided dwellers with a sense of connection to natural environment. Close observation reveal that dense pattern of a vernacular city is a amalgamation of numerous courtyard buildings in various sizes and the overall area covered by green courtyards amounts to some 30% of occupied area by the entire city. This is a large proportion of the city which has been lost by extensive and poorly planned developments in modern Iranian cities.

Chapter 4: Summary and conclusions

4.1 Summary

The principle aim of the study is to explore the potential of vernacular Iranian cities and their development to help us understand sustainable ways of building and living in contemporary cities in better harmony with the natural environment. In this way, different aspects of individual buildings and urban neighbourhoods have been analysed to better comprehend their architectural response to climatic conditions through centuries of evolution and formal development.

Walking through different parts of historic cities in Iran, one is struck by immense differences between the old parts of the city and newly developed modern districts. Although the historic parts look unplanned and disorganised at first sight, but these tightly connected buildings set in a dense urban fabric have expanded gradually and organically through time. In many traditional Iranian cities the bazaar complex established itself as the main core of the city and public buildings and residential districts built in close proximity to bazaar, enabled locals and visitors to walk freely from one place to another. In contrast to urban morphology of traditional cities, the modern districts developed mainly during the twentieth century have been conceived around network of wide roads with great dependence on private cars for urban transport. Wide boulevards have been built with apartment blocks or high-rise commercial buildings on both sides. Although this new modern features of cities are perceived by some as signs of progress and advancement, but underlying issues of environmental pollutions, increasing dependency on fossil fuels, congested roads, excessive energy use in buildings, have become more obvious to city dweller including city planners and architects.

Traditional cities in general are not immediately associated with successful and sustainable built environment. They are much more appreciated for their historical significance and great skills and craftsmanship of builders but social and environmental aspects of these cities have hardly been debated or investigated. The admiration of traditional built environment in Iran is currently limited to preservation of individual buildings dotted around the old town and conversion of these building into museums and cultural centres.

4.2 Aims and objectives

By revealing the practical solutions behind climatic adaptation of vernacular cities, the study aims to make relevant references to urban design challenges and strategies in contemporary cities as well as raising awareness about the significance of urban development of traditional built environment and its relevance to urban life in contemporary cities. The research question presented in chapter one concentrates mainly on what could be learned from vernacular cities in terms of environmental adaptation and how traditional cities managed to sustain and flourish under severe climatic conditions imposed on them.

4.3 Research question

The present research argues that vernacular Iranian cities can be examined as environmentally sustainable human habitats and in order to understand design principles of vernacular built environment, the study seeks to answer the following question:

- What could be learned from environmental awareness and climatic adaptations in vernacular cities

In absence of modern heating and cooling technologies and abundant energy resources, vernacular Iranian cities in similar manner to many other cultures around the world evolved and adapted to their local climate. The intelligence behind construction of habitable buildings and vibrant cities suitable has developed through centuries and passed on from one generation to another.

4.4 Summary of findings and results

Focused mainly on vernacular Iranian cities, the study directs readers' attention to two cities of Tabriz and Shiraz. Located on the Silk Road these two historic cities have developed from small market towns into large cities where commercial, cultural and political activities are concentrated. However, Tabriz is located in the northwest of Iran with dry and cold climate whereas Shiraz is located in southwest of the country with hot and dry climate. The distribution pattern of traditional Iranian cities has been influenced largely by availability of water, suitable topographic conditions for agriculture and trade routes. Construction and maintenance of city walls and gates for defence reasons are immediately recognisable in historic maps of both cities. The urban structure of the old town is mainly consisted of bazaar as a linear

street with shops on both sides stretching from one city gate to another. Public buildings such as bathhouses, caravanserais together with residential districts expanded around the bazaar structure.

Second chapter attempts to provide historic evidence for organic expansion of traditional cities. Large neighbourhood districts or *mahalle* developed independently but also in close connection to bazaar and public buildings. Tightly-built introvert courtyard houses shared their external walls with neighbours from all side except the entrance from street. These buildings populated residential districts where narrow and twisting passageways were built for climatic and defence reasons. Central hub for each neighbourhood is called *markaz-e mahalle* where public buildings such as a bathhouse, mosque, grocery shops and a bakery were collected to serve local residents. In traditional Iranian cities, people from similar ethnic and religious background would live in one neighbourhood. This homogenous background created a strong sense of place and identity for people but it would also be in conflict with a sense of diversity and social equality in contemporary cities.

Due to its numerous environmental advantages, courtyard layout was also used in larger public buildings. Caravanserai buildings inside bazaar structure, religious schools or *madrase* and larger mosques also contained a central courtyard with functioning rooms organised around it. Similar patterns of compact urban forms and courtyard layout can be observed in both traditional cities of Tabriz and Shiraz with a vibrant permanent bazaar at the heart of the city. However, in Tabriz with its dry and cold climate, private dwellings and public building were constructed with smaller indoor spaces which were easier to heat in winter.

Fundamental changes to Iranian cities and their urban structure initiated during the late 19th century and accelerated during the 20th century. The transition from a traditional agricultural society into a modern and industrial society, population rise, migration to cities and construction of European style network of roads to ease traffic for imported cars challenged the relevance and usability of traditional cities. The street widening act of 1933 were applied to many cities throughout Iran with minimum attention to historic fabric of cities. In large cities such as Tabriz, the main bazaar structure was partially demolished to create space for modern buildings in city centre and also make way for new wide boulevards to access these buildings. In particular, grid pattern of street network were adopted in newly developed parts of cities, creating extrovert buildings facing the street. Some examples of this sharp

contrast between old and new, organic versus planned city have been presented in this chapter with aerial images and maps.

In order to be able to make a reasonable connection between environmental benefits of vernacular cities and current understanding of environmentally sustainable cities, chapter two contains a very brief review of environmental features of successful contemporary cities such as liveable city environment, urban density, car-free cities and potential and problems of urban life in twenty first century.

Chapter three contains main findings of this research in connection with vernacular built environment and its response to local climate. Early research into vernacular architecture was initiated by researchers such as Bernard Rudofsky and Paul Oliver. Egyptian architect Hassan Fathy was an influential figure in directing researchers' attention to vernacular Egyptian architecture in contrast to global style of modern architecture in his home country and abroad. Inspired by traditional Egyptian architecture, Fathy designed few projects which one of them was a compact rural settlement for New Baris in Egypt. Influenced by writings of Jane Jacobs and her criticism of modern urban planning in American cities, New Urbanisms was widely recognised in North America and proved to be influential in directing urban planners and policy makers' attention to historic patterns of cities, urban density, mixed-used neighbourhoods, investment in urban transport and reduction in private care ownership.

An introduction to formal development and climatic adaptation of vernacular Iranian cities has been presented in first part of chapter three followed by four separate sections dedicated to most dominant environmental factors in formation and development of traditional built environment in Iran. Due to their importance and significant impact on urban shapes of cities, these four environmental elements have been selected to include wind, water, solar gain and green spaces.

The first part examines the impact of local wind in urban environment. The orientation of streets and large open areas in traditional cities has been mostly defined by topographic condition and direction of favourable winds. Homogenous building heights and dense structure of vernacular cities protected narrow streets and open areas from direct contact with hot and sandy winds. This pattern was also recognised and used in dry and cold climate to protect buildings, urban areas and city dwellers from frosty cold winds during lengthy cold seasons. Functional analysis of winds towers and their orientation towards pleasant winds in hot and dry regions of Iran was demonstrated through diagrams and photos in chapter three. This

analysis reveals a good understanding of passive cooling and its impact on indoor comfort levels and building structure by vernacular builders.

The second environmental element discussed in chapter three is water and its function in cities. The study reiterates the fact that human settlements in Iranian plateau sustained and developed in areas where water was available. Many cities developed in foothill of mountains where water was directed through a network of connected wells called *qanat*s into towns and surrounding fields. The extended underground water network supplied water to public buildings, water cisterns and larger houses and irrigated agricultural fields and fruit gardens. Surface water appeared in open channels along streets and shallow pools inside courtyards, increased humidity and created a pleasant micro climate in their immediate environment.

The third environmental element analysed in this study is the absorbed heat from the sun. In absence of electricity and mechanical cooling devices, traditional designer devised various solutions to minimise heat gain during summer and still benefit from solar heat in winter. Large thermal mass of external walls and double skin roof structure reduced heat exchange between indoor and outdoor spaces. Brick was a common building material and it was widely used in private and public buildings. Due to its effective structural solution to cover large spans, brick domes were constructed to cover living rooms in houses and linear bazaar structure. From an environmental point of view, hemispherical shape of brick dome also enabled external surface of the roof to be partially protected from direct exposure for most of the day. Floor plans of typical houses presented in the study from different cities illustrate how courtyard patterns evolved according to local climate. In Tabriz due to dry and cold climate south facing rooms take priority and are used as main living areas with larger sash windows and elaborate details. In contrast in hot and dry climate, larger rooms and main living areas are located in cooler north facing side of the courtyard to avoid excessive heat in summer. Solar adaptation in vernacular Iranian architecture is more evident in larger urban scale. Densely built buildings are connected with twisting narrow streets where travellers are protected from direct sunlight. Planted deciduous trees inside courtyards, streets and urban squares, act as shadow umbrellas to cover people and external surfaces in hot summer days. Presented maps and photographs from Tabriz and Shiraz reveal that the extended bazaar structure at the heart of the city is mostly covered by brick domes or flat timber roofs. The linear stretches of bazaar called *raste* are covered by a series of connected brick domes to provide a semi-open space for visitors and shop owners.

These covered streets remain few degrees cooler than outside in summer due to continues shading and also remain warmer in winter because of protection from cold wind and human activities inside bazaar. Due to climatic stress, large open squares and wide streets are not common inside compact fabric of old cities.

The last and fourth section of chapter three demonstrates integration and effect of green spaces in vernacular cities. Green courtyards inside buildings contained fruit trees, plants and flower beds accompanied by a shallow pool in centre. These small gardens increased humidity and moderated temperatures for surrounding living rooms and semi-open balconies. Taller deciduous trees reduced penetration of sunlight inside the courtyard space and living rooms. Underground water distribution network or *kariz* in traditional Iranian cities provided water for gardens, bathhouses, water cisterns and larger houses. Figure 3.29 in chapter three demonstrates urban areas covered by green courtyards and gardens in a dense city. This area would constitute about 30% of land covered by the entire city, a proportion which is hardly imaginable in any modern Iranian city.

4.5 Answer to research questions

Urban analysis of traditional Iranian cities has been presented in this study to demonstrate examples of climatic adaptation in vernacular built environment. The study also highlights the significant changes occurred during the twentieth century and how rapid urban development and urban policies in favour of generic modernisation established a different approach to what was learned and practiced in vernacular cities over centuries.

The main solutions in climatic adaptation in Iranian vernacular cities can be listed as of followings:

- Dense urban structure with narrow streets and shared external walls between buildings to reduce heat exchange through external envelope
- Construction of dense urban fabric with uniform buildings in height to protect buildings, streets and public areas from hot and sandy winds in summer and cold winds in winter
- Compact urban pattern with small-scale open areas with partially or fully covered public areas to increase shadow-casting and reduce direct exposure to sunlight

- Appropriate urban orientation and use of ventilation structures such as wind catchers according to favourable local winds to increase passive cooling on streets and inside buildings
- Urban development according to topographic conditions and right orientation of buildings to benefit from solar gain during winter and to avoid excessive heating in summer
- Flexible use of living areas in residential buildings and migratory approach to occupy appropriate part of the building according to season
- Extensive use of shaded balconies in private buildings and public space to create shaded walkway and protect external walls and windows from direct sunlight in summer
- Use of surface water on street levels and inside courtyards to increase humidity and provide comfort
- Wide application of locally available materials such as wood, straw, stone and earth in construction of buildings and public realm
- Significant impact of green areas in supporting a pleasant microclimate inside buildings and urban areas due to shadow-casting and rise of humidity from trees and plants

The findings of this study do not suggest that traditional built environment offers a complete solution for urban planning and sustainable living in contemporary cities. For instance planning of low density urban pattern of two or three storey courtyard buildings would be an inefficient use of land in a populous city, however, right orientation of apartment blocks according to solar pattern and effective use of green spaces in close proximity to buildings are important design principles which can be learned from courtyard houses to increase comfort levels inside houses and reduce energy demand for heating and cooling. Another important lesson from vernacular cities is comfortable urban spaces shaped for people where social interactions between neighbours are encouraged. Planning and promotion of bustling neighbourhoods and climatically comfortable public realm is closely associated with decline in demand for large air-conditioned shopping centres.

Compact and diverse nature of vernacular city has encouraged people to explore the city on foot and manage their daily travels within short distances. It is no surprise to see remaining old parts of historic cities such as Tabriz and Shiraz have become more popular with residents and visitors in comparison to recently constructed large developments. The study supports the fact that local knowledge of building houses

and neighbourhoods in vernacular cities should not be disregarded but, on the contrary, be celebrated and encouraged in contemporary cities. Rigorous attention to local climate, correct orientation of buildings and streets, use of appropriate local material, diversity and accessibility of public places and relevant use of green spaces are vernacular approaches which will benefit everyone to create sustainable liveable cities and immensely reduce the negative impact of modern cities on natural environment.

4.6 Limitations of research

Due to multidisciplinary nature of urban studies, historic and environmental research of buildings and urban districts, requires a comprehensive approach and a mix of research methods, however, to make this study feasible for MPhil degree, the main focus of the study was to observe and uncover the environmental adaptations and architectural response to climatic conditions in vernacular Iranian cities. Therefore other dimensions of urban sustainability such as economical, social and cultural aspects have not been examined in context of traditional built environment.

One of the main challenges faced during this research was the lack of historic maps and detailed layout of cities. The study aimed to review and analyse city maps to uncover urban development from the early 16th century to present day, but it proved to be very difficult and time-consuming to find and access archived material of detailed historic maps earlier than the 18th century. It has proved to be very difficult to access historic map of Iranian cities from online resources.

Another major challenge for the author was work commitment in the UK during the life of the study. In particular, full-time work commitment made it difficult to plan multiple trips to Iran and visit national libraries and heritage institutes in Tabriz, Tehran and Shiraz in order to access archive materials which have not yet been made available online for researcher and general public.

The approach adopted in this study was mainly based on qualitative research from available literature, drawings and images and direct on-site observations by the author. A comprehensive approach was used to study several environmental elements and their impact on vernacular cities. This inclusive approach had its limitations such as the lack of detailed quantitative research into each element in urban scale. Due to defined scope and dedicated time for this project, the study presents a wide approach to understanding of climatic adaptation in vernacular

Iranian cities, however further in-depth research is required into each environmental element to quantify efficiency of various design methods used in traditional cities.

4.7 Further study in the future on this subject

The present research is a first step and a brief introduction into vast realm of climatic sustainability learned from traditional built environment. Further in-depth research could reveal the appropriateness of vernacular climatic solutions in large populous contemporary cities. Energy demand for buildings, urban transport and infrastructure in present day is vastly different from pre-industrial traditional cities but essential human needs for safety, comfort and harmonious living conditions have remained relatively unchanged.

The findings of this research can be expanded to specifically measure and analyse data for environmental elements such as wind, water, solar radiation in traditional buildings, urban squares and street levels. Data collected from smaller building scale to larger neighbourhood districts can be compared to present-day urban districts in cities to reveal similarities and contrast in various aspects such as comfort levels, energy savings and reduction in air pollutants.

The current study aimed to explore cities in two climatic regions in Iran categorised as hot and dry region and cold and dry region. This subject could be further studied in other climatic regions such as hot and humid to identify the impact of climatic conditions on vernacular built environment.

There is also a great potential to conduct research on other dimensions of urban sustainability such as social, economic and cultural aspects in context of vernacular cities. Social isolation, loss of privacy, widening gap between rich and poor, rapid urban transformation and identity crisis constitute only few of challenges in modern Iranian cities. These topics can be further investigated for comparative and analytical research into vernacular built environment and their relevance to urban life in contemporary cities.

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