FROM HERITAGE TO SUSTAINABLE DESIGN

Focus on Traditional Neighborhood Design in Iran

Analyzes and Recommendations for Sustainable Design
In Hot and Arid Region
Case Study: Traditional and Contemporary Neighborhood Design in Yazd, Iran

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ABSTRACT:

In spite of the western countries, sustainability is a new phenomenon in Iran. In recent years architects in this country have begun to pay attention to this issue, but due to lack of sufficient research background in this area, usually the criteria and solutions of the western countries in sustainability are followed by Iranian architects and designers.

Generally adaption of western patterns and styles of architecture and urban design has been a usual trend in contemporary era in Iran as a developing country. This western effect on architectural organization, forms, plans and details of the projects is clearly visible.

The significant problem in terms of sustainability, resulting from following western patterns and rules in Iran appears here. Since many sustainability features belong to the local environment and climatic conditions as well as social and cultural conditions of each region, these important features are therefore missed in these imitations. It is substantial to define local and regional criteria for sustainability in city planning and architectural scale for each region by considering specific local environmental and socio-cultural characteristics.

On the other hand, vernacular architecture and urbanism in regions with old history and civilization have several features that could survive over centuries. These features and patterns can be considered as some local sustainability factors and maybe they can be applied as some useful criteria for defining sustainability rules for contemporary architecture in the region.

This research aims to show that definition of local criteria of sustainability is possible by using the historical features and patterns of architecture and neighborhood design, however does not claim to define an efficient rating system of sustainability for one country, while this is a quite extensive work that can be achieved through national cooperation of different researchers.

Similarly sustainability is a wide concept including social, economic and environmental aspects. Due to the author's field of study, this research focuses on the environmental aspects of sustainability. So this research tries to show there are some potentials in vernacular architecture that can conduct to features and patterns of environmental sustainability.

For this purpose this research tries to know and analyze those mentioned features in one of the oldest civilizations: the hot arid region of Iran. So the first aim of this research is to find out the sustainability features of Iranian historical urban design in the past and the

second aim is to show those features and solutions can be adapted to the modern life and be used as patterns of sustainability for the contemporary life in this region.

Therefor some of the most important environmental features of the historical cities in Iran are specified. The city of Yazd as one of the most important cities in hot and arid zone of Iran is selected as the case study. Seven districts of Yazd are selected and analyzed in contribution to environmental sustainability features.

In order to perform the research in a more scientific way, the case studies and their features have been tried to be evaluated by considering the criteria of an existing evaluation system for sustainability. According to lack of such sustainability evaluation system in Iran, LEED[1] rating system- as one of the most worldwide well-known systems that was originally established in the United States to evaluate sustainability- is selected due to the most climatic similarities between Iran and some parts of USA.

It is obvious that all of the items of LEED can't be used for evaluation of Iranian case studies and they should be adapted to special condition of Iran. This research tries to make a combination of LEED items and some local items defined by author to define the baselines for evaluation.

For better understanding of the degree of sustainability in the historical case studies, some contemporary districts are selected as well, and evaluated to be compared with the historical results. So the analyzes were made on both historical and contemporary districts of Yazd to know which part of the city is more sustainable.

By evaluating both parts of the city the results will show if the historical parts of the city are more sustainable or not. If the historical districts are more sustainable, do their features have the potential to be adapted to the contemporary city?

Results reveal that the historical parts of the city are in most features more sustainable than the contemporary parts.

Then this research tries to apply and adapt some of those sustainable features for the contemporary city design in Yazd in form of some general recommendations.

This is an empirical research and it is made by both qualitative and quantitative methods, using an inductive approach.

Keywords

Historical architecture and urban design, Sustainability, Evaluation, Contemporary life

[1] Leadership in Energy and Environmental Design

CHAPTER 1: DESCRIPTION OF THE RESEARCH PROBLEM

1.1 Iran

Iran is a large country with an area of 1,648,195 km² located in the Middle East. According to the most recent Iranian National Census in 2012, more than 75 Million people live in urban and rural regions inside the borders of Iran (SCI 2012).

Figure 1: Iran's location comparison to Austria, drawn by Afsaneh Soltani, on basis of **(Google Maps 2015)**

As one of the oldest countries in the world, Iran has been home to civilizations with ancient roots (Elke Pahl-Weber 2013, 110).

Archaeological excavations have revealed remaining of the pre-history period in Iran as old as Paleolithic era; such as primary tools and weapons in Bakhtiari Mountains in southeastern Iran and rock paintings in Lorestan area dating back to 15000 BC.

Various findings dating back to Mesolithic and Neolithic periods also confirm the agricultural and livestock-dependent living of the people in Iran during the following (Mesolithic and Neolithic) pre-history periods (Marzban 2007, 26)

Tappe Zagheh is one of the first agricultural settlements in Iran (Malekshahmirzadi 1993) constituting of important properties belonging to late 8th to mid-6th millennium BC. The residential units in this village follow specific patterns that are in harmony with the climatic characteristics of the area, such as the rural fabric's orientation for preventing the hot desert winds, and adaption of local building material like rammed earth or adobe (Pirnia and Memarian 2008, 41).

During the late 4th millennium BC, the Elamite Empire was founded in Southeastern Iran who possessed a perfect civilization (Marzban 2007, 27). The Elamite Empire succeeded to achieve a high position in culture and history of the near East that lasted for more than two thousand years (Hintz 1992). They adapted Susa as their capital city and established all the required urban elements such as governmental citadel as well as the Choghazanbil ziggurat temple, built with adobe and covered with burnt bricks. Their architectural remainings in Haft Tappeh in Khuzestan, Iran is an evidence of their advanced knowledge of building techniques, with rectangular plans and vaulted roofs. (Pirnia and Memarian 2008, 44)

Later, the original Iranian empire, the Achaemenid (550-330 BC) became the largest empire in the world (Elke Pahl-Weber 2013, 110) that ruled over extensive territories from India and central Asia to North Africa, Balkan and Greece peninsula (Safa 1977).

At present, Iran is bordered by Iraq and Turkey to the west; by Armenia, Azerbaijan and Turkmenistan to the north; and by Afghanistan and Pakistan to the east. Iran's southern border is a coastline of 2,440 km on the Persian Gulf and the sea of Oman. A part of Iran's northern border is also coast, with 740 km along the Caspian Sea (Sabetghadam 2006).

Figure 2: Iran borders, provinces and neighbors, drawn by Afsaneh Soltani, on basis of **(Google Maps 2015)**

1.1.1 Iran's Climatic condition:

The Iranian plateau is located in an arid region of the world (Ghobadian 1994, 34) (Figure 3). A large part of this great plateau encompasses the present country of Iran, an immense area covering 1,648,195 square kilometers with a variety of climates.

Mountains from the north, east, south, and west surround the central Iranian plateau. With an area of about 320,000 km², the central Iranian plateau includes the Lout and Salt deserts (Badi'ee 1998).

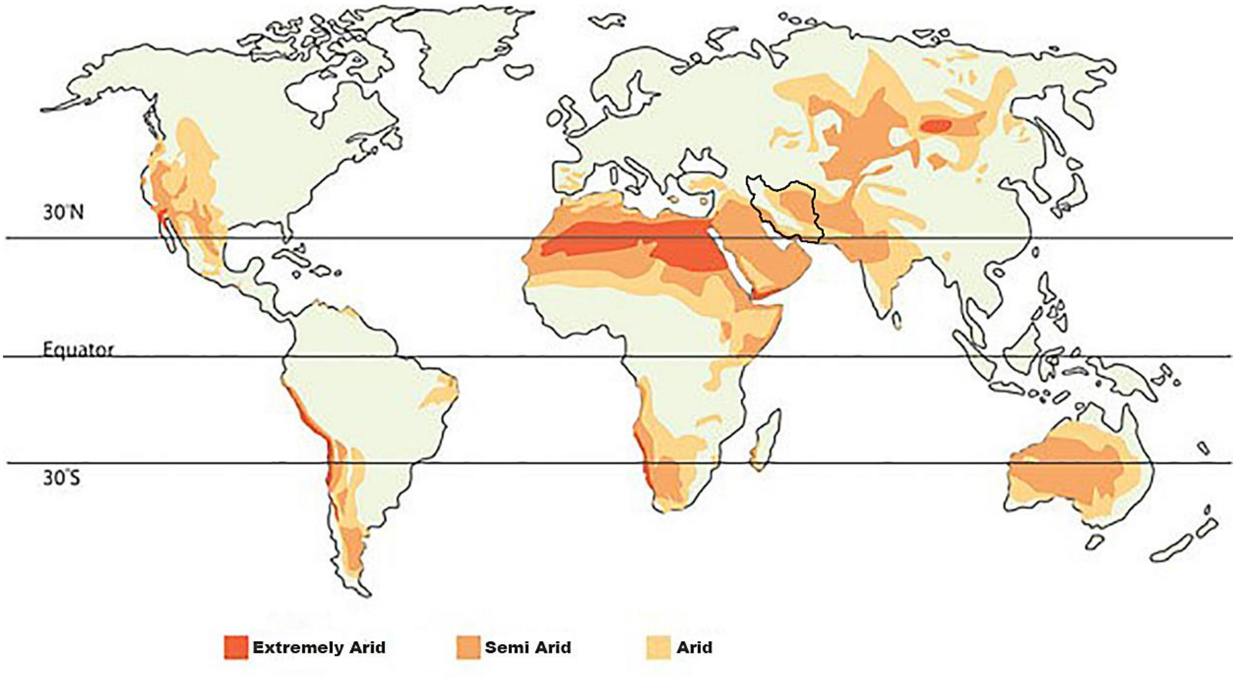


Figure 3: Distribution of arid land and location of Iran. Image from: **(Nature 2011)**

Iran has a great geographic variety's from the Kavir desert to the Zagros Mountains in Western Iran or the Alborz mountain range with the 5,671 meter Damavand peak (Elke Pahl-Weber 2013, 110).

Some 65% of Iran's territory is arid or hyper arid, and approximately 85% has an arid, semi-arid or hyper arid environment. Like many of the neighboring countries in the region, a large area of the country is covered by desert areas with severe climatic conditions (Badripour 2004)

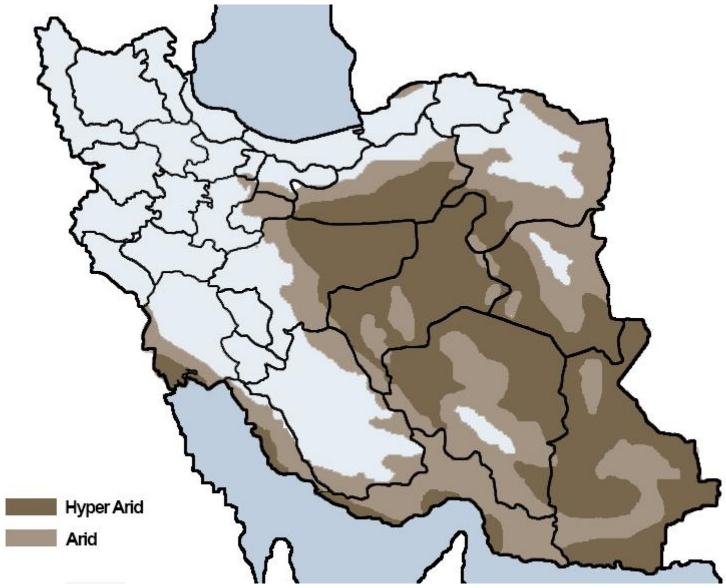


Figure 4: Distribution of arid and hyper arid areas of Iran, drawn by Afsaneh Soltani on basis of **(FAO 2015)**

Also in its climatic classification for Iran, FAO profiles (Badripour 2004) define the Irano-Turanian zone as the largest climatic zone in Iran that covers approximately 90% of the country. This climatic zone includes the most arid part of the central Iranian plateau, the Subdesertic zone, with annual precipitation below 100 mm, average temperature in January between 4 ºC (north) and 10 ºC (south) and the average temperature in July being between 29 and 34 ºC, containing the towns of Yazd, Bam and Zabol.

The towns in this zone have at least three summer months of total drought extending up to nine months in the most arid regions. Relative humidity in winter between 80% and 55% (central desert) falling in summer to below 40% and down to 20%.

These severe climatic conditions create a real challenge for the inhabitants of this sub-desert zone. Due to the constrained natural resources in this area, achieving the comfort conditions for living in houses requires specific strategies adapted by house designers. (ibid)

1.1.2 Architectural Trends in Iranian cities

As Ehlers and Floor describe: "Before 1920, the Iranian cities were characterized by features that are considered to be typical for the "traditional" city. In the traditional world, every element, from architectural scale to the whole city, was made on the basis of local patterns that involve cultural, social and environmental aspects of vernacular architecture and urbanism" (Ehlers and Floor, Urban Change in Iran 1993, 251). These traditional cities have survived over centuries by considering local and environmental criteria.

After 1920, this continued process was ended with the modernization of the country. As researchers describe, the reforms that initiated during the 1930's changed not only the cultural patterns of urban life in Iran and the economic structure of the country, but even the spatial organization of the cities (ibid). Darab Diba, an Iranian architect, believes that "after this period, architecture [in Iran] was modernized in a new way: socio-political planning under the authoritative rule of government with the aid of westerners." (D. e. Diba 2004)

Modern Iranian architects and city planners largely imitated and imported western patterns and styles in both urban planning and architectural scale projects. They rarely attempted for localizing them. This trend is still in progress.

1.1.3 Sustainability Approach in Iran and the Neighboring Countries

Sustainability as a whole in Iran has recently become the center of debate and discussion. Even here, the designers rely on sustainability criteria defined by developed countries. In this regard, the evaluation systems of western countries are followed without consideration of local and vernacular features of environmental sustainability.

In a general view, the image of sustainable building in Middle Eastern countries like Iran, that have recently begun to consider sustainability, is a smart city in the heart of the desert, or high-tech constructions that have low energy requirements or zero carbon distribution, with attached green spaces on the facades or roofs, bearing equipment to provide the building with renewable energy (Figure 5).

Figure 5: Bahrain trade tower. Image from: **(Flickr 2014)**

These are the typical buildings or cities that have been constructed by neighboring countries, spending large amounts of resources to build them. These buildings are mostly considered as examples of sustainable buildings for architects in the region. This confirms how often the term sustainability is misunderstood or misused, specifically in oil based countries like Iran, who believe that they are able to spend large amounts of cheap fossil fuel energies to build high-tech or smart buildings. Although these buildings may low energy consumption after usage, but they consume huge amounts of energy and resources during construction process, that results in resource depletion and environmental pollutions.

1.1.4 Iranian authorities for architectural urban design regulations

There are several organizations and authorities in Iran[2] whose duty is to prepare instructions for urban planning and construction, institute design regulations, and control and supervise building constructions in Iran. One such authority is *The Ministry of Roads and Urban Development.*

One of the duties of The Ministry of Roads and Urban Development (BHRC 2013) is the codification of *National Building Code* (MRUD 2010).

Volume 19 of these codes discusses energy saving in buildings (Ahmadi et al. 2009) and offers some practical instructions for reduction of energy exchange and therefore reduction of energy consumption in different types of building functions by application of insulation panels on the building envelope. The suggested solutions and details in this booklet are largely duplicated from developed countries' building codes that can be implemented with existing technologies in Iran.

Other organizations, such as Renewable Energy Organization of Iran, have also made some surveys on renewable and passive energies such as wind and solar power (SANA 1995), but research is still in its primary stages and is usually replicated from western research and experience.

1.1.5 Lack of National Sustainability Evaluation Tool in Iran

Despite the recent efforts of authorities and private organizations in Iran to develop resource and environmental policies, the building construction sector still suffers from the lack of a comprehensive national system for the standardization and assessment of sustainability.

[2] Iran Construction Engineering Organization, Municipality, Iranian Fuel Conservation Organization, Iran Energy Efficiency Organization, Renewable Energy Organization of Iran

This leads engineers and authorities to implement the rules and regulations used by developed countries.

According to Figure 6, international rating systems for sustainability, such as LEED and BREEAM, are used in many countries around the world. This map shows that Iran follows the LEED system.

Figure 6: rating systems for sustainability around the world. Image from: **(Annie R. Pearce 2012, 152)**

Although these assessment systems claim that they are applicable on the international scale, one of the main objectives of sustainability is the utilization and consideration of local natural resources and settings, and this requires each region with its different climatic, environmental, social, and economic characteristics to implement its own rating system.

1.1.6 Existing Challenges of Sustainability Debate in Iran

Two major challenges become apparent while discussing sustainable design in Iran:

The first is the lack of a national sustainability rating system that considers the existing local and vernacular potentials in Iran's traditional architecture and historical cities.

The second is the scale of research conducted on sustainability in Iran. A review of previous research on sustainability in Iran reveals that there are two major categories of research:

a. General descriptions of the benefits of historical architecture that include a large emphasis on aesthetic features and general descriptions of environment-adaptive features of Iranian traditional architecture and cities. These surveys are too general, without sufficient empirical analysis. The following description is an example of such Iranian researchers' attitude toward sustainable features of Iranian architecture. It is more akin to a beautiful poem than an architectural analysis:

> *"The traditional city is very similar to a cactus in a desert. It has a very hard skin and is completely closed. Consequently, people spend their lives inside this skin. All spaces are well protected against dusty winds and they are shaped to use cool wind in the summer and sun in the winter. The urban fabric is dense. Alleys with tall walls and a zigzagging form do not let the wind blow easily…"* (Ahmadkhani Maleki 2011)

b. Detailed analysis of the small case studies, including measurement of energy performance of one or more historical buildings by architectural simulation tools and assessing them using western evaluation systems (Figure 7).

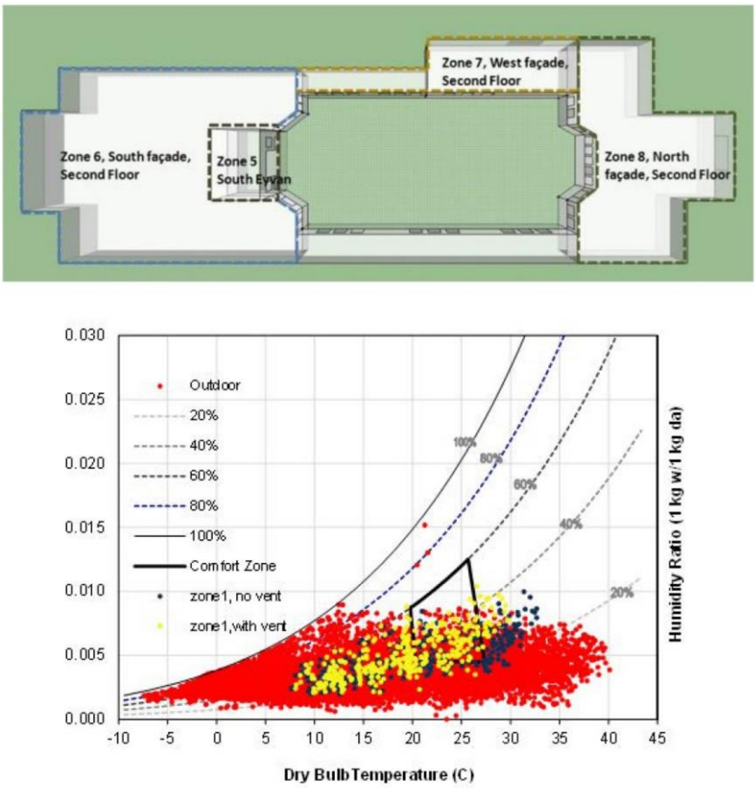


Figure 7: Simulation of Brojerdi-ha house in kashan and its thermal results. Image from: **(IBPSA 2015)**

After this brief discussion, it is observed that practical studies are missing between the two previously mentioned scales of research. Studies are either too wide and general or too focused and restrictive.

Research between these two scales is required in order to implement general and detailed studies by identifying structures and criteria that can be helpful in specific, practical projects.

1.1.7 Summary of the Research problem(s)

After the previous discussions, the following research problems are set as the main focuses of this dissertation:

1. The severe conditions of the subdesertic areas in Iran require adaption of specific strategies for creation of comfort conditions for the inhabitants, without depletion of the rare resources in the region.
2. Since the 1920s dramatic changes in Iran, contemporary city design uses western patterns of design and construction methods for buildings without adaption of these patterns with the local climatic conditions.
3. The sustainability approach in cities is a new debate in the oil-dependent countries like Iran and other neighboring countries. The term sustainability is majorly misused for high-tech, low-energy dependent buildings that consume large quantities of resources in their construction phase.
4. Contemporary authorities in Iran do not offer any specific rules for contemporary city design in contribution to environmentally friendly urbanism.

1.2 Research Field

This dissertation focuses on neighborhood design at urban scale in Iran's Hot and Arid Region. A parallel dissertation investigates the same subject at the architectural scale (by Afsaneh Soltani).

The well-preserved historical city of Yazd as a sample that generates sufficient knowledge of Iranian traditional housing in hot and rid region is selected as the case study.

The LEED system has been adapted as the main tool to define the baseline for assessment of the case studies regarding environmental sustainability.

Analyzes are made on several districts in Yazd that are selected from among both historical and contemporary houses from various areas in Yazd to be compared

1.3 Research question

1.3.1 Target Group, Objectives and Aims of the Research

This research aims at the designers and architects who wish to design districts, houses and residential projects in hot and arid regions of Iran. However due to socio-cultural and environmental similarities between Iran and the neighboring countries in the region such as Saudi Arabia, Iraq or Arab Emirates… who share the same climatic conditions with sub-desert area in Iran, the outcome of this research can be developed to inspire the designers and architects who aim to design houses in those countries too.

While as will be discussed in Chapter 3, Figure 36 investigations imply that the urban and architectural design strategies and decisions taken at the primary stages may have more influence on the environment than the construction stage.

The ultimate concern of this dissertation is to provide contemporary architects and designers with general knowledge of the local traditions of housing architecture in the hot and arid region of Iran in order to create more environmentally sustainable housing.

Therefore the following objectives are defined for this dissertation:

1. The first objective of this research is to show that the modern approach to urban and architectural design that raised after the abandonment of the traditional system in recent century and does not consider local and traditional systems and values, is not a sustainable design approach. The traditional systems and values used in the past possessed more sustainability features, which have the ability to be adapted to and utilized in contemporary living.
   This is achieved by evaluation of both traditional and contemporary houses by means of a proper sustainability evaluation tool. The attempt for finding the right evaluation tool in this research can be considered as an introduction to more extensive research on the development of Iranian evaluation systems of sustainability.
2. Ultimately, this dissertation intends on defining and addressing helpful sustainability solutions, derived from Iranian traditional architecture and city design, to adapt to modern life in hot and arid regions of Iran. In other words, this research aims to inspire from traditional architecture and to identify some features of sustainability on basis of Iranian traditional architecture patterns and values.

1.3.2 Research questions:

Therefore this research aims at the following research questions:

1. Which is more environmentally sustainable, the traditional or the contemporary neighborhood design in the hot and arid region of Iran?
2. If the Iranian traditional architecture and urban design reveals sustainability features, what are its sustainable features that can be adapted again in contemporary design? And how can we suggest general recommendations as the main aim of this research?

In order to answer the first question, the following questions must be replied in advance:

- When and why did the traditional system in the hot and arid region in Iran, surviving over centuries, discontinue?
- What is the right evaluation tool to assess the degree of sustainability in both traditional and contemporary design in Iran hot and arid region?

For answering the second question, the sustainability features in both traditional and contemporary cities must be compared and analyzed. The results will be demonstrated in form of architectural illustrations, small sketches and schematic drawings, including general design recommendations as the conclusion for this research.

1.4 Methodology and Approach

This research begins by defining sustainability and analyzing the role of urban design and architectural design in environmental sustainability and a short review on the most outstanding efforts already made by architects for adaption of Iranian traditional architecture's strategies. This is followed by an introduction to Iranian traditional cities and architecture and their features regarding environmental sustainability criteria. This research focuses on Iran’s extensive and resource-limited desert area, with a climate spanning semi-arid to very hot and arid, and the city of Yazd is selected as case study. Several sample districts from the historical part of Yazd are selected as case studies. In order to attain to a better understanding of the potentials and weaknesses of the historical case studies regarding environmental sustainability, contemporary case studies from the new parts of Yazd are selected and contrasted.

The first part of this dissertation then aims to show which is more sustainable, the traditional or contemporary city. For this purpose, an empirical method with an inductive approach is performed. (Chart 1)

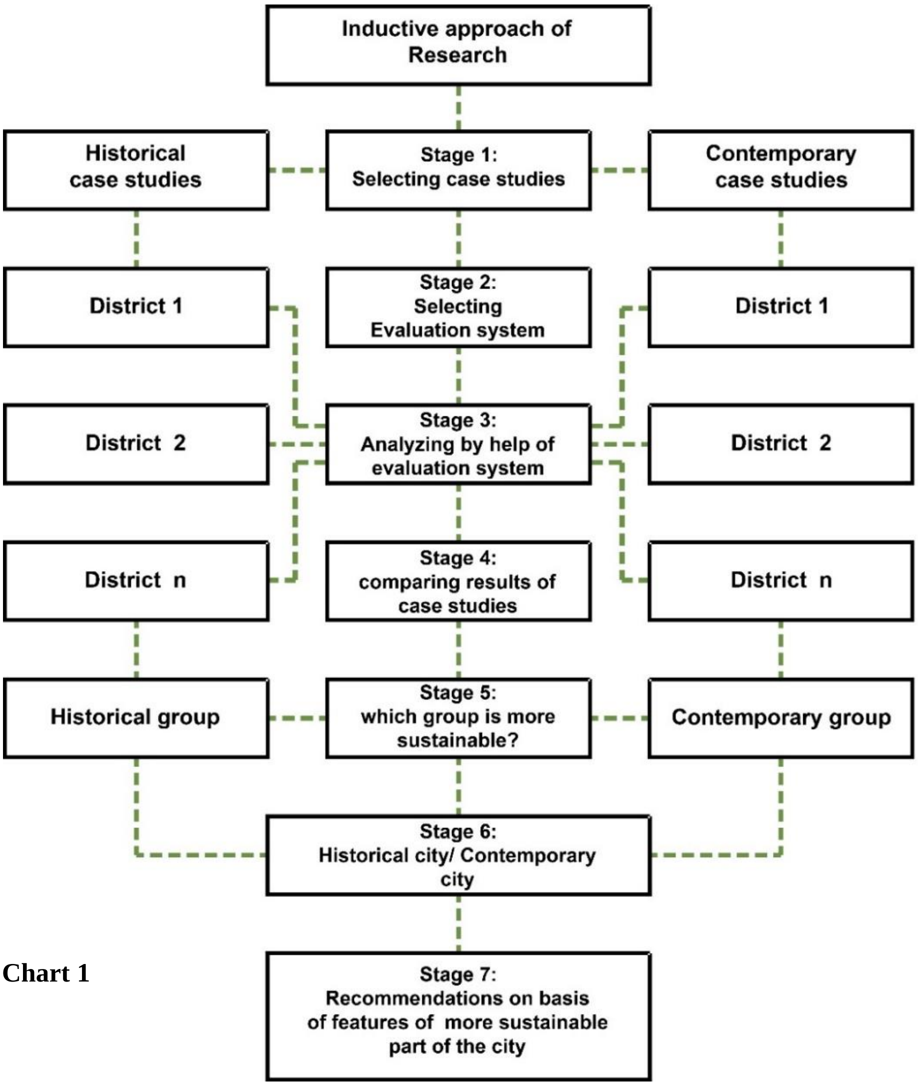


Chart 1

Five historical districts and two contemporary districts are selected to be analyzed and assessed with the criteria of sustainability. Evaluation of several districts in terms of sustainability will demonstrate whether the whole city is sustainable or not.

The five selected historical districts are from different zones of the old city, which each date back to different historical periods. They are selected with different sizes and locations to cover all features of the old city.

Contemporary districts are also selected for based on features such as size, organizational type, and building types. One of them, for example, is a district containing two-level single-family houses with southern courtyards. Another district comprises of a residential complex with midrise buildings.

Evaluation

Next step is to define the right evaluation systems for assessment.
There are various existing environmental assessment systems and tools worldwide for sustainable urban design that focus on two main objectives:

- Reduction of environmental impact
- Improvement of quality of living and working space

These systems and tools try to reach these objectives by:

- Helping designers to improve their designs
- Evaluating and certifying the actual performance of the districts

The two challenges in this research are:

- Lack of a sustainability evaluation system in Iran
- Evaluation of historical districts (in their original context) with modern systems

Therefore, chapter 5 of this dissertation makes a short review of existing evaluation systems worldwide and then extracts an outline out of them to establish a simple but comprehensive tool to evaluate the amount of sustainability in the selected case studies.

As mentioned, one major problem regarding sustainability in countries like Iran is the lack of a local evaluation system. Like many other developing countries, evaluation systems from developed countries such as LEED (USA) and BREEAM (UK) are used in Iran. Researchers who consider local solutions and values usually attach some features of vernacular urbanism and architecture to their projects, in addition to parts of international systems. The result is a heterogeneous mixture of local and international items of sustainability. Defining a national evaluation system is essential to connect all projects and research in the country using a comprehensive and uniform approach.

However, this dissertation does not claim to define a national sustainability evaluation system for Iran because this would require the cooperation of several experts from various engineering fields and many organizations at the national scale.

Although these evaluation systems claim that they are internationally compatible, one of the prerequisites is locality. This means that the more similar the climatic factors, the less need for changing and adapting the rules.

Hence, the main reason for the selected evaluation system in this dissertation, i.e. LEED, is that the climatic conditions in Iran are more similar to the US than Europe, the UK or Japan. LEED is established in the United States and is applicable in Iran due to the similarity of the conditions of central deserts of Iran and the central-west semiarid steppes of the USA.

Therefore, by choosing from among different evaluation systems in the world, this research focuses on LEED (Leadership in Energy and Environmental Design, developed by US Green Building Council since 1994) as one of the oldest and most used systems in the world. However, this dissertation extracts the central feature from LEED and adapts its properties to important, local characteristics of Iranian deserts. It then develops its own evaluation system. We do not use LEED's grading system, because such evaluation systems target at a minimum of points, earned by projects, through variety of possibilities such as additional mechanical equipment or specific certified building materials, etc., to certify them by earned points. In contrast, this dissertation aims at urban strategies taken at the design stage, such as orientation, proportions of passageways and spaces, forms, and divisions of spaces.

Resources other than sustainability certifications are also taken into consideration, in order to achieve a better evaluation tool to assess both historical and contemporary housing in the hot and arid region of Iran.

It should be noted that although sustainability phenomena includes social, cultural and economic aspects too, due to the author's field of study, this research only focuses on environment-based factors.

Finally, the provided evaluation system evaluates case studies for the following features:

1. Water
2. Energy
3. Site and land-use
4. Material
5. Health and well-being

Several sub category items are defined under these five main categories by learning from items of LEED and also by considering traditional Iranian city design strengths and opportunities.

It must be taken into consideration that it is not possible to apply all LEED items into Iranian case studies; some of them are irrelevant to Iranian architecture characteristics. Therefore, some additional evaluation points are defined on the basis of Iranian's specific urban design and local criteria. These are added to points derived from LEED. The final evaluation, thus, includes a combination.

Conclusion

By the evaluation of different historical and contemporary case studies using this combined system, this research demonstrates that in the majority of evaluation categories, historical case studies yield better results regarding sustainability criteria.

Finally, some recommendations and solutions are suggested on the basis of these historical patterns of sustainability, adapting them to contemporary living standards.

In some ways, traditional city design revealed environmental sustainability advantages. These findings will be presented as recommendations, not only as guideline notes, but also with the aid of small sketches, in order to give the reader a better understanding of what the author has achieved during this project.

Some of these sketches are very general and schematic, not exact and detailed. They present general ideas for designers to gain inspiration from, to make their own design for their own specific cases.

Where traditional system shows a disadvantage, e.g. in case of an earthquake, the author tries to provide the designers with some ideas for developing corrections and improvements.

CHAPTER 2: STATE OF THE ART

This chapter makes a short review on the most outstanding efforts already made by architects for adaption of Iranian traditional strategies of hot and arid region to use them in contemporary design either in the framework of constructed projects or published theoretical guidelines.

Regarding evaluation of traditional districts in terms of environmental sustainability, this dissertation has a novel approach in evaluating and comparing the traditional and contemporary existing districts with modern evaluation systems for sustainability.

In other words, no attempt for evaluation of traditional aspects of Iranian cities by modern evaluation systems has ever been made on Iranian cities in such a scale. The majority of previously made investigations aim at introduction of the environment-friendly aspects of this system, but lack of an integrate assessment on this traditional urban design to find out its weaknesses or strength is apparent.

There are however instances in this regard i.e. the investigations already made on limited features in one single building, such as Simulation of Brojerdi-ha house in Kashan and its thermal performance.

For the first time, this dissertation evaluates the traditional aspects of Iranian cities in hot and arid region in comparison with the contemporary parts of the cities by application of a modern evaluation systems for assessment of sustainability (LEED evaluation system).

Regarding the adaption of features of traditional city in contemporary era, there have been various approaches in Iran in recent century.

During the past decades, the economic crisis in fuel consumption, when debates for optimization of energy was raised seriously in Iran (G. Memarian 2007, 26) by the increase of public awareness of the energy and environmental issues, e.g. the depletion of resources and environment pollution in the region, sustainability has become a topic of debate amongst Iranian architects and designers.

As Memarian describes: "Although several books and articles on climatic features of Iranian local architecture have been published in Iran during the past four decades, thousands of buildings have been built without any consideration towards the climatic conditions of their location during the same period. These buildings follow the western architectural features that are responsive to neither the climatic and cultural conditions in Iran, nor the seismic hazards in the region.

Lack of a united management system for coordination of research and implementation that guarantees the accomplishments of the buildings due to the specific climatic and environmental conditions in each region is the main reason for this inconsistency.

It seems that as long as the country possesses abundant cheap petroleum products, this irresponsible attitude towards construction of high energy dependent buildings that are not designed in harmony with environment and climate continues in Iran goes on.

Meanwhile national authorities and organizations have published rules and regulations regarding energy saving in buildings, such as "Iran National Building Codes: Booklet 19: Energy Saving in Buildings", but such references are placed unused in library shelves, according to lack of legal obligations for their implementation." (G. Memarian 2007, 50)

Following is a short review of the background of such researches, including the most significant of them, in Iran.

2.1 Academic researches on adaption of climatic solutions of Iran's traditional architecture in contemporary architecture

After publication of Olgay's book in 1963 "Design with Climate" (Olgay 1963), a number of books about climate and architecture were published in Iran during 1970s (G. Memarian 2007, 24). The authors of these books investigated the formal and spatial logic grounds that lay beyond the local architecture and urban fabric in various climatic zones in Iran in confrontation with the climatic issues and conditions (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 59).

In 1974, the book "Architecture in Hot and Semi-Arid Climate in Dezful and Shushtar" (Rahimieh and Robubi 1974) was published (in Persian language) in Iran. The authors in this book investigated the influence of hot and humid climate on local architecture of the two towns of Dezful and Shushtar in South of Iran (G. Memarian 2007, 25).

Afterwards until early 1980s no other book in this regard was published. In 1981 another book titled "Urban Structures in Hot and Arid Climate" by Mahmoud Tavassoli was published in Persian too (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002). This book has had an important influence on the attitude towards Iranian architecture since then. At that time, the architecture education system in Iran suffered from lack of architecture books that introduce and investigate the local Iranian architecture and urban design.

Afterwards until early 1980s no other book in this regard was published.

Until the mid-90s, several investigations were made on climatic oriented architectural design in Iran. Although their results have hardly been used in practice due to lack of related compulsory construction codes in Iran, but these investigations have succeeded to motivate the academics to draw public attention among architects towards the existence of the technical sustainable solution in Iranian traditional system. These researches have been mostly sponsored by the former Iran Ministry of Housing and Urban Development.

One of such researches was undertaken in at the beginning of the 21st century in Iran as part of a broader research undertaken by the Technical Office for Research and Education at Shahid Beheshti University in Tehran, Iran, being sponsored by Iran Ministry of Housing and Urban Development.

The major focus of this research was to codify the principles for design of mosques in Iran. One part of the research aiming at improvement of contemporary architecture of mosques to be compatible with climatic conditions in Iran and to benefit from natural resources passively was published in the framework of a book in 2008 as a reference for architecture students and professors: "Architectural Design Principal Compatible with Climatic Conditions of Iran, with Focus on Mosque Design, by M. Tahbaz and Sh. Jalalian. (Tahbaz 2008).

This book starts by proposing a new climatic division for Iran and makes a categorization to address the climatic zone that each city of Iran is placed in. For each of the five defined climatic categories, firstly the climatic conditions is introduced, and the climatic needs for achieving the comfort conditions in buildings is investigated, and for this, the solutions suggested by the local architecture in the region is studied and at the end of each chapter, for that specific climate, instructions for designing the mosques in that climatic zone is recommended.

The authors of the book believe that due to the similarities of architectural patterns of mosques and houses in hot and arid region, the recommendations of this research can be applied in housing design too.

The following graphic shows the research structure applied in this book:

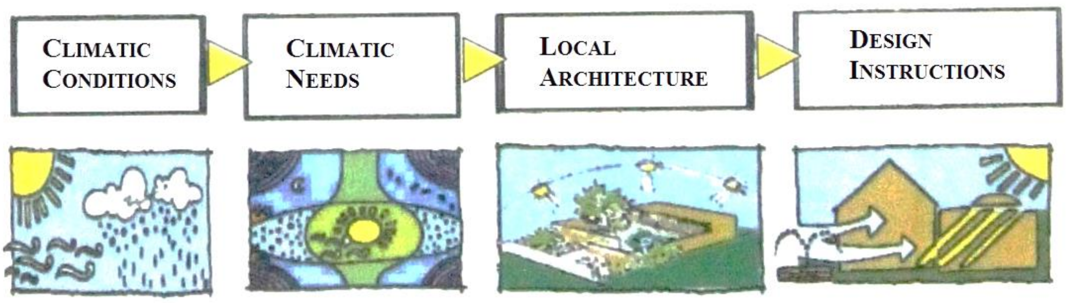


Figure 8: the four successive stages for study of each climatic zone in the book, Source: **(Tahbaz 2008, 5)**

The recommended design criteria for each climatic zone for each climatic zone involve with general design features, architectural characteristics of open air space, semi open space, closed space, building envelope and construction methods.

2.2 Trends for adaption of traditional patterns into modern Iranian architecture and urban design

Besides the researches on climatic aspects of traditional architecture in Iran, that made sparkles for adaption of the traditional architecture and local construction solutions into modern architecture at least among the scholars and academics in Iran, another flow that raised during the past decades in Iran, aiming at revitalization of Iranian traditional architecture's values in modern design, was established during 1970s.

The 1973 wake of the oil crisis made some western critics turn from formal concerns in architecture towards environmentalism[3], and even anti-building ambitions (Westbrook 2014, 386). Meanwhile Iran experienced a very different context due to its booming economy aiming at accompanying the infrastructural reforms by regional identity, in extensive industrial, cultural, civic and governmental projects with the cooperation of western architects such as Louis Kahn (Emami 2011). The Iran government therefore, seeking to refine Iran's urban policies, sponsored several international architectural congresses[4] and competitions during 1970s[5], exploring the relation between regional cultures and international construction techniques (Westbrook 2014, 387).

The first congress "The Interaction between Tradition and Technology" in Iran was held in the historical city of Isfahan[6] in 1970 (Westbrook 2014, 389). The congress explored the possibility of a viable regional architecture counter posed to the "international" modern

[3] The codification of the modern movement made by the older generation of The Congrès Internationaux d'Architecture Moderne (CIAM) in 1930s was associated by critics in 1950s and 1960s (Pedret 2013). Contemporary culture was to be reconnected to tradition not through historicism, but through a rediscovery of what Van Eyck termed the "archaic principles of human nature", and significantly, an emphasis on "habitat" rather than "dwelling" (Tzonis and Lefaivre 2012).

[4] There were three major architectural Congresses in Iran in the decade before the Islamic Revolution: 1970, "The Interaction between Tradition and Technology", Isfahan; 1974, "Towards a Quality of Life", Persepolis, and in 1976, "Architecture and Identity", Ramsar, a special "Women in Architecture" conference. A fourth congress was planned for 1978, but does not appear to have taken place (Westbrook 2014, 386)

[5] Supported by the queen Farah Diba, the former architecture student at Beaux Arts, Paris.

6 Invited international participants to the 1970 congress included: A. Ali (Morocco), Y. Ashihara (Japan), G. Candilis and O. Zavaroni (France), A. Damian and M. Nicalescu (Romania), Buckminster Fuller, P. Will, Jr., P. Rudolph and L. I. Kahn (USA), M. l Hosseinoff (USSR Azerbaijan), A. Kuran (Turkey), M. Mistry and I. M. Kadri (India), J. Moravec (Czechoslovakia), L. Quaroni (Italy), L. Blanco Soler (Spain), and O. M. Ungers (Germany). Gropius, Mies and Neutra were invited to the conference, but died before it took place. Iranian delegates included M. Foroughi, the secretary K. Diba, S. Afkhami, H. Seyhoun and N. Ardalan (Farhad and Bakhtiar 1972, 19).

architectural design that was dominant in Europe, the United States and increasingly the Third World (Cantacuzino and Browner 1976).

The main topics of the congress were about tradition, technology and the possibility of combining traditional architecture with modern construction technologies (Westbrook 2014, 390) and the debates included a wide range of architectural views including the neo-traditionalism of Nader Ardalan (Nadar Ardalan 1970) to Paul Rudolph's criticism of Ardalan and Louis Kahn (Westbrook 2014, 392).

This congress emerged the discrepancy between an appeal to the social and aesthetic unity of traditional settlements proposed by traditionalists such as Kamran Diba and Nader Ardalan supported by O. M. Ungers' call for collective consensus on the form and function of social habitat on one side and the urbanization crisis by migration of large numbers of villagers to the Iranian cities and the need for provision of mass housing to accommodate displaced villagers on the other side (Bakhtiar and Farhad 1972, 87). This became the main focus of the second congress "Towards a Quality of Life"[7] in 1974 taking place in the 2500 year former capital of Iran; Persepolis, where the issue of tradition was again there in the background of the congress discussions (Westbrook 2014, 395).

As Nigel Westbrook in his paper "The Regionalist Debate in the Context of the 1970s Architectural Forums in Iran" (Westbrook 2014, 396) concludes: "The respective positions at the 1970 and 1974 congresses were later accommodated in the Persepolis Declaration written by nominated conference delegates[8], and presented as a Shelter Bill of Rights by the Iran delegates to the United Nations (UN) Conference on Human Settlements in Vancouver in 1976 (HABITAT 1976). This document, which reprises a central theme of the later CIAM congresses and Team 10 discussions (Pedret 2013, 81), balances a call for architects to learn from the organic unity of the traditional village structure, while calling for greater political control of citizens over their social and physical environment (Habitat 1976, 14)."

Inspirations from such congresses accelerated the new architectural trend in Iran established by the intellectual architects in 1960s and 1970s aiming at a modern architecture with local and historical tendencies (Bani Masoud 2009, 243) and searched its path parallel with the existing modern architecture that was affected by the major European modern architects and architectural styles.

In this regard some architects, like Nader Ardalan, were influenced by the mystic thoughts of contemporary traditionalist philosophers who made a division between the two worlds of

[7] Invited delegates to this second conference included Josep Luis Sert, the former president of CIAM, Buckminster Fuller, Moshe Safdie, Balkrishnan Doshi, Jaap Bakema, Dolf Schnebli and Kenzo Tange (Westbrook 2014, 396).
Safdie, Balkrishnan Doshi, Jaap Bakema, Dolf Schnebli and Kenzo Tange.
[8] Josep Lluis Sert, Moshe Safdie, Balkrishnan Doshi, Georges Candilis, and Nader Ardalan

tradition and modernity, and tried to create an eastern modernity on basis of Iranian traditions, intuition as well as Islamic believes.

In 1973, Nader Ardalan and Laleh Bakhtiar published their impressive book in English "The Sense of Unity: The Sufi Tradition in Architecture" (Ardalan and Bakhtiar, The Sense of unity, The Sufi Tradition in Persian architecture 1973) which was an architectural interpretation of the traditional Iranian philosophy (Bani Masoud 2009, 247).

This book is mentioned as the first and foremost book on Iranian architecture theory, but the authors of this book seem to relate every aspect of Iranian traditional architecture to philosophy, theosophy and mysticism, ignoring the structural or climatic responsive role of many elements and features of the Iranian architecture.

Figures 9 and 10 show Iran Center for Management Studies (in association with Harvard Business School) in Tehran, designed by Nader Ardalan Iran (1972-75). He aims to integrate this architectural project with a contemporary interpretation of the classic Persian garden (*Pardis*) and the traditional school (*Madrasa*) using the Iranian traditional construction material, brick (Ardalan Associates 2016).

The overall project is rather a modern physical reading of the Iranian traditional forms and spatial organization than revitalizing the technical grounds beyond these traditional elements, but it is truly successful in transferring a sense of being Iranian and being modern at the same time to the observer, and this, is a brand new pattern in traditional architecture of Iran, used simultaneously by some other architects like K. Diba and A. Saremi too.

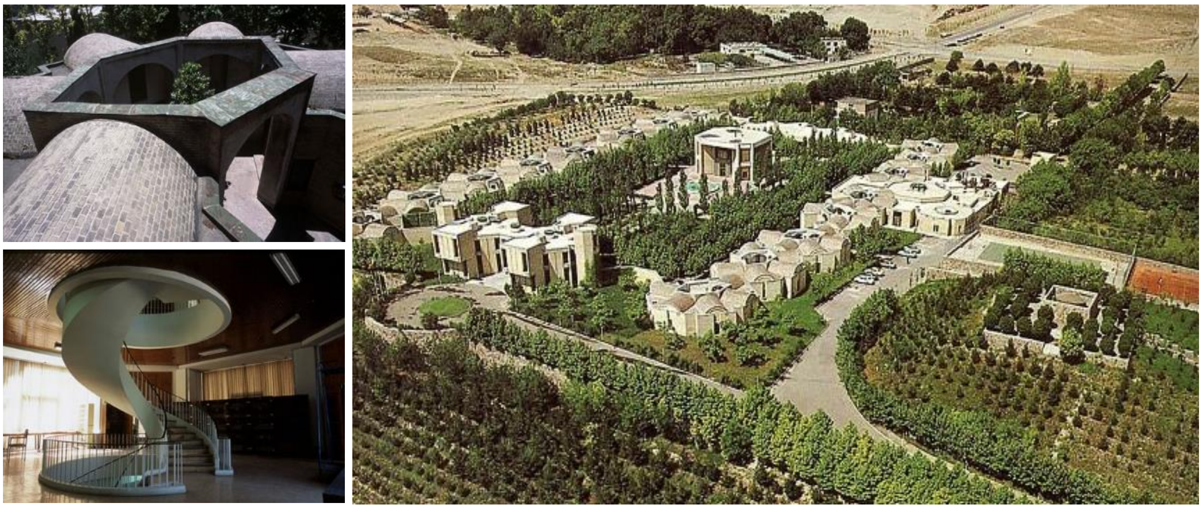


Figure 9: Iran Center for Management Studies in association with Harvard Business School, Tehran, Iran, (1972-75), Nader Ardalan, Founding Partner Mandala Collaborative **(Naqsh 2012)**

Figure 10: comparison of the main axis of the project with the Persian gardens, Left: Iran Center for Management Studies by Ardalan, right: Fin garden in Kerman, Iran,
Source: (ISU 2016)

This ambition for creating a purely Iranian architecture that is also modern is traced in the works of a group of Iranian modern architecture pioneers during the second Pahlavi era (1940-1977).

Although the first generation of modern architects in Iran, many of which were non-Iranians, symbolically used the elements of Iranian architecture in their contemporary projects, like the brick building of the Museum of Ancient Iran designed by the French architect Andre Godard in the early 20th century, influenced by Sassanid vaults, particularly the Eyvān-e-Kasrā at Ctesiphon (see figure 11), but the latter generation who were Iranian architects educated in Iran as well as Europe or the US were more involved with defining an interpretation of the traditional architecture's features into their modern projects.

Figure 11: Museum of Ancient Iran designed by Andre Godard, Source: **(Parinoush 2008)**

These designers are rather influenced by the cultural values of the Iranian traditional architecture, tightly integrated with the Islamic and cultural traditions e.g. *Mahramiyat* (privacy in spaces).

Most of their fascinating projects which were implemented either in the second Pahlavi period (like Dolatabadi house by H. Seyhoun or Tehran Museum of Contemporary Art by K. Diba) or after the Islamic revolution (Jolfa Residential Complex by A. A. Saremi and colleagues 1987-1989) still seem to be revitalizing the forms and spatial organization of Iranian local architecture e.g. central courtyards and vaulted roofs, domes or wind catchers, as formal representatives of the original Iranian architecture's cultural identity than making a contemporary interpretation of the technical logic that lays beyond the traditional architecture such as climatic factors or structural grounds regarding environmental sustainability.

However it must be mentioned that they were majorly successful in creating a brand new design style that transfers a "modern Iranian" sense to the audience and their works have been welcomed by public, like Tehran Museum of Contemporary Art by K. T. Diba. The author believes that this success is indebted to the architect's attention towards the context of the project, including the physical as well as cultural context of the place where project is implemented.

Figure 12: Tehran Museum of Contemporary Arts, Tehran, architect K. Diba, Source: (K. Diba 2014)

Other tendencies towards modern revitalization of traditional architecture are traced in the works of architects that have a semi-post-modern attitude. Such attitude is observed in Dezful Cultural Center, in Khuzestan, designed by Farhad Ahmadi (1987-1992) for instance. The architect collects symbols of Iranian architecture and unites their modern formal translation together, regardless of the context of the project. Many elements in this project do not even belong to the local architecture of Dezful such as the wind catchers (Figure 13).

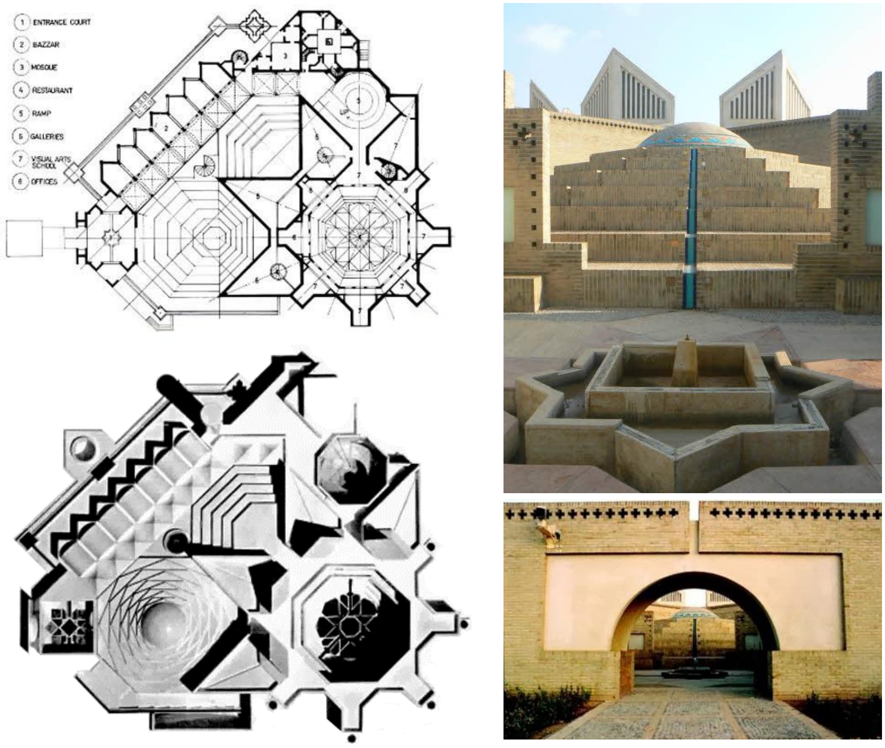


Figure 13: Plan, model and photos for Dezful Cultural Center, designed by Farhad Ahmadi (1987-1992),

Source: **(Arel 2016)**

The most significant project from this period that adapts the environmentally sustainable features of the Iranian traditional architecture in a modern design is the Aga-Khan Award winning project (1986) "Shushtar New Town" conducted by Kamran Diba (DAZ Consulting Engineers) during 1970s, a new development near the ancient city of Shushtar in the hot and arid region in Southwest of Iran, Khuzestan province.

This exemplary small town belongs to the 70's, when there were no specific design trends in the country reflecting a sustainable attitude. After the dramatic changes in Iran during 1980s (the 1979 Islamic revolution and the eight year war) many Iranian architects of this generation left the country. This project will be reviewed in the following section in this chapter.

After the decline of architectural activities due to revolution and the eight year war during 1980s, the next decades until present time, witnessed various trends and flows among Iranian architects including a wide spectrum from pure traditionalism (in religious architecture) to exclusive advocating to the western patterns such as high-tech etc. (Figure 14) (see (Bani Masoud 2009, 338)

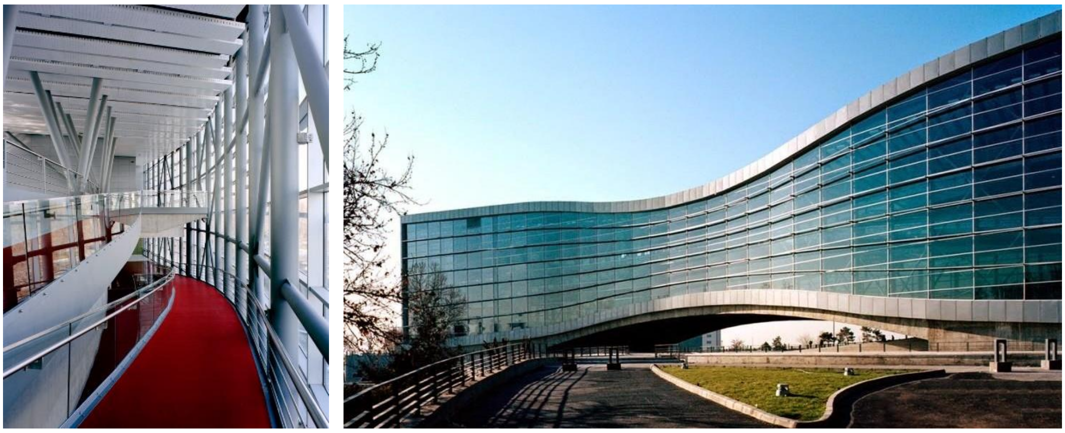


Figure 14: Mellat Park Cineplex in Tehran, Reza Daneshmir, Catherine Spiridonoff, Source: **(Pardismellat 2016)**

2.3 Energy efficient design with inspirations from Iranian traditional architecture's patterns

In recent years, by cooperation of European countries, projects for improvement of energy operation of houses in Iran has been undertaken. One of the most recent instance of such projects is the 35 ha Housing Area in Hashtgerd New Town, Alborz province that targets the design of passive solar design in houses, and makes advantage of the traditional patterns of Iranian architecture I hot and arid region of Hashtgerd.

The Young Cities Project (Schäfer 2011) is an Iranian-German Research Initiative in the framework of the research program “Future Megacities” of the German Federal Ministry for Education and Research (BMBF), led by the Technische Universität Berlin (TU Berlin) and the Building and Housing Research Centre of Iran (BHRC) (Mir-Moghtada, Weber and Seelig 2009). This project aims at elaborating solutions and strategies for a sustainable, energy-efficient development of new urban developments in Iran as a contribution to a significant CO2 reduction (Schäfer 2011), by realizing sustainable and energy-efficient housing settlements in semi-arid regions, explored within the case study of Hashtgerd New Town (Mir-Moghtada, Weber and Seelig 2009).

A total of five pilot projects were defined to be implemented in Hashtgerd New Town in Alborz province, Iran from 2005 to 2013 (Mir-Moghtada, Weber and Seelig 2009) in order to examine different strategies and solutions for energy efficient urban planning. The following pilot projects are elaborated at different spatial levels:

- The 35 ha Housing Area
- The New Quality residential building
- Three New Generation buildings for residential, office and educational uses (Schäfer 2011)

2.3.1 The 35 ha Housing Area

The 35 ha Housing Area as one of the main research sub-projects of the Youmg Cities in Hashtgerd New Town, aims at the production of the following outcome:

- Criteria and objectives for energy-efficient and resilient urban development in Hashtgerd New Town and other semi-arid regions on the neighborhood scale.
- Appropriate planning and design strategies tested on the basis of pilot projects, including their evaluation according to the project goals.
- Policies for urban planning and design for climate change in Iran that might result in adapted or new planning (S. Seelig 2011, 547)

Figure 15 describes the various aspects of design that are considered in 35 ha Housing Area project including architecture, transport and mobility, urban form, urban planning, environmental assessment, climate, energy, water, landscape and awareness rising.

Figure 15: Design features for the 35 ha Housing Area project in Hashtgerd New Town, Source: website for Embassy of Germany in Tehran, (DBT 2010)**, ©T**U Berlin

2.3.2 Inspiration from the traditional Iranian architecture and city planning

One major characteristic of the 35 ha Housing Area project that is interesting to be mentioned here is that it investigates the main characteristics of the traditional Iranian cities and their climatic advantages which form the underlying spatial rationale of the urban design in hot and arid region of Iran (S. Seelig 2011, 550) in order to adapt them, as the main concept of the design, to modern living norms.

The following characteristics found throughout the region of “Islamic Urbanism” (Ehlers, Bonine, et al. 1994) form the basic principles for the 35 ha area’s urban design, though being adapted to contemporary needs e.g. concerning path dimensions and building sizes:

- The access system in the historic city with a clear spatial hierarchy from public to private spheres
- The introverted courtyard house that combines privacy, social interaction and protection against climate and provides light in the interior

- The compact, attached housing arrangement that minimizes the amount of exposed surfaces (reducing cooling and heating demand) providing thermal comfort by creating external spaces sheltered from direct sunlight
- Narrow lanes bordered by high walls in the densely built traditional city structure that create well-shaded spaces during hot summer afternoons and protect inhabitants against harmful winds
- The proximity of land uses, though functionally separated by the access network, that provides an appropriate amount of privacy and easy accessibility of services at the same time (Manzoor 1989) (Kheirabadi 2000).

The project also mentions the introverted pattern and the central courtyard as a very effective feature in traditional Iranian architecture in hot and dry region as Sebastian Seelig explains (S. Seelig 2011, 553):

"Energy demand is also significantly influenced by housing types (Santamournis 2006). The courtyard house supports ventilation and permits natural cooling (Fathy, Shearer and Sultan 1986), while reducing direct exposure to the sun.

At the same time its introverted building form reduces the amount of exposed surfaces. The courtyard house is also culturally sensitive because it creates private and introverted spaces in dense urban form, which is why it is the prevailing housing type in the traditional Islamic city." The urban design for the 35 ha Housing Area makes use of these potentials by introducing a contemporary interpretation of the courtyard house.

Figure 16: 3D presentation of the design for one part of the 35 ha Housing Area project in Hashtgerd, Iran, Source: website for Embassy of Germany in Tehran, (DBT 2010), ©TU Berlin

In a "research by design" process the typology based on a modular space system was developed, offering a large variety of dwelling sizes and qualities (Pahl-Weber, Wolpert and Wehage 2013).

The project proposing two to three story stacked courtyard house buildings with widths of between six and fifteen meters.

The majority of plots have a north–south orientation and are between 20 to 35 meters deep so as to maximize energetic potentials. In order to increase solar radiation for energy production, the building volumes have terraces and niches in the upper floors.

The dominant vertical organization of the building volumes provides sun for every residential unit.

The orientation of the living zones within the units around the courtyard combines the need of privacy with microclimatic advantages (Seelig, Wehage and Pahl-Weber 2011).

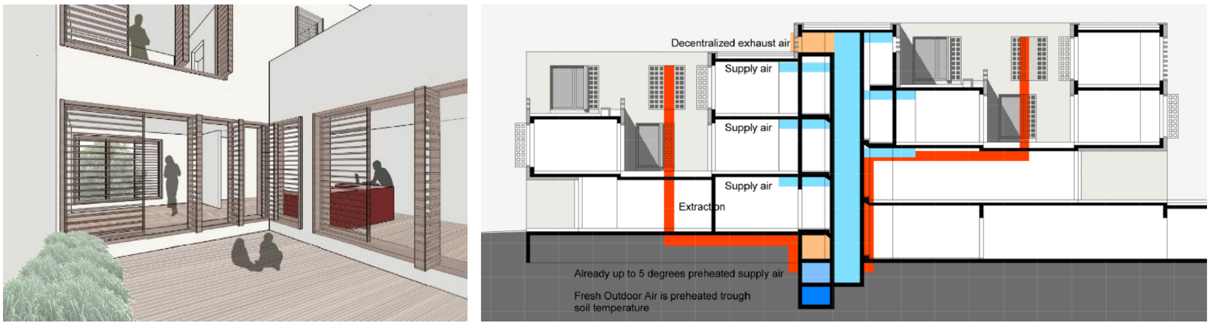


Figure 17: Private courtyard in Energy-Efficient-Home (left) and heat recovery in buildings (right), Source: **(Pahl-Weber, Wolpert and Wehage 2013)** ©TU Berlin

Following photos show the opening of New Quality Housing Project as the first constructed phase of the 35 ha Housing Area in 2010 (Hosseini 2010).

Figure 18: Residential buildings in 35ha Housing Area project, Hashtgerd New Town, Source: BHRC website, **(Hosseini 2010)**

As mentioned before, one of the most significant projects in Iran that has succeeded in understanding the traditional technical solutions of Iranian traditional architecture and adapting them in contemporary architecture is Shushtar-Now in Khuzestan, Iran by Kamran Tabatabaei Diba.
Following is a review of this project:

2.4 Shushtar New Town (*Shushtar-Now*)

The ancient city of Shushtar is located in the hot and arid region in Southwest of Iran, Khuzestan province.

Figure 19: Locatio of Khuzestan province in Iran (left) and location of Shushtar town in Khuzestan province (capital city Ahwaz) (right), map by author, base from (Maphill 2014)

The historical background of this town dates back to 4000-3000 BC, one of the oldest fortress cities in Iran, the home for valuable mud-brick architecture from the Islamic period which are characterized for their specific brickwork façade ornamentations (Soltani and Abbasimehr 2013).

Figure 20: Historical buildings in Shushtar, source: Official website for Shushtar World Heritage Site, (CHTB 2013)

Lack of rain in this hot and arid region makes it necessary to irrigate the lands with a system of dams and canals (DAZ Architects 1986, 4) and Shushtar is best known for its historical hydraulic system consisting of dams, tunnels, ancillary canals and watermills which is inscribed in World Heritage List of UNESCO in 2009 (SHHS 2009).

In 1973, the Karoun Agro-Industries Corporation decided to build a satellite town to house the employees of a sugar cane processing nearby (DAZ Architects 1986, 41) and *Shushtar-Now* was designed close to the historic town of Shushtar for 30,000 inhabitants (Figure 21) (ibid, 57) conducting by Kamran Diba who supervised the construction of the phase 1 of the town consisting of two storey residential houses with several units around a small common central courtyard. After 1979 Islamic revolution in Iran, construction of the rest of the project was abandoned.

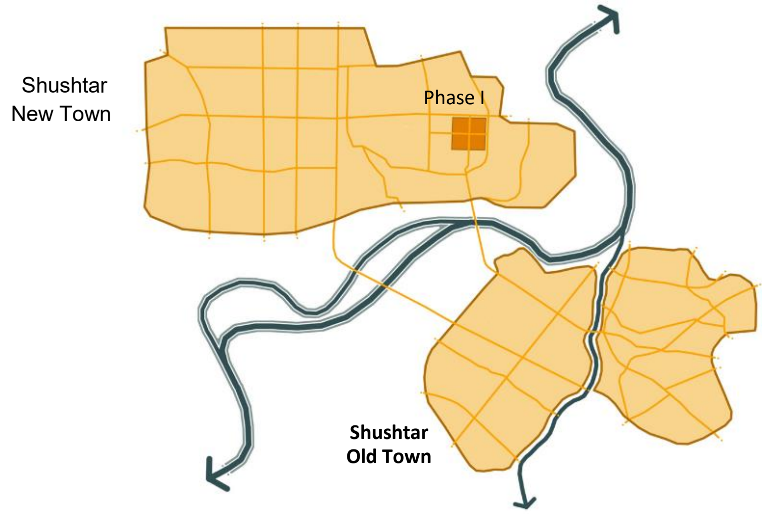


Figure 21: Location of Shushtar New Town and old town, and the seasonal rivers, Graphic by author (Soltani and Abbasimehr 2013)

2.4.1 Design Features

The architecture team (DAZ) and Kamran Diba explain in their technical report for Aga Khan Award, their approach to adapt the valuable patterns of traditional architecture to modern life:

- INTROVERT PATTERN; The design of New Shushtar follows the pattern of traditional Iranian architecture which is introverted, taking its forms from climatic constraints, available local technology and the country's culture (Aga Khan Awards 1986, 161).
- URBAN LAYOUT; The new settlement retraces the patterns of the old one, articulating compact segments of differentiated living units around a pedestrian spine, along which it distributes gardens, squares, bazaars, resting places and other public activities (DAZ 1986, 57).

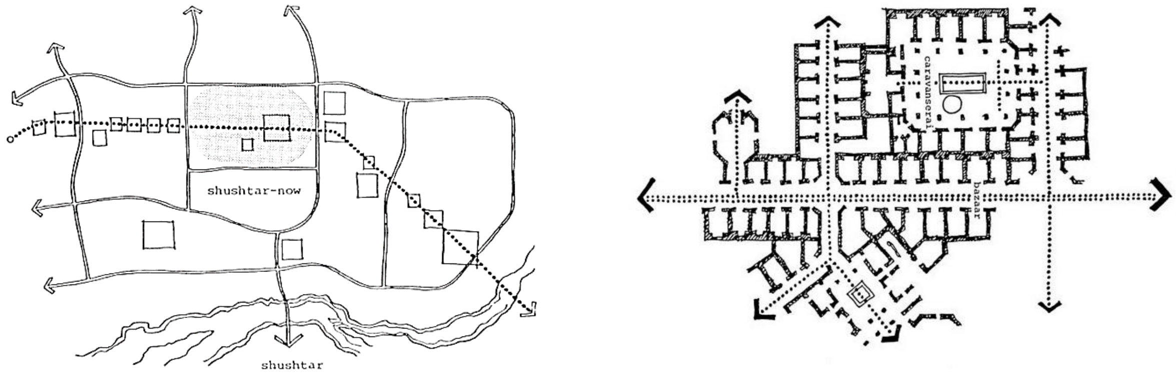


Figure 22: urban functions layout, Shushtar New Town (left) and an Iranian Islamic city (right), Source: (DAZ 1986)

- URBAN STRUCTURE; Adaption of the Iranian city structure in Islamic period is apparent in residential part (Phase I) of the new town.

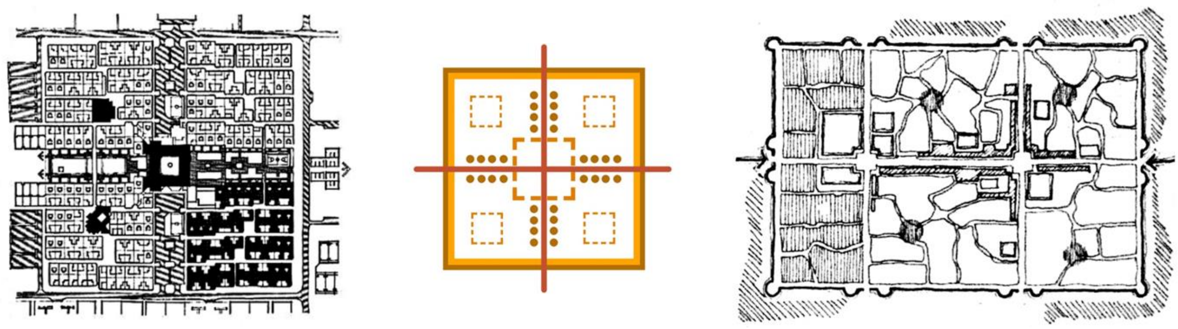


Figure 23: Common urban structure, Shushtar New Town (left) and an Iranian Islamic city (right), Source: (Habibi 1996, 78) (Soltani and Abbasimehr 2013)

- DENSITY; The phase 1 of Shushtar includes an area of 10.4 hectares designed for 4200 residents. This results in a density of more than 400 persons per hectares. The predicted local facilities in Phase I matches is the criteria of sustainability (compact city with mixed use).

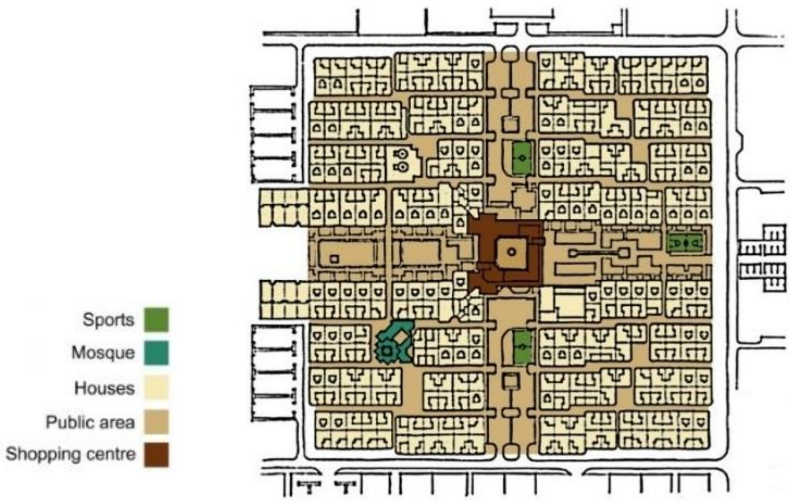


Figure 24: Density and distribution of urban services in phase 1, Shushtar New Town, Source: (Soltani and Abbasimehr 2013)

-    PASSAGEWAYS; Most of the inner passageways in phase 1 are narrow and on an east-west axis. Thus houses face either South or North, which is an orientation that helps the shading.

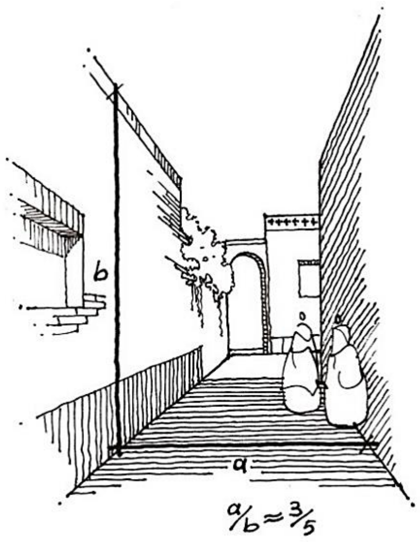


Figure 25: Right: Proportion of a sample passageway in Phase 1, the proportion of the dimensions of Width: Height is 3:5, Graphics by author **(Soltani and Abbasimehr 2013)**

The non-linear layout of the passageways in relation to the climate closely follows the local customs and architectural tradition. The local access in residential part are indirect and designed for pedestrians with limitation for cars (only emergency cars). This strategy provides some secure spaces especially in expansions spaces for social connections as neighborhood centers.

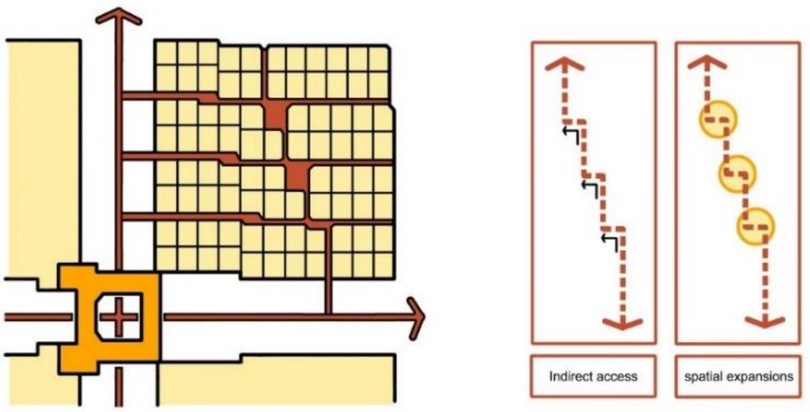


Figure 26: Phase I, non-linear passageways, Graphics by author (Soltani and Abbasimehr 2013)

-    SPATIAL HIERARCHY IN HOUSES; There is a specific hierarchy from inner spaces in houses to public area, modeled from traditional patterns of Iranian architecture, from closed spaces to semi-open space (*Eivan*) and then the open space. The vestibule (*Hashti*) plays the role of a vision and circulation filter for connection of outer passageway into the house (Figure 27).

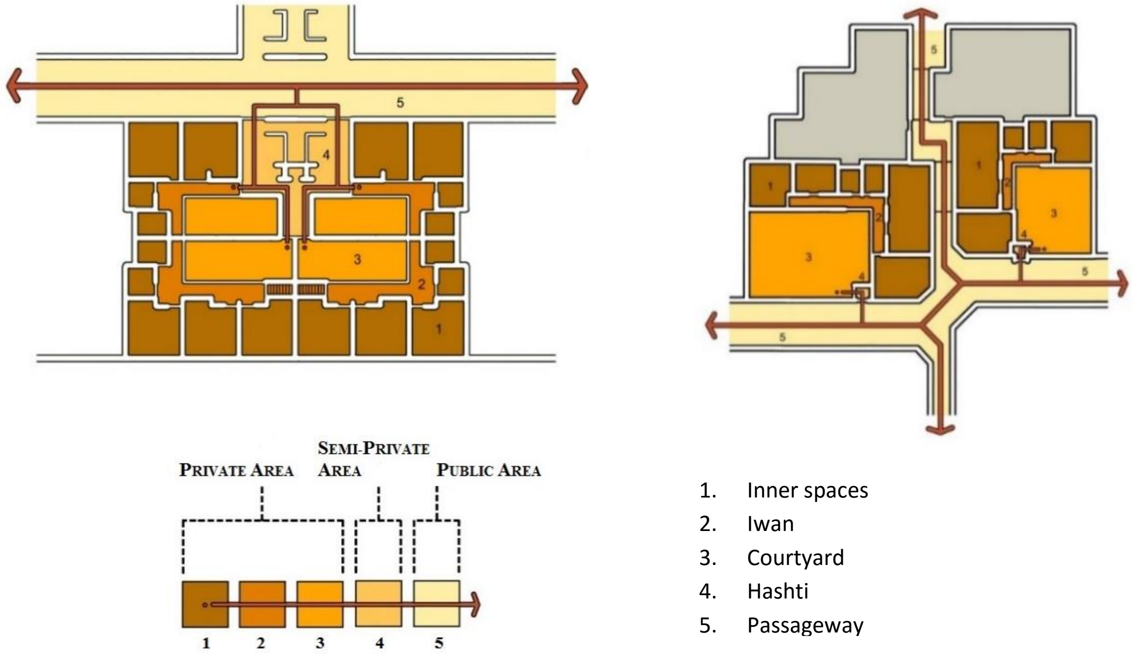


Figure 27: two different types of housing near in phase I and their spatial hierarchy in houses in phase 1 (figure 24), Graphic by author **(Soltani and Abbasimehr 2013)**

- PRIVACY DIVISIONS; At the architectural scale, there is a privacy zoning in locating the private and public areas. In the traditional Iranian architecture it is common that the house includes two courtyards. These courtyards are called *Andarouni* and *Birouni* in Persian. *Andarouni* is the private spaces for the use of the family and the *Birouni* part is built for guests and public communications.

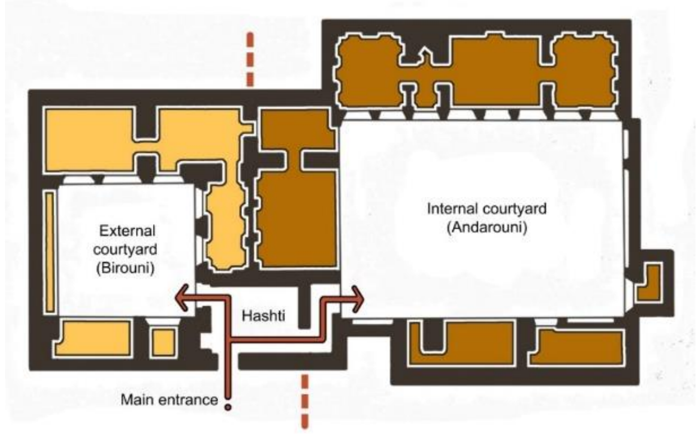


Figure 28: Mojahed traditional house in Yazd, privacy divisions, Graphic by author (Soltani and Abbasimehr 2013)

Shushtar-Now housing types reveal zoning patterns similar to traditional houses in hot and arid zone but in a simplified way: one of the rooms owns a separate access to public space for the use of non-family-members (Figure 29).

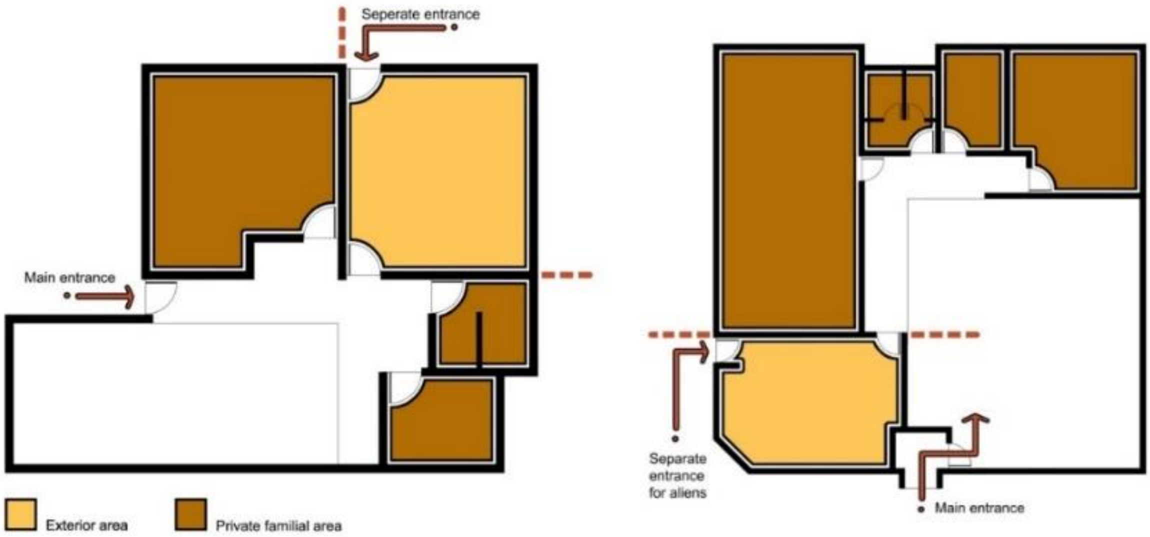


Figure 29: two types of Shushtar now houses, privacy divisions adapted from Iranian traditional architecture, Graphic by author (Soltani and Abbasimehr 2013)

- NATURAL VENTILATION; Orientation of the houses towards the fresh north wind with their central courtyards exclusively open to the wind, modeled from the traditional architectural patterns in the hot and arid region that balances the excessive summer heat and lack of air flow (DAZ Architects 1986, 13)

Decorative brickwork grilles beneath the windows, on the roof parapets, and the entry arcades also provide ventilation (award book 1986, p 165)

Figure 30: *Shushtar New Town, central courtyards and brickwork grilles assisting in better air ventilation, Source:* (DAZ 1986)**,** ©*Kamran Adle*

- SHADING; The planning concept is one of a close-textured city so that the buildings themselves shade, as much as possible, traffic and living spaces. Streets, paved in insulating bricks, are deep and narrow (Figure 31).

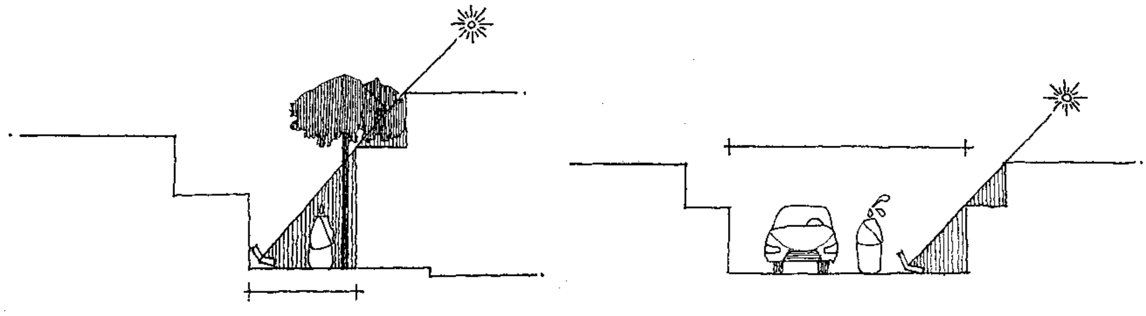


Figure 31: Comparison of two access systems: Shshtar-Now/ preservation of private pedestrian space
Graphic by author on basis of (DAZ 1986)

- COOLING STRATEGIES AT ARCHITECTURAL SCALE; Thick walls, small windows on the shady side of the house, usually facing a small inner courtyard. Entry from the street is usually through a small protected space, between the street and the entry door, which provides a cool space for people walking down the street to meet and talk. The flat rooftops are accessible by steps for evening sleeps. The parapet walls surrounding the roof are often perforated for ventilation using brick grilles, high enough to provide shading, though not enough to give privacy from neighbors (DAZ Architects 1986, 6).

- LOCAL MATERIALS AND CONSTRUCTION TECHNOLOGIES; Traditional Construction methods were used by the local contractor who used local materials and mostly local, unskilled labor.

Load-bearing walls are built of locally made bricks and footings are of concrete. Roof frames are with steel beams.

Wall finishings are mostly of brick. Streets are paved in patterned brick with tile borders.

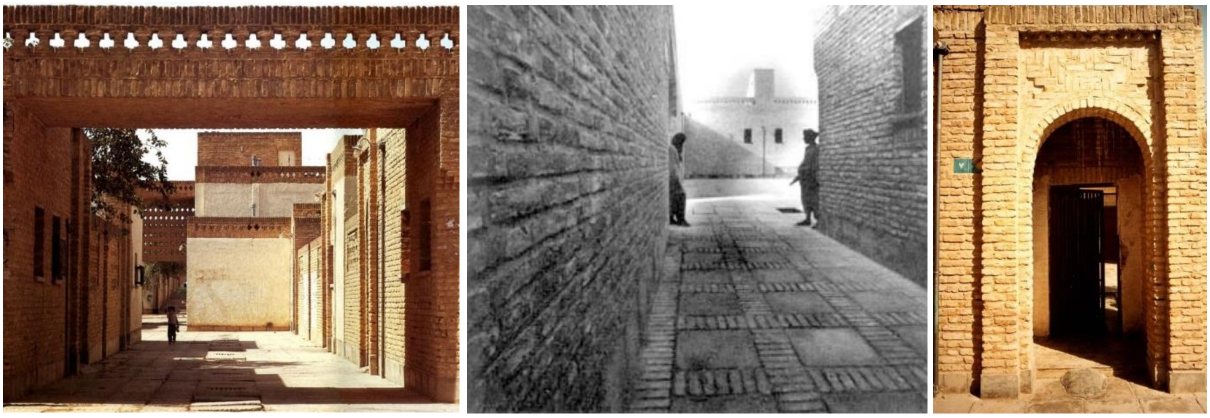


Figure 32: Local material in Phase 1, Source: (DAZ 1986)**,** ©Kamran Adle

The elegant brickworks frames the pedestrian street designed at a human and inviting scale. The streets are primarily for pedestrians and act as outdoor extensions of the homes where neighbors may interact in a peaceful atmosphere (DAZ Architects 1986, 41).

SUMMARY:

After the raise of the second generation of modern architects in Iran in early 1970s, various approaches for application of the features of traditional system into modern life started in Iran including:

1. Remarkable researches and published books on climatic design in architecture that raised attentions towards the climatic-responsive strategies in traditional architecture. Although these samples could open a path for the academics and architecture students, but the results were not applied into modern architecture in practice due to lack of an efficient system for coordination of research and implementation that guarantees the accomplishments of the buildings due to the specific results found on basis of these mentioned researches.

2. The series of international architecture congresses and competitions being held in Iran since 1970s, seeking to refine Iranian traditional urban and architectural policies by exploring the relationship between regional cultures and international construction techniques.
These debates brought up the neo-traditionalist approaches by a group of Iranian architects, being supported by western post-modern and environmentalists.

3. Thirdly are the implemented projects of the modern architects with trends towards traditional Iranian architecture and urbanism, since 1970s till present.
The only outstanding project that can be mentioned as a successful investigation of the technical values of traditional Iranian city planning and then adaption of them in a modern life is the Shushtar New Town by K. T. Diba.
Other architects are either too much involved with the mystic characteristics of Iranian traditional architecture, like Nader Ardalan, or totally concerned with cultural or aesthetic values or interpretation of the meanings laid beyond the traditional system.
The projects built by these two groups are mostly symbolic and formal interpretation of the traditional elements in a modern language, by adapting the traditional organization or geometry missing technical rationalization.
However, in such projects, when the contextual features (including the urban context or cultural context) are taken into consideration, the outcome is successful in transferring a sense of modern-Iranian architecture to the public like the cases of Tehran Contemporary Museum of Art by Kamran Diba or Center for Management by Nader Ardalan.
But ignoring the contextual considerations in such projects, results in an eclectic adaption of irrelevant symbols of Iranian architecture, and the project fails in achieving public acceptance, like in Dezful Cultural Center by Farhad Ahmadi.

4. The latest activities that pay attention to the Iranian traditional architecture in their contemporary projects are the energy-efficient projects in Iran implemented by cooperation of European partners, like Hashtgerd New Town. These projects focus majorly on energy saving strategies while environmental sustainability covers a broader spectrum of features than energy saving in buildings. Other sustainability features have remained further more ignored.

CONCLUSION

This dissertation has a novel approach in evaluation of Iranian traditional urban design in terms of environmental sustainability by application of a modern assessment tool (LEED).

Since 1970s various debates on understanding the hidden values of Iranian traditional architecture and adapting them into modern design has been raised from different points of view. The outcome of adapting them in modern architecture has been, in most cases, a modern formal repetition of the Iranian architecture's elements. Such architectures have a modern but Iranian impression on the audience, but miss the right technical performance of the adapted traditional elements.

This dissertation aims to focus on technical solutions in traditional urban design, and reuse or upgrading of their sustainability features in Iranian modern life.

Chapter 3: General Context

3.1. Sustainability; General Definitions

3.1.1 Sustainable development, a local concept

Today, sustainability is a global concept, and it is known to every region and country in the world. Meanwhile, as Emmanuel declares, there are many definitions of sustainable development (Emmanuel 2015, P337). There are different interpretations of this concept. In the following part, some of the different definitions of sustainability are presented: As argued in DETR report (2000):

"Sustainable development is about ensuring a better quality of life for everyone, now and for generations to come, through:

- Social progress which recognizes the needs of everyone
- Effective protection of the environment
- Prudent use of natural resources
- Maintenance of high and stable levels of economic growth and employment (DETR March 2000).

Chaharbaghi & Willis show the different aspects of sustainability in different professions (Figure 33) (Chaharbaghi 1999, 41-48).

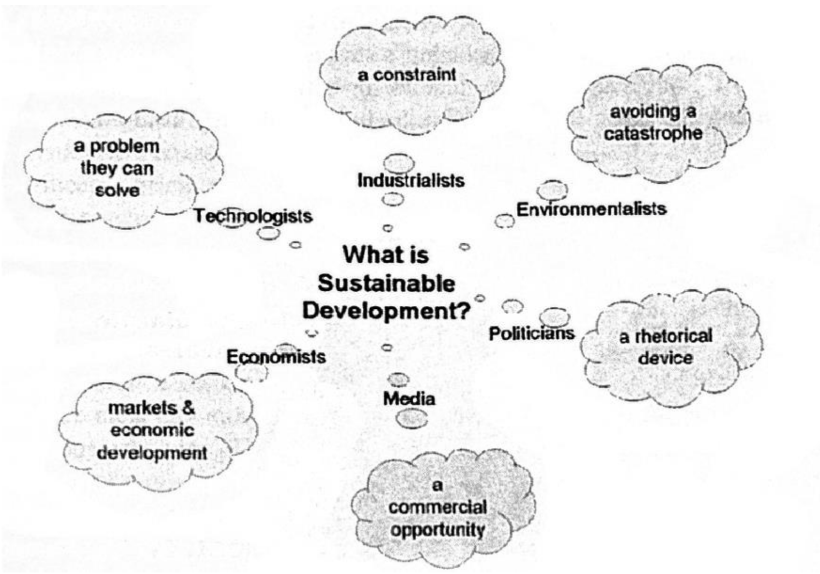


Figure 33: Different aspects of sustainability. Image from: (Emmanuel 2015, 337)

As Pearce defines "sustainable design and construction has a focus on reducing or eliminating environmental problems and issues associated with built facilities and construction activities while maximizing the potential benefits to society and the economy" (Pearce 2012, 7).

According to the above definitions and in spite of the similarities and common issues in different definitions for sustainability, each emphasizes different aspects of sustainability. Most of these definitions are defined on the basis of subjective viewpoints and focuses.

It seems that the reason for the variety of definitions for sustainability is the generality and extensive borders of the concept. Sustainable development encompasses a large scope of phenomena and involves many elements, such as social and cultural features, economy, environmental issues and climatic conditions of human societies. Each definition of sustainability focuses on specific features of this concept.

In addition, because of the relationship between the concept of sustainability and the environment and socio-cultural conditions in different regions, this concept can be defined with different meanings in different countries and regions.

So it seems that sustainability is a relative phenomenon and its meaning is different for different nations and regions. As Guy expresses:

"There is a paradox for defining sustainability. For example a timber structure doesn’t need the energy that goes into smelting aluminum. On the other hand, aluminum structure can easily be recycled, while timber cannot” (Guy and Moore 2005, 6).

So how can we agree on which construction is more sustainable, timber or aluminum?

Maybe the answer is that each can be considered as a sustainable solution in its own specific, relevant environment, where the other one cannot be used in the same context as a sustainable solution.

The following example shows the relativity and locality of sustainability, highlighting it as a context-dependent issue.

In climates such as the hot and arid region of Iran, one of the main problems at the city scale is the harsh solar radiation, inspiring the question of how to protect the city and passageways and make shaded areas for more comfort. While Europe, in contrast, benefits from more solar radiation. Either using sunlight or escaping from it is related to the climatic and environmental conditions of each region and country.

As Pearce describes “each national context has resulted in a variety of approaches to sustainability for the built environment and actions to move toward sustainability have evolved to meet the specific needs of the people of each nation and the conditions in which they live” (Pearce 2012, 24).

So it is important to define a local definition of sustainability in a country such as Iran, with its unique environmental, social and cultural context.

The aim of this research is to introduce some special and local aspects of sustainability that can support further research, which aims to define a local definition of sustainability and its criteria for the hot and arid region of Iran.

Nonetheless, before reaching that aim, this research benefits from the most accepted and general definitions in the world. According to Jenks, "the most commonly cited definition of sustainable development has been drawn from the Brundtland report (Jenks 2000, 3):

"*Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987, 16).

The Brundtland Report emphasized a variety of actions needed to achieve the goals of sustainable development. To achieve its stated goals, the report emphasized three fundamental components for sustainable development: environmental protection, social equity and economic growth (Pearce 2012, 23).

As Jenks states, "those three categories (economy, society and environment) are three pillars of sustainable development" (Figure 34) (Jenks M. 2005, p1).

This research focuses on the environmental aspects of sustainability because of the reasons that will be explained in the next part.

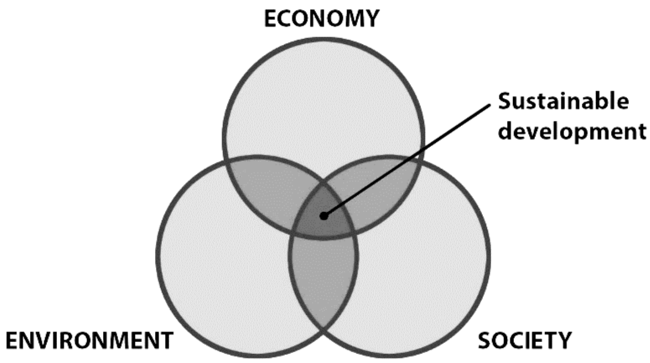


Figure 34: Three pillars of sustainable development. Image from: (Emmanuel 2015, 338)

3.1.2 The Role of Cities

According to Brundtland report (Brundtland 1987), the world of the 21st century is a large urban world: in 2003, about 48% of the world's population lived in urban areas and the predictions are that by 2030, 61% of the population will be urban (Jenks M. 2005, p1).

In this urban world, construction is one of the largest industries (Pearce 2012, p1). A great amount of energy is consumed by construction activities, mainly the operation of buildings. For example, in the United States, more than 68% of the total energy is consumed by buildings and transportation systems (Pearce 2012, p1).

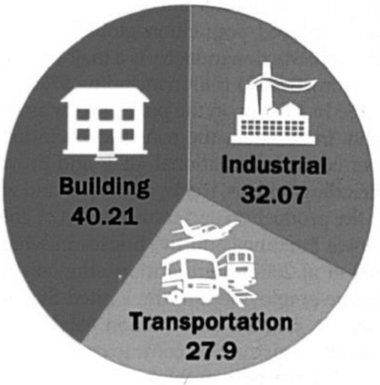


Figure 35: Energy use by sector of the economy in the United States. Image from: (Annie R. Pearce 2012, 2)

Due to the important role of urban activities and buildings in energy consumption and their effect on environment, decisions and strategies in the urban and architectural scales are important for sustainability. On other hand, decisions that have a primary effect on the performance of buildings are taken in the first steps of the design and management of the building (Pearce 2012, p1).

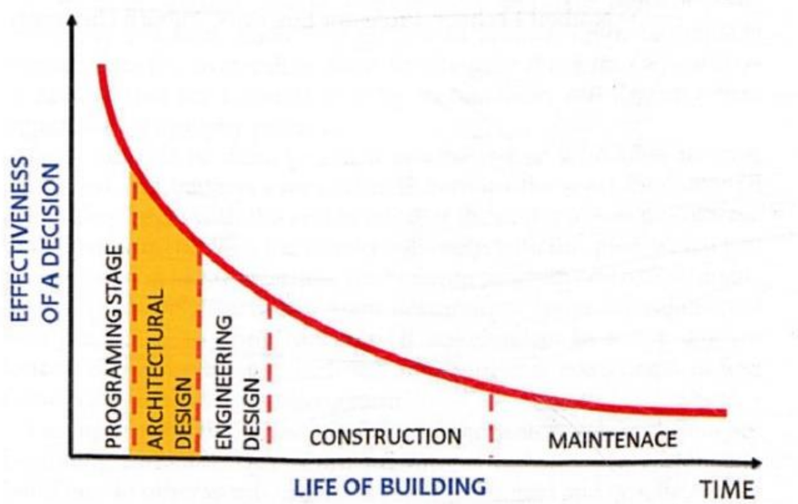


Figure 36: The change in the effectiveness of a decision over the life of a building. Image from: (Annie R. Pearce 2012, 21)

This means that the urban and architectural design strategies and decisions taken at the primary stages may have more influence on the environment than the construction stage.

Hence, urban and architectural design and strategies play an important role in environmental sustainability.

Urban design and architecture influence the economy, society, and environment. As Jenks explains, “the cities must be economically viable, socially equitable and contribute to environmental protection” (Jenks M. 2005, 1).

Without a doubt, there is an interconnected relationship between economic, social, and environmental features of the communities on one side and urban decisions on the other side. But development of cities and their constructions has the most profound effect on environment. As Baycan states, "the environmental problems especially in the third world associated with rapid urbanization include specific problem manifestations such as:

a. Pollution from urban wastes (municipal and industrial wastewater, storm water drainage, municipal solid wastes, hazardous wastes, and ambient as well as indoor air pollution
b. Urban transport externalities (increasing motorization, poor traffic management, insufficient bicycle paths and walkways, etc.)
c. Resource management issues (unsustainable patterns of resource consumption include depletion and degradation of water supplies, inappropriate land development, inefficient urban fuel consumption and loss of natural and cultural heritage)
d. Environmental hazards (urban areas are subjected to natural hazards: severe storms, floods, earthquakes, volcanic eruptions, wildfires, etc.) (Baycan 2008, 132).

After defining and explaining the issue, this dissertation aims to find sustainable strategies for contemporary architecture and city design by drawing upon local and traditional strategies for inspiration.

Considering the strong environmental effect of city planning and architectural design, and also according to the author’s field of study, this research focuses on environmental aspects of sustainability.

Of course it is very difficult to make definite borders for different aspects of sustainability i.e. environmental, social and economic items in analyzes, while there is a very close relationship in these three categories of sustainability, and some factors of analysis may affect or contribute to all three of them. For example, a compact urban texture with connected buildings can reduce environmental effects by minimizing fossil fuel energy consumption by reducing the external walls’ energy exchange. From another point of view, these shared walls can develop social communications between neighbors. These further social connections can have the benefit of forming a united local community, but they can also cause social interferences between neighbors. Economic exchanges in society may also be an influential factor. Analyzing social benefits or problems of this exemplary case needs different social experts.

This dissertation concentrates on environmental aspects of sustainability and does not intervene with its social or economic features.

3.2. Contemporary Architecture in Iran; Discontinuity of the Traditional Architecture

Traditional architecture of Iran, known as Islamic architecture, reveals an integrate unity in principles (Beheshti 2015). These traditional patterns have had a continuing unity in concept, design and construction throughout history.

But dramatic changes happened in Iran's architecture in contemporary era. Sometimes these changes happen faster due to special events e.g. nationalization of oil industry (1951), land reformations (the White Revolution) in Pahlavi era, Islamic revolution (1979), war with Iraq (1980-88) etc.

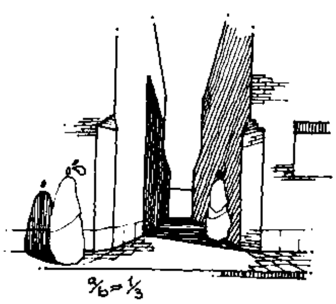
In this part some of the features of this traditional architecture and cutting this system are explained.

In this part, the features of this traditional Iranian architecture and the grounds that resulted in cease of this continuous system are discussed.

Ehlers and Floor describe the Iranian traditional city (Ehlers and Floor, Urban Change in Iran 1993, 251): "Iranian traditional urbanism and architecture owes its form to the climatic constraints, the locally available technology, and the prevailing customs and culture."

Kamran Diba, in his investigations on Iranian traditional architecture, describes the following features as some characteristics of this traditional system:

- Introverted architecture:
  - Preservation from sunlight
  - Preservation of the familial core; social (privacy) and religious (*Mahramiyat*) factor
- Human scale
- Narrow streets preserving from the heat and sunlight
- Open meeting spaces in each small neighborhood
- Spatial transitions
- Generating a communal sense (Aga Khan Awards 1986).



Pirnia (1922- 1997), the father of Iranian traditional architecture, enumerates five principles for the Iranian traditional cities and architecture:

- Humanism: attention to human needs, human behavior and human scale
- Avoiding idleness: minimizing non-functional decorative elements and materials
- Durability**:** paying attention to building statics and the application of the best techniques and most persistent materials
- Self-sufficiency: using local materials and techniques
- Introversion-ism: attention to social, cultural and climatic principles (Pirnia and Memarian 2008, 26-35).

Another research adds two more aesthetic principles to these features stated by Pirnia:

- Homogeneous proportions
- Symmetry and anti-symmetry (Iranreview 2014).

Many of the above mentioned features share common characteristics with other traditional architecture around the world.

Specific climatic conditions in Iran's hot and arid regions, which has its own environmental challenges—lack of natural resources such as water and high aridity, in combination with the cultural characteristics of the inhabitants as well as the thousands of years of architectural and urban background in the Persian plateau—results in a specific sort of living. Throughout history, people in this region have learnt to adapt their life and buildings to this condition.

Most of the mentioned features in the previous part have climatic and environmental influences, and this expresses the vital role that the environment plays on the definitions and features of architecture and urban style in a special region.

As mentioned in the introduction chapter, the main aim of this dissertation is to redefine some design strategies from traditional Iranian city and architectural features that have the capability to be adapted and used in contemporary architectural and urban design.

These lessons and inspirations can be further developed to lead to Iranian sustainability criteria for contemporary life.

This effort will be discussed and developed in the following chapters, but now some of these features will be explained in more detail.

3.3 Structure and pattern of Iranian city and architecture in the hot arid region:

- Structure:

The traditional Iranian desert city includes the Friday Mosque in its center, with its high minarets as landmarks. Around this, the grand bazaar with vaulted roofs forms the central spine of the city. In addition, *public baths*, *madrasas*, *mosques*, and *cisterns* are located in almost every city center (Figure 37).

The residential areas surround these public structures.

Narrow passageways often link the bazaar (the commercial parts of the traditional cities) on the one side to the houses on the other. These passageways are only used for local access by the residents of each neighborhood house and are dead-ended (Ehlers and Floor, Urban Change in Iran 1993, 251-252).

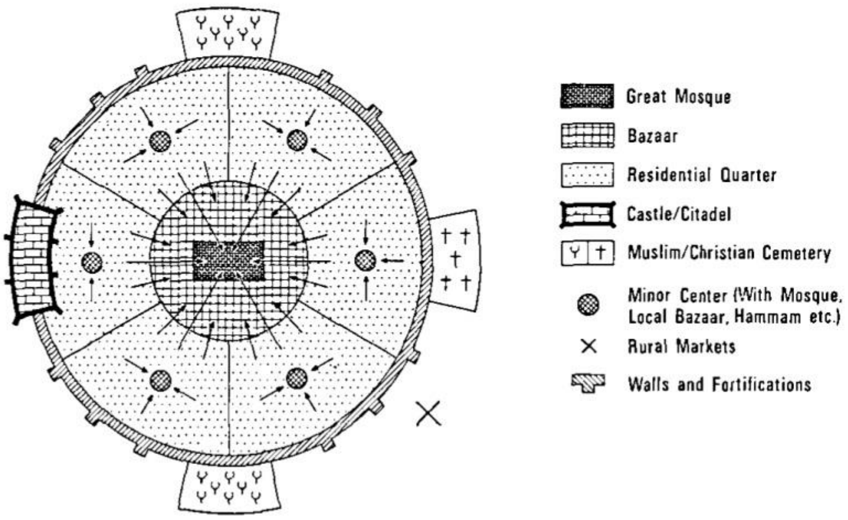


Figure 37: Model of a traditional Islamic city. Image from:
(Ehlers and Floor, Urban Change in Iran 1993, 252)

- Organization:

The main center of the city, including the bazaar and other urban facilities, usually has a linear form and the residential districts are branched from this main axis.

In some cities such as Isfahan, the grand mosque is located at a plaza or square (as a public urban space). This square is connected to the main bazaar and its urban facilities (Figure 38).

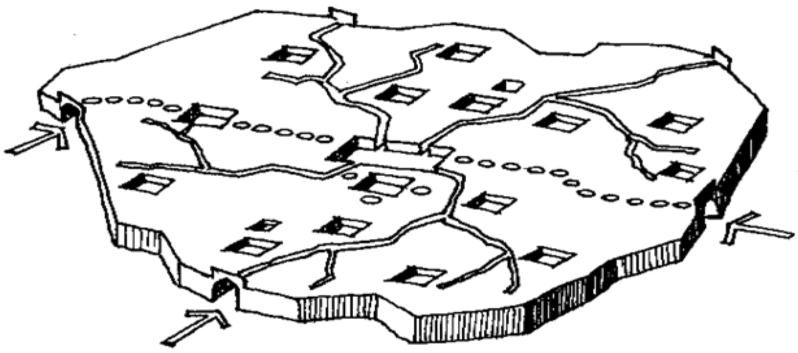


Figure 38: Big square and main bazaar as the main center and axis of the Iranian traditional city. Graphic by author

Residential districts are located around this main spine of the city (the grand bazaar), with a hierarchy of access from the main city center to the private houses.

-Urban fabric:

The buildings in the Iranian city are connected together in a compact, interwoven urban fabric. This is one of the most important features of the city for surviving in a desert climate. Common walls between neighbors reduce the energy exchange and waste through external walls.

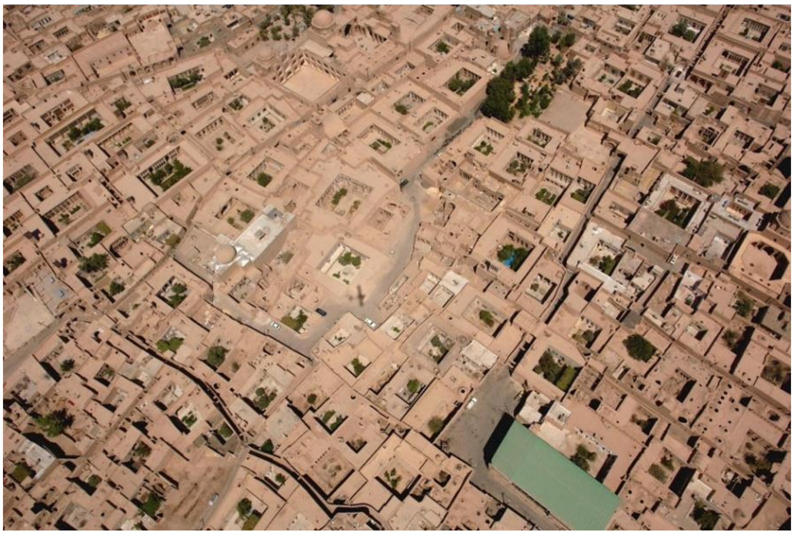


Figure 39: Urban texture of traditional city of Yazd. Image from: **(ICHTO 2013)**

Passageways are narrow and non-straight in order to provide more shading and protect the residential areas against frequent sand storms in cities such as Yazd.

The sky line of these desert cities is mostly a straight, low horizontal line. Only the mosques' domes and minarets in some parts break this sky line.

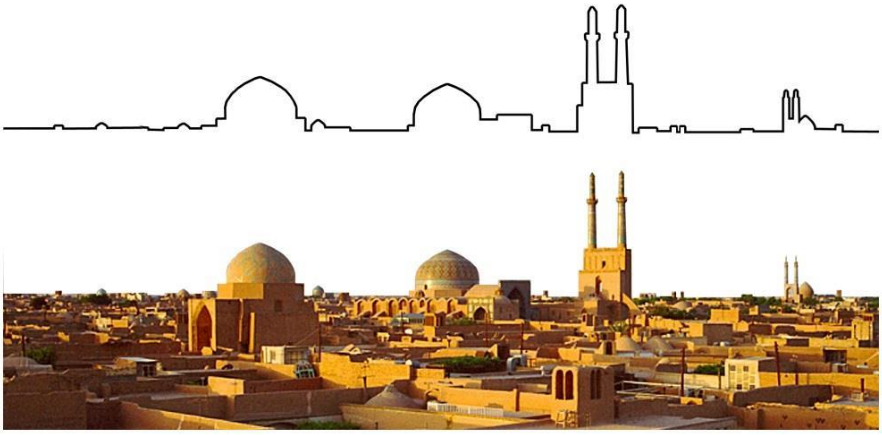


Figure 40: sky line of Yazd. Image from:
(Fotografia 2014)

-Hierarchy of facilities distribution:

Traditional Iranian historical cities follow a pattern of hierarchy in the distribution of facilities from the urban scale to district and neighborhood scales. In the center of each district, there are several local facilities, such as retail shops on a small bazaar, public bathhouses, cisterns and a small mosque. These facilities are for supplying the daily needs of the inhabitants. For further urban services, people use the main bazaar's facilities, which connect different parts of the city as a central spine (Figure 41).

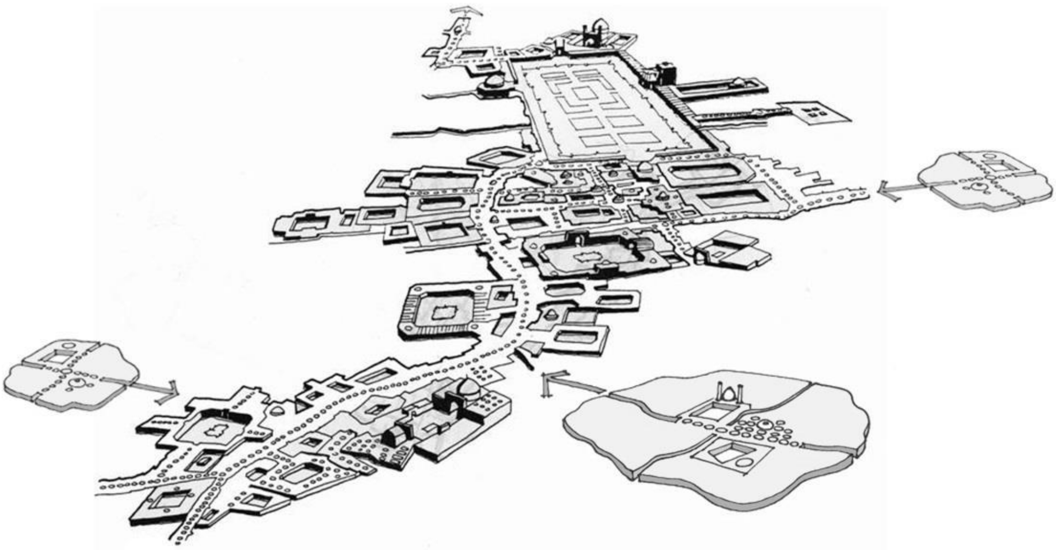


Figure 41: districts facilities that are connected to the main spine of the city. Graphic by author in **(Ahari and Habibi 2001)**

- City fortress:

The previously mentioned structure of the city is surrounded by a continued fortification that organizes an introverted city. Only a few gates around the city fortifications connect the inner parts to the outside, which is usually a desert.
This introverted organization, comprising of high thick adobe walls, protects the city from the threats of enemies and also sand storms (Figures 42-43).

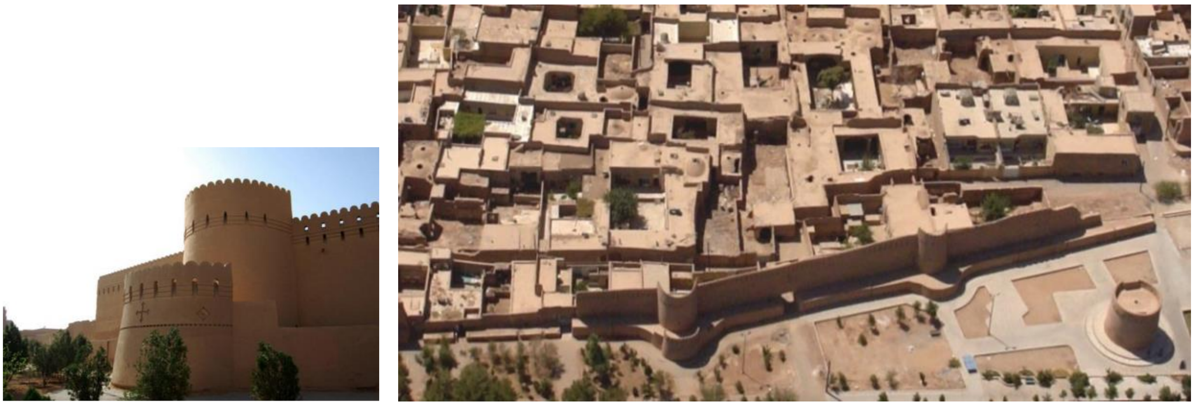


Figure 42: One part of Yazd's fortification. Image from:
(ICHTO 2013)

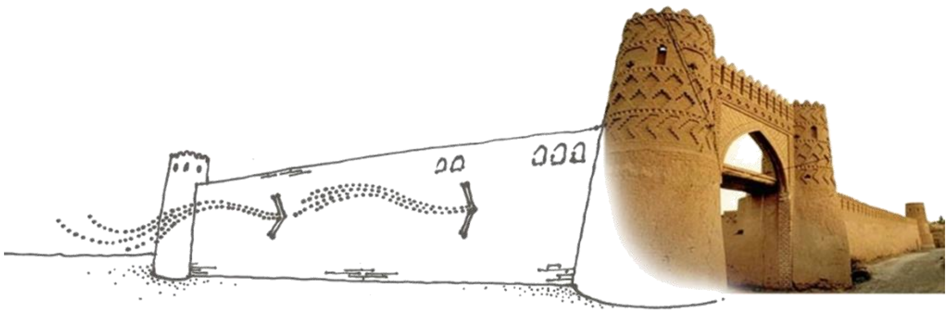


Figure 43: Usual fortification and gates around the historical cities. Graphic by author on basis of image from:
(Aftabnews 2014)

-Architectural scale:

At the architectural scale, the ancient pattern of organization (central courtyard) is used in different facilities such as *mosques, caravanserais, madrasas* (religious schools), and houses. The courtyard pattern has been used for 8000 years in Iran (G. H. Memarian 1996, 16).

This pattern produces an introverted organization. All the living spaces are arranged around one or several central courtyards.

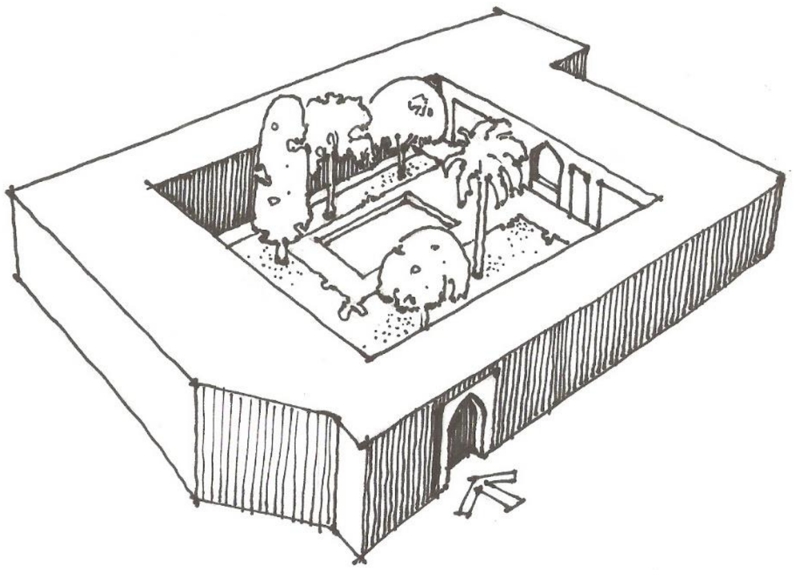


Figure 44: Central courtyard in the Iranian architecture. Graphic by author

According to this pattern, the building doesn't have any view toward the outside and only one simple entrance provides access from the outside to the internal parts of the building.

This is a beneficial organization regarding the climatic conditions of the hot and arid region. This introverted courtyard system, with its elements such as a *Bād-gir* (wind catcher: traditional architectural element to create natural ventilation in buildings), water pool, and vegetation, creates a microclimate system that provides the inhabitants with comfort zone conditions.

This introverted system, which is closed to outside, helps create a controlled climatic system in the central courtyards against the severe conditions of exterior deserts. Inside the houses, there is a policy for organizing the living spaces around the courtyard. Major larger rooms are located at the center of each side of the courtyard, and secondary spaces are located at two sides of them. The corners accommodate the service spaces which do not need natural lighting (Figure 45).

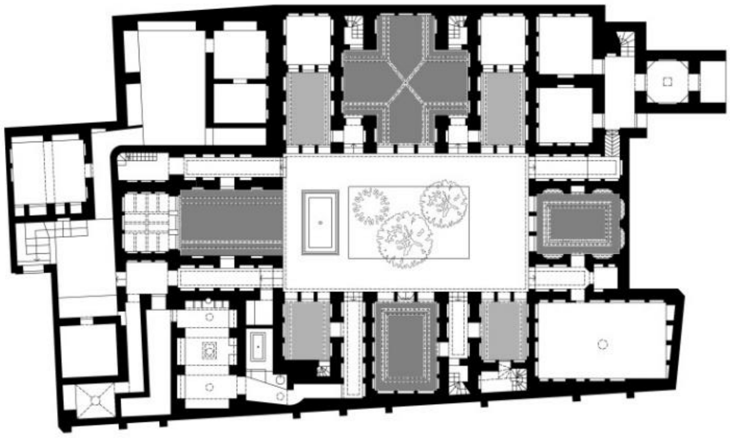


Figure 45: Distribution of the main and secondary spaces around the courtyard (Tehraniha house in Yazd) Image from: **(Haji- Qassemi 2005, 34)**

Larger traditional houses contain two or more courtyards. These courtyards are divided into one courtyard for guests and form the so-called external part of the house (*Birouni*), and the other courtyard(s) is for the private family use, so called Internal or *Andarouni*. In aristocratic houses, there were also other courtyards for the servants' living spaces or stables for keeping horses (Aga Khan Awards 1986).

An indirect entrance called *Hashti,* comprises of a small waiting and communication space with an octagon plan and an indirect corridor; this gives access from the outside to the courtyard. This strategy creates more privacy for the living spaces in the house, because it obstructs any view from the outside to the inside. (Figure 46).

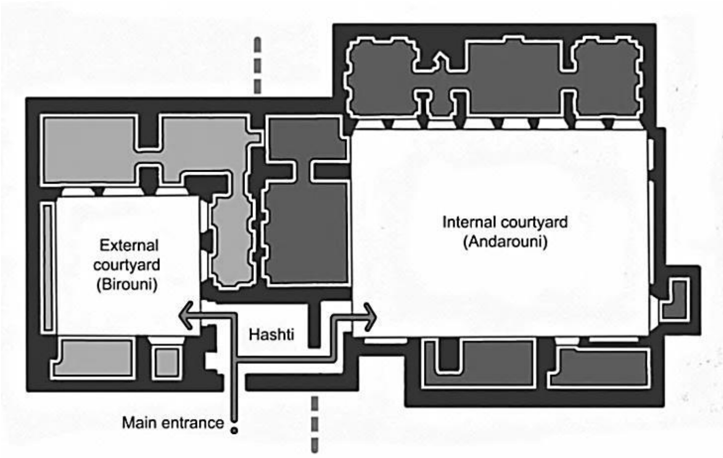


Figure 46: *Hashti* in Mojahed traditional house in Yazd. Graphic by author (Soltani and Abbasimehr 2013)

This research claims that this system of architecture and urbanism has several advantages to respond to the socio-cultural and environmental context of the hot and arid region. That's why it has survived for thousands of years. This is built from features that are marked by local sustainability. As Samizay argues, this traditional system and its features in the cities like Yazd, over the years responded to the forces of the environment which guaranteed its sustainability in harsh conditions (Samizay 2012, 127).

In order to prove this claim, these features will be analyzed and assessed with sustainability evaluation systems in the following chapters. Before that, some features of the contemporary system of city designing and architecture, and how and why this contemporary architecture ignored the traditional system in the past decades will be explained in the following.

3.4 Cutting the traditional system:

As Diba argues, the traditional system of architecture and urbanism has survived until beginning of modern life in Iran. With the rule of the Pahlavi dynasty (1925-1979), architecture was modernized in a new way. Socio-political planning under the authoritative rule of the government, aided by westerners, was the style of the period (D. e. Diba 2004, 32).

Ehlers also mentions that the reforms initiated during 30s changed not only the cultural patterns of urban life in Iran and the economic structure of the country, but even the spatial organization (Ehlers and Floor, Urban Change in Iran 1993, 251).

Figure 22 shows the spatial alternations, with the new wide car-scaled streets and boulevards that cut the traditional city structure and added a new meaning of spatial organization, with its new forms and elements taken from European cities, such as squares and straight passageways.

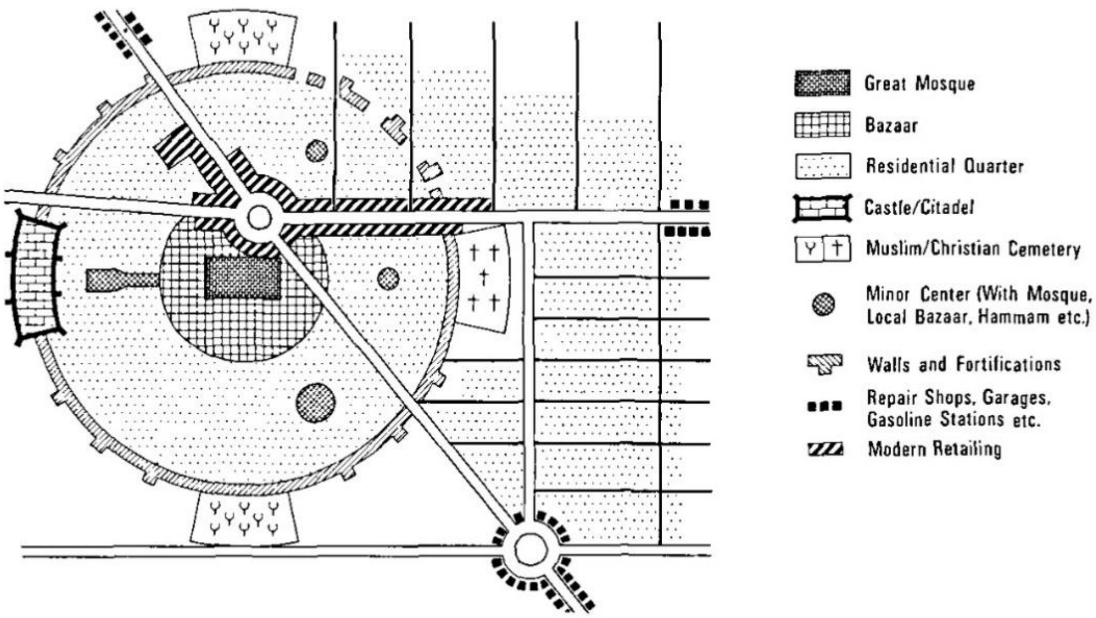


Figure 47: Model of a modernized Islamic city. Image from:
(Ehlers and Floor, Urban Change in Iran 1993, 264)

A comparison of figure 47 and figure 37 illustrates the spatial changes in the Iranian cities and the clumsy transfer of the old city to a modern city. The city was developed without consideration of the existing structures. Many of the important traditional buildings and urban spaces such as urban plazas and bazaars, as well as single buildings such as bathhouses and houses, were destroyed from the addition of new streets and facilities (Figure 48).

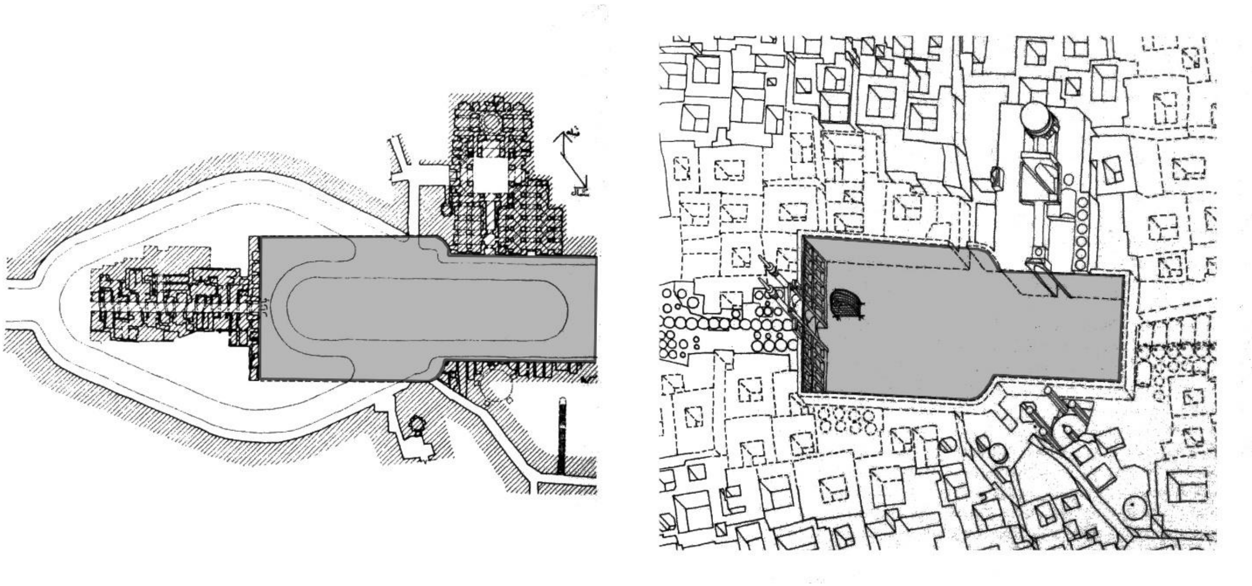


Figure 48: Amir-Chakhmagh square changes by modernizing city and new streets and squares (Right: traditional original square. Left: contemporary changes by adding new streets with different form and destroying the old square and bazaar). Image from: **(Tavassoli and Bonyadi, Urban Space Design 1993)**

As mentioned before, a definition of new organizations in modern cities and therefore new building facilities such as banks, hospitals, universities etc. have imposed a new structure to large cities. These new definitions mostly formed on the basis of a grid organization defined by a network of streets. This urban grid pattern was imposed onto the ancient city pattern, a mostly a centralized pattern (with the Friday mosque in the center). This means that these contemporary changes took place while neglecting the former characteristics and organization of the traditional city.

Many features of traditional cities, as explained before, are created for adaptation to climatic and environmental conditions. Features such as the orientation of the urban fabric, narrow and indirect passageways that prevent sun light in hot summer, and compact and connected urban fabric are direct examples of this conscientious building. These features are missing in modern urban organization, which was imitated from the west.

This blind imitation of western patterns defines a city with cars as the dominant feature of modern living.

The previous traditional hierarchy of passageways, starting from the grand bazaar and ending at neighborhood centers, was replaced by street grids, which cut the urban fabric, neglecting the hierarchy and privacy of the previous passageways. They cut the whole urban fabric and let the streets pass through all parts of the city, from across the bazaar to residential districts. This new pattern misses a logical connection with the former urban structure, functions and passageways (Figure 49).

Figure 49: Confrontation of traditional urban texture of Yazd with new structure and its streets. Image from: **(ICHTO 2013)**

All changes in the socio-cultural and spatial condition of the cities were misdirected trends, from a sustainable city, with its original and vernacular architectural and urban design system, towards an imported western system and style of urban design, which ignores the local values and sustainability potentials.

Contemporary Iranian architecture does not share any features with the traditional and local architecture. Its rules originate in contemporary international design styles and is largely homogeneous across differing climates in the country (from cold mountains in the west to a moderate climate in the north on the coasts of the Caspian sea, to the hot and arid central deserts of Iran, and the hot and humid climate along the coasts of the Persian Gulf). The local, traditional architecture in each region is left ignored.

Following, are some of the major grounds to see how and why the hundreds of years of continuous chain of traditional architecture was broken in recent century.

3.4.1 Modernization in Iran

According to architecture historians, the first sparkles of modernization in Iran began in Qajar era (1785-1925 AD) as a result of increasing communications with Europe. This caused transformations in Iran’s traditional architecture (Dehbashi and Diba 2004, 31)

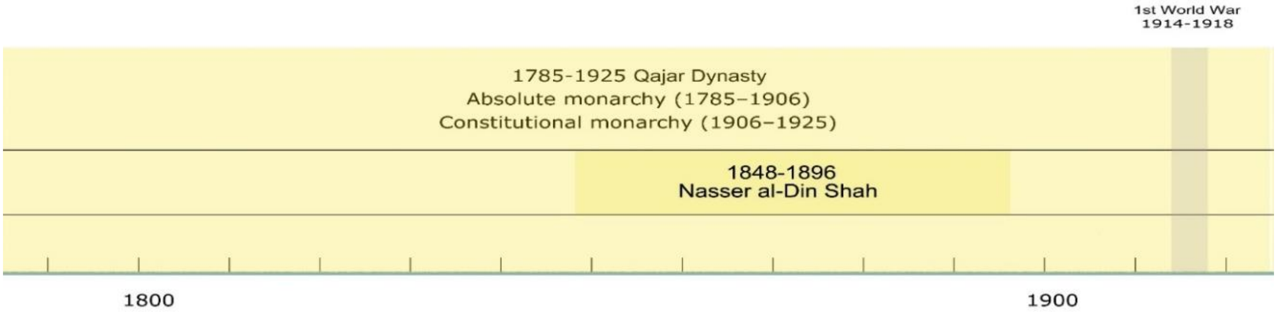


Figure 50: timeline for Qajar period in Iran. Graphic by Afsaneh Soltani

It happened as a result of the reforms enacted by the princesses and authorities and those who pursued the rational rule of law as well as the development of public education and welfare with economic independence as their real aim (ibid).

Nasser al-Din Shah (1848-1896)

Briefly, the following reasons in Qajar period, specifically during the long monarchy of Nasser al-Din Shah (about 50 years) who was interested in travelling to Europe, laid the groundwork for the appearance of a new architecture in Iran since the second half of the 19th century:

- Education of Iranian students in European sponsored by the government.
- Presence of European and mostly French architects in Iran.
- Penetration of Western modernity into Iran that happened mostly through travels to Europe, translation of texts and activities of educational organizations.

These, influenced all aspects of daily life, culture, art, etc. including buildings and architecture which was mostly a non-conscious adaption of the western civilization, majorly a copy of Iranians' observations.

The outcome was therefore a mixture of the European technology with Iranian traditional architecture. Architecture with western tendencies began from royal palaces and then enfolded the urban design in Iran (Bani Masoud 2009).

New construction technologies brought about the opportunity for building new dimensions of buildings and construction patterns such as multilevel palaces, which totally reveal an extroverted non-Iranian architectural pattern (Figure 51).

Figure 51: Shams-ol-Emareh, Qajar Palace in Tehran Source: (Iran Review 2016)

First Pahlavi (Reza Shah 1925-41)

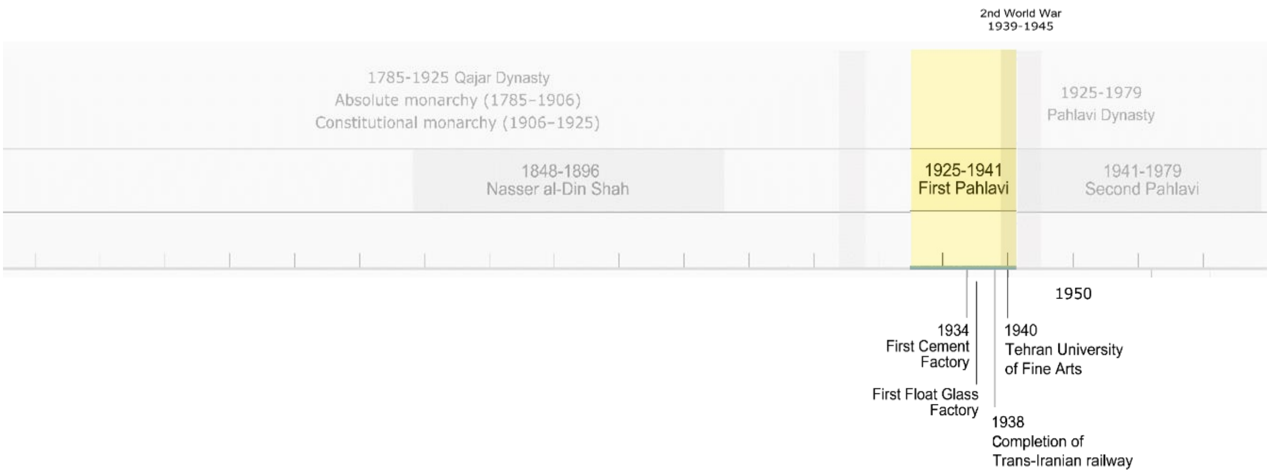


Figure 52: timeline for First Pahlavi period in Iran. Graphic by Afsaneh Soltani

By the decline of the Qajar dynasty after Nasser al-Din Shah's rule and after the First World War, this dynasty was replaced by the Pahlavi dynasty in 1925.

During the first period of Pahlavi dynasty, two decades of Reza Shah’s rule (1925-1941), Iran experienced dramatic developments. Industrialization of the country started**.**

This was in conjunction with a marked Europeanisation of social behavior. Education, the economy, and culture all figured on the agenda of Reza Shah under the influence of the West.

The government played an active role in the execution of civil projects. Roads and rail networks were constructed**.**

Western architects were invited to design new buildings such as factories, governmental offices, universities and hospitals for the first time, and the reconstruction plans were executed with great speed. As a result, the traditional design of many cities changed significantly.

For providing the required building materials to implement civil projects at a higher pace, factories such as cement and float glass were set up by the aid of Europeans.

In different years according to the political relations of Iran with Britain, Germany or France, different types of contemporary European architecture specially the Neo-Classic style was designed and implemented in Iran. (Ayatollahi 2002, 292), (Darab Diba 2004, 32).

The return of the architects who were educated at the École des Beaux Arts in Paris (Wilber 1986, 349-351) and establishment of the School of Fine Arts at Tehran University (Diba 2004, 33) brought up a new trend in Iran's architecture (Ayatollahi 2002, 292). The traditional pedagogy in architecture that passed the talents from master to trainee from one generation to the next was discontinued and replaced by education of architects along with the lines of European architecture universities.

The architecture of the first Pahlavi period can be divided into 3 major categories, which originated from different existing social flows at the time, with tendencies towards continuation of traditional (Islamic) architecture, western architecture or Iranian ancient architecture:

1. The architecture, which used traditional Islamic architecture of Iran, and was indeed a Continuation of the Late Qajar Architecture (Bani Masoud 2009).

2. Modern architecture, with a sense of being Iranian: the early-Modern architecture which was mostly designed by the foreign architects or the Iranian architects educated in Europe, who were influenced by the Wien style, and early German expressionism, and also the French Art Nouveau (Bani Masoud 2009). These architects usually tried to remain loyal to the principals of the Modern architecture, with a sense of being Iranian.

3. The third orientation was a combination of European Neo-classic architecture with the elements and motifs belonging to ancient Iran (Bani Masoud 2009). These architects tried to revitalize the principles of the Great Persian Empire.

Second Pahlavi (Mohammad Reza Shah, the son 1925-41)

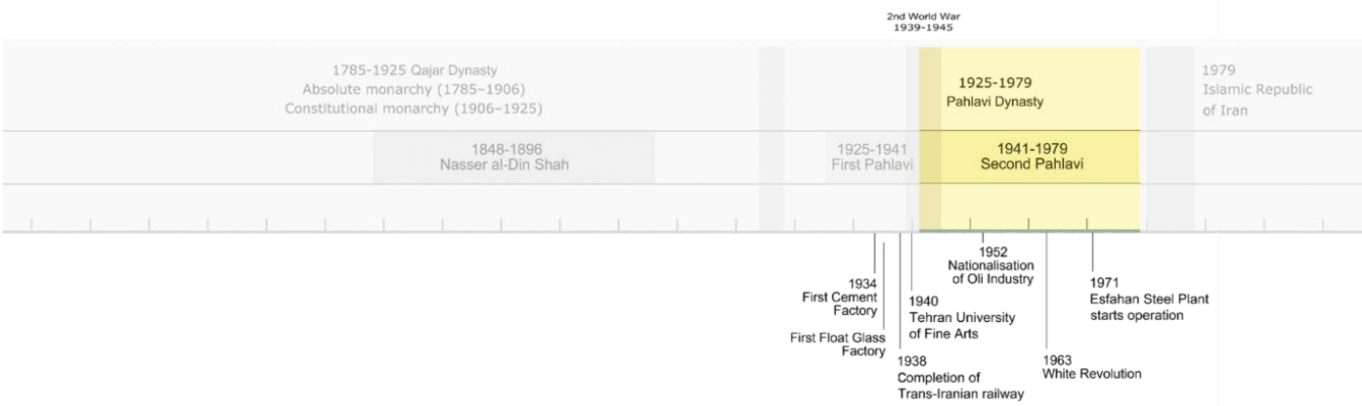


Figure 53: timeline for Second Pahlavi period in Iran. Graphic by Afsaneh Soltani

The second Pahlavi period was influenced with Mohammad Reza Shah's attitude. He was educated in Switzerland and instilled with new Western values, and sought to shape the image of Iran.

The decline in architecture and urban development projects in the first decade after the World War II was followed by nationalization of Oil industry in 1951. The emphasis on rapid development sometimes resulted in hurried and uncalculated import of western solutions for solving the urban and civil issues of Iranian cities (Dehbashi and Diba 2004, 33) (Ardalan, Architecture viii. Pahlavi, after World War II 1996).

From the architectural point of view, development of the School of Modernism and the International Style in Architecture was the major characteristic of this period.

This process, which occurred in the design of some structures from 1953 to 1963, was then applied to almost all buildings. During this period (1941-1979) numerous governmental and commercial buildings were erected and many residences were built without consideration for local characteristics or climatic conditions in Tehran and in other cities like Tabriz, Yazd, Mashhad and Kashan (Diba 2004, 33).

The two flows of architecture in this period were:

1. Following the international style that was imitated all over the world, with multi-level to high rise buildings of concrete structure or steel and glass facades.

2. Modern Architecture, with a Sense of being Iranian, implemented by new generation of educated architects who knew values of Iranian traditional architecture and were committed to use them in their design. The outcome of their work was a modern Iranian architecture.

In addition, the following factors, specifically in the past decades, caused dramatic changes in traditional patterns of construction in Iran:

- The urban population has been growing up in Iran in recent years according to different factors such as better job, education and living opportunities in larger cities like Yazd. This has resulted in ascending request for cheaper and more rapid construction and has therefore changed the appearance of architecture.

The following graphs show the urban population growth in recent decades.

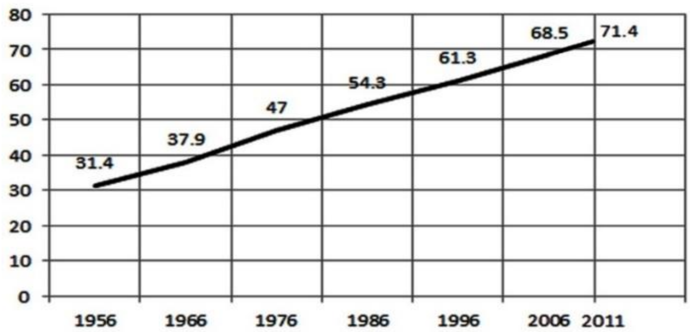


Figure 54: Percentage of urbanization in Iran (1956- 2011)
Source: (Statistical Center of Iran 2013)

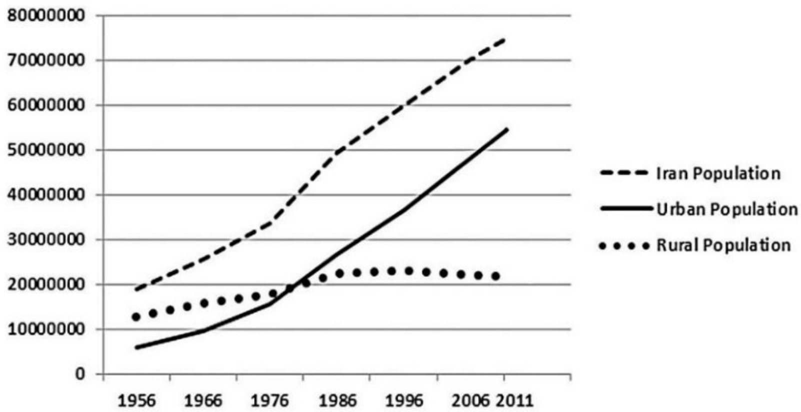


Figure 55: Population of Urban and rural areas in Iran (1956-2011) Source: (Statistical Center of Iran 2013)

- Due to expansion of cities and population growth and migration to cities from rural areas, building and housing development has become a growing profit-making business in recent decades. Investigators at different scales have had the possibility to enter this business. This led to cheaper, faster mass housing construction which resulted in uniform structures regardless of climate and context (Diba 2004, 33) unlike the traditional architecture.

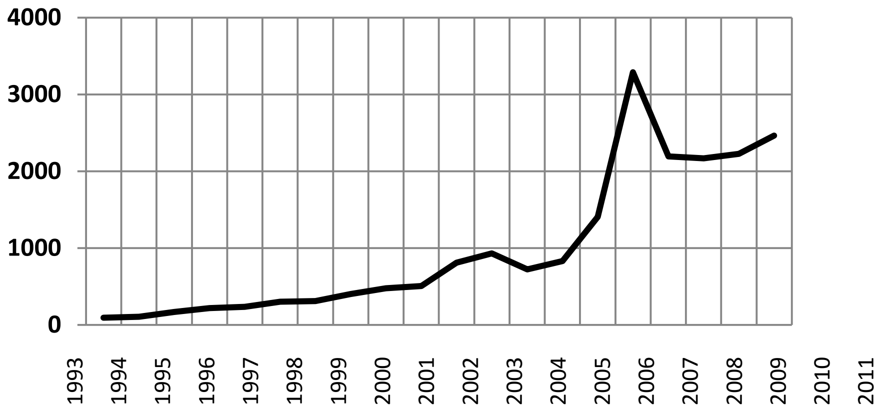


Figure 56: Average price of residential land per m² in 1000 IR. Rials in Yazd (1993-2011)
Source: (Statistical Center of Iran 2013)

- Modernization of the society especially the women's education and work totally changed the texture of the traditional Iranian families. In Iranian traditional families, children did not live their home after getting married, but stayed in their parents' large houses with many rooms. Different generations lived together in different rooms of a traditional house around central courtyard.

But in modern Iran, young generations leave their parents to live more independently. This also caused an emerging demand for small affordable hoses for young small families and made the traditional large houses more abandoned.

The following table shows the mean number of family members (ibid) which is now at an average rate of 3-4 persons per family. This also demonstrates the increasing demand for independent affordable housing especially in larger cities with more expensive lands.

Year	1956	1966	1976	1986	1991	1996	2006	2011
Person	4.8	5	5	5.1	5.2	4.8	4	3.5

Table 1, Average number of persons per family in urban and rural families

Table 2 shows the mean age of the Iran population from 1956 to 2011 (S. C. SCI 2012). This shows that Iran has a young population.

Therefore there is a high demand for small affordable housing when the young generation's request for independent living is increasing.

Year	1956	1966	1976	1986	1991	1996	2006	2011
Mean Age	23.7	22.2	22.4	21.7	21.6	24.03	27.97	29.8

Table 2, Mean age of population in Iran

SUMMARY

Briefly, the following facts caused the discontinuity in the hundreds of years of traditional architecture in Iran 20th century.

- Development of communication with Europe, westernization and Europeanization
- Industrialization
- New building materials
- Western Architects in Iran
- Education of Architects
- Development of the School of Modernism and the International Style in Architecture
- Oil Income

In addition, the following features has also resulted in increasing demand for construction of small, rapid housing

- rapid growth of population of larger cities
- transformation of definitions of family
- transformation of living style of the youth

3.5 Building Design in Iran, Regulations and Authorities

In modern era, simultaneously with the graduation of architects and separation of the design process from construction in Iran, different national and regional organizations have been responsible for establishing principles for integrate design rules and regulations at a national scale.

Following, is a short review of the most important authorities in this area in Iran to see how they contribute in making and controlling the design and construction in the country, and to see if they have any tendency or attention for sustainability or environmental considerations.

3.5.1 Architecture and Construction Institutions and Legislators in Iran

Ministry of Roads and Urban Development (MRUD 2010)

The Ministry of Housing and Development was established in 1968 in Pahlavi era (MRUD 2010). In 2011 Ministry of Roads and Urban Development was established by merging the Ministry of Housing and Urban Development and the Ministry of Roads and Transportation. This ministry consists of different departments including acoustics, architecture, housing and building systems, building installation, building materials and products, concrete technology, economic and social research, engineering services, environmental and energy design, fire, geotechnical department, Iran strong motion network, seismology engineering, structural engineering and polymer department

National Building Codes (MRUD 2010)

National Building Codes are a compilation of rules and regulations that must be observed in building constructions. These rules have been established for the provision of safety and comfort.

National Building Codes are formulated according to the available technologies in Iran and have proved their usefulness in different fields. In recent years, before the formulation of National Building Codes, some codes had been adopted from other countries which were then localized, according to the conditions prevalent in different regions of the country. However, as the number of buildings and construction increased, there was a need to formulate codes which could be designed specifically for different regions in Iran.

Due to occurrence of earthquakes in recent years, low service life of buildings, constant need for maintenance, etc. proved that traditional construction of buildings is not effective any more. Therefore, formulation of National Building Codes is regarded as a top priority in the country (BHRC 2013).

The 22 booklets of Iran national building codes and their dates of edition (INBR 2013).

Vol.	Title	1st Edition	2nd Edition	3rd Edition	4th Edition
1	Definitions	2013			
2	Administration	2005			
3	Building Fire Protection	2001	2013		
4	General Building Requirements	2008			
5	Building Materials & Products	1990	2003	2010	
6	Design Loads for Buildings	2001	2006		
7	Foundations	1990	2009	20013	
8	Masonry Buildings	2005			
9	Design and Construction of Concrete Structures	1989	2006	2009	
10	Design and Construction of Steel Structures	1989	2005	1387	
11	Industrialized Construction	2004			
12	Safety and Precautions in Construction	1993	2001	2006	2013
13	Electrical Installations	1993	2003		
14	Mechanical Systems	2001	2012		
15	Elevators and Escalators	2001	2008		
16	Plumbing systems	1993	2003	2012	
17	Natural Gas Piping	2002	2008	2010	
18	Acoustics and sound Control	2001	2011		
19	Energy Conservation	1991	2002	2010	
20	Signs and symbols	2005			
21	Passive Defense	2012			
22	Maintenance				

Table 3, list of booklets for Iran national building codes published by Iran Ministry of Roads and Urban Development

Booklet 19: Energy Conservation

The Booklet 19 of the Iran national building codes is a 90 page book written by a group of engineers and building professionals of the National Building Codes Professional Committee in Ministry of Roads and Urban Development (previously Ministry of Housing and Urban Development) and Building and Housing Research Center (BHRC). It was published for the first time in 1991 and has been updated in 2002 and 2010 (ibid). Chapter 2 describes the general rules for design and among the required documents to obtain a building permit, it asks for physical characteristics of heat insulator (materials and systems).

Generally this booklet introduces specific building physics calculations and construction detailing for better insulation of the building envelope by application of chemical insulation panels in the exterior shells.

This booklet also teaches calculations for better utilization of solar energy due to building function and location.

Other instructions include mechanical installations as well as lighting and electrical systems and equipment.

This is almost the only official reference that has been largely developed and encouraged to be used by architects and engineers, but energy considerations in this book is not yet mandatory to be implemented in buildings.

Iran Construction Engineering Organization (IRCEO 2013)

ICEO is a Non-Governmental Organization established in 1995, aiming to assist more effective contribution of engineers of different orders into construction industry.

This organization focuses on education of graduated engineers and creating the opportunity for them to update their knowledge in different courses or workshops.

This NGO also issues professional certifications for engineers in each province, and confirms the license for professional working permit through periodical examinations on design or construction supervision. Hence, every single building needs to be confirmed from the very early design stages, by an authorized engineer in the same province, who is a licensed member of ICEO.

This organization comprises of various professional groups such as architecture, urban planning, civil engineering, mechanical engineering, electronic engineering, cartography and traffic engineering.

Municipality

The Municipality in each province together with the ICEO have the duty to supervise and control the design for the buildings and to verify them after they are built and issue the license to confirm that they have the necessary standards and are habitable.

Only some small detailing such as usage of insulation panels for roofs or double glazed windows are the obligatory rules asked by the municipality in some cities in Iran for receiving the certificate for the building.

3.5.2 Other energy related organizations and authorities in Iran

There are other organizations in Iran that are responsible to conduct the right consumption of energy and reduction of environmental pollutions in different industries in the country. Although these organizations are not in direct relation with building and construction, but their policies may influence building industry due to the high share of this sector in energy consumption. Following is a short introduction of these authorities:

Iranian Fuel Conservation Organization (IFCO)

The National Iranian Oil Company (NIOC) established the Iranian Fuel Conservation Organization (IFCO) in 2000 as a subsidiary branch with mission to regiment the fuel consumption in different sectors through review and survey of the current trend of consumption, and to execute nationwide conservation measures.

The energy conservation policies of this organization focus on wise energy consumption and cooperation in the reduction of greenhouse gas emission.

The IFCO uses the three methods of rulemaking (regulations, rules and standards, and practical systems), support (tax exemption, subsidization, and technological improvement) and information (labeling, education, advertisement) (Nasrollahi, Farshad 2009, 58)

Iran Energy Efficiency Organization (IEEO)

Established in 1995, administers the plans of Energy Affairs deputy of Ministry of Energy to promote a culture of energy conservation and productivity, and to encourage participation from the private sector.

It has a record of energy auditing in factories in various industries, a collection of measuring instruments, experienced staff, modern laboratories for the formulation of energy consumption standards (for household appliances and industrial elements), a collection of information, books and professional publications related to energy management, and it organizes national and international seminars and training courses) (Nasrollahi, Farshad 2009, 58-59)

Renewable Energy Organization of Iran (SUNA)

In 2000, the energy deputy of the Iranian ministry of Energy established the Renewable Energy Organization of Iran (SUNA) with the mission to investigate and promote the use of renewable energies over primary energies. This organization is divided into the sub organization of solar, biomass, geothermal and wind energy) (Nasrollahi 2009, 59).

SUMMARY

The main policies of construction activities in Iran are defined by the Ministry of Roads and Urban Development.

Construction Engineering Organisation together with the Municipalities in each province have the task to take care of the right implementation of the policies made by this ministry.

In recent decades policies for reduction of energy consumption in buildings have been one of the main focuses of these authorities and many courses and workshops are presented to educate the engineers.

Due to high share of construction industry in energy consumption, other organizations such as Iranian Fuel Conservation Organization (established by The National Iranian Oil Company) and Iran Energy Efficiency Organization (established by Iran Ministry of Energy) are also now eager to assist the construction industry to reduce the energy consumption in building sector.

However, these activities are still at the stage of guidelines and encouraging policies, and have not yet reached a real implementation or mandatory points in construction activities.

Note. Although Booklet 19 issued by the Ministry of Roads and Urban Development discusses practical guidelines for reduction of energy consumption in buildings, but only very primitive solutions such as application of double glazed windows or layers of heat insulation for roofs have been mandatory for houses in the last few years.

Chapter 4: Case Study: Yazd and its Districts

4.1 Yazd and its special features:

According to the very extensive borders of the hot and (semi)arid region in Iran (see chapter 1, figure 4) and necessity of selecting and focusing on one smaller target, this dissertation focuses on the city of Yazd as the target city of the research due to the following considerations:

- **Yazd is still standing as an integrated lively organism, unlike many historical cities in Iran which have experienced major changes in recent decades.**
- **Yazd is a very good collection comprising of a large scope of architecture and urban elements of different periods in a harmonious combination with climatic conditions** (UNESCO 2013)**.**
- **Considering the geographical location of Yazd near the central deserts of Iran, this city is a good pattern to extend to other desert cities even in neighboring countries.**

It has a challenging desert climate, and its architecture has created enough elements in response to these environmental and climatic severities during history.

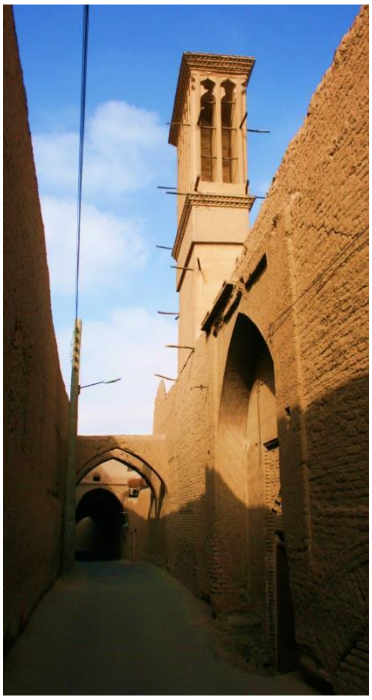


Figure 57: Urban texture of historical part of Yazd. **(ICHTO 2013)**

Figure 58: One passageway in the historical parts of Yazd. Image from: author

4.2 Yazd and its climatic conditions:

One of the most recent surveys on climatic zones of Iran has been done by Tahbaz and Djalilian in 2008 on the basis of:

- The effect of building envelop
- Human comfort in open air
- The effect of construction materials

This survey divides the country into 8 major climatic zones (Tahbaz 2008, 11-12).

Among these eight climatic zones, Yazd is in category 5, with hot and arid summers, and cold winters (ibid 16).

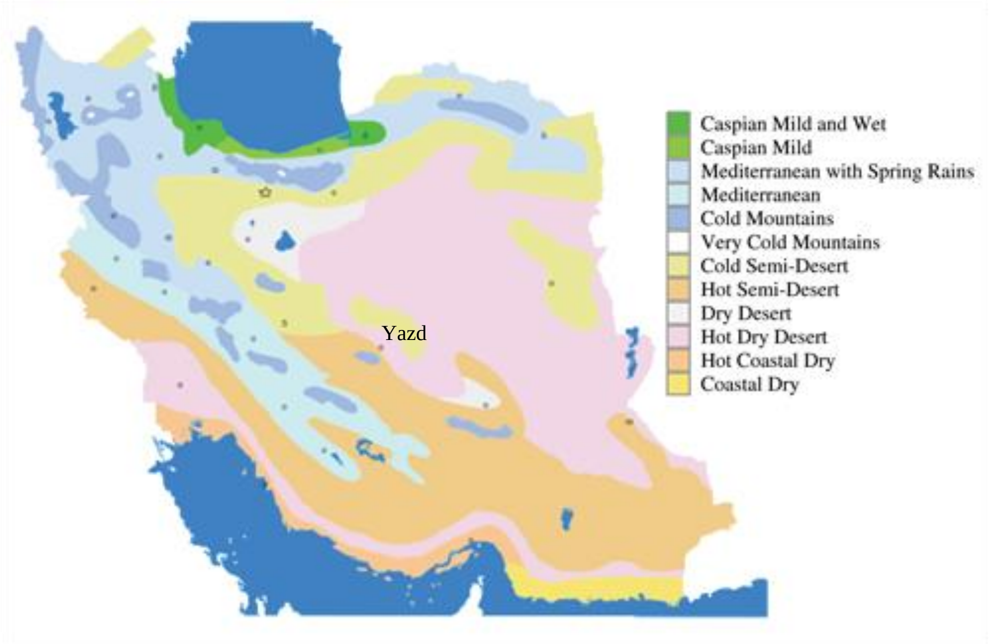


Figure 59: Climatic zones of Iran and location of Yazd. Image from: **(Iran politics 2015)**

Comparing to other cities in Iran, Yazd stands among the cities with low energy requirements (Ahmadi et al. 2009, 65) (Table 4).

No.	City	Low energy Requirements	High Heating Requirements	High Cooling Requirements	Hot And Humid
216	Yazd	✔	-	-	-

Table 4: Geographical typology of annual heating-cooling requirements due to building location in Yazd

The location of Yazd is around the center of the country near the desert parts in one of the driest parts and its average of annual raining is less than 60mm (Zanganeh 2011).

4.3 Urban form of Yazd and its different zones:

The city of Yazd includes three major zones: ancient zone with urban fabric that is over 500 years old, historical zones (until 1925) and contemporary parts (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 27). The historical and ancient parts of Yazd are located in the center. The contemporary parts have developed from northwest to southeast, surrounding the core zones (Figure 60). Due to the development of this contemporary part since 1968 (ibid), the area of the city has expanded more than 12 times larger than the historical town's area. Its area is 8700 hectares at present time (Golkar 2000).

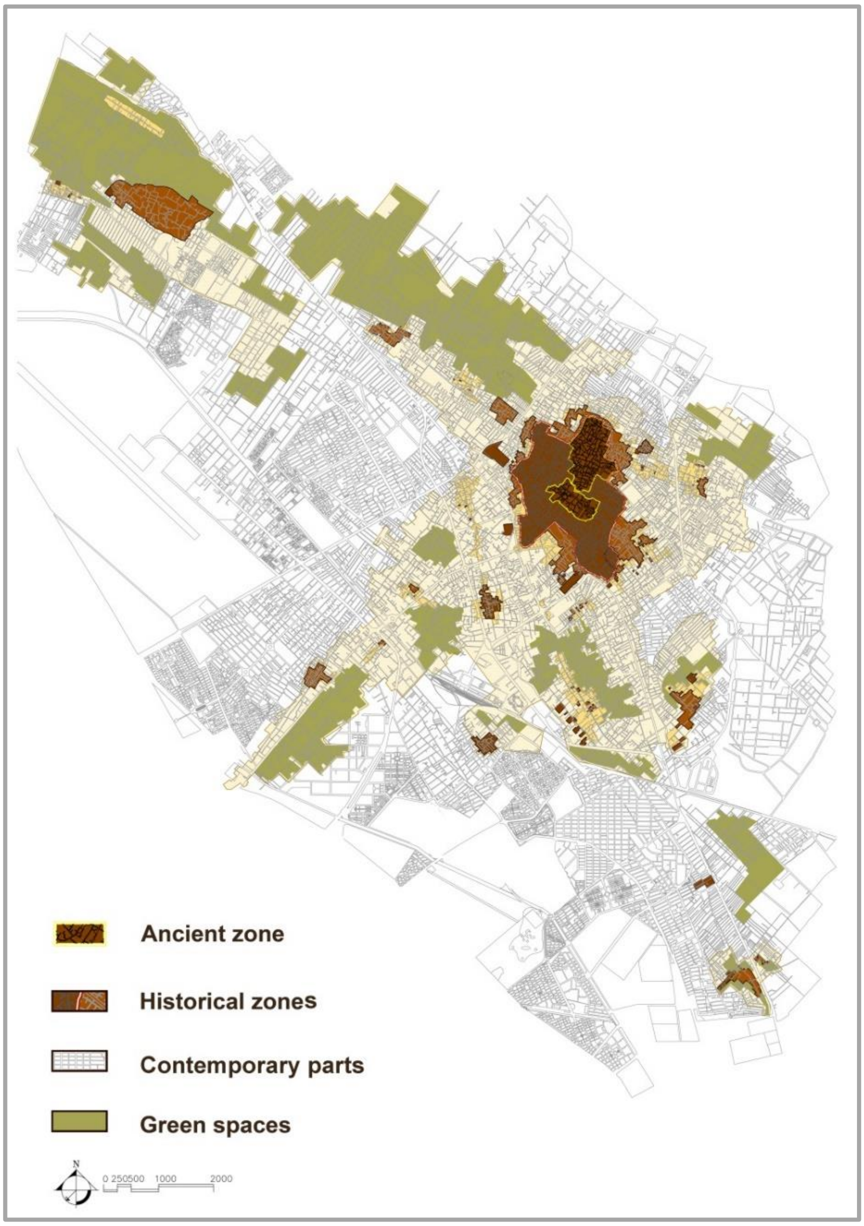


Figure 60: City of Yazd and its historical and contemporary zones.
Source: **(ICHTO 2013)**

4.3.1 Growth of Yazd:

Figure 61 shows the rate of Yazd growth during history: Before 1400 AD the city was a castle with 37 hectares of area. By development of the city during more than 500 years its area became about 240 hectare until 1925 (the beginnings of modernization in Iran). After 1925 due to the rapid development in the country, the city of Yazd began to develop like other cities in Iran. Its current area is more than 80 times larger than its area in 1925 (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002). According to Zanganeh, from 1975 to 2009 while the area of Yazd grows up about 7.5 times, the population becomes about 3.5 times more. It means that its density becomes less than half comparing with 1975 (Zanganeh 2011) (Figure 61, right). This big horizontal and low-density city (contemporary parts of Yazd) is recognizable from the historical parts. These contemporary parts have a different city planning style inspired from the western styles which is in a clear contrast with the traditional urban and architectural system of the old town. This means that there are at least two types of urban structure in Yazd (modern and traditional). Therefore this research tried to select the case studies from both traditional and contemporary parts in order to compare both urban systems in terms of sustainability.

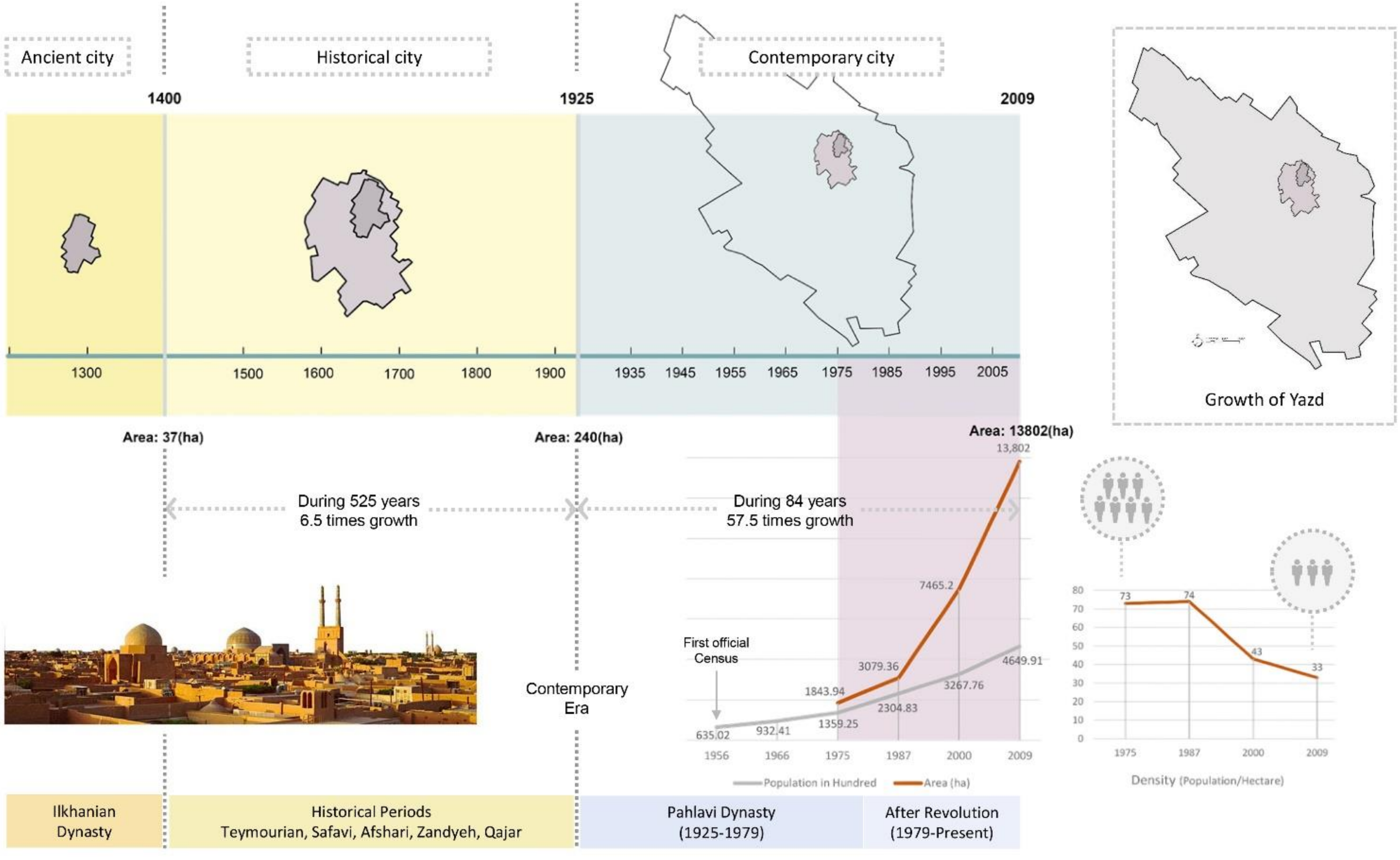


Figure 61: Growth of Yazd during the history. Graphic by author on basis of: **(Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002) (Zanganeh 2011)**

4.4 Selection of case studies:

As mentioned in chapter 1, an inductive methodological approach is selected for this research: different districts are selected from both historical and contemporary parts of the city. Each district is evaluated with sustainability criteria. The results of the analyses for each district are compared with others in the case studies of each traditional or contemporary part in order to determine which one is more sustainable.

This is done via an inductive approach: analyzing the case studies (districts) one by one and comparing the results to achieve a general result for the whole city (analyzing from details to general scale).

The following is a brief introduction of how case studies from historical and contemporary parts of Yazd are selected, in order to make the analyses and comparisons.

4.5 Historical parts of Yazd:

The historical parts of Yazd, which include different historical zones dating back to different eras, are developed around an ancient core (Figure 62). In the center, the grand bazaar forms the main spine of this core, around which urban functions and facilities are located (Figure 63).

Although many parts of this spine have been destroyed and replaced by new streets, the remaining parts of it operate as the main center of historical city. Residential parts are set around this city center in a compact organization.

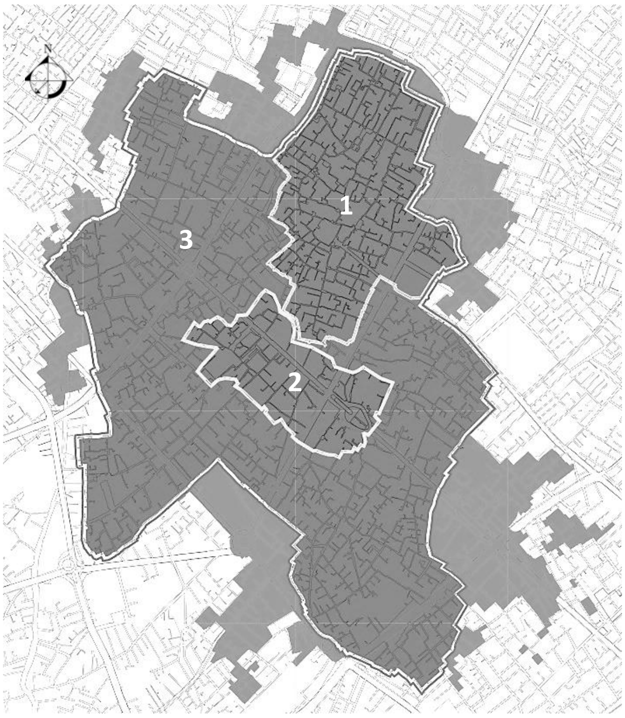


Figure 62: Historical zones of Yazd 1: Ancient zone 2, 3: Historical zones. Source: **(ICHTO 2013)**

Figure 63: Main axis of the historical city of Yazd (main bazaar). Image from: **(Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 46)**

4.6 Historical districts:

The ancient and historical zones of Yazd consist of about 40 districts (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 40-42) (Figure 64). The historical districts have different sizes and forms. They are organized both spatially and by distribution of service facilities in a hierarchy from urban scale to district and neighborhood scales, such that all residents are able to have their daily needs met and their privacy preserved too (ibid 27-31).

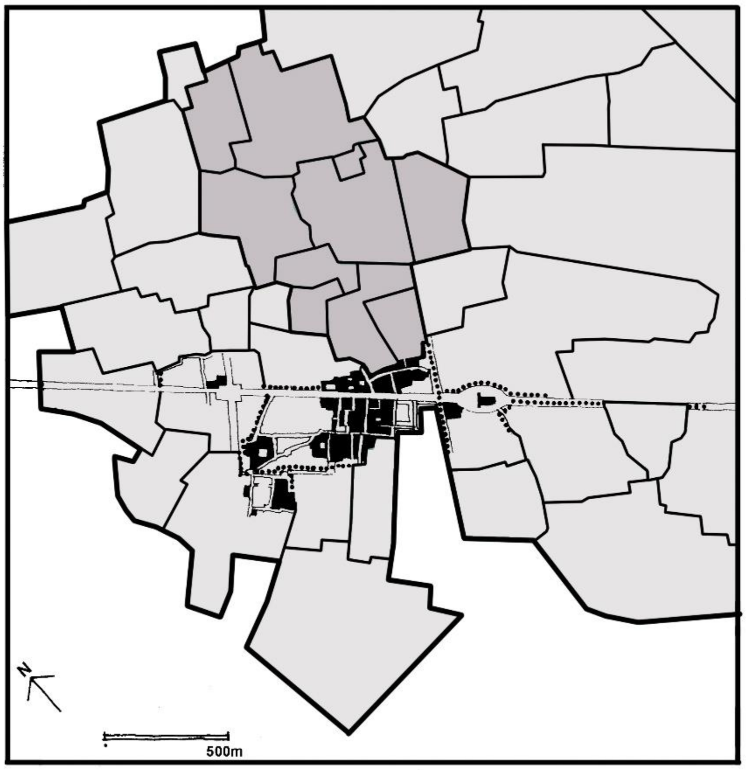


Figure 64: historical districts of Yazd. Image from author on basis of: **(Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 41)**

These historical districts share some similarities. All of them are introverted and organized around a district center. The district centers embed local facilities for the daily needs of its inhabitants. The number of these facilities differs in each district, with differing size and location, but they all share similar structure.

4.7 Selecting historical case studies:

Though historical districts share similar features, they date back to different periods of history and have different sizes and location in the old city. Some districts have features that have changed in recent decades, due to modern developments in the urban structure. Therefore this research tries to select a variety of different case studies to cover all kinds of different features in the districts. These case studies are selected according to:

History: There are at least two historical zones in Yazd: the ancient zone (dating back to 13th to 15th centuries AD) and the historical (16th to 19th centuries AD) zone (Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002). Case studies are selected from both of these zones to include all historical periods of Yazd.

Location: as mentioned before, the grand bazaar includes the main urban services and facilities. Historical districts are located at different distances from this spine. Due to the important role of this city center for supporting the districts and supplying them with urban facilities, the districts' distance from the bazaar becomes important. Therefore, case studies are selected from various distances from the bazaar.

Original condition: many of the historical districts have been divided with new streets and squares in the recent decades. But some of them have kept their original structure and form. This research focuses on the districts that have the most original conditions, as representative of the historical town.

Size and form: selected districts in this research have various sizes and shapes. Some of them are linear and others are centrally organized.

Considering these criteria, five historical districts are selected for this research: two of them from the ancient zone and three from the historical zones. According to figure 65, case studies are located at different distances from the grand bazaar: some near the main bazaar and some far away from it. The selected case studies have different forms and spatial organizations.

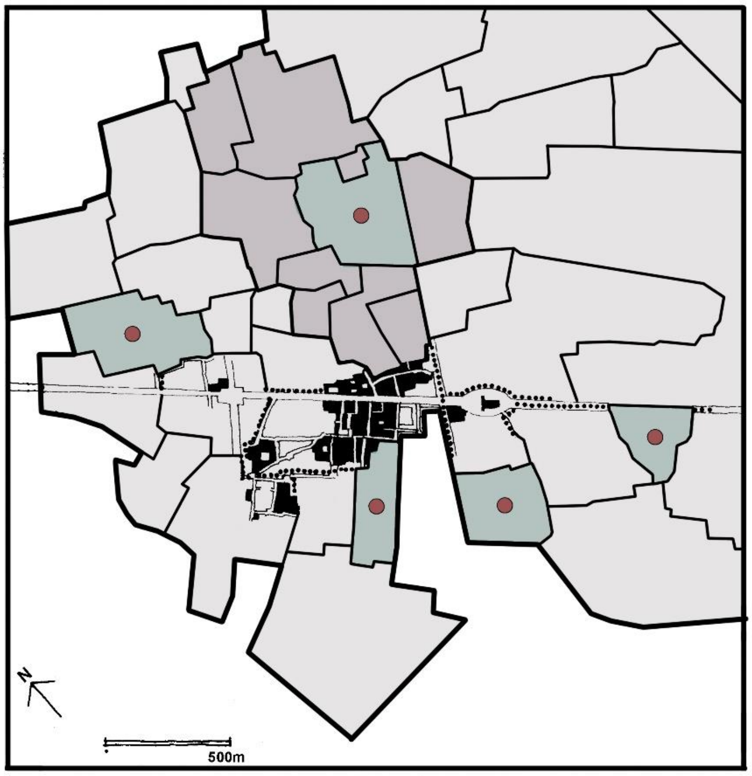


Figure 65: Five districts are selected in different locations and conditions in the historical parts of Yazd. Graphic by author on basis of image from author on basis of: **(Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 41)**

4.8 Description of historical case studies:

4.8.1 Ghodal mosalla:

This district is located in the second historical zone of Yazd. The area of Ghodal district is 49,772 m². It is a semi-triangle shaped district with three main internal passageways. Its center is located on the southwest corner of the district.

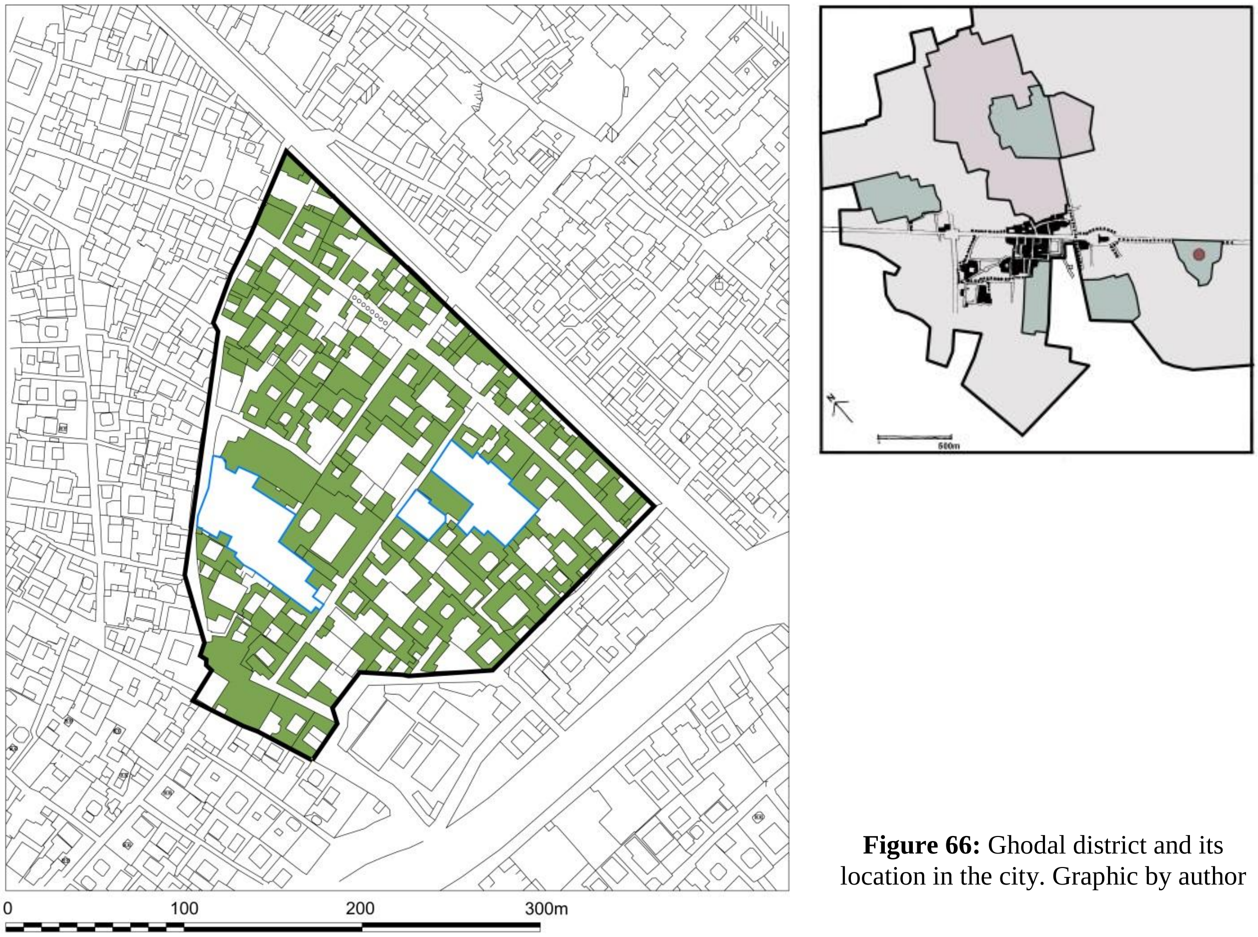


Figure 66: Ghodal district and its location in the city. Graphic by author

Figure 67: Some views from Ghodal district. Images by author

4.8.2 Hashem Khan:

Hashem Khan district is located in the first historical zone of Yazd (ancient core zone). Its area is 62,384 m². It has a linear form that includes several passageways passing though the district that access the residential parts. Its main district center is located on the southwest side.

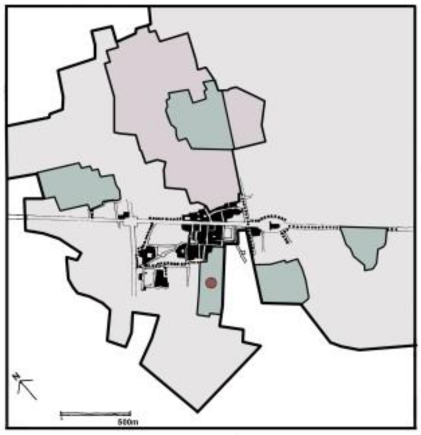


Figure 68: Hashem district and its location in the city. Graphic by author

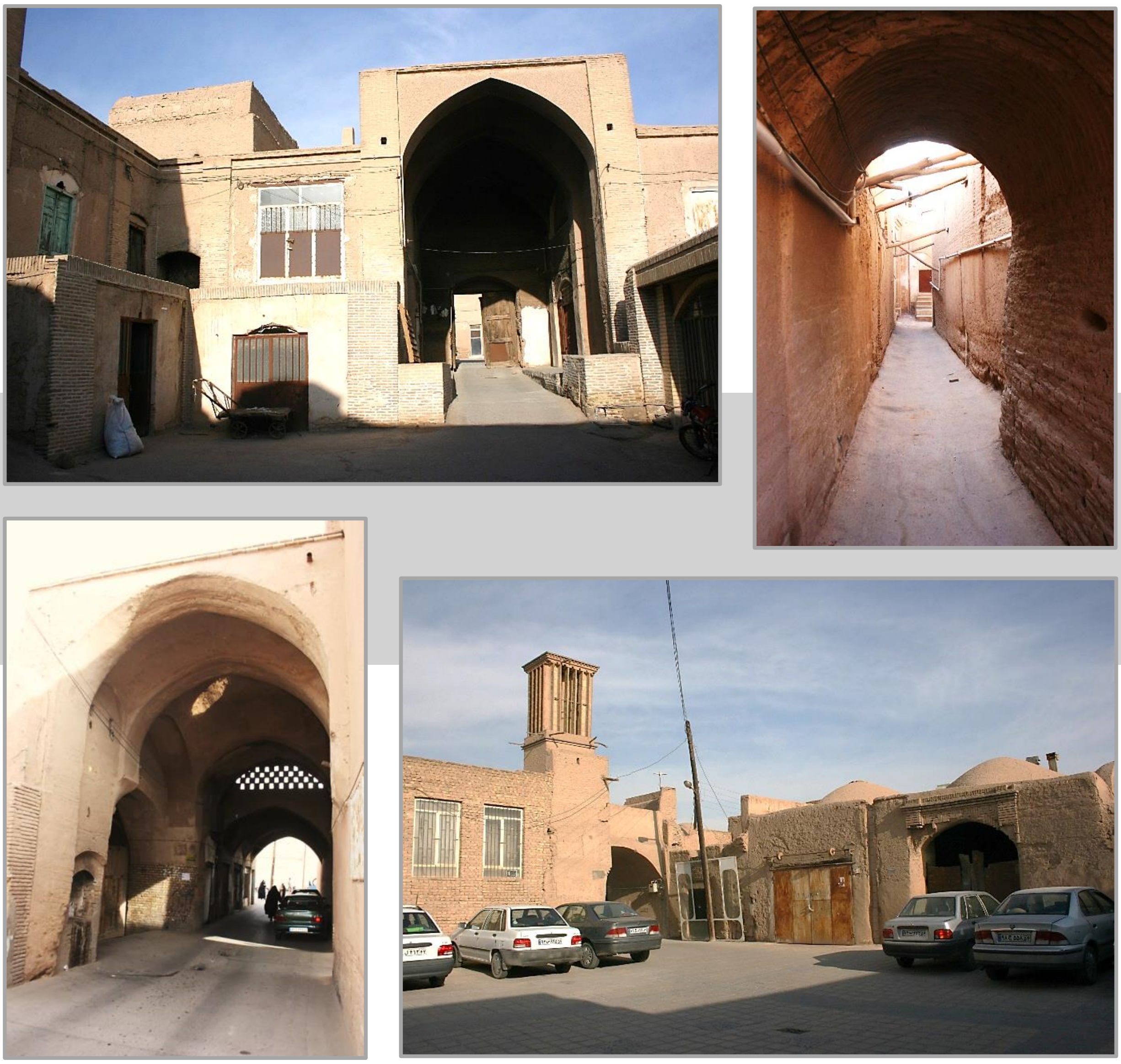


Figure 69: Some views from Hashem district. Images by author

4.8.3 Khajeh Khezr district:

Khajeh Khezr district is located on the second historical zone of Yazd and its area is 97,303m². It has a square form and there are some organically shaped passageways that access different parts of the district. The district center is located on the northwest corner of the district.

Figure 70: Khajeh district and its location in the city. Graphic by author

Figure 71: Some views from Khajeh district. Images by author

4.8.4 Abolmaali district:

Abolmaali district is located in the second historical zone of Yazd. Its area is 12,9810m². Its structure and form is semi linear, with two crossed main passageways through the district. The district center and its facilities are located on the intersection of the two main passageways.

Figure 72: Abolmaali district and its location in the city. Graphic by author

Figure 73: Some views from Abolmaali district. Images by author

4.8.5 Vghat-o-saat district:

This district is located on the core historical zone of Yazd (ancient zone). Its area is 150,801 m². It is the largest amongst the historical case studies. Due to the large size of this district, there exist many passageways in different parts of it. These passageways create a semi-grid structure within the district. In the center of this district, there is a plaza that serves as the district center, and most of the urban facilities are located around this center.

Figure 74: Vaght district and its location in the city and location of its district center. Graphic by author

Figure 75: Some views from Vaght district. Images by author

4.9 Contemporary parts of Yazd:

As mentioned previously, contemporary development of Yazd in recent decades has taken place mainly toward the south and southwest regions of the historical core (Figure 76) (Zanganeh 2011).

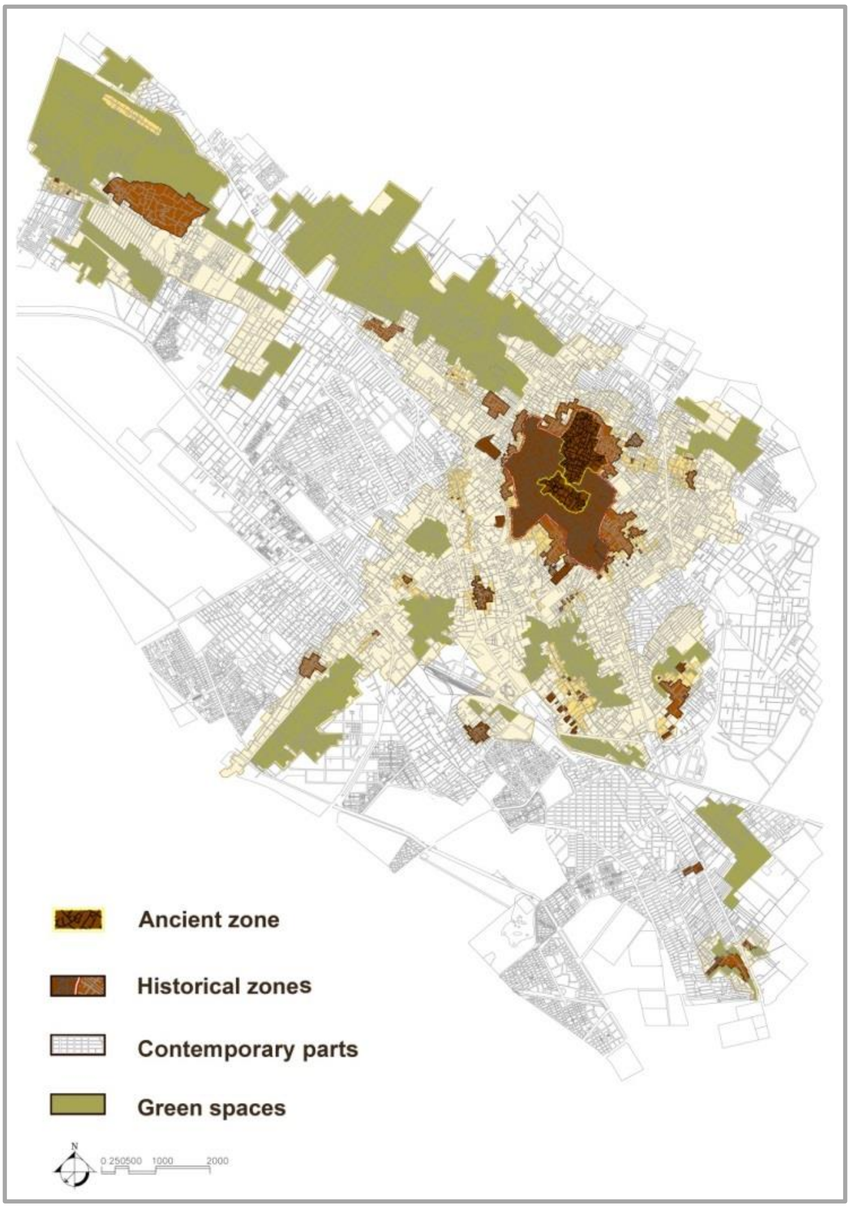


Figure 76: City of Yazd and its historical and contemporary zones.
Image from: **(ICHTO 2013)**

The usual structure of these parts is based on a grid-form structure with wide streets that provide access to the inner parts of the districts (Figure 78). Most of the houses are single-family houses with southern courtyards (Figure 77). This structure is a typical urban design style that is used in most of the new Iranian cities.

Figure 77: One passageway in the contemporary parts of Yazd. Image from: author

Figure 78: Urban texture of contemporary parts of Yazd. Image from: **(Google Earth 2014)**

4.10 Description of contemporary case studies:

Most districts in contemporary parts of Yazd have a similar pattern and structure. Their usual housing style designed for a single family with one or two-story buildings. In some parts, there are some residential complexes with mid-rise buildings.

These two major types of district structures have been replicated in different parts of the contemporary parts of the city, and most of these districts are similar. Therefore, this research selects two case studies from the contemporary parts of the city: one district with single-family houses and the other one with residential complexes. Contemporary districts are usually unnamed; therefore, in this research, these two contemporary case studies are named as New District 1 and New District 2.

4.10.1 New district 1:

New District 1 is located on the southern part of the city, about 6 kilometers away from the historical city center (Figure 80). Its area is 295,718m². This district comprises of single-family houses with southeastern courtyards. The structure of the district is a grid organization with a large, open space in the center and two open spaces on two sides of the center. This district is surrounded by several wide streets, which connect to other parts of the city (Figure 79-81).

Figure 79: Location of new district 1 and its distance to the historical core zone of Yazd. Graphic by author

Figure 80: New district 1 and its structure (below). Graphic by author

Figure 81: Two views from new district 1. Images by author

4.10.2 New district 2:

New District 2 is a mid-rise residential complex located not far from New District 1 (Figure 82). Its area is 10,697m². Its structure is defined by two large courtyards, which are surrounded by several residential blocks (Figure 83-84).

Figure 82: Location of new district 2 and its distance to the historical core zone of Yazd. Graphic by author

Figure 83: New district 2 and its structure. Graphic by author

Figure 84: Residential buildings in new district 2. Image by author

Figure 85 shows all historical and contemporary case studies.

The next chapters discuss the criteria of sustainability and the standard systems for the evaluation of selected case studies in terms of sustainability.

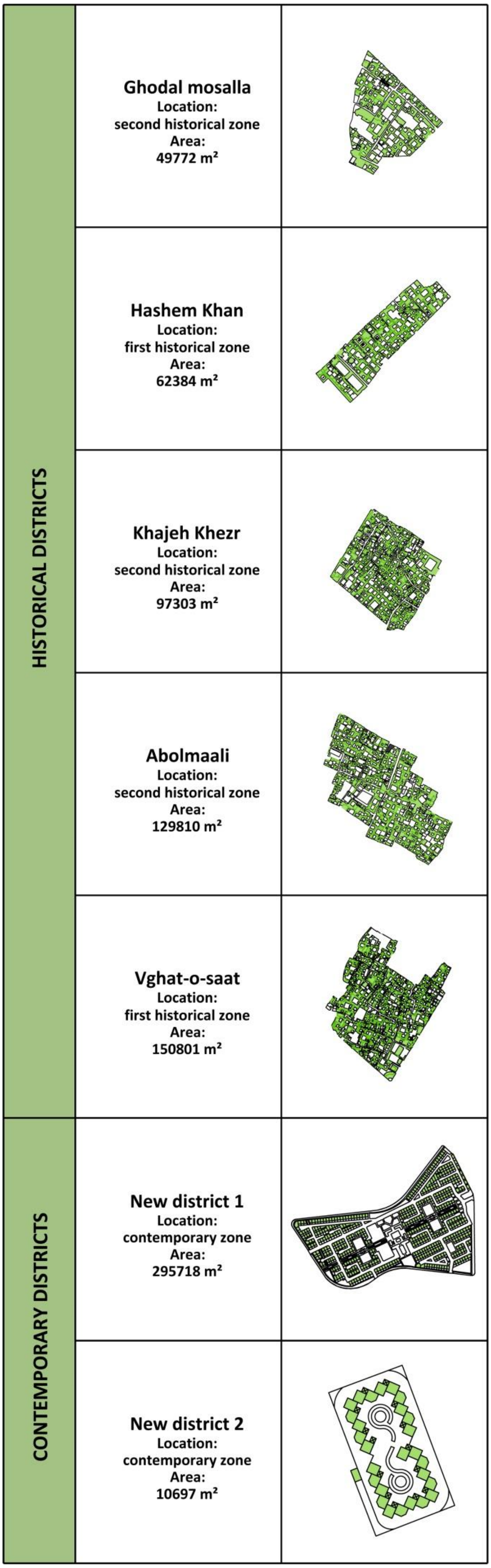


Figure 85: Seven districts selected as case studies for analyzing in terms of sustainability. Graphic by author

CHAPTER 5: SELECTING AN EVALUATION SYSTEM

Introduction:

In this chapter, the existing evaluation systems for assessing the rate of sustainability in buildings and neighborhood scales are discussed first and then the proper evaluation system for defining baselines for the assessment of the degree of sustainability in selected case studies in hot and arid region of Yazd, Iran will be selected.

The facing challenges are:

- At the moment, there are no specific evaluation systems for assessment of sustainability in Iran. Therefor the most relevant evaluation system among the existing systems in the world must be selected.

- The existing evaluation systems mostly originate from regions that have very different climatic conditions from the hot and arid region in Iran. Therefore the selected evaluation system must be adapted to the Iranian climatic and architectural conditions.

- To find the strategies out of the evaluation system, with which both traditional as well as contemporary systems could be evaluated.

- To evaluate the traditional case studies in their original context, which does not really exist now, as it was at the time they were built. Even their original social context has dramatically changed.

5.1 Evaluation:

Evaluation of environmental sustainability covers a wide range of features, which are also in close relation to the economic and social aspects of sustainability.

Although sustainability at first glance, brings to mind a wide range of meanings, concepts and contents, but as architects, after all, we have to find a physical tool to assess and evaluate the performance of buildings in relation to sustainability. This is not a new question, and has, during past decades, been a challenge for researchers to measure and evaluate sustainability in buildings and cities.

As Pearce et al. discuss the sustainability evaluation and assessment in 2020 in their book: "specific challenges abound with regard to measuring the sustainability of the built environment and the products, services and organizations associated with it. At the foundation of the problem is the lack of a widely accepted operational definition of the construct of sustainability. As a context-dependent attribute, the sustainability of a system or artefact will be affected by different factors in different situations. It will also necessarily involve different factors and considerations for different types of products or systems. Thus, there is no ‘one size fits all’ approach to evaluating sustainability (Pearce 2012, 180).

One of the many professionals like Edwards and Hyett imply that the alternative visions of how we might best live in harmony with nature can be adequately expressed through an energy-rating model (Edwards and Hyett, Rough Guide to Sustainability 2001, 18).

Harry Gordon concurs from a US perspective when he argues that the ‘LEED (Leadership in Energy and Environmental Design) standards, issued in 2000, are creating a common understanding of what it means to build green (Gordon 2000, 34). [9]

Farmer and Guy in part A of the book “Sustainable Architectures” state “physical performance has become a critical issue in several contemporary models of sustainable architecture. The main outcome of the global focus for sustainability in terms of building production has been a continuing emphasis on improving physical performance generally and the efficient use of energy in particular (Guy and Moore 2005, 20).

These few arguments show how far architects and designers have tried to figure out a tool to measure sustainability in the built environment.

5.2 Environmental Assessment Methods:

Following from these assumptions is the belief that the ‘greenness’ of a project can effectively be predefined or assessed through the use of objective technical analysis such as life-cycle analysis, ecological footprint analysis or environmental assessment methods. Of these methods, the environmental assessment methods (EAMs) in particular have come to be viewed as a key way of both modelling and categorizing the environmental performance of a building, and during the last decades several different environmental rating schemes have been developed throughout the world (ibid 21-22).

5.3 Existing Rating Systems for Environmental Sustainability in Buildings:

As Pearce et al. describe in chapter 4 “Green Rating Systems” of their book “Sustainable Buildings and Infrastructure”, at the scale of whole buildings, various rating systems have been developed around the world to evaluate capital project sustainability. Most green building rating systems include explicit performance thresholds that buildings must meet

[9] Employing similar logic, in their very influential book Natural Capitalism, argue that consumers will automatically embrace radical resource efficiency once they understand that they can reduce consumption ‘without diminishing the quantity or quality of services that people want’ (Hawken, Lovins and Lovins 1999, 176).

in order to be certified. They also typically come with guidelines that help project teams meet or exceed those performance thresholds.

Most of the green building rating systems on the market today were developed in a particular country to serve the specific needs of that country's buildings. However, many of these tools have been applied across multiple countries to meet the demand for green building ratings in countries that do not yet have their own rating system (Pearce 2012, 151-152).

In the UK the Building Research Establishment (BRE) developed its own environmental assessment method (BREEAM) in 1990, claimed to be "the world's most widely used means of reviewing and improving the environmental performance of buildings" (Guy and Moore 2005, 21-22).

Since then many other national and international evaluation systems were launched and developed one after the other.

The following figure shows the green building rating systems, mapped by country of origin and initial application.

Figure 86: Green building rating systems by country of origin. Image from:
(Annie R. Pearce 2012, 152)

As seen in the above figure, some of the rating systems such as BREEAM and LEED have been widely applied in countries outside their country of origin.

Following, is a short introduction to the rating systems originating in specific countries:

- **Building Research Establishment Environmental Assessment Method (BREEAM)**

One of the first assessment methods to be developed for evaluating project sustainability. Developed in the United Kingdom, specific versions of this rating system exists for the UK, Europe and the Gulf, and it has also been adapted for use in other contexts to take into account environmental weightings; local codes, standards and building methods; and important local environmental issues.

- **Comprehensive Assessment System for Building Environment Efficiency (CASBEE)**

Developed by the Japan Sustainable Building Consortium and Japan Green Building Council in conjunction with several other Japanese government agencies in 2002.

- **Green Globes**

Initially developed in Canada, modelled after the BREEAM rating system as an offshoot of the BREEAM Canada in 2000

- **GreenStar Australia**

Developed by the Green Building Council of Australia (GBCA) based on British BREEAM system and the North American LEED system.

- **GreenStar New Zealand**

Launched in New Zealand in 2007, based heavily on the Australian version of Green Star

- **Leadership in Energy and Environmental Design (LEED)**

Developed by US Green Building Council (USGBC) since 1994 (USGBC 2009), and has been applied to projects in the United States and beyond.

- **MOHURD 3 Star Rating System (China)**

A voluntary, context-specific rating system developed in 2008 developed by the Ministry of Housing, Urban and rural Development to encourage the development of green buildings beyond what has already occurred due to use of international rating systems such as LEED.

- **South Korea Green Building Certification System (GBCS)**

Development and implementation of the green building rating system GBCS beginning in 2001, one of Korea's initiatives as part of the effort for comprehensive environmental action plans to achieve the goals of sustainability in the construction industry

The two international rating systems are also as follows:

- **Sustainable Building Challenge (International Rating Standard)**

Managed by the International Initiative for a Sustainable Built Environment (IISBE), this program began as the Green Building Challenge in 1996, and is a continuing program to feature high-performance buildings worldwide and examine their performance at World Sustainable Building conferences.

- **Living Building Challenge (International Rating Standard)**

Developed by the International Living building Institute for rating built facilities in terms of the degree to which they restore the natural and social environment and function effectively as contributors to, not parasites of, the context in which they are built.

In addition to the national and international rating systems described above, many other local and regional building rating systems have also evolved over time specifically at the level of residential construction.

The performance areas comprising each of these national or international evaluation systems discussed previously are as follows:

SUSTAINABLE BUILDING CERTIFICATES		
BREEAM	▪ Energy ▪ Management ▪ Health and wellbeing ▪ Transport ▪ Water	▪ Materials ▪ Waste ▪ Land use ▪ Pollution ▪ Ecology
CASBEE	Environmental Quality	▪ Indoor environment ▪ Quality of service ▪ Outdoor environment on site
	Environmental Load	▪ Energy ▪ Resource and materials ▪ Off-site environment

Green Globes	
GreenStar Australia GreenStar New Zealand	▪ Energy ▪ Emissions ▪ Transport ▪ Material ▪ Water ▪ Land use and ecology ▪ Indoor environmental quality ▪ Management ▪ innovation
LEED	▪ Sustainable sites ▪ Water efficiency ▪ Energy and atmosphere ▪ Materials and resources ▪ Indoor environmental quality ▪ Innovation in design
MOHURD	▪ Land saving ▪ Energy saving ▪ Water saving ▪ Material saving ▪ Indoor environment ▪ Operations
GBCS	▪ Land use and commuter transportation ▪ Energy resources consumption and environmental loads ▪ Ecological environment ▪ Indoor environment quality
Sustainable Building Challenge	▪ Site selection, project planning and urban design ▪ Energy and resource consumption ▪ Environmental loadings ▪ Indoor environmental quality ▪ Service quality ▪ Social and economic aspects ▪ Cultural and perceptual aspects
Living Building Challenge	▪ Site ▪ Water ▪ Energy ▪ Health ▪ Materials ▪ Equity ▪ Beauty

Table 5: The national and international evaluation systems for sustainability, and their performance areas

As shown in the table above, all the national and international evaluation systems share almost the same features for evaluation such as building's approach towards site, energy, water, material, health….

5.4 Selecting Evaluation Tool:

Due to similarities of approach in different evaluation systems in the world, amongst all, this dissertation chooses the LEED[10] evaluation system (developed by US Green Building Council since 1994) regarding its wide range of utilization worldwide and in the Middle East. Although most of the evaluation systems claim that they are internationally compatible, but one of the main concepts of sustainability is locality. It means that the more the common climatic factors, the less we need to change and adapt the rules. However the main reason to choose this system is the climatic similarities of its origin, the United States, to Iran's hot and arid region in comparison to other evaluating systems that originate from the cold and humid climate in Europe or climatic conditions of the far eastern countries like Japan with too much rain and humidity (Figure 87).

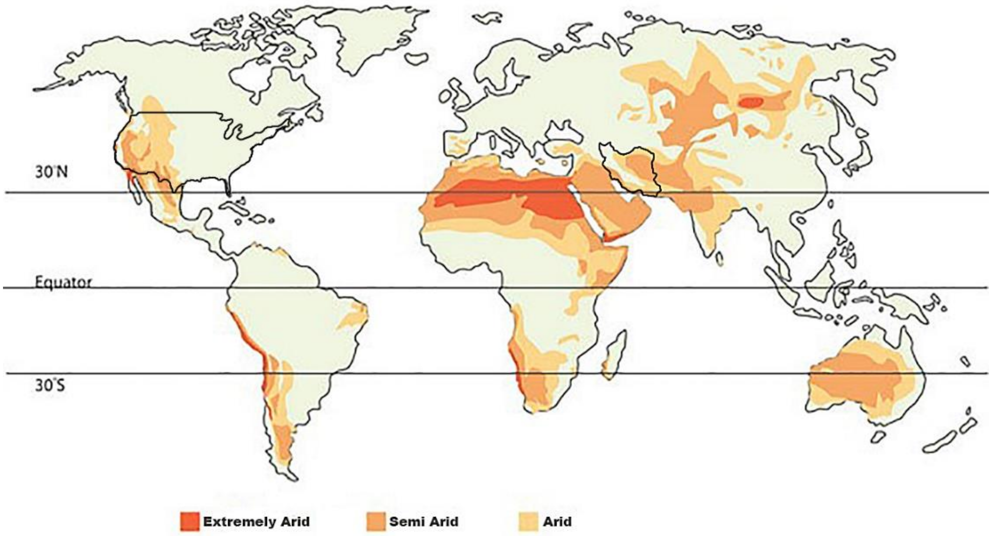


Figure 87: Distribution of arid land and location of Iran and the USA. Image from: **(Nature 2011)**

5.4.1 LEED Leadership in Energy and Environmental Design:

LEED rating system was initially modeled after the BREEAM system (Pearce 2012, 159). Among all the existing tools described previously, LEED rating system is one of the most well-known systems worldwide. This system was launched by the United States Green Building Council (USGBC 2009), and has been applied to projects in the United Sates and many other countries. It has been applied across multiple countries worldwide as a base for making new national evaluation systems.

LEED has four levels of certification (Certified, Silver, Gold and Platinum). The LEED rating system consists of a series of performance goals and requirements in the following six categories (ibid 160):

[10] Leadership in Energy and Environmental Design

1. **Sustainable Sites**, covering issues related to the location of the project site, impacts to the site during construction, site amenities and impacts resulting from building operations.
2. **Water efficiency**, deals with water consumption and waste-water generation by the building in operation.
3. **Energy and atmosphere**, addresses all aspects of the building's energy performance, energy source(s) and atmospheric impacts.
4. **Materials and resources**, pertains to the sources and types of materials used on the project, the amount of waste generated and the degree to which the project makes use of existing buildings.
5. **Indoor environmental quality**, covers aspects of the building's indoor environmental ranging from ventilation to air quality to daylight and views.
6. **Innovation in design**, rewards the project for going beyond the minimum credit requirements and for using a LEED accredited professional.

The newest version of the US LEED rating system, released in 2009, attempts to accomplish this goal via a system of region-specific credit requirements applied to buildings based on location. The following table shows the evolution of approach to this issue over the multiple versions of the LEED rating system (ibid 181).

Version	Launch	Approach to Context Specificity
LEED v1	1998	Somewhat prescriptive; limited building types – application guides proposed as mechanism for customization
LEED v2.0, 2.1 and 2.2	2001 ff	More performance-based; most credits converted; additional application guides developed; additional core rating systems developed for homes, neighborhood development, existing buildings, core and shell, and commercial interiors
LEED 2009	2009	Regional priority credits introduced; credit point values changed to reflect new weightings for relative importance of environmental issues (USGBC 2008)

Table 6: Context specificity and the LEED rating system, From: **(Annie R. Pearce 2012, 181)**

The LEED rating system applies to a wide variety of project types, including new commercial construction and major renovations, existing buildings, commercial interiors, building cores and shells, residential construction and neighborhood development.

5.4.2 LEED as utilized rating system:

As mentioned before there are some similarity between Iran's hot arid region and the western part of the United States so because of them there are some items in LEED system that can be adapted with the special condition of Iranian hot arid region. For example one item in LEED is "Heat island" that is usual in the hot region cities and it is a helpful item for calculating the problem of sun heating of the districts in the countries such as Iran. This item can't be found in the other evaluation systems like BREEAM. So by analyzing different systems it seems that LEED system is more adaptive with the Iranian environment and climate.

But as mentioned before many features of sustainability have relationship with the local features and condition and in order to evaluating the local architecture and cities some special items with considering the local condition and climate and vernacular patterns and styles should be defined and used.

So in this research one table is prepared on basis of the general categories of the LEED system and other references[11], but in some parts some items are defined and created by the authors on basis of the Iranian character of architecture and city planning by considering their features and patterns (Table 7).

[11] Paola Sassi in his book "Strategies for Sustainable Architecture" also makes much the same division as LEED and other evaluation systems make, with a wide range of strategies for sustainable design. He divides the environmental sustainability to 5 categories: **Site and land use, Community, Health and well-being, Materials, Energy, and Water** (Sassi 2006).

As table 7 shows, analyzing seven historical and contemporary case studies is done by the five general categories that they are divided to several subsets:

1- Site and land use:

- Footprint
- Compactness
- Reduction of transport impact (Distance from the urban facilities)
- Mixed-use (District facilities)

The items *Footprint* and Compactness are defined on basis the items of LEED system with considering the local feature of Iranian architecture with a massive construction that increases the footprint and compactness. The items Reduction of transport impact and Mixed-use also are borrowed from LEED system.

2- Health and well-being:

- Green area
- Hierarchy (Neighborhood spaces)
- Shaded area
- Passageway proportion
- Garbage management

In LEED system there is no item about Green area so this item is defined on basis local definitions. The item of Hierarchy also is defined on basis of the Iranian urban design feature (all of the reasons of selecting the items and criteria for evaluating them will be explained in the chapter of body of research). The items of Shaded area, Passageway proportion and Garbage management are selected from LEED system.

3- Energy:

- Common walls
- Orientation (Sun radiation)
- Orientation (Favorable winds)
- Heat islands

The item of Common walls is a special feature of Iranian urban design that effects on energy use in the cities and this item is defined by the author on basis of the local criteria. The items Orientation and Heat islands are selected from the LEED system but they are analyzed on basis the local criteria.

4- water:

- Existing water (*Qanāt* system)

The item of Existing water belongs to LEED system and one of the existing water systems in Iran is *Qanāt* system and the case studies are analyzed by considering their connections to this system as an alternative water source and existing water.

5- material:

- Local material
- Reusable material

The items Local and Reusable material are selected from the items of LEED system by considering the local features.

In the next chapter each of introduced items are used for analyzing several historical and contemporary case studies. In each part of the analyzes in the next chapter, the reasons of using each of those items and also how to use them for evaluating case studies will be explained and the results of each part are showed in some charts and tables.

	Site and land use										Health and well being					Energy				Water	Material	
	Foot print(massive construction)	Compactness	Distance from facilities	Mixed-use (District facilities)							Green area	Hierarchy (neighborhood spaces)	Shaded area	Passageway proportion	Garbage management	Common walls	Orientation(sun radiation)	Orientation (favorable winds)	Heat island(SRI)	existing water (Qanat system)	Local material	Reusable material
				Bazaar	Public bath	Mosque	Cistern	School	Public space	Grade												
Ghodal (49772m2)																						
Hashem khan (62384m2)																						
Khajeh (97303m2)																						
Abolmaali (129810m2)																						
Vaght (150801m2)																						
New district 1(295718m2)																						
New district 2(10697m2)																						

Table 7

Chapter 6: Body of Research: Analyzing Case Studies by Criteria of Sustainability

Introduction:

The main objective of this research is to determine whether there are any environmental features in the Iranian historical cities and architecture that can be adapted as sustainability strategies in contemporary city design in the hot and arid region of Iran.

For this purpose, some environmental features of this architecture and urban design are selected and categorized in one table (table 7) under the standard categories and items of the existing rating systems. Those features are proposed in 5 categories of "site and land use", "health and well-being", "energy", "water", and "material", which are defined on basis of sustainable items in LEED and other references.

As explained in the case study chapter, seven case studies (five historical and two contemporary districts in Yazd) are selected in order to provide enough input for understanding the design strategies related to the climatic conditions in Yazd.

These seven case studies are analyzed in this chapter, and their environmental features are evaluated by the criteria of LEED, and in some items by the local criteria, because as mentioned before, it is impossible to adapt all items of LEED and its criteria for the case studies in Iran.

Generally, in this analysis, the author attempts to use a quantitative method with clear numbers and percentages as baselines for evaluation.

In the upcoming parts of this chapter, the case studies will be analyzed in each of the categories and sub category items of table 7. The results will shortly be described after each evaluation.

Finally, this chapter will discuss and show whether the historical case studies reveal benefits in terms of environmental sustainability, compared to the contemporary parts of the city of Yazd. This will be the answer to the first research question in this dissertation.

The next research question is: in the case that the historical case studies possess sustainable features, how can we learn from the traditional Iranian cities such that we can adapt these features, propose some sustainable solutions, and make some general recommendations for contemporary city designers? This question will be answered in the last chapter.

In the next pages, the items of analysis are applied to case studies. The results of each analysis are shown in a table with positive and negative points. This grading is made by comparison of each item with the specific standard criteria.

Total points earned by each case study shows the degree of its environmental sustainability, compared to points earned by other case studies.

6.1 Site and land use:

The following part of the evaluation concentrates on a comparison of *footprint*[12] and compactness as well as distance from the facilities and mixed use in the cases studies (Figure 88).

6.1.1 Footprint and compactness:

The ground management and the way of construction of land (urban sprawl or compact urban texture) is an important factor for the analysis of urban fabrics in terms of sustainability.

Usually, in hot and arid regions, compact cities show more benefits in contrast to the vast scattered urban textures.

As Sassi states, compact cities have many advantages, including better supporting services such as public transport, recycling, and district heating (Sassi 2006, 16).

Also, a compact city with minimized horizontal development helps save the green spaces and gardens that traditionally surround the Iranian desert cities. These gardens of local trees that need little water act as a green belt around the city and help protect the city from dusty winds in hot and arid regions such as Yazd.

	Site and land use									
	Foot print(massive construction)	Compactness	Distance from facilities	Mixed-use (District facilities)						
				Bazaar	Public bath	Mosque	Cistern	School	Public space	Grade
Ghodal (49772m2)										
Hashem khan (62384m2)										
Khajeh (97303m2)										
Abolmaali (129810m2)										
Vaght (150801m2)										
New district 1(295718m2)										
New district 2(10697m2)										

Figure 88: First part of the table 4: site and land use. From: author

Other advantages of cities with compact construction and dense urban texture in the hot and arid zone include the minimization of energy waste and producing more shaded spaces. These parameters will be analyzed in the energy chapter.

While identifying the advantages of compact urban texture in desert cities, this part calculates the percentage of *footprint* in each case study district.

---

12 The ratio of built area to total area of a district

Figure 89 illustrates the percentage of footprint in each case study. A comparison of the results shows that the average quantity of historical districts' *footprint* is about two times more than the average *footprint* in contemporary districts.

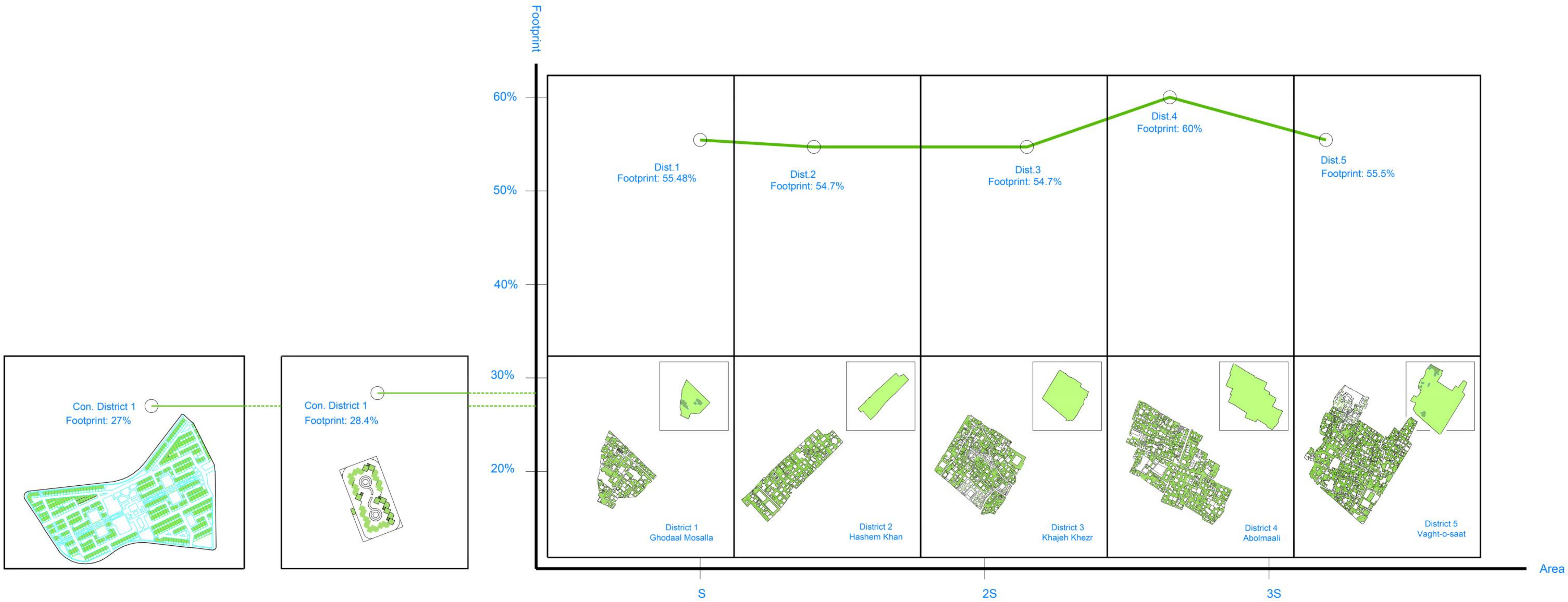


Figure 89: comparing *footprint* item in the historical and contemporary districts. Image from: author

Criterion: In the LEED rating system, there is no item for the standard range of *footprint* at the neighborhood scale.

Therefore, as mentioned before, for those criteria that are not included in LEED, a baseline is defined on the basis of existing local criteria or the average percentage of the group that reveals a better performance of that item for cities in the hot and arid region.

According to Figure 89, the historical case studies show a higher percentage of *footprint*, which means a more compact neighborhood that is more beneficial in deserts, as explained before.

Therefore, in this evaluation category, the average percentage of *footprint* in historical case studies, which is 56%, is selected as the baseline.

A comparison of the results shows a higher percentage of *footprint* in the historical case study districts; this means more massive construction than in the contemporary case study districts (Table 8).

District name	Footprint	Grade
Ghodal	55.4%	+
Hashem khan	54.7%	+
Khajeh	54.7%	+
Abolmaali	60%	+
Vaght	55.5%	+
New district 1	27%	-
New district 2	28.4%	-

Table 8

Compactness:

As Cheng says, the meaning of compactness or density is familiar at first glance, but it is a complex concept with different definitions in various contexts and situations with differing factors such as physical density, population density, and residential density. Each has their own specific meanings and definitions in the various contexts (Cheng 2010, 3).

That's why there are several ways for measuring this item in the cities: determining the ratio of the number of population for each hectare of the district (Sassi 2006, 18), or the number of dwelling units per hectare, and the ratio of floor area (LEED 2009).

Using the first and second ways for calculating compactness is difficult for this research, because there is no information about the number of population of historical districts in the past at the time they were constructed (the first census of population in Iran was in 1956 after start of modernization in Pahlavi dynasty when the districts undertook dramatic changes) (SCI 2012).

This research aims to analyze the historical case studies in their original condition in the past. For this, we need the population of people for example 200 years ago, which is indeterminable.

According to the special style of living in the historical houses, where several families lived in one courtyard house, it is difficult to estimate how many dwelling units were located in historical districts.

Criterion: According to LEED criterion, measuring the floor-area ratio is used for non-residential uses but as mentioned before, there is no possibility to use other ways for this item. So the FAR item (floor-area ratio) of LEED is applied to the case study districts.

LEED demonstrates the following strategies for this item:

- For residential components located within the walk distances: 12 or more dwelling units per acre.
- For non-residential components located within walking distances: 0.80 floor-area ratio (FAR) or greater of buildable land available for nonresidential uses (LEED 2009).

As observed in table 9, according to LEED and a calculation of the FAR item in the case studies, all historical districts are qualified by this item with a FAR of more than 0.8.

The new District 2 is also qualified, because this district is a mid-rise housing complex with a compact construction.
Generally, the historical districts illustrate better performance in making compact construction.

District name	Compactness	LEED evaluation system	Grade
Ghodal	0.83	≥ 0.8 floor-area ratio (FAR)	+
Hashem khan	0.82	≥ 0.8 floor-area ratio (FAR)	+
Khajeh	0.82	≥ 0.8 floor-area ratio (FAR)	+
Abolmaali	0.90	≥ 0.8 floor-area ratio (FAR)	+
Vaght	0.83	≥ 0.8 floor-area ratio (FAR)	+
New district 1	0.54	≥ 0.8 floor-area ratio (FAR)	-
New district 2	1.13	≥ 0.8 floor-area ratio (FAR)	+

Table 9

Result 1: *historical districts are more massive and compact than contemporary districts*

6.1.2 Distance from urban facilities:

This item is defined by LEED with the goal to reduce vehicle trips and to ease access to urban services by locating the project near existing neighborhood shops, services, and facilities (LEED 2009).

As Sassi explains, locating residential developments close enough to general urban facilities reduces urban journeys and energy consumption for both transportation and car dependency (Sassi 2006, 25).

In the historical parts of Iranian cities, there is a hierarchy for the distribution of urban services from urban scale to the neighborhood centers. So each district owns its local facilities such as a small bazaar, mosque, public bath, school, and cistern.

While in a bigger scale, the districts are usually located near the main axis of the city, where the general facilities such as the grand bazar and other general services are located (Figure 90).

This part observes the location of the case studies in the city and calculates their distance from the main urban facilities.

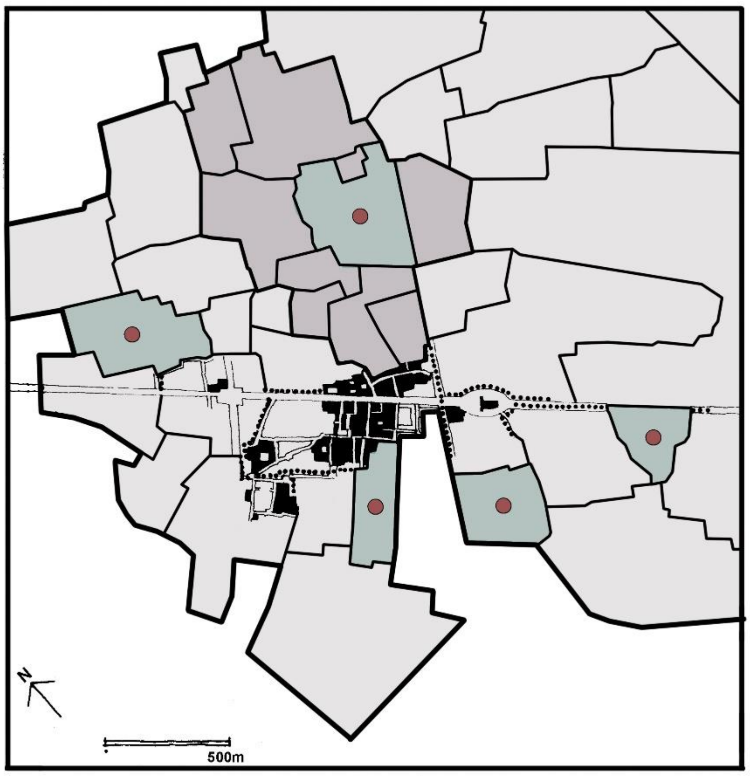


Figure 90: location of historical districts of Yazd around the main urban facilities. Graphic by author on basis of: **(Tavassoli, Urban structure and architecture in the hot arid zone of Iran 2002, 41)**

- **Historical districts:**

The farthest historical district to the main center of city is the **Ghodal Mosalla district,** with a 844 meter distance from its center to the first bazaar and square of the city. It takes about 12 minutes on foot to arrive to the first urban facilities.

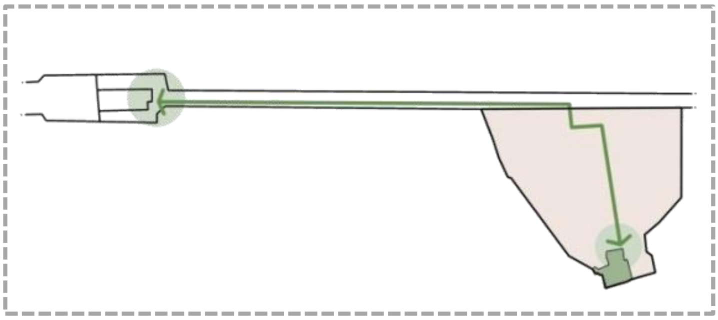
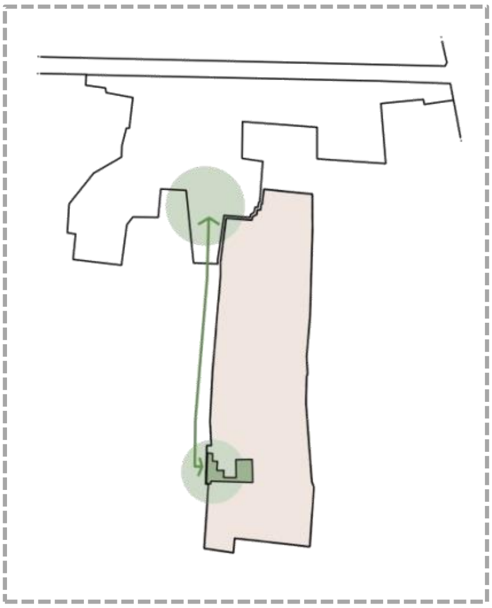


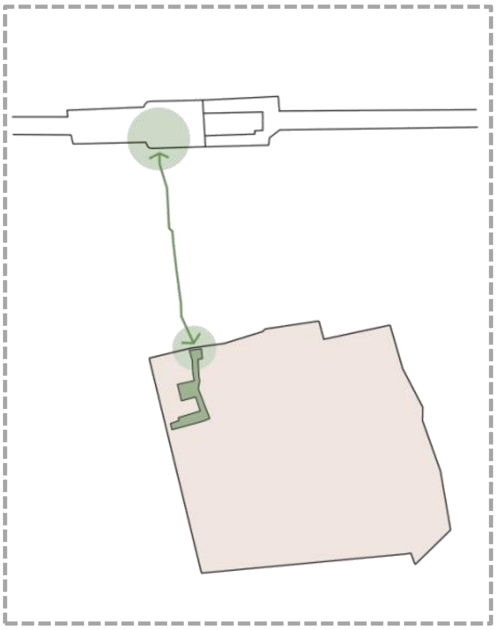
Figure 91: Location of Ghodal Mosalla district and its distance to the city center. Graphic by author



Hashem Khan district is located near the main bazaar of Yazd and the distance of its center from the nearest urban facilities is 374 meters, less than five minutes on foot.[13]

Khajeh Khezr district has a distance of 270 meters to the main facilities, about 3.5 minutes on foot.

Figure 92: Location of Hashem Khan district and its distance to the city center. Graphic by author



Abolmaali district is located near the main axis of historical city and the distance from main urban facilities to the center of Abolmaali is about 453 meters, less than 6 minutes on foot (Figure 94).

Figure 93: Location of Khajeh Khezr district and its distance to the city center. Graphic by author

[13] As Sassi says: four hundred meters can be walked in five minutes (Sassi 2006, 23).

Vaght district is the nearest district to the main city center with a distance of 85 meters, about 1 minute on foot (Figure 95).

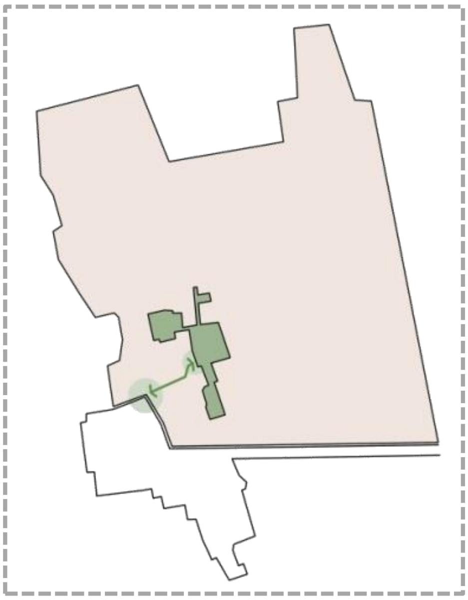


Figure 95: Location of Vaght Saat district and its distance to the city center. Graphic by author

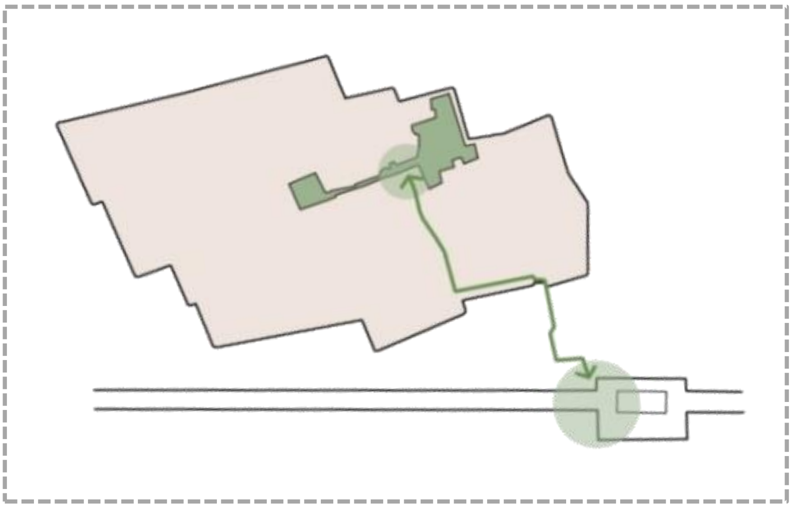


Figure 94: Location of Abolmaali district and its distance to the city center. Graphic by author

- **Contemporary districts:**

Unlike the historical districts, most contemporary case studies are located far away from the city center (Figure 96).

Some scattered urban facilities, such as shopping centers and offices, are located in the new parts of Yazd, but access to these facilities is usually made by car, it being difficult to reach them on foot.

Contemporary district 1 is 1670 meters away from the first urban facility, more than 20 minutes on foot (Figure 98).

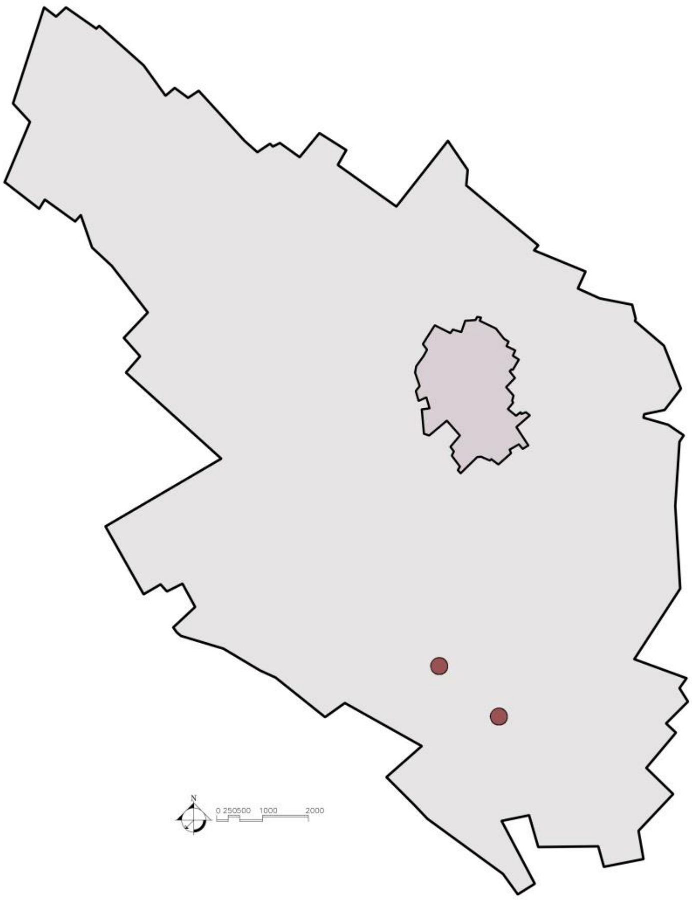


Figure 96: Location of contemporary districts and their distance to the main city center. Graphic by author

Contemporary district 2 is 645 meters away from the nearest urban facilities, about 8 minutes on foot (Figure 97).[14]

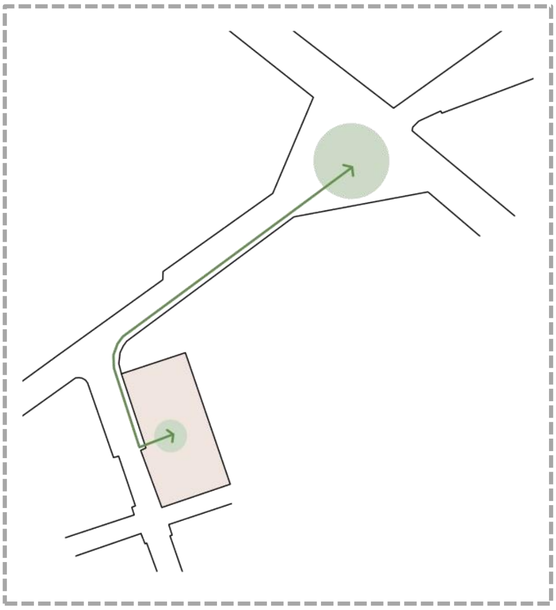


Figure 97: Location of contemporary district 2 and its distance to the city center. Graphic by author

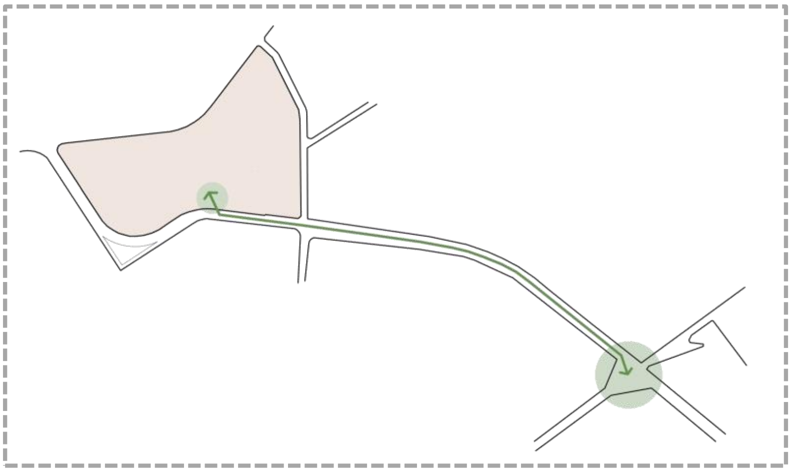


Figure 98: Location of contemporary district 1 and its distance to the city center. Graphic by author

Table 10 demonstrates the distances of the case st
According to this table, the average distance from the urban facilities in the historical districts is less than that of the contemporary case study districts.

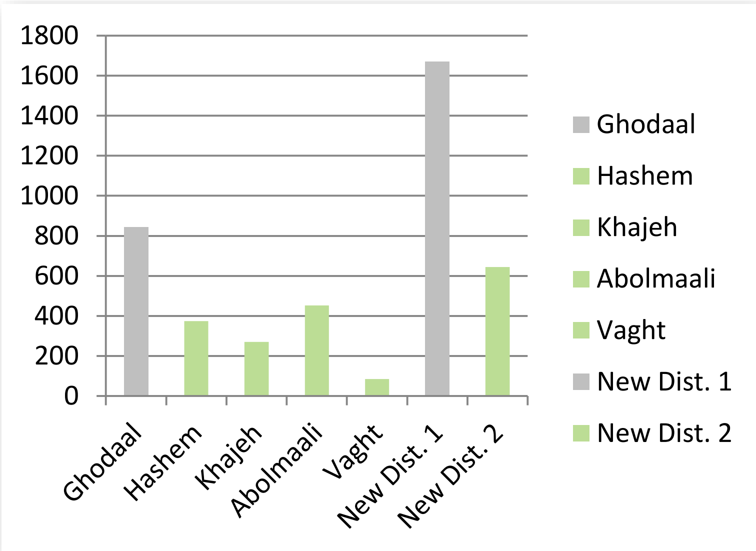


Table 10: Distance of case studies to urban facilities (meter)

[14] It is important to know that the new districts usually don't have much facilities in the neighborhood scale and the habitants have to go to the main streets out of the residential parts for the minimum daily needs.

Criterion: LEED defines the distance of the district center from the nearest service to be less than ½ mile or 804 meter (LEED 2009). According to this criterion, most of the historical case study districts are qualified in this item (Figure 99 and Table 11).

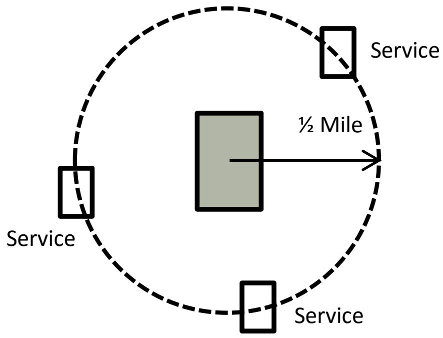


Figure 99: Image from author on basis of **(LEED 2009)**

District name	distance from facilities	LEED evaluation system	Grade
Ghodal	844m	≤ 804m	-
Hashem khan	374m	≤ 804m	+
Khajeh	270m	≤ 804m	+
Abolmaali	453m	≤ 804m	+
Vaght	85m	≤ 804m	+
New district 1	1670m	≤ 804m	-
New district 2	645m	≤ 804m	+

Table 11

Result 2: *historical districts have better act to reaching urban facilities in comparing to the contemporary districts*

6.1.3 Mixed-use (district facilities):

Combining work, retail, leisure, and living accommodation (mixed-use) in a district reduces the need for daily journeys in the city and car dependency (Sassi 2006, 24).

As mentioned before, the Iranian historical districts usually include a combination of several facilities, such as a small bazaar, mosque, public bath, school, and *cistern* in the center of the district, and they provide the inhabitants with their daily needs at the minimum distance from their houses, making it unnecessary to go to the city center for the daily living requirements (Golkar 2000, 48).

For example in the Abolmaali district, the distance of furthest place to the district center's facilities is about 4 minutes on foot, where several daily services are located to support the people's daily needs (Figure 100).

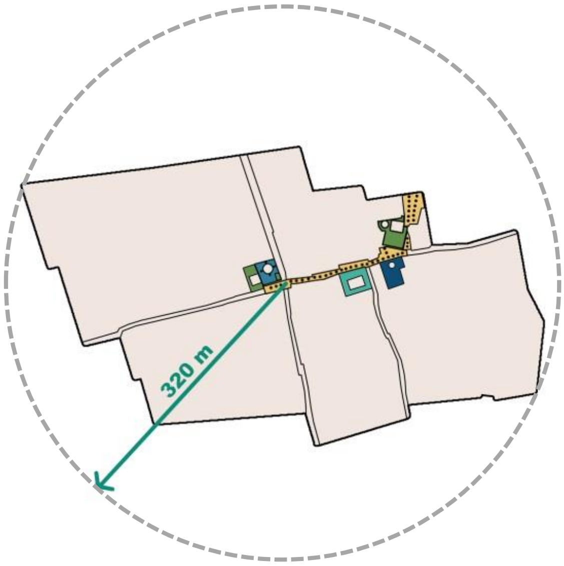


Figure 100: The farthest places in Abolmaali district. Graphic by author

Criterion: LEED defines the minimum point for mixed-use item to locate at least 20% of dwelling units within a ¼ mile walking distance of 4 to 6 diverse uses (LEED 2009).

This means that if at least 4 local facilities are located in the center of each case study district, with their average size close to the size of the Abolmaali district, those case studies can be qualified by this criterion.

- **Historical districts:** all of the historical case studies have at least 4 local facilities in their center (Figures 101 and 102).

According to Figures 101 and 102, the usual daily services are located in the center of each district, following the usual structure of the historical cities. The following is a brief introduction of various local facilities in historical case study districts:

Abolmaali district: A relatively large Bazaar in its center, public bath, religious school, *cistern*, and two mosques.

Vaght-o Saat district: Three small Bazaars in three spots of the district, public bath, religious school, *cistern*, four mosques, and a square as the shared public space.

Khajeh district: A relatively large Bazaar, public bath, *cistern*, a traditional sport center, and two mosques.

Hashem Khan district: Three small Bazaars, a *cistern*, two mosques, a public space, and several Caravanserais (this district is located near the main Bazaar of the city; the Caravanserais are usually located around the main Bazaar).

Ghodal district: Two small Bazaars, a religious school, two mosques, and one shared public space

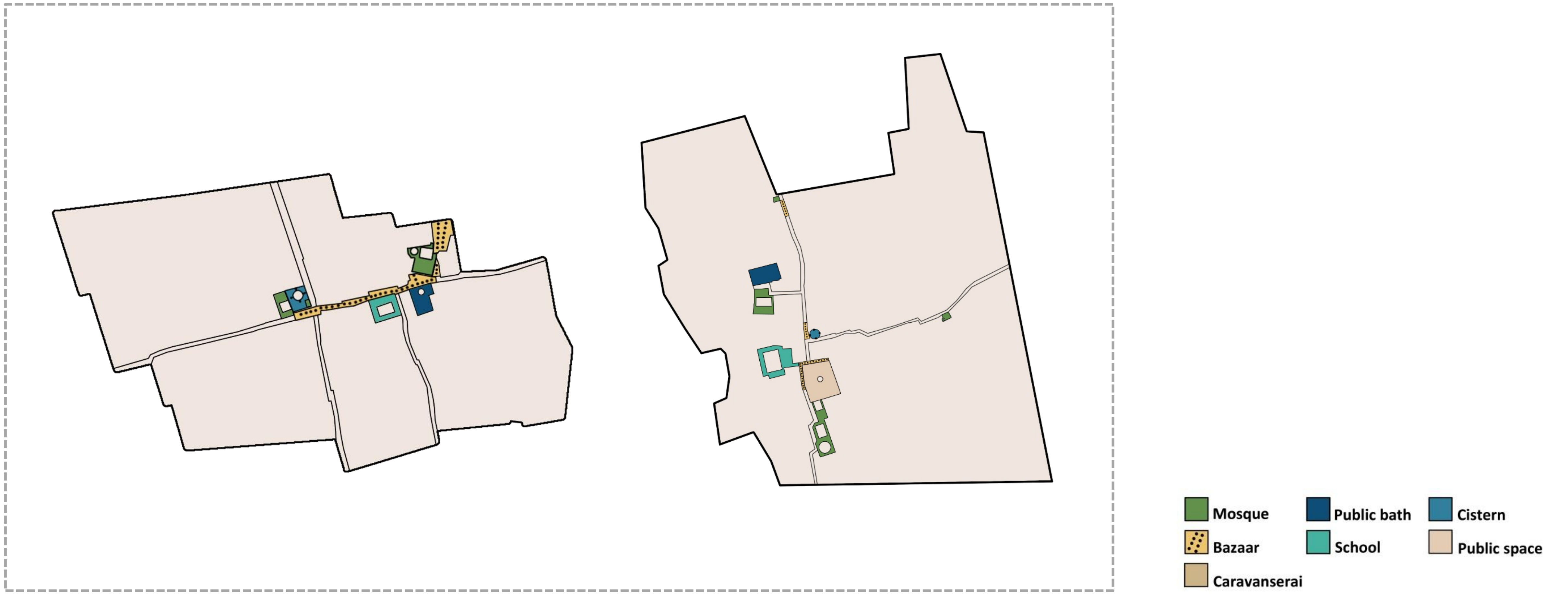


Figure 101: Local facilities of Abolmaali (Left) and Vaght districts (Right). Graphic by author

Figure 102: Local facilities of Ghodal (Left), Hashem Khan (Middle) and Khajeh (Right) districts. Graphic by author

- **Contemporary districts:**

In the new parts of Yazd, the districts' area consists mostly of residential functions, on the basis of the modern living style of car dependency. The inhabitants should supply their daily needs from the shopping malls and main streets usually located out of the residential parts. So the district facilities can rarely be found in district centers (Figure 103).

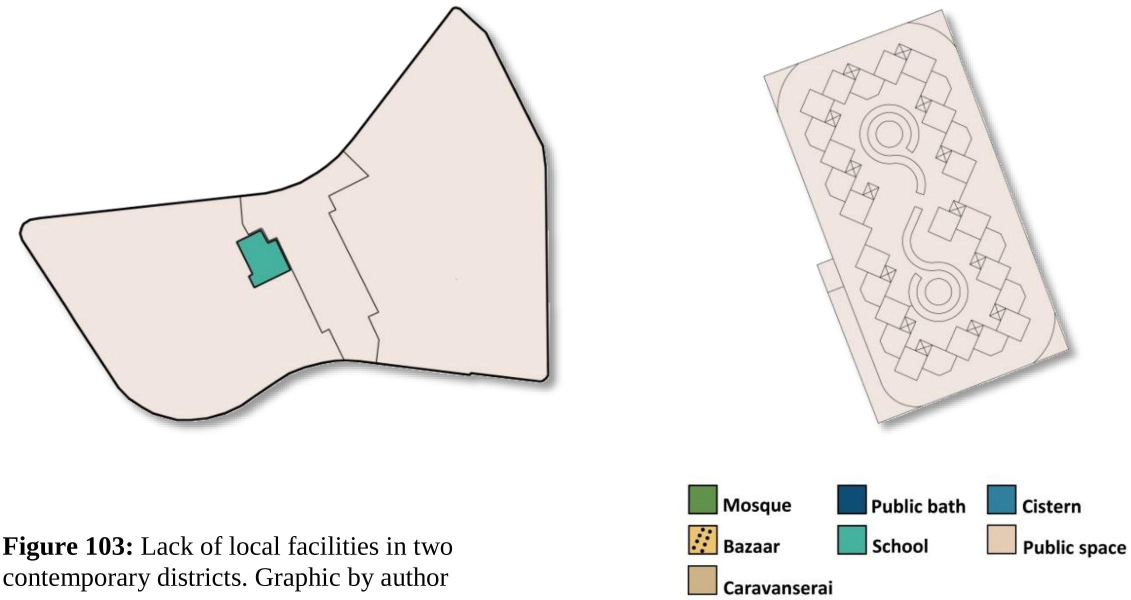


Figure 103: Lack of local facilities in two contemporary districts. Graphic by author

Regarding the LEED criterion for the mixed-use item and considering the local facilities and the size of the historical case studies, all of the historical districts are qualified by this item, in contrast to the contemporary districts, which fail in this qualification (table 12).

District name	Mixed-use (Num. of diverse uses)	LEED evaluation system	Grade
Ghodal	4	At least 4-6 diverse uses in the district	+
Hashem khan	4	At least 4-6 diverse uses in the district	+
Khajeh	4	At least 4-6 diverse uses in the district	+
Abolmaali	5	At least 4-6 diverse uses in the district	+
Vaght	6	At least 4-6 diverse uses in the district	+
New district 1	1	At least 4-6 diverse uses in the district	-
New district 2	0	At least 4-6 diverse uses in the district	-

Table 12

Result 3: *historical districts have better act for reducing needs of travel in the city by their local facilities in comparing to the contemporary districts*

6.2 Health and wellbeing:

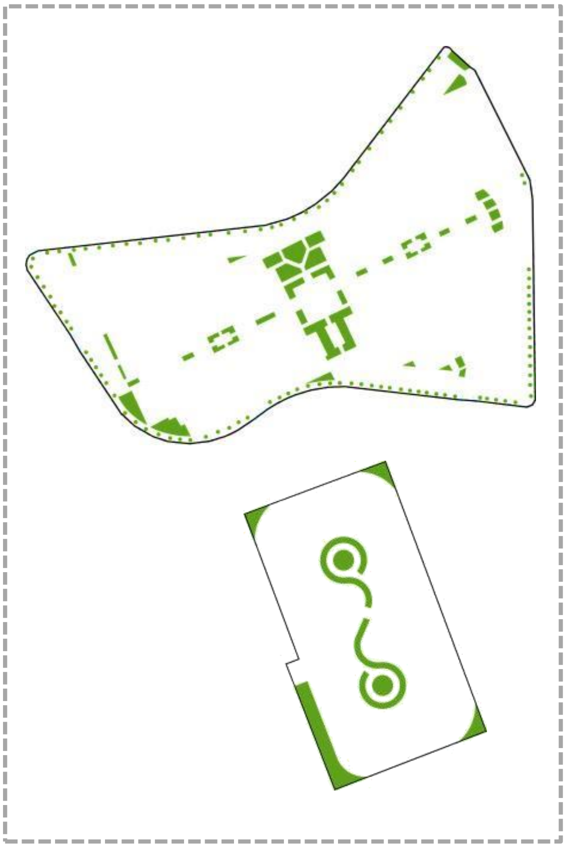
Health and wellbeing is the second category of the evaluation tool defined in table 7, chapter 6. Items that contribute in healthy living such as green area, hierarchy, shade, garbage management etc. are surveyed in this part.

6.2.1 Green area:

One of the most important features of hot and arid region of Iran is the low amount of rain and humidity which results in lack of vegetation and green area (Ghobadian 1994, 123).

The inhabitants of traditional cities in this region planted trees and green spaces in the central courtyards in order to increase humidity and create a moderate (micro) climate inside the houses (ibid 23).

In this part the area of the green spaces in each district is calculated and compared with other case studies (Figures 104-105). Table 13 shows the ratio of green area in each district to each 1 square meter of residential spaces.



District name	Green area
Ghodal	0.042 m2
Hashem khan	0.058
Khajeh	0.047
Abolmaali	0.063
Vaght	0.052
New district 1	0.127
New district 2	0.105

Table 13

Figure 104: Green area calculated in the contemporary districts. Graphic by author

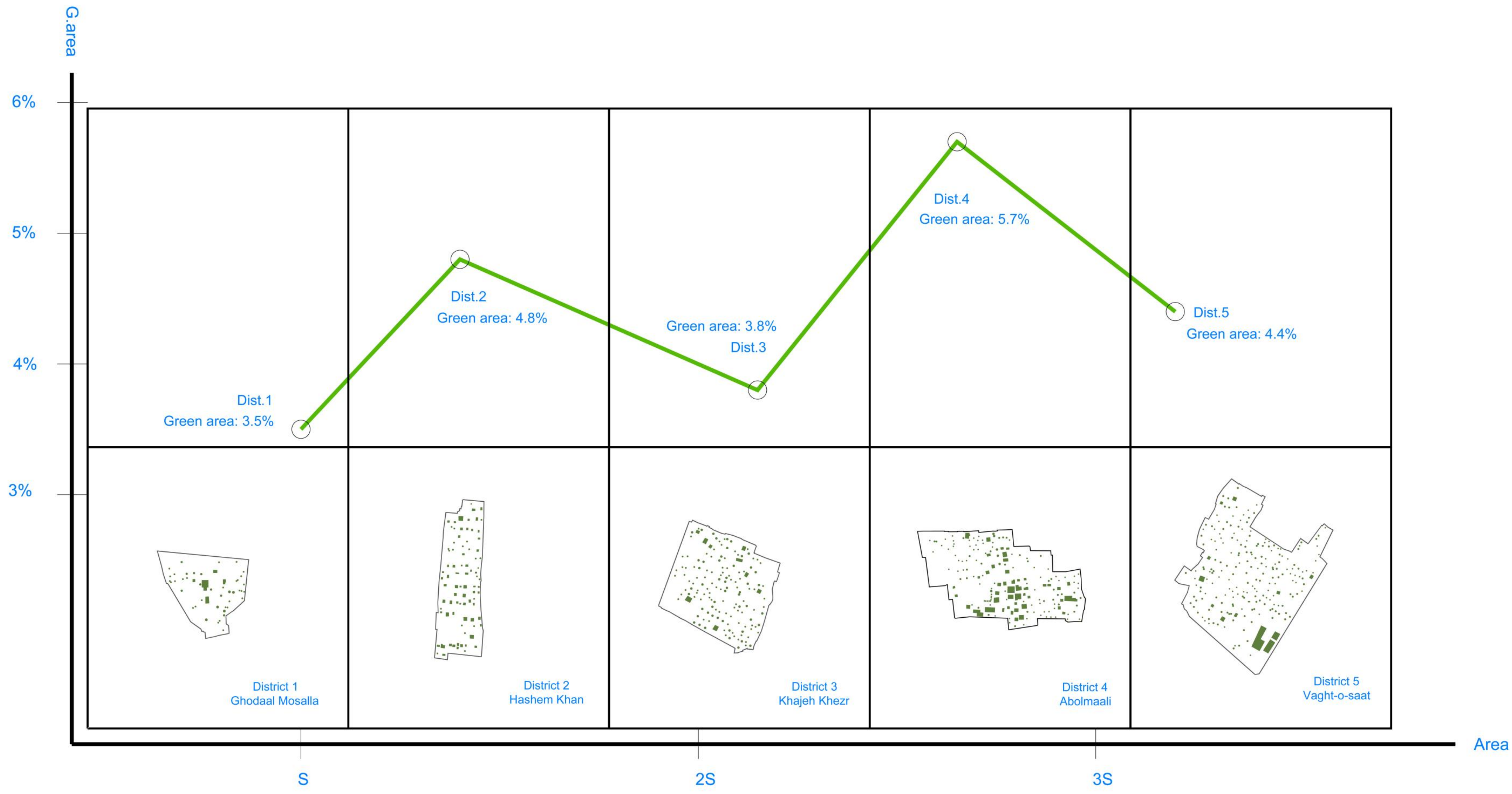


Figure 105: Green area in the historical districts. Graphic by author

According to table 13 the ratio of green area in the new parts of Yazd is higher than the historical parts. The average of this item in New Districts is about 0.115 m² per each m² residential unit. As illustrated in Figure 106, this ratio is almost like a square network with 8 residential units and one unit of green space.

Criterion: LEED system does not include this item in the neighborhood scale.

The local Iranian standards define this item on basis of population (The standard green area in Iran is defined 7-12 square meter per capita) (Nezafati and Shaghaghi 2014).

As mentioned before there is no information about population in the historical city in the past and it is impossible to use this standard of green area per capita for the historical parts.

According to the higher ratio of average green area in the contemporary parts of Yazd, this average is adapted as the baseline for evaluation of case studies (Table 14).

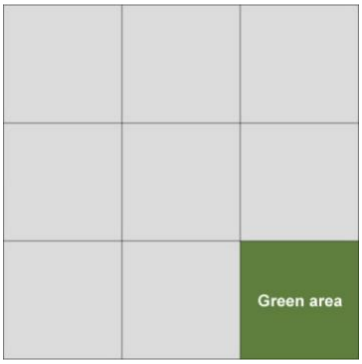


Figure 106: Schematic sample for Green area. Graphic by author

District name	Green area	Local criterion	Grade
Ghodal	0.042 m2	≥ 0.115 m2	-
Hashem khan	0.058	≥ 0.115 m2	-
Khajeh	0.047	≥ 0.115 m2	-
Abolmaali	0.063	≥ 0.115 m2	-
Vaght	0.052	≥ 0.115 m2	-
New district 1	0.127	≥ 0.115 m2	+
New district 2	0.105	≥ 0.115 m2	-

Table 14

Result 4: *contemporary districts possess larger green area per square meter compared with the historical districts*

6.2.2 Hierarchy (neighborhood spaces):

Using this item helps make more privacy and comfort in the neighborhood centers by defining a hierarchy from public to the private spaces. This strategy regulates the form and size of the passageways for making more private and secure spaces (Figure 107).

Iranian traditional cities define some kind of realms at different scales. Dead ended passageway is a semi private space that acts as a neighborhood center shared between several neighboring houses and defines is their shared realm (Tavassoli, Principles and Techniques of Urban Design in Iran 1997, 68). This is a secure space for children to play and a small social community center between the neighbors.

In this part, the area of these neighborhood spaces are calculated to show how much area of each district has the potential to be used as a semi-private space shared between the neighbors. In other words, the ratio of dead ended passageways area to the total area of the passageways in each district is calculated (Table 15).

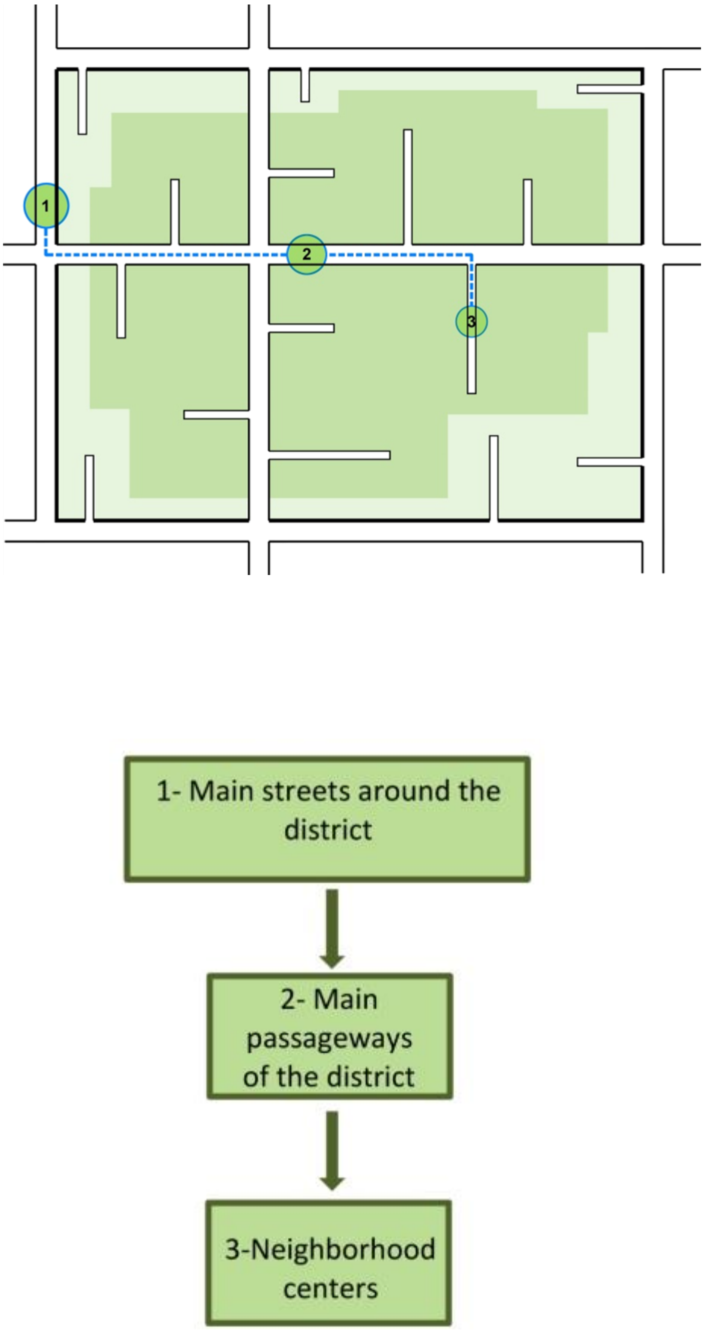


Figure 107: Hierarchy of the passageways in an Iranian district. Graphic by author

District name	Neighborhood spaces
Ghodal	22.8%
Hashem khan	56.1%
Khajeh	16.6%
Abolmaali	40%
Vaght	34.4%
New district 1	3.3%
New district 2	24.8%

Table 15

Figure 108: Neighborhood spaces in Hashem Khan district with the highest amount of dead ended passageways. Graphic by author

Criterion: LEED system has no item for evaluation of this special feature of Iranian cities.

According to table 15, the historical districts usually have larger amounts of neighborhood spaces than the contemporary districts. The average percentage of the dead ended passageways in historical districts is used as a baseline (Table 16).

District name	Neighborhood spaces	Average of historical districts	Grade
Ghodal	22.8%	34%	-
Hashem khan	56.1%	34%	+
Khajeh	16.6%	34%	-
Abolmaali	40%	34%	+
Vaght	34.4%	34%	+
New district 1	3.3%	34%	-
New district 2	24.8%	34%	-

Table 16

According table 16 in two historical districts (Ghodal and Khajeh) the amount of this item is low. A survey of the structures of these districts reveals that in recent decades, the development of new passageways has connected many original passageways together for easier vehicle access. So the structure of these districts have changed and many historical neighborhood centers have disappeared (Figure 109).

But the districts that have preserved their original structure reveal a larger amount of neighborhood centers area.

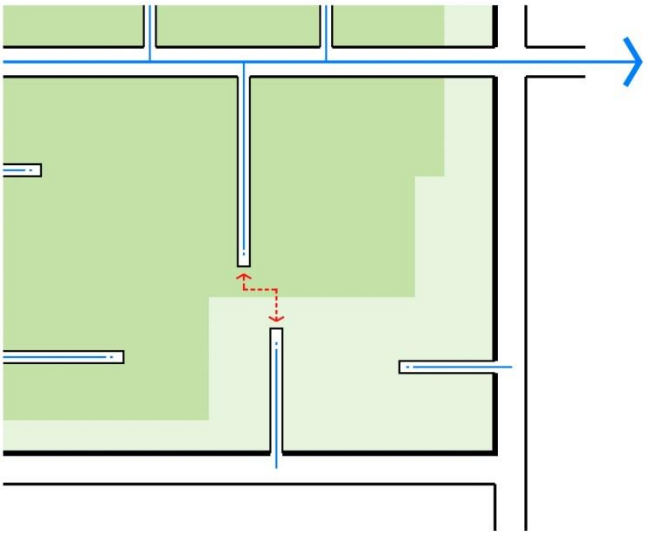


Figure 109: Connecting dead ended passageways in Ghodal district. Graphic by author

In the contemporary case studies, New District 2 owns a high amount of neighborhood centers (24.8%) comparing with the usual modern districts in Iran.

This is a residential complex with a big introverted open space between the residential blocks. Most of this big courtyard's area is closed for the cars and has pedestrian routes. This structure increases the area of dead ended spaces as neighborhood centers (Figure 110). But its range of neighborhood spaces is still not as high as that of the original historical districts.

Figure 110: Structure of contemporary district 2. Graphic by author

Result 5: *Historical districts provide more secure and private neighborhood spaces than the contemporary districts*

6.2.3 Shaded area:

According to chart 2 the average number of clear days in Yazd during the year is about 243 days (about 2/3 of the year) (Chaharmahalmet 2014). This amount of sun radiation in hot and arid region is annoying for the inhabitants during their daily activities.

The traditional Iranian cities in hot and arid region adapt specific strategies such as compact urban texture, specific orientation of the urban texture, indirect and narrow passageways with high walls.

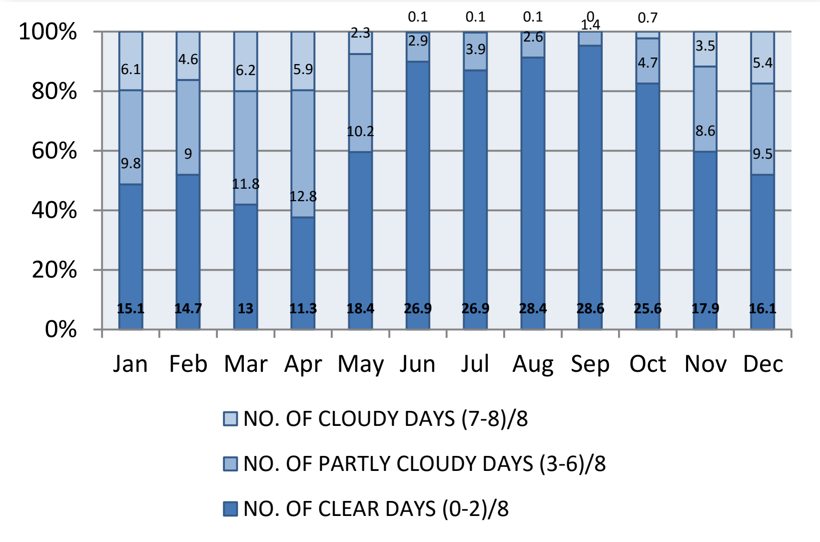


Chart 2: Monthly average number of clear, partly cloudy and cloudy days in Yazd (1952-2005). From: (Chaharmahal 2014)

These strategies create more shaded spaces and provide more comfort for the inhabitants (Ghobadian 1994, 124).

This part analyses the "shaded area” in the case studies as the following. One specific time and date is selected to calculate the shaded area in each district and compare it with other districts at the same time and date.

Selecting this time is an example and cannot be generalized to the whole year. But selection of the hottest time of the hottest month of the year in Yazd can demonstrate the operation of each district at least in the hot times of the year with annoying sun radiation.

For this purpose the hottest month of the year in Yazd, July, with the maximum monthly average temperature of 39.2°C and the hottest hours of the day (between 2 to 4 pm) is selected (Kasmai 2003, 294).

Solar path diagram of Yazd shows that at 2:00 pm in July, the horizontal degree of the sun (azimuth) is 100° and its vertical degree (altitude) is 63° (ibid 138).

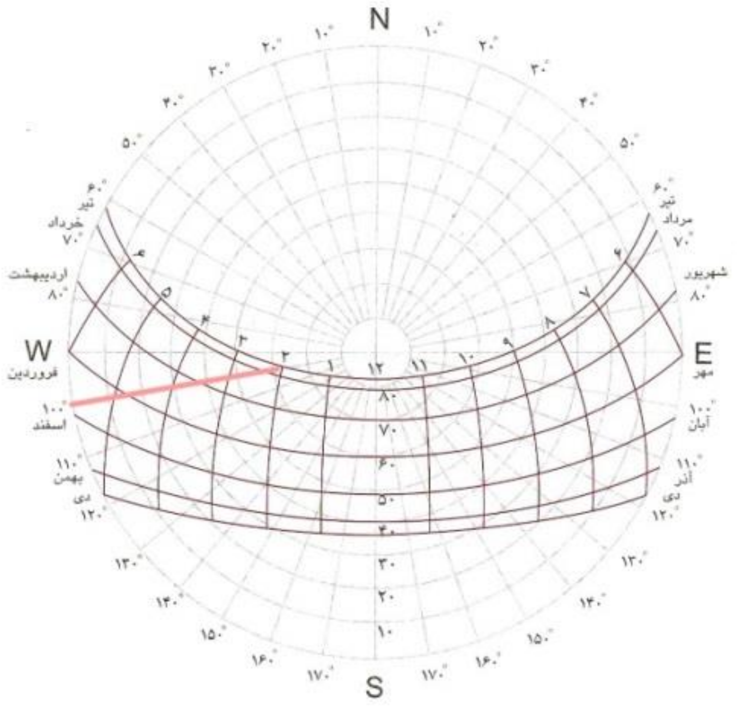


Figure 111: Solar path diagram in Yazd and sun direction at the time 2:00 pm. From: **(Kasmai 2003, 294)**

For analyzing this item, the ratio of shaded area on the passageways to the total area of passageways in each district in the exact time mentioned is calculated.

- **Historical districts:**

Calculation of this item shown in table 17 demonstrates that in some historical districts such as Abolmaali, more than 45% of the passageways are shaded at the hottest time of the year. This high amount of shaded area in passageways provides a comfortable route for walking even at the hottest hours during the year (Figures 113-114 and Table 17).

As figure 113 and table 17 show, generally the area of shaded spaces in the historical case study districts is higher compared with the contemporary case studies. This is because of the special structure of the urban texture in the historical parts, with a compact texture and narrow passageways.

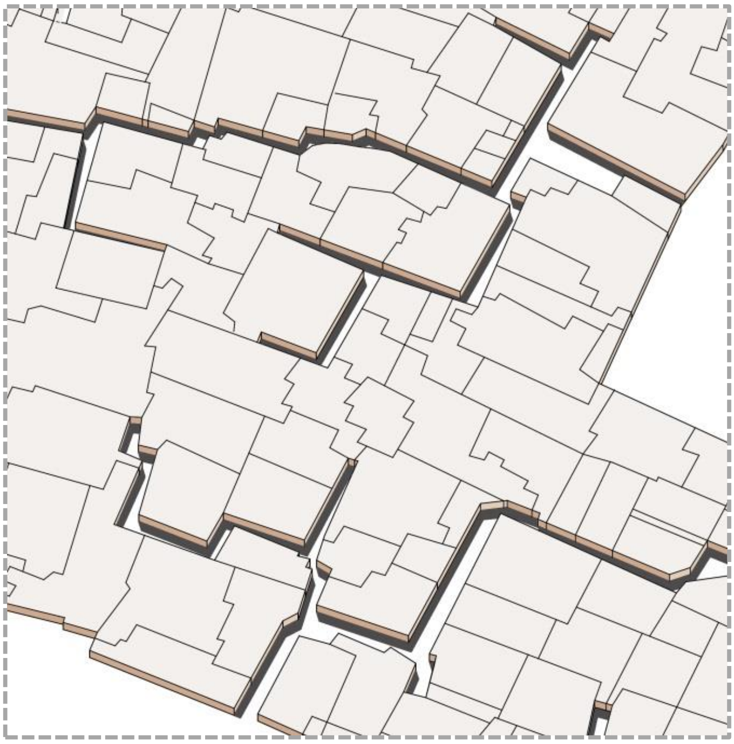


Figure 112: Zoomed in one part of historical districts and its shaded area. Graphic by author

District name	Shaded area
Ghodal	34.3%
Hashem khan	40.6%
Khajeh	39%
Abolmaali	45.1%
Vaght	36.6%

Table 17

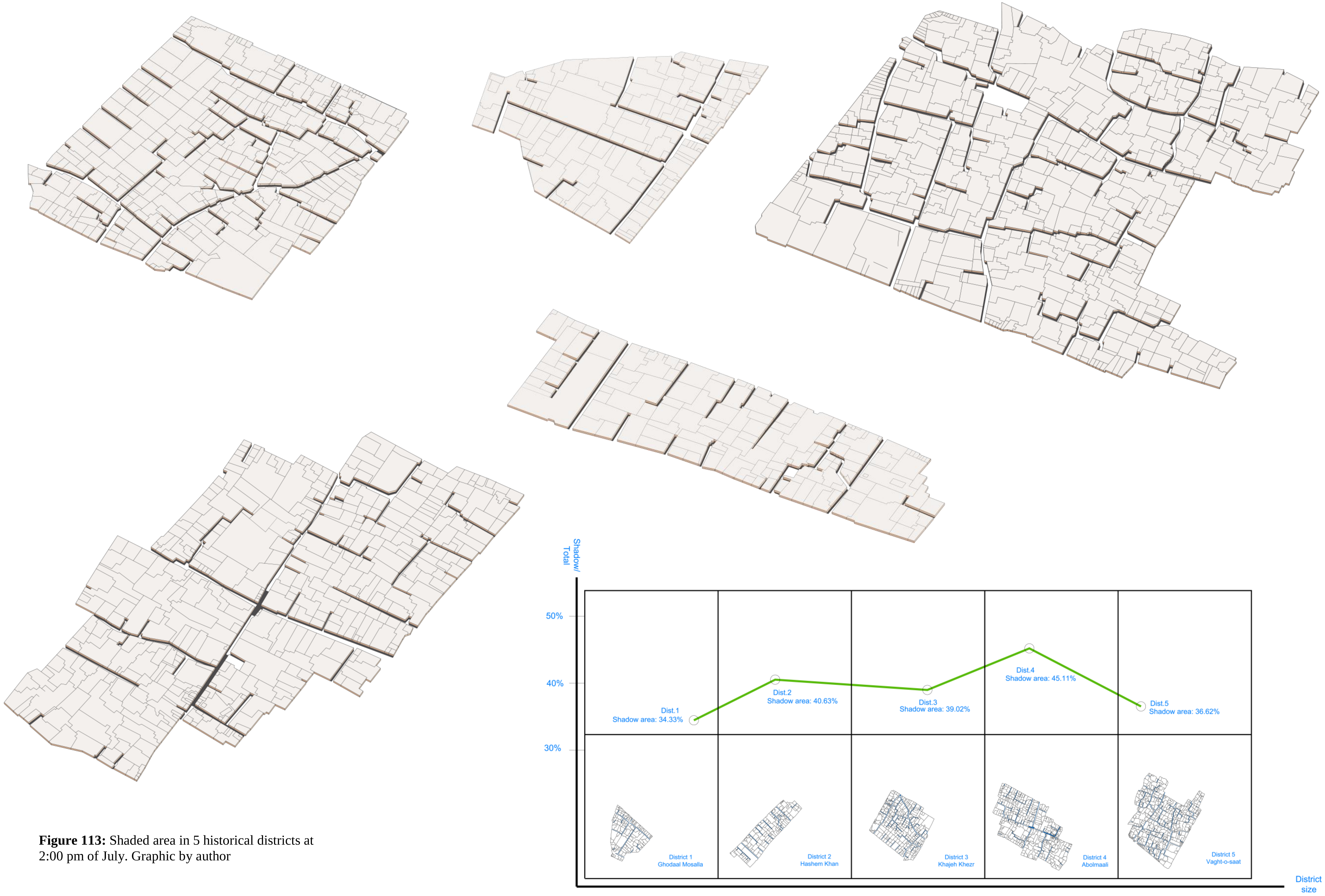


Figure 113: Shaded area in 5 historical districts at 2:00 pm of July. Graphic by author

- **Contemporary districts:**

In the new parts of Yazd because of the scattered urban texture and wide streets, the amount of shaded passageways is very low. Most of the residential parts of contemporary districts of Yazd are single family houses like New District 1. Its area of shaded passageways is about 5%. In New District 2, the situation is different: the shaded area is pretty large because of this district's structure (Figure 114, Table 18). This is a residential complex with midrise buildings. However this is an exceptional contemporary district and the majority of contemporary districts of Yazd are similar to New District 1 in this research.

District name	Shaded area
New district 1	5.3%
New district 2	27%

Table 18

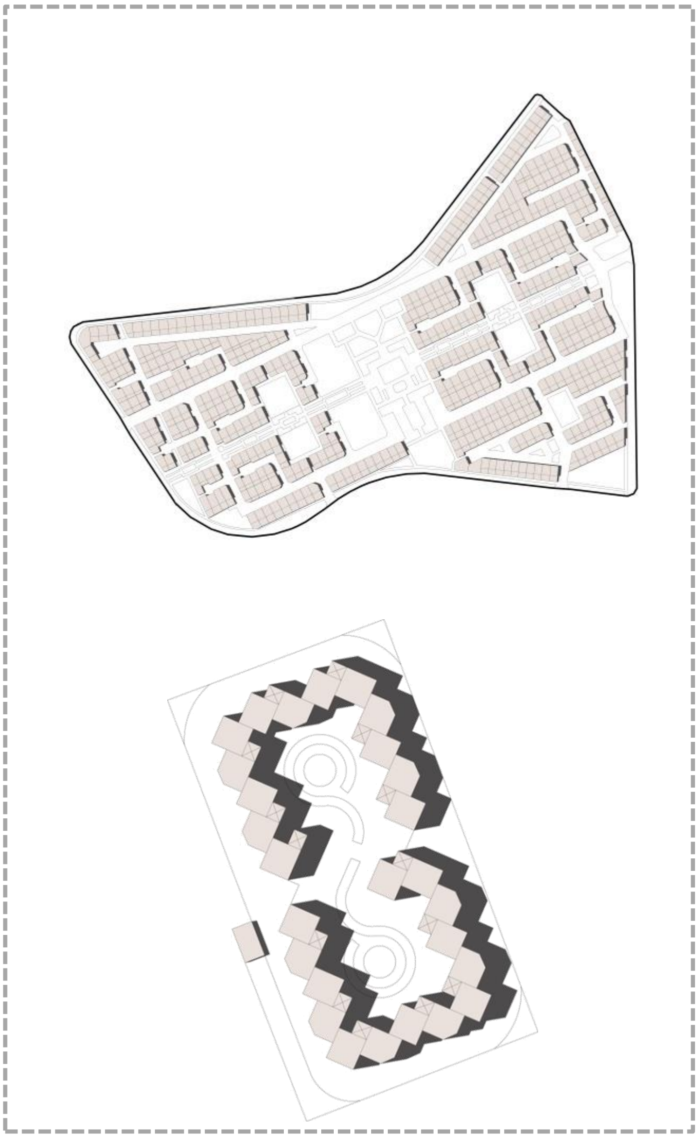


Figure 114: Shaded area in the contemporary districts at 2:00 pm of July. Graphic by author

Criterion: According to LEED system, at least 40% of the length of sidewalks and passageways on streets of the project should be shaded (LEED 2009).

District name	Shaded area	LEED evaluation system	Grade
Ghodal	34.3%	≥ 40%	-
Hashem khan	40.6%	≥ 40%	+
Khajeh	39%	≥ 40%	-
Abolmaali	45.1%	≥ 40%	+
Vaght	36.6%	≥ 40%	-
New district 1	5.3%	≥ 40%	-
New district 2	27%	≥ 40%	-

Table 19

Applying the LEED criterion to the data of table 19, two of the historical districts can be qualified by this item, due to their shaded area more than 40%. The other historical districts also have shaded area around 40%. These two districts reveal better shading performance.

Result 6: *Historical districts provide more shading for daily activities than the contemporary districts*

6.2.4 Passageways proportions:

The proportion of passageways is an effective factor for providing shaded area. In hot and arid region of Iran the passageways are non-linear in plan, narrow with high walls, and some of them are covered[15] with arches and vaulted roofs (Ghobadian 1994, 124) (Figure 115).

These strategies produce more shading and also have other advantages such as protecting the passageways from dusty winds that happen a lot in cities near desert like Yazd (ibid 126).

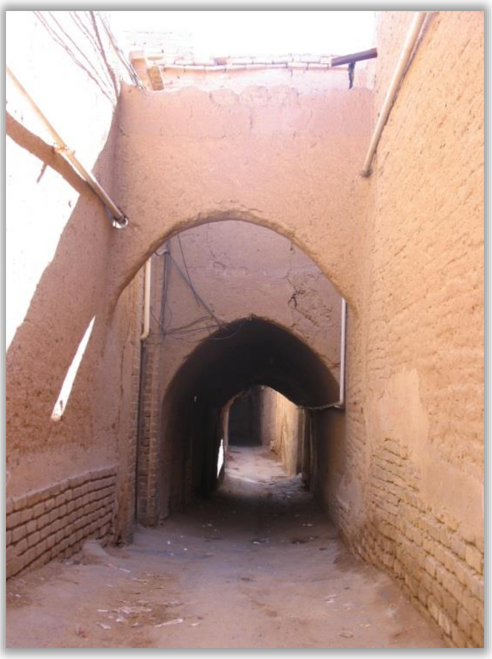


Figure 115: one narrow and covered passageway in Yazd. Image from: author

In this part the average of passageways proportions (width/height) are surveyed in each district (Tables 20-21).

Passageways are classified in three categories:

1- Main passageways around and in the districts
2- Dead ended passageways
3- Covered passageways (*Sābāts*)

[15] The covered passageways in traditional cities are named "*Sābāt*".

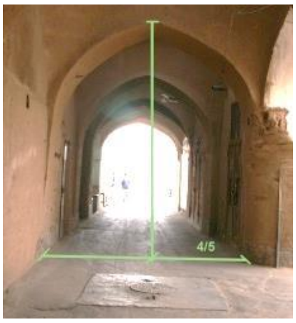
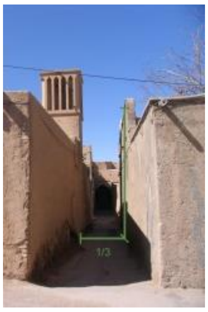
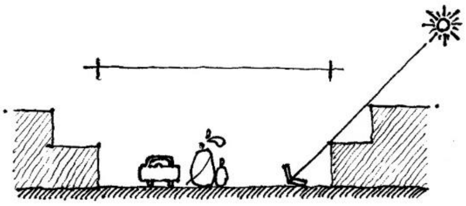
Table 20	Main passageways	Covered passageways (*Sābāts*)	Dead ended passageways
Ghodaal Mosalla			
Hashem Khan			
Khajeh Khezr			
Abolmaali			

Table 21	**Main passageways**	**Covered passageways (*Sābāts*)**	**Dead ended passageways**
New district 1		----------------------	
New district 2		----------------------	----------------

Results of tables 20-21 show that the average proportion of main passageways in the historical districts is about ¾ **(Width/Height)**. This proportion is even higher in dead ended passageways.

But in the contemporary districts passageways and streets are extremely wider and the average proportions is more than **2/1 (Width/Height)**.



It is clear that existing proportions of new streets are because they are designed to provide more space for transportation and daily activities. But these dimensions of passageways and streets are not responsive to the special environment and climatic condition in this region. Considering the climatic advantages of the historical passageways and responding to the modern facilities of the traffic systems and contemporary functions, some solutions for improvement of new passageways' shading performance must be recommended (see the final chapter).

Chart 3 shows the average of passageways proportions in different case studies. (Height/Width)

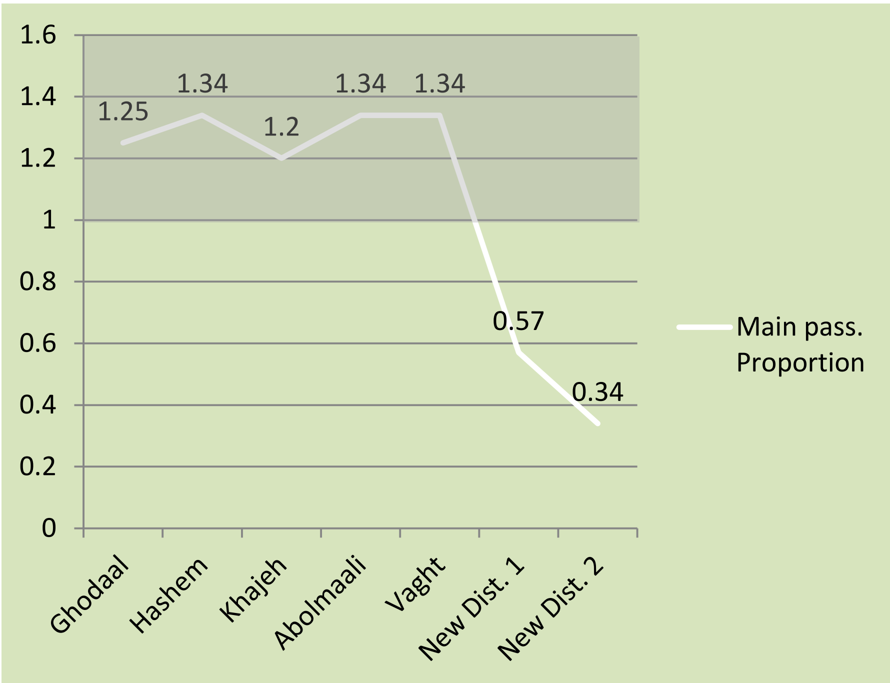


Chart 3: main passageways proportion of the districts

Criterion: According to LEED system, 100% of existing and new street frontage within and bordering the project must have a minimum building-height-to-street-width ratio of 1:1 (LEED 2009). This item in LEED does not include covered passageways.
Also the dead ended narrow passageways are special forms of passageways that is usual in the Iranian cities, so in this research this criterion is only applied to the main passageways of each district.

Chart 3 and table 22 show that all the historical districts have higher proportions of passageways'-height-to-length than the LEED's criterion and they can be qualified by this item.

The contemporary districts have wider proportions than LEED's proposal.

District name	Passageway proportion	LEED evaluation system	Grade
Ghodal	1.25	≥ 1	+
Hashem khan	1.34	≥ 1	+
Khajeh	1.2	≥ 1	+
Abolmaali	1.34	≥ 1	+
Vaght	1.34	≥ 1	+
New district 1	0.57	≥ 1	-
New district 2	0.34	≥ 1	-

Table 22

Result 7: *Historical districts have better passageways proportion for matching with the environmental conditions*

6.2.5 Garbage management:

According to the field survey by the author and using observation method, the process of waste management in Yazd especially in the historical parts is a non-advanced and primary method:

- People leave the garbage packs near abandoned and ruined buildings and there is no specific place or trash container for this purpose. Some nonstandard trucks collect and transfer the packs to the outside of city (Figure 116).

About the recycling process, an interview with the mayor of Yazd city explains:

- About 500g garbage is produced by each person in Yazd per day and the garbage managing organization of Yazd collects and recycles a part of them as compost. But waste separation and solid waste management is a new issue in municipals in Iran and there are some plans in the future in Yazd for these programs.[16]

United Nation's report shows that in Iran, generally 90 percent of all produced wastes are sent to landfills and only 10 percent are recycled, of which 8 percent are disposed by composting (UN 2015).

These facts demonstrate that currently, there are no comprehensive plan for garbage management in the Iranian cities including Yazd.

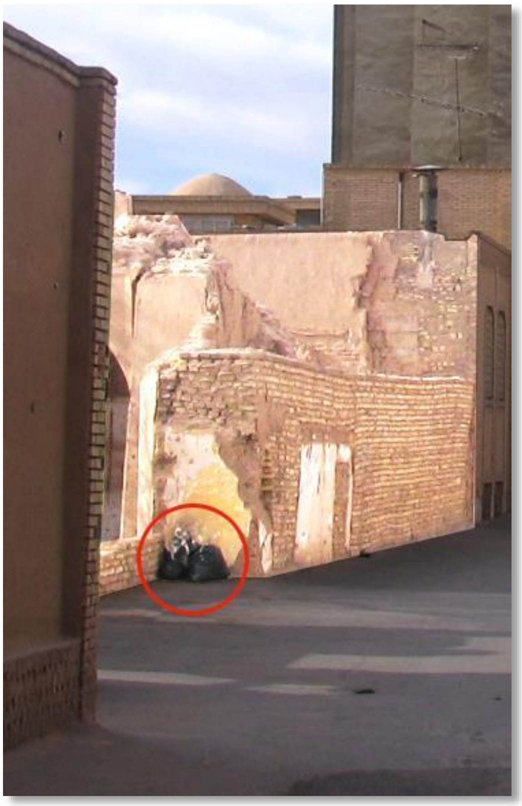


Figure 116: Garbage management in Yazd. Image from: author

[16] Interview of Yazd city mayor's deputy with the garbage managing organization of Iran (Pasmandiran 2014).

As following table shows, on basis of the previous results none of the case studies show an acceptable operation in terms of garbage management.

District name	Garbage management
Ghodal	-
Hashem khan	-
Khajeh	-
Abolmaali	-
Vaght	-
New district 1	-
New district 2	-

Table 23

6.3 Energy:

6.3.1 Common walls:

The compact urban fabric of the cities in hot and arid region of Iran reduces the area of surfaces of buildings that face the external severe environmental condition. Many houses are adjacent to their surrounding houses on four sides (Golkar 2000, 49). These connections increase the rate of common walls between the buildings. These common walls play an important role in saving energy and sharing Heat or coldness between neighbors (Figure 117).

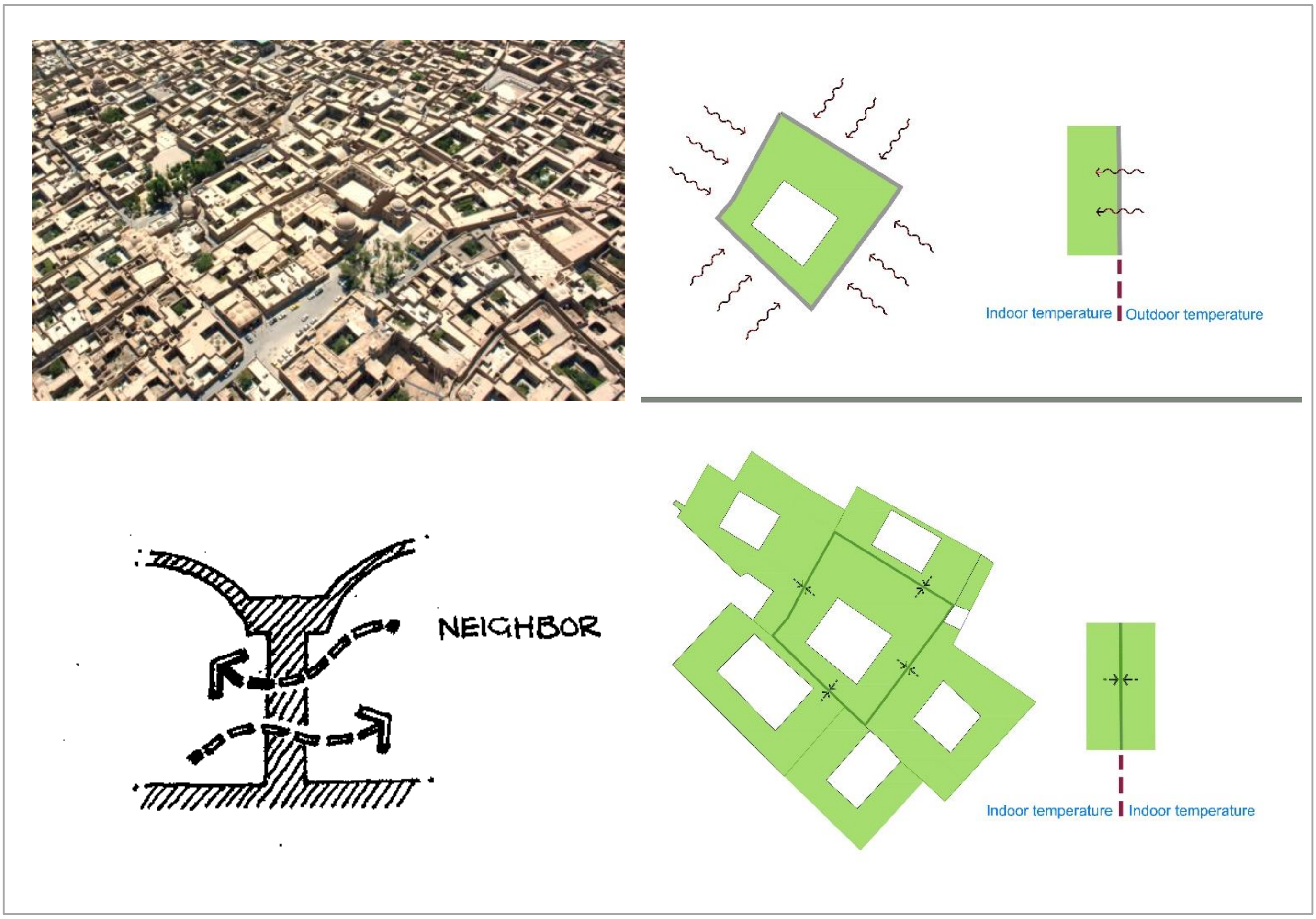


Figure 117: Special style of Iranian cities (connected buildings with maximum common walls). Graphics by author

In some cases because of the interwoven structure of the urban fabric, some parts of a building move to top of the lower parts of the nearby buildings and form some common floors between the neighbors too.

All these strategies create a constant indoor temperature inside the neighboring spaces as a result of common surfaces between different buildings of one district.

The calculated results in this item show that in some cases, the area of common walls is more than 50% of total walls in the district (Figure 118). It means that more than half of the walls in the district assist in preventing energy loss through the buildings' external envelope.

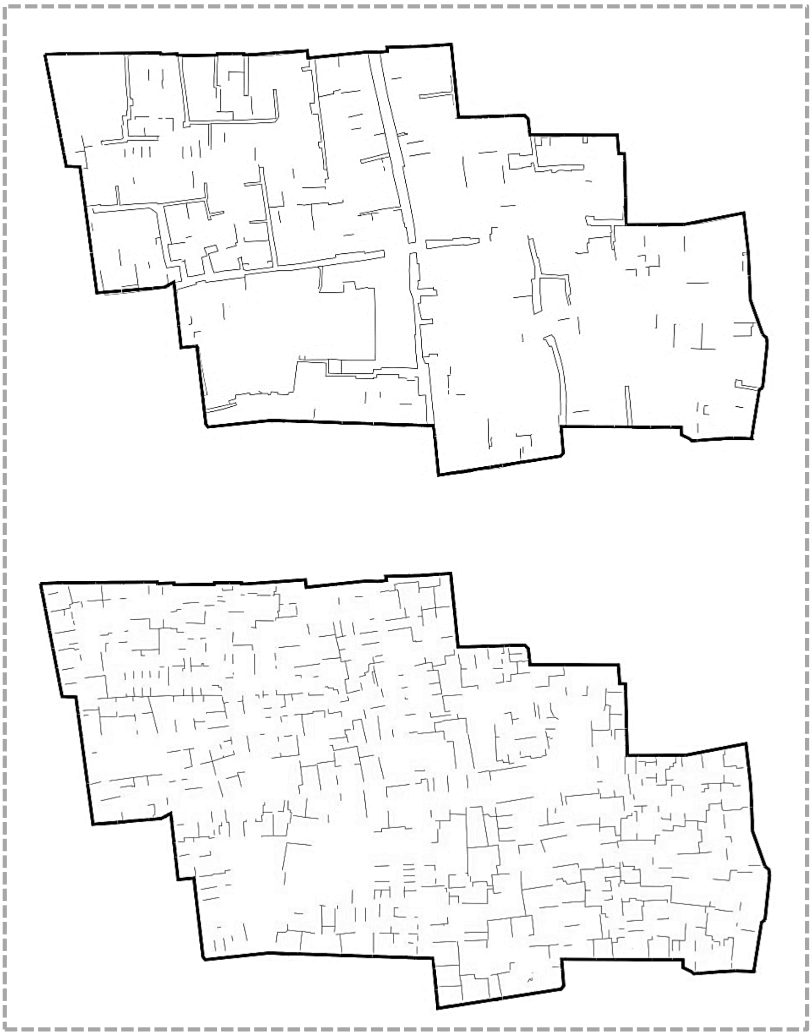
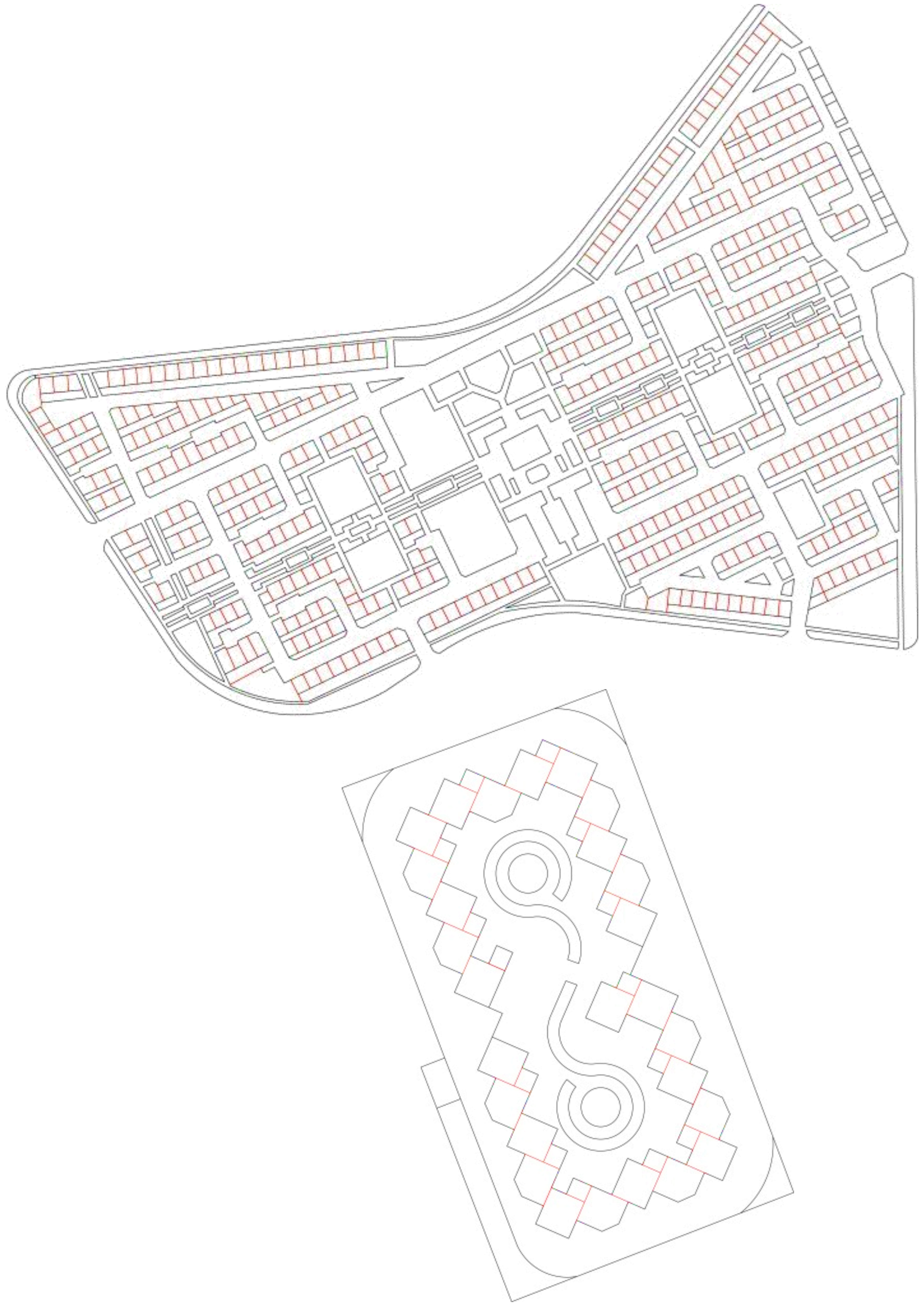


Figure 118: External walls (above) and the common walls (below) in Abolmaali district. Calculation and graphic by author

In the upcoming part, the ratio of common walls area to the total walls in each district is calculated. (Figures 119-120)



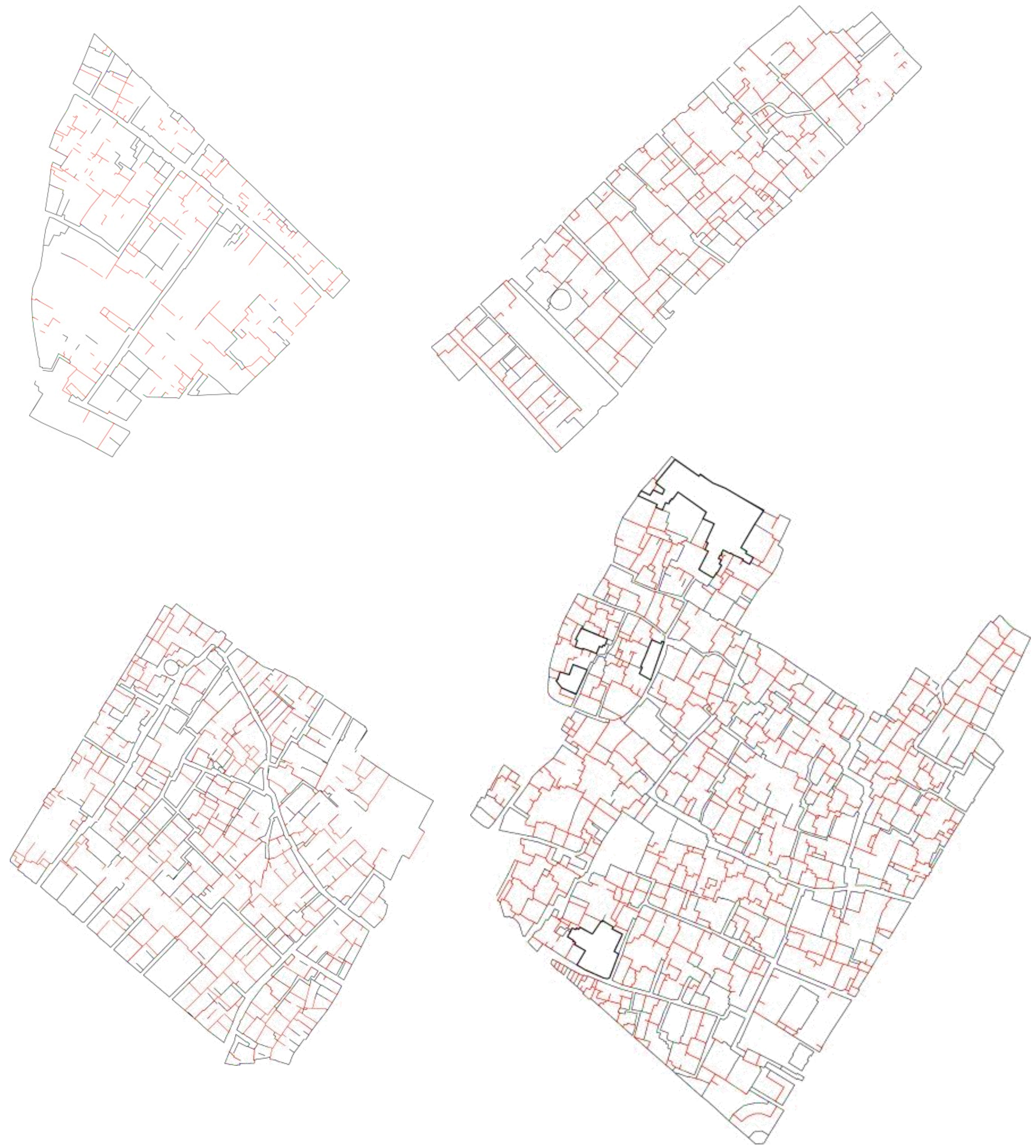


Figure 120: Common walls in the contemporary districts (red colored lines). Graphic by author

Figure 119: Common walls in the historical districts (except Abolmaali district that its common walls were showed in figure 85). Graphic by author

As table 24 shows, results demonstrate that the average rate of common walls in the historical districts is more than contemporary districts.

Criterion: LEED system does not define any item to match with this special feature of Iranian cities. Therefore in this part, the criterion is defined on basis of the average of the results from historical districts that act better in this item.

The average ratio of common walls to total walls in the historical districts is about 43%. This ratio is almost like a house with two of its external walls common with the neighbors (Figure 121).

In the new parts according to the modern urban structure, the average ratio of common walls to total walls is about 28%.

District name	Common walls	Local criterion	Grade
Ghodal	36.5%	At least 43%	-
Hashem khan	43.2%	At least 43%	+
Khajeh	44%	At least 43%	+
Abolmaali	50.3%	At least 43%	+
Vaght	40.7%	At least 43%	-
New district 1	29.7%	At least 43%	-
New district 2	27.5%	At least 43%	-

Table 24

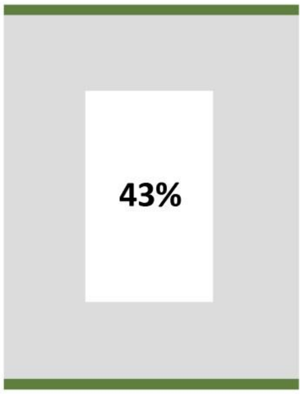


Figure 121: Simulation of average of common walls in the historical districts. Graphic by author

According to the table, most historical districts can be qualified by this defined criterion. However the rate of common walls in non-qualified historical districts is also near to the criterion percentage and much higher than the average of contemporary districts' results.

Result 8: *Historical districts perform better for saving energy through the common walls*

6.3.2 Orientation:

Traditional Iranian architecture and urbanism benefits from a strategy for taking advantage of favorable winds and insolation named "*Ron*" (M. Pirnia 2013, 155). *Ron* is defined as the direction and angle of urban fabric that matches the best orientation to benefit from winds and solar radiation.

There are three *Rons*, located in different regions of Iran: *Raasteh*, *Kermani* and *Isfahani*.

These *Rons* are resulted from a rectangular shape in different directions inscribed in hexagon (Figure 122).

Yazd's urban texture orientation follows the *Raasteh* Ron in the due northeast-southwest direction (ibid).

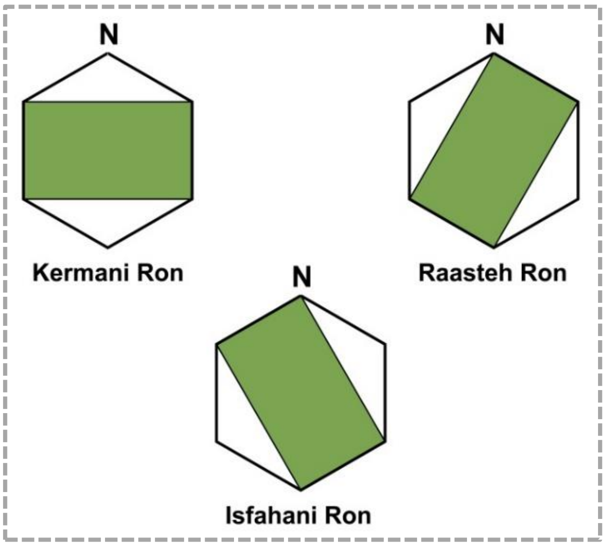


Figure 122: *Rons* in Iran. Image from: **(M. Pirnia 2013, 155)**

According to local references, the more accurate Ron of Yazd is created by rotation of urban fabric between 20 to 45 degrees due southwest (Figure 123). This is regarding the favorable wind's direction in Yazd that flows most of the year from northwest (from Isfahan direction) and southwest (from Shirkooh mountains direction) (ICHTO 2013) (Figure 124).

As mentioned before in *Shaded Area*, this rotation of urban fabric also contributes in providing shade in passageways and protecting the city from extreme sun radiation in summer.

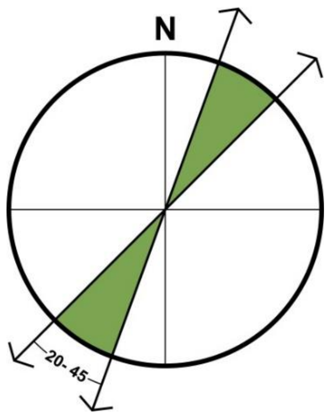


Figure 123: *Ron* of Yazd. Graphic by author

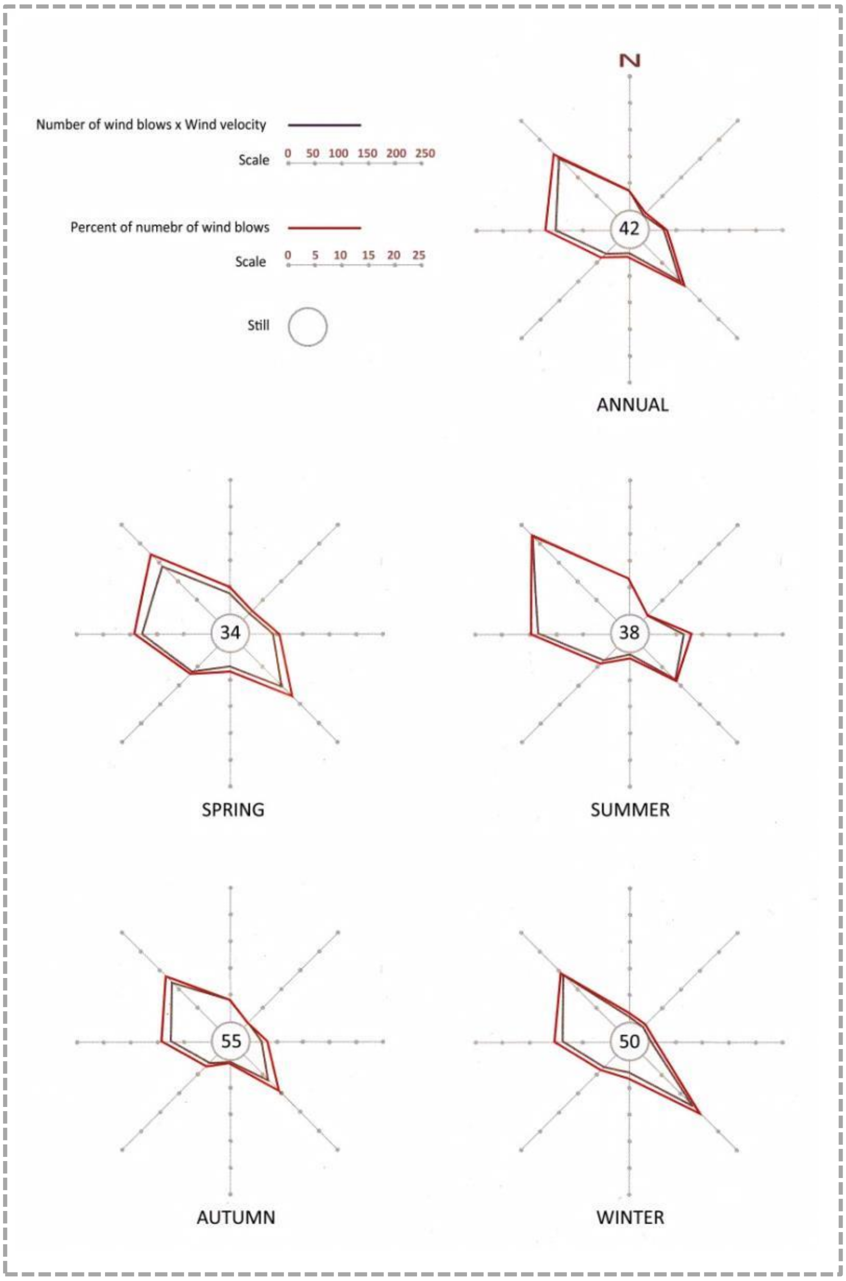


Figure 124: Diagrams for wind direction and velocity in Yazd. Image from: **(Kasmai 2003)**

In this part the urban fabric of each district and the degree of their compliance with the *Ron* of Yazd is analyzed.

According to figure 125 all the historical districts urban fabrics are oriented in the range of Yazd's *Ron*.

In some cases in historical districts, there are some passageways that do not match with the *Ron* because of the complexity of the historical urban texture that is a result of the non-linear climatic adaptive forms of the passageways, but generally the majority of buildings and passageways follow the *Ron's* orientation.

According to Figure 126 one of the contemporary districts matches the Yazd's *Ron* and one of them does not. By analyzing other contemporary parts of the city it is observed that matching with the Ron is not usual in this part of the city and most of urban texture is oriented towards south-north direction (Figure 127).

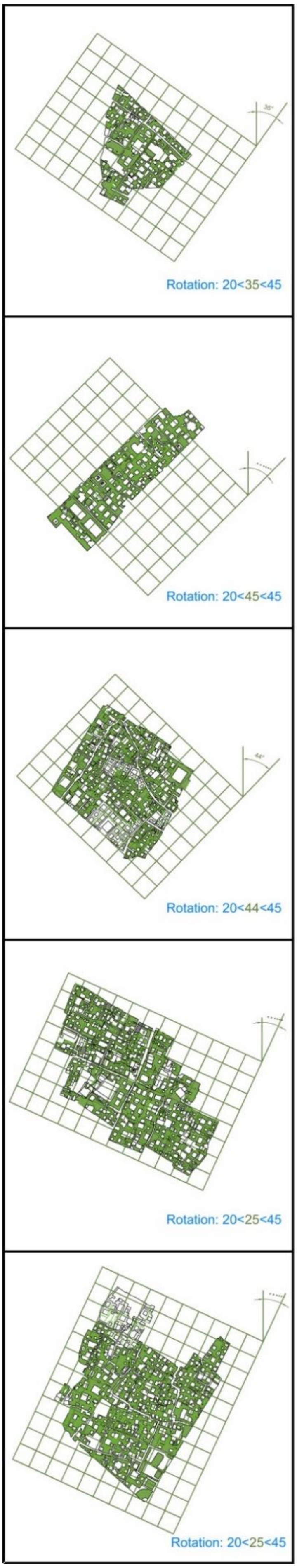


Figure 125: Orientation of historical districts. Graphic by author (Right)

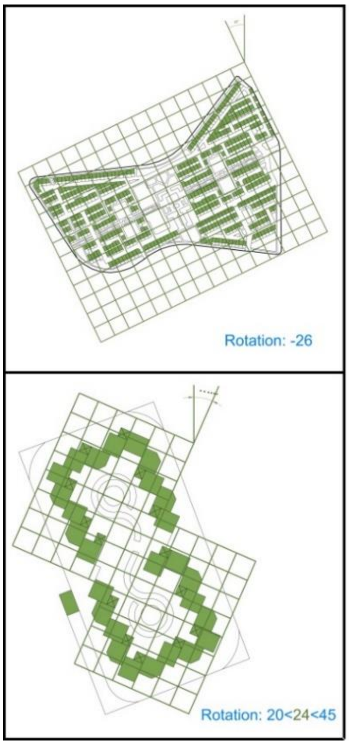


Figure 126: Orientation of contemporary districts. Graphic by author (Left)

Figure 127: Urban texture of new parts of Yazd. Image from: **(Google Earth 2014)**

Criterion: LEED system has defined this item as solar-oriented blocks with east-west lengths equal to or greater than north-south lengths, and east-west axis within 15 degrees of geographic east-west (LEED 2009) (Figure 128).

But this item depends on climatic features of the area and buildings style of vernacular architecture.

As mentioned before, local criteria in Yazd define orientation of buildings' length towards north-south, within 20 to 45 degrees rotation due southwest. Therefore this local criterion is adapted in this research for qualifying the case study districts.

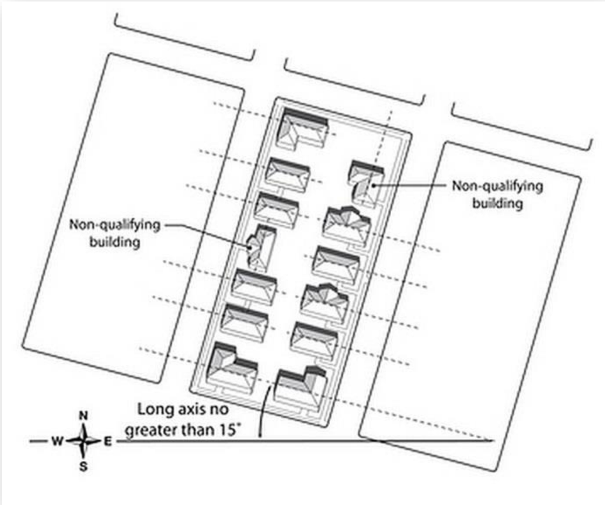


Figure 128: Proposed orientation in LEED. Image from: **(LEED 2009)**

District name	Orientation	Local criterion	Grade
Ghodal	35°	20°-45°	+
Hashem khan	45°	20°-45°	+
Khajeh	44°	20°-45°	+
Abolmaali	25°	20°-45°	+
Vaght	25°	20°-45°	+
New district 1	-26°	20°-45°	-
New district 2	24°	20°-45°	+

Table 25

Result 9: *Historical districts match the climatic and environmental criterion of orientation (Yazd's Ron)*

6.3.3 Heat island:

LEED defines this item for minimizing effects on microclimates by increasing reflection of sun light from the surfaces (LEED 2009).

Color and texture of materials can influence heat island effect. Therefore in LEED system, SRI factor (solar reflectance index) is used as an index for calculating the range of reflection of surface materials (ibid).

In this part SRI of Iranian brick that is used on the majority of surfaces in Iranian traditional buildings is calculated.

SRI index consists of two items: Solar reflectance and thermal emissivity:

Solar reflectance of silica Brick (Kasmai 2003, 27): 0.48	Thermal emissivity of silica brick (MIC 2014): 0.8

Table 26

On basis of those two items and calculation formula of SRI (SRI 2014): SRI of silica brick is: **52**

Criterion: LEED system obligates to use paving materials with an SRI (solar reflectance index) of at least 29 for at least 50% of the no roof site (LEED 2009) e.g. courtyards, sidewalks etc.

According to the field survey for this project most of the surfaces (more than 50%) of historical districts as well as contemporary case studies are covered by brick (Figure 129).

Figure 129: Facades and surfaces in contemporary district 1. Image from: author

In spite of many other cities in Iran like Tehran, where application of modern materials regardless of their climatic adaptivity is usual, in Yazd most of the contemporary buildings are covered by brick due to the historical values of this city.

Generally in valuable historical cities like Yazd and Isfahan, there are some recommendations in urban design rules to encourage people to use materials such as brick or to at least use materials with the nearest color to the traditional brick (Isfahan 2015).

So according to above paragraphs as following table shows, all of the districts (historical and contemporary) can be qualified by this item.

District name	Heat island SRI (solar reflectance index)	LEED evaluation system	Grade
More than 50% of historical and contemporary districts facades and surfaces are covered by Iranian light brick and mud	52	SRI≥29	+

Table 27

Result 10: *all of the case study districts (historical and contemporary) reduce heat island effect*

6.4 Water:

From among the usual architectural elements in each district center in Iranian traditional desert cities, were a *cistern* and a public bath that were located near other facilities such as bazaar, mosque etc. (Figures 130-131). *Cisterns* were used as public drinking water sources and supplied the demanded water for inhabitants during the year (Dehghani 2009, 108).

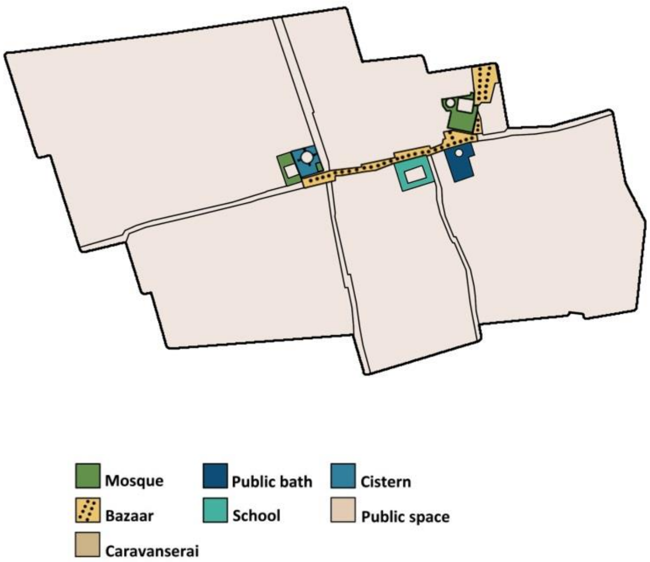


Figure 130: Cistern and public bath of Abolmaali district near other facilities. Graphic by author

Figure 131: Cistern of Khajeh district near a traditional store. Image from: author

Water for these *cisterns* and public baths was supplied by an underground system named "*Qanāt*" (Figure 132). As Roaf mentions, "the role of *Qanāt* system is more than only supplying drinking water. It is used from clean to dirty uses such as: filling cisterns, using for public bath, washing of kitchen ware and clothes, dropping down to turn the horizontal mill wheels, providing drinking water for the animals and at the end providing water for the fields" (Roaf, Fuentes and Thomas 2007, 253) (Figure 133).

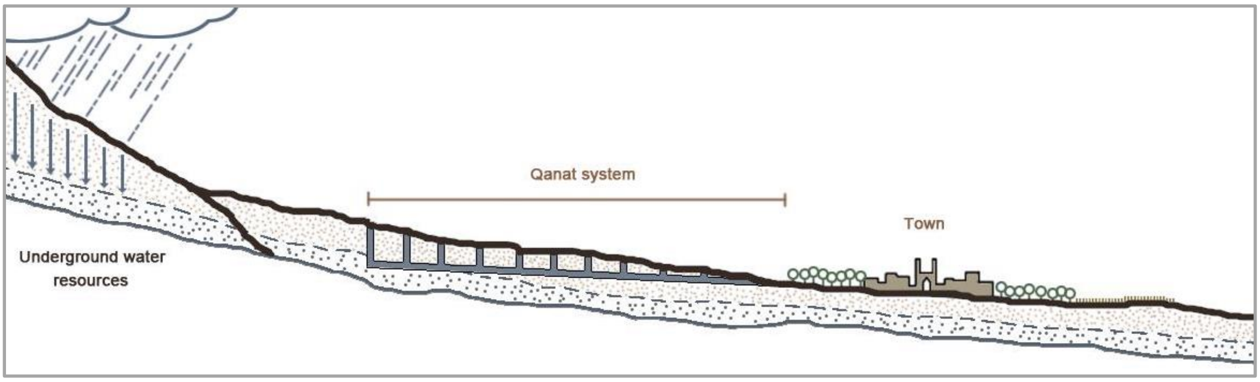


Figure 132: *Qanāt* system. Graphic by author on basis of image from: **(Ghaffari 2000, 26)**

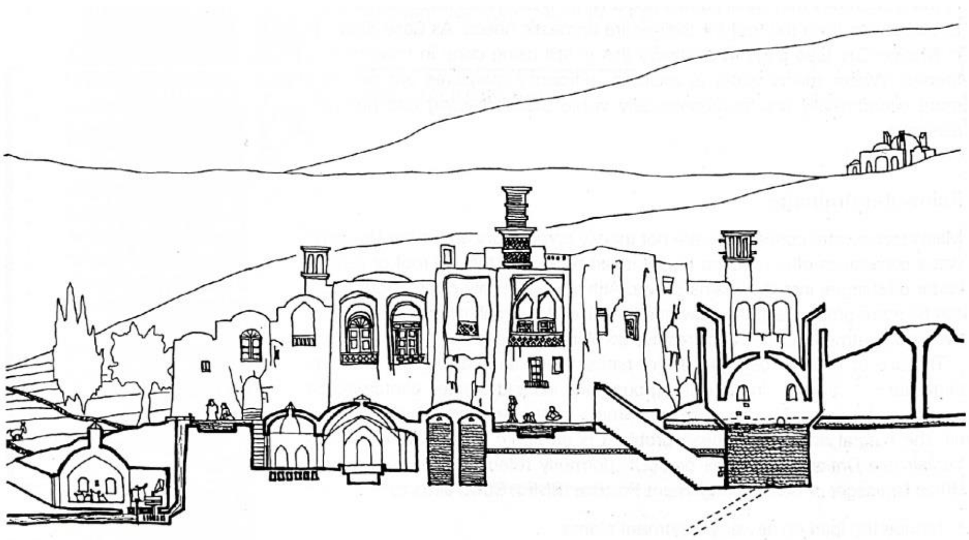


Figure 133: Section through Khoranaq and the role of *Qanāt* to provide water for clean to dirty uses. Image from: **(Roaf, Fuentes and Thomas 2007, 253)**

Several *Qanāts* in Yazd pass beneath the city with the previously mentioned roles in the historical parts of the city. (Figure 134)

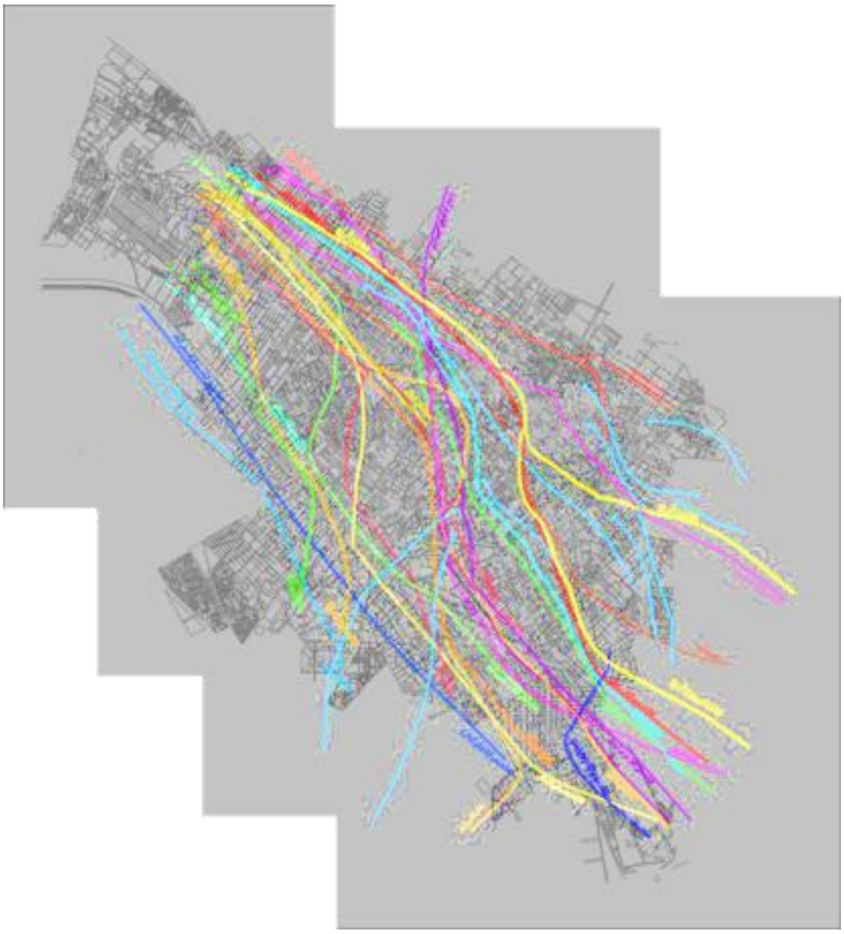


Figure 134: *Qanāts* routes in Yazd. Image from: **(ICHTO 2013)**

6.4.1 Qanāt as a passive system:

The natural slope of the land from hillsides to the city is used to conduct water through the *Qanāt* canals with a slight slope. So the water automatically flows on this regulated slope (Figure 132).

Cisterns and other functions like public baths in the district centers are connected to the nearest *Qanāt* and they will be filled by the *Qanāt* water automatically because of the difference between the depth of *Qanāt* and *cistern* floor level (Figure 135).

This process is done automatically so this is a passive system because it doesn't need any physical and electrical energy for transferring and storing water. After digging wells, for thousands of years, this system has worked automatically. It only needs maintenance and sometimes repairing some parts.

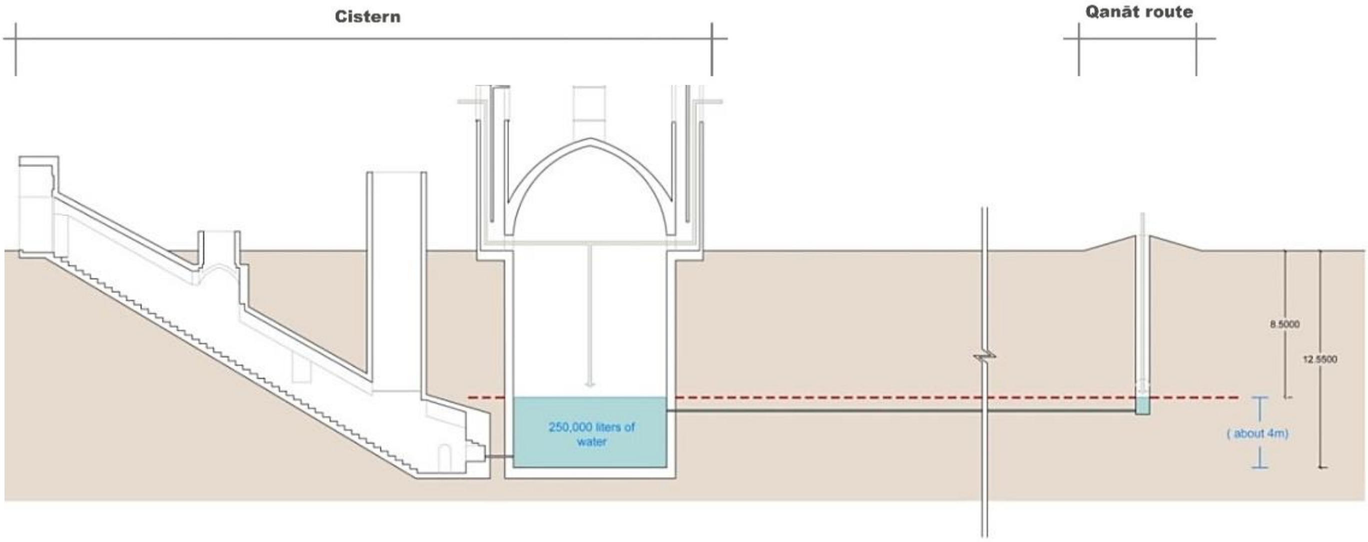


Figure 135: The connection of Youzdaran *cistern* and Firouz Abaad *Qanāt* in Yazd. Graphic by author

In this part the location of *Qanāts* in the city and their connection with the center of historical districts are surveyed. According to figure 136 all of the historical case studies have a district center including cisterns that are connected to the nearest *Qanāt* route.

Contemporary districts:

At present century, by application of the National Pipeline System in Iran cities, the *Qanāt* system and cisterns in Yazd were abandoned. A part of the required water for the city is supplied by deep wells. Also due to extensive drought in Yazd province, most of potable water is supplied by transferring water from other cities and rivers such as Isfahan (Yazd 2013).

Transferring water from Isfahan means that water should be brought from more than 300 kilometers away which results in consumption of a huge amount of energy in behind. Unfortunately this non-sustainable solution has been replacing the existing passive system of *Qanāts* and cisterns.

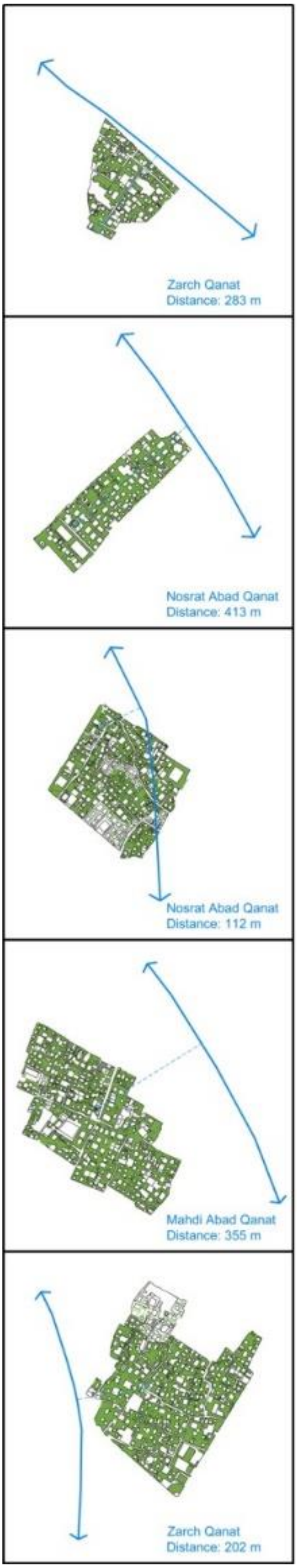


Figure 136: *Qanāts* and their distances to the districts centers. Graphic by author

Criterion: LEED qualifies the project if it is located on a site served by existing water.

In case the *Qanāt* system is supported by an existing active water canal that passes under the case study district in the nearest distances to the buildings, the historical districts can be qualified by this item according to LEED criterion.

District name	Water supply	LEED evaluation system	Grade
Ghodal	*Qanāt* system (passive and existing water)	Site served by existing water	+
Hashem khan	*Qanāt* system (passive and existing water)	Site served by existing water	+
Khajeh	*Qanāt* system (passive and existing water)	Site served by existing water	+
Abolmaali	*Qanāt* system (passive and existing water)	Site served by existing water	+
Vaght	*Qanāt* system (passive and existing water)	Site served by existing water	+
New district 1	Without existing water	Site served by existing water	-
New district 2	Without existing water	Site served by existing water	-

Table 28

Result 11: *Historical districts benefit from Yazd Qanāt and cisterns as a passive water system*

6.5 Material:

6.5.1 Reusable and local material:

One of the main factors for sustainability is how to produce, transfer and use materials for construction. "Using local and reusable materials help to reduce the cost of construction and support the local industries" (Sassi 2006, 145-148).

Traditional materials usually have advantages such as reduced production and transfer costs and reusability, but in comparison to the modern materials such as concrete and steel, the traditional materials such as clay are weak for construction of multi-level buildings and resistance against earthquake.

Figure 138: New construction with concrete in contemporary parts of Yazd. Image from: author

Figure 137: Historical materials. Image from (Jahansofal 2013)

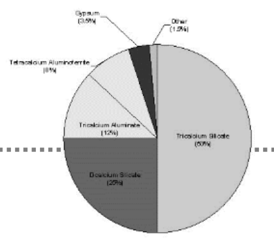
In this part, two common building materials in Yazd including adobe as the traditional material in the historical parts and concrete as the modern material used in contemporary parts of Yazd have been compared in terms of sustainability in the following three stages (Tables 29-30).

	Before construction			During the construction			After Construction	
Material	Formation And Production	Producing Pollution	Transfer	Construction Method	Height Limitation	Construction Pace	Earthquake Resistance	Reusability
▪ Concrete								....
♦ Clay		....	....					

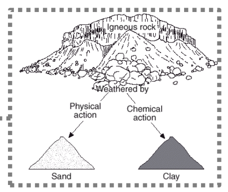
- ▪ Natural process for mineral components of cement and extra industrial process for producing
- ♦ Natural process for formation of mineral components of clay

- ▪ Air pollution by cement factories
- ♦ No pollution

- ▪ Nearest Factory: Mehriz: 45.7 Km
- ♦ Existing under the city!



(Pavement 2015)



(Edusolution 2015)

1- Preparing Raw materials (Calcium Carbonate ($CaCo_3$), Silica (SiO_2), Al_2O_3, Fe_2O_3)
2- Grinding the raw materials
3- Mixing materials in a certain proportion
4- Heating materials in 1400 °c
5- Grinding and mixing with Gypsum

- ▪ Mechanical devices and expert workers
- ♦ Local techniques and workers

- ▪ Non-Reusable
- ♦ Reusable

- ▪ Resistant against Earthquake
- ♦ Non-Resistant against Earthquake

- ▪ Faster construction
- ♦ Slow construction

- ▪ No limitation for midrise buildings
- ♦ Maximum 3 levels: 2/underground

Table 29

	Pre-Construction			Construction process			After Construction	
Material	Formation And production	Producing Pollution	Transfer	Construction Method	Height Limitation	Construction Pace	Earthquake Resistance	Reusability
Concrete	More Required Energy	Air Pollution	More Distance	Non-Local Techniques	No Limitation	Rapid	Resistant	Non-Reusable
Clay	Less Required Energy	No Pollution	Minimum Distance	Local techniques	Height Limited	Slow	Non-Resistant	Reusable

Table 30

As table 30 illustrates, Clay has more benefits in terms of sustainability than concrete i.e. lower amount of energy for production, less air pollution, shorter distance from the source, local techniques and reusability.

As Pirnia, the father of Iranian traditional architecture, explains; usage of local materials with minimum distance from the project's location and application of local construction techniques has been a strategy in Iranian traditional architecture: "Over centuries the Iranian architects and builders have attempted to earn materials from the nearest sources. They could then construct the buildings at a faster pace. This also made the renovation of buildings easier regarding accessible material" (Pirnia and Memarian 2008, 31).

In spite of the mentioned benefits, as table 26 shows, there are limitations about the height of buildings and resistance against earthquakes in usage of historical materials like clay.

According to the Iranian construction rules, maximum height for adobe buildings is two stories including underground floor (Ahmadi et al. 2009).

These weaknesses can be solved by reinforcement techniques explained in the final chapter in this dissertation (Recommendations).

While adobe, as the major building material in historical districts of Yazd, has more potential to be reused for reconstruction of new buildings by already used materials in existing buildings, but in the contemporary parts, such as the two new case studies of this research, most of new buildings are costructed by concrete structure.

As mentioned before, concrete construction is not sustainable in comparison to local materials such as adobe and mud-brick in terms of reusability of materials.

This part calculates the volume of concrete in one contemporary existing building in Yazd to get to an approximate estimation in the larger scale (Figure 139, Table 31).

Building type: Residential - **Concrete skeleton frame** - **4 floors building** - **Total volume of materials: 463.13 m3** - **Volume of concrete parts(including beams, columns, ceilings and foundation): 236.82 m3**
51.1% of material's volume is concrete

Table 31

According to the table more than half of building material used in this building as a sample of common contemporary buildings in Yazd is concrete and the reinforcing steel for reinforcement. This reinforced concrete is neither a reusable and nor a local material.

Criterion: Comparison of historical and contemporary districts reveals better performance of historical districts in usage of sustainable material. So historical case studies can be qualified by this item (Table 32).

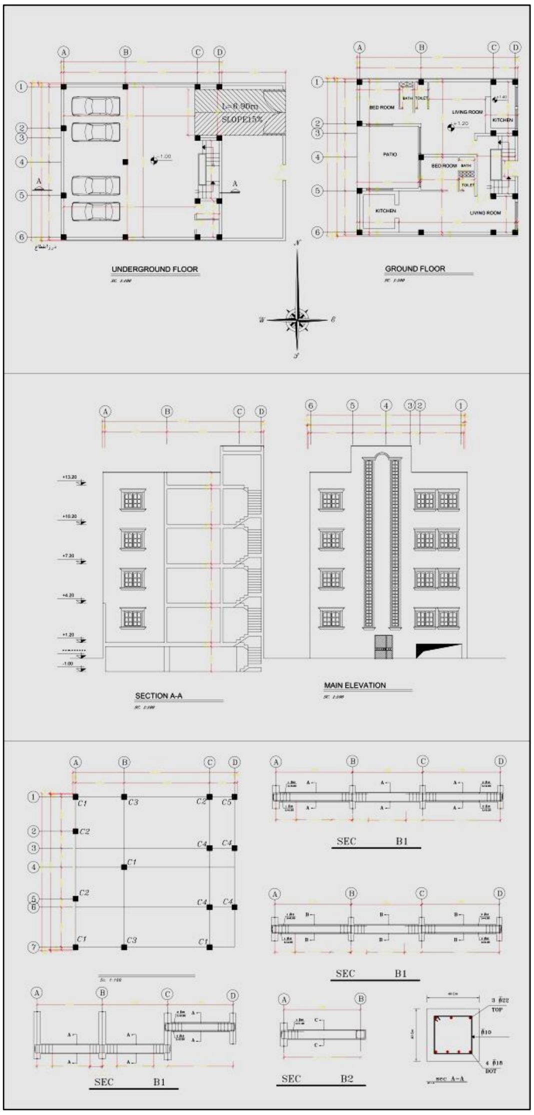


Figure 139: One typical contemporary building in Yazd. Maps from: author

District name	Grade
Historical districts	+
New districts	-

Table 32

Result 12: *Historical districts have more sustainable material than contemporary districts*

Summary: Following is a collection of previous analyzes, prepared in one table for overview and comparison of case study maps and their performance in each item.

	Site and land use									Health and well being			Energy		Water
	Footprint and Compactness	Mixed-use (District facilities)							Distance from Urban facilities	Green area	Hierarchy	Shaded area	Common walls	Orientation	Existing water (Qanat system)
		Mosque, Public bath, Cistern, Bazaar, School, Public space, Caravanserai	Bazaar	Public Bath	Mosque	Cistern	School	Public space							
District 1: G. Mosalla	55.48%		+		+		+	+	844m	3.5%	Neighborhood centers: 22.8%	34.33%	Common walls: 36.5%	Rotation: 20<35<45	Zarch Qanat Distance: 283 m
District 2: Hashem Khan	54.7%		+		+	+		+	374m	4.8%	Neighborhood centers: 56.1%	40.63%	Common walls: 43.2%	Rotation: 20<45<45	Nosrat Abad Qanat Distance: 413 m
District 3: k. khezr	54.7%		+	+	+	+			270m	3.8%	Neighborhood centers: 16.6%	39.02%	Common walls: 44%	Rotation: 20<44<45	Nosrat Abad Qanat Distance: 112 m
District 4: Abolmaali	60%		+	+	+	+	+		453m	5.7%	Neighborhood centers: 40%	45.11%	Common walls: 50.3%	Rotation: 20<25<45	Mahdi Abad Qanat Distance: 355 m
District 5: Vaght-o-saat	55.5%		+	+	+	+	+	+	85m	4.4%	Neighborhood centers: 34.4%	36.62%	Common walls: 40.7%	Rotation: 20<25<45	Zarch Qanat Distance: 202 m
New district 1	27%						+		1670m	6.9%	Neighborhood centers: 3.3%	5.3%	Common walls: 29.7%	Rotation: -26	Not passive system
New district 2	28.4%								486m	11.9%	Neighborhood centers: 24.8%	27%	Common walls: 27.5%	Rotation: 20<24<45	Not passive system

Discussion and conclusion:

According to the analyzes, comparison of the sum of points earned by districts demonstrates higher grades earned by historical districts in comparison with the contemporary districts (Figure 140). It means that considering the defined items for evaluation of the degree of environmental sustainability, the historical districts show better performance in comparison with the contemporary districts.

It is clear that the referred items in this dissertation are not the comprehensive evaluation tool required for evaluation of case studies. As mentioned at the beginning of this dissertation, one national Iranian evaluation system should be defined by co-operation of a wide scope of building expertise to cover all features of sustainability from economic to social and also environmental features.

This research doesn't claim to reach such comprehensive evaluation tool. As mentioned before, it aims to introduce major features of Iranian architecture and urban design that contribute in environmental sustainability. Comparing of these items with the standard systems such as LEED, can guide to definition of sustainable guidelines that can be adapted to the contemporary design of buildings and cities in hot and arid region.

On the other hand are the disadvantages of the Iranian historical architecture. Some of these major problems are as follows:

- One of the problems in Iranian plateau is earthquake. Although Yazd is not categorized among cities with medium earthquake risk, but historical mud brick buildings are not safe enough against this threat.
- Another disadvantage of the traditional urban texture are the limitations of narrow, non-linear passageways in the historical districts regarding establishment of new infrastructures and emergency access.

However it must be considered that these systems worked efficiently in the past and it is too hard to evaluate the past life style with the new criteria of sustainability. One of challenge in this dissertation was how to evaluate the historical case studies in their original and previous conditions in the past.

But this research tries to select and analyze those historical features that can be evaluated by rating systems in a quantitative way, and then be adapted into new architectural and urban design.

The author also aims to acquit mentioned problems of historical system in the recommendations by enhancing the historical patterns with application of the contemporary standards of urban design and construction.

So the recommendation chapter will consider the specific problems of the historical districts as well and will try to use the advantages of each historical or contemporary groups of districts to propose the best solution as guidelines for the designers.

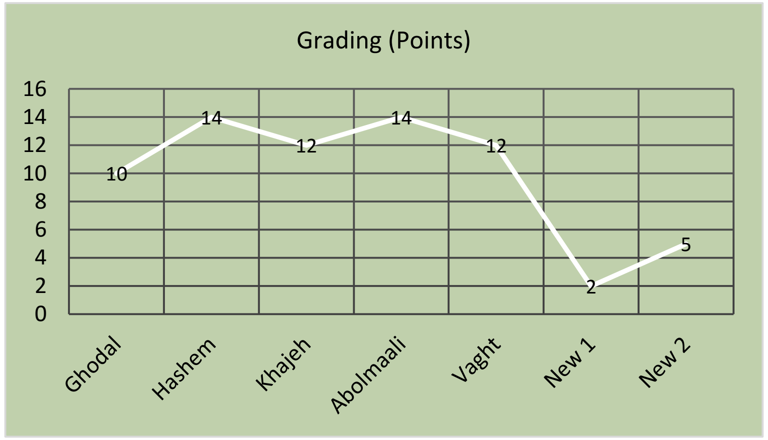
However, as observed in Figure 140, the overall grading for the historical case studies reveal better performance of the historical case studies in comparison with the contemporary districts, regarding environmental sustainability criteria.

Hence the answer to the first question of this research "Are there any environmentally sustainable features in the Iranian historical cities like Yazd?" will be replied here positive. The historical case studies are more sustainable than the contemporary districts.

By comparing the results of the historical group of case studies with the contemporary parts, the average points earned by the historical districts are higher than others.

On basis of the selected inductive approach for this research, the historical parts of Yazd generally have a better operation in terms of sustainability, in spite of their problems discussed before in previous page. Their features have the potential to be learned from and adapted with the contemporary design regulations and modern living.

The target of this dissertation at the next stage is how to use and adapt these sustainable features into the contemporary living. This question will be discussed in the following chapter.



	Site and land use										Health and well being					energy				water	Material		
				Mixed-use (District facilities)																			
	Foot print(massive construction)	Compactness	Distance from facilities	Bazaar	Public bath	Mosque	Cistern	School	Public space	Grade	Green area	Hierarchy (neighborhood spaces)	Shaded area	Passageway proportion	Garbage management	Common walls	Orientation(sun radiation)	Orientation (favorable winds)	Heat island(SRI)	existing water (Qanat system)	Local material	Reusable material	**Grading**
Ghodal (49772m2)	+	+	-	✔	°	✔	°	✔	✔	+	-	-	-	+	-	-	+	+	+	+	+	+	**10 points**
Hashem khan (62384m2)	+	+	+	✔	°	✔	✔	°	✔	+	-	+	+	+	-	+	+	+	+	+	+	+	**14 points**
Khajeh (97303m2)	+	+	+	✔	✔	✔	✔	°	°	+	-	-	-	+	-	+	+	+	+	+	+	+	**12 points**
Abolmaali (129810m2)	+	+	+	✔	✔	✔	✔	✔	°	+	-	+	+	+	-	+	+	+	+	+	+	+	**14 points**
Vaght (150801m2)	+	+	+	✔	✔	✔	✔	✔	✔	+	-	+	-	+	-	-	+	+	+	+	+	+	**12 points**
New district 1(295718m2)	-	-	-	°	°	°	°	✔	°	-	+	-	-	-	-	-	-	-	+	-	-	-	**2 points**
New district 2(10697m2)	-	+	+	°	°	°	°	°	°	-	-	-	-	-	-	-	+	+	+	-	-	-	**5 points**

Figure 140: Grading case studies

CHAPTER 7: RECOMMENDATIONS: PROPOSED SOLUTIONS INSPIRED FROM THE TRADITIONAL SYSTEM FOR THE MODERN LIFE

7.1 Introduction:

According to the results, historical districts reveal some features of sustainability. This part will attempt to adapt these features and patterns to define strategies for sustainable architecture and urban design for contemporary life in hot arid region of Iran.

These design strategies will be proposed as general recommendations for neighborhood planning in Yazd.

In many items, recommendations with clear and specifics numbers, values and dimensions are proposed. For example in the item "distance to urban facilities" there is a specified distance defined by LEED (Maximum 804m) and this number is used as a criterion for the contemporary developments.

But in some items such as "structure and form for proposed district" it is hard to recommend exact numbers and values. Such items use a creative and qualitative method on basis of the author's earned acknowledge in this research about the traditional patterns and systems. The form and structure of sample district are then proposed and illustrated by some design sketches.

So one mixed method (quantitative and qualitative methods) is selected for this part of the research.

Proposed recommendation items are classified from general scales of ultra-neighborhood scale to one sample district's details.

Ultra-neighborhood scale:

7.2 Districts organizations:

The usual organization of districts in the new parts of Yazd is a grid and straight network. The main streets form and define the districts' borders and shapes. In other words, districts can be considered as some islands that are trapped between main straight streets (Figure 141).

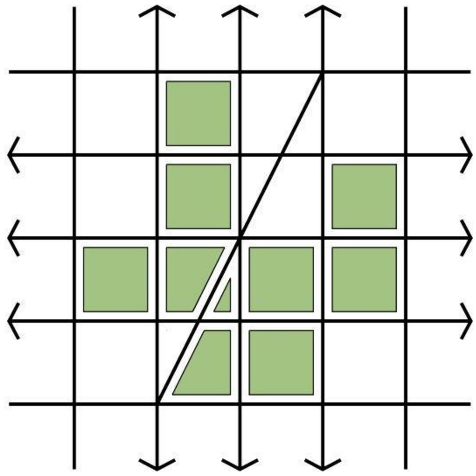


Figure 141: Usual organization in the contemporary parts of Yazd. Graphic by author

Analyzing the structures of historical districts in this research reveals that their organizations is formed in an opposite way comparing with the new districts: the form and border of districts- built up of various neighboring single buildings- affect the shape and forms of surrounding passageways. The interwoven organization and flexible form and borders of districts match with the neighboring districts like a puzzle. In this organization the form and edges of the district change the shape of passageways and usually the passageways become non-straight and indirect. These non-straight passageways have advantages such as: making more shade by increasing the quantity of edges and corners through the routes, reduction of sand storms' effect and reduction of cars' speed in the residential parts. These features can be proposed as a new organization for contemporary life by a combination of historical features and modern facilities such as cars and transportation systems (Figure 142).

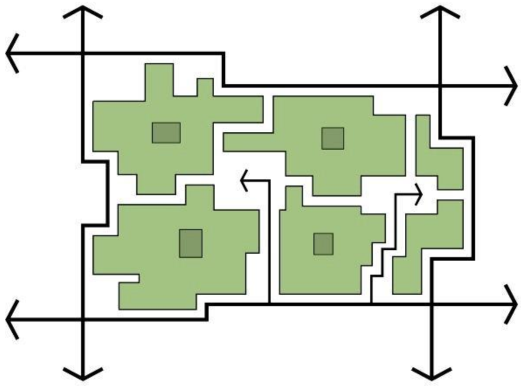
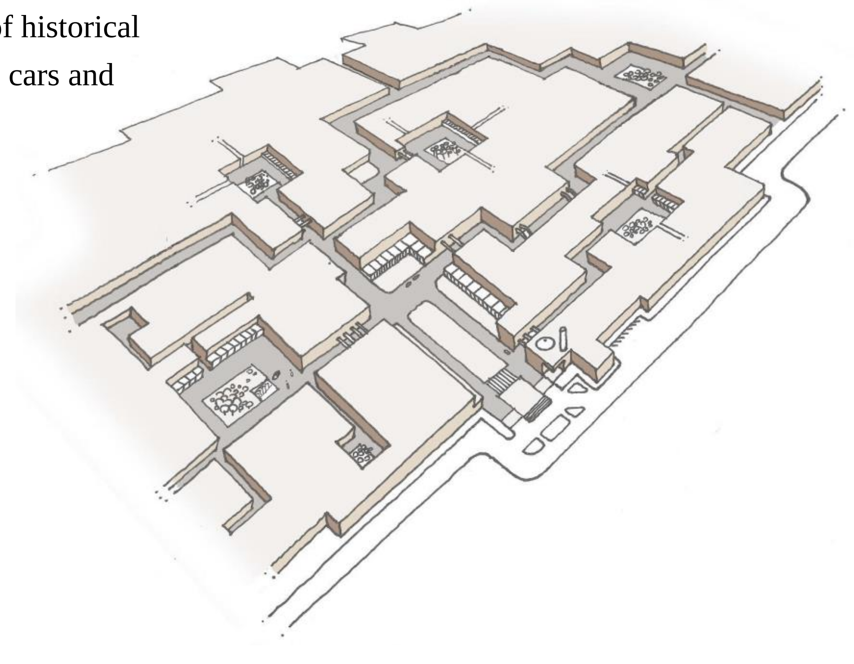


Figure 142: Proposed interwoven organization for several nearby districts. Graphic by author



7.3 location of the proposed districts and their distance to the urban facilities:

Considering LEED's criterion as well as the usual location of historical districts in Yazd, the maximum proposed distance of district to the urban facilities and services is defined.

So according to LEED criterion, the distance of center of proposed district should be maximum ½ Mile (804 meters) to the first urban facilities (Figure 143).

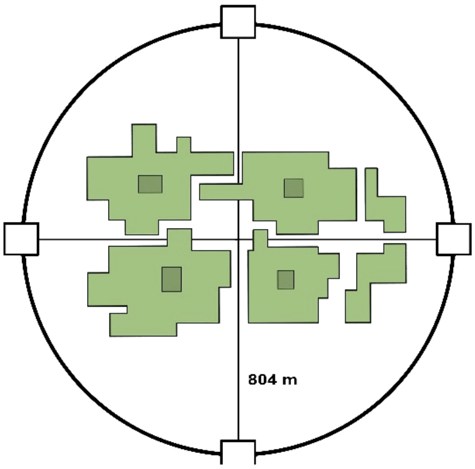


Figure 143: Graphic by author

7.4 Orientation of the proposed districts:

Orientation of urban fabric of the districts affects their environmental sustainability features such as better shading performance in hot times as well as higher passive solar gain in buildings in cold times.

As mentioned before, local criterion defines the proper orientation of urban texture for Yazd.

The most efficient geographical orientation of the district's urban fabric in Yazd is recommended to be inside a range of 20 to 45 degrees due southwest (Figure 144).

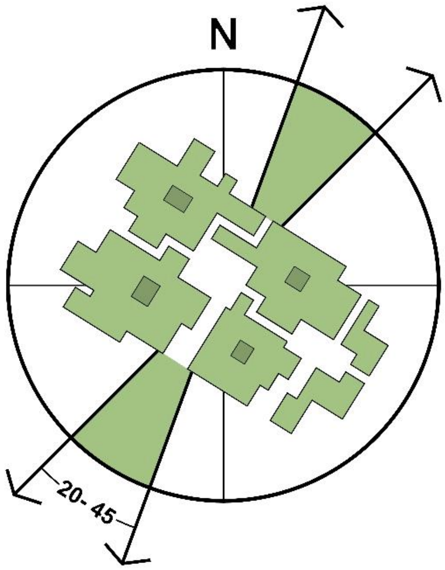


Figure 144: Graphic by author

7.5 Hierarchy for distribution of facilities from urban scale to district scale:

In historical districts of Yazd there are some local facilities in the center of each district to obviate the daily needs of the nearby inhabitants.

At a larger scale the main bazaar as the spine of the city includes several urban facilities. Districts are located around this spine.

This strategy is a useful pattern for the proposed district including facilities for a modern contemporary living (Figure 146).

7.6 Hierarchy of traffic and pedestrian access:

According to the analyzes in this dissertation, in the contemporary case studies there is no hierarchy for reducing cars' speed as approaching the residential houses. As mentioned before the residential parts are like some islands between the main streets and usually there is a grid structure of alleys that cut the residential parts and connect them directly to the main streets (Figure 145).

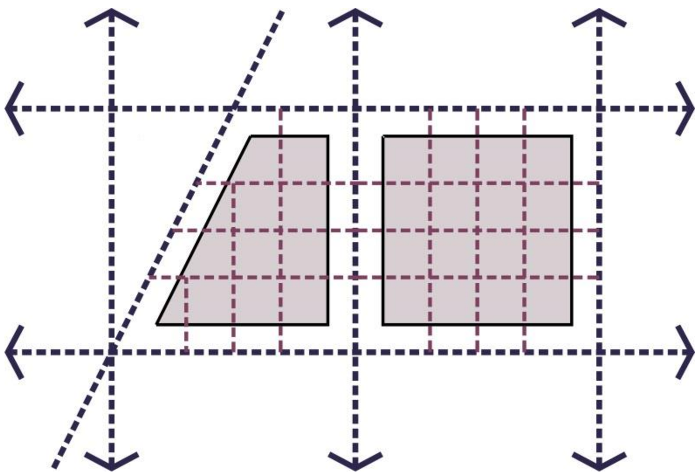


Figure 145: Usual structure of contemporary districts. Graphic by author

In order to create calm and secure residential parts and also reduce car dependency, the pattern of Iranian passageways system is used for this part. Strategies for traffic system are suggested for the proposed district by using non-straight passageways and making limitation for the car routes and developing the public transportation system and pedestrian routes (Figure 147).

District facilities:
- Grocery
- Bakery
- Small mosque
- Primary school and kindergarten
- Neighborhood park

Ultra-district facilities:
- high school
- Small bazaar
- Mosque and community center
- Park

Urban facilities:
- Offices
- Mall
- Cinema and cultural center
- Sports
- College

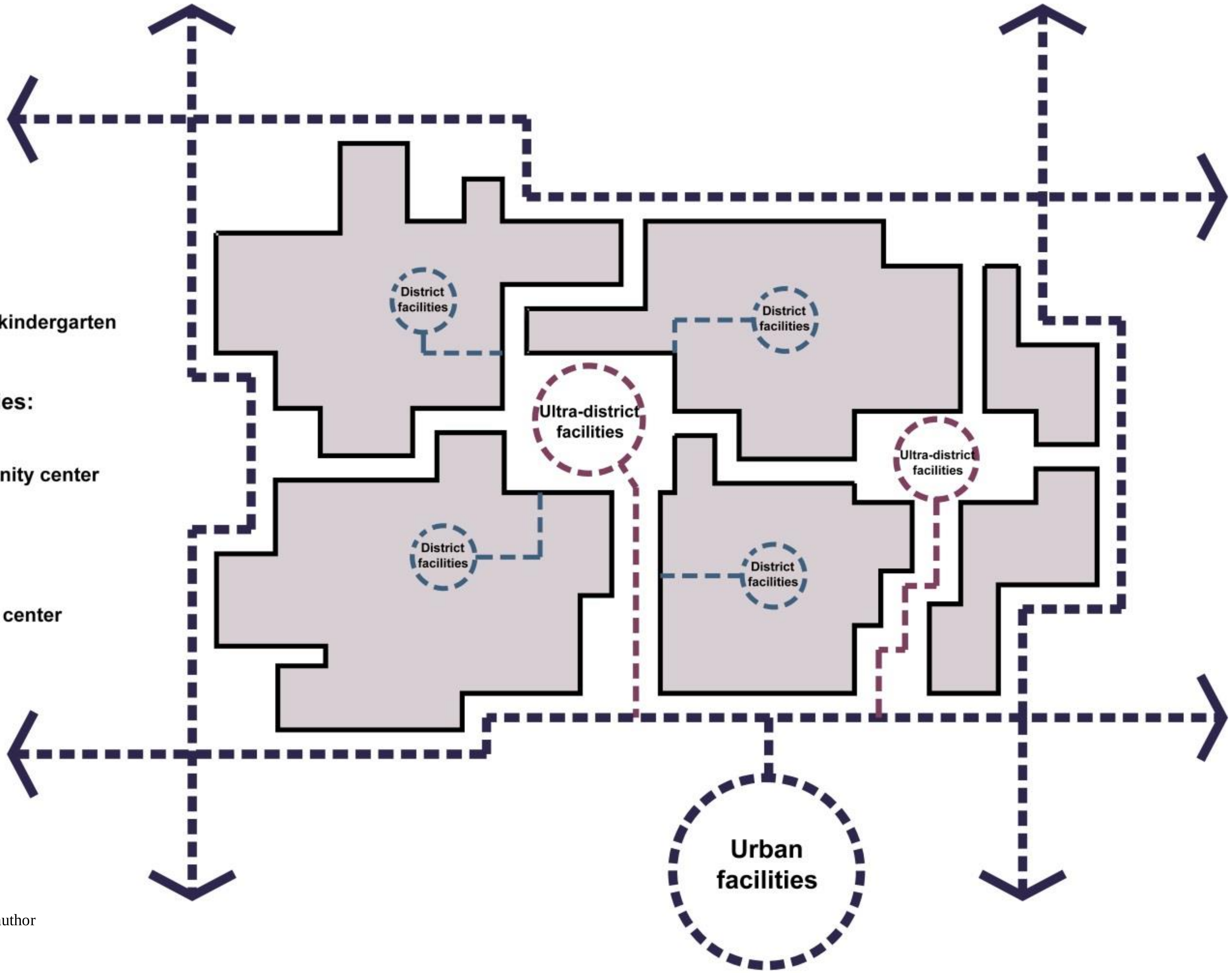


Figure 146: Graphic by author

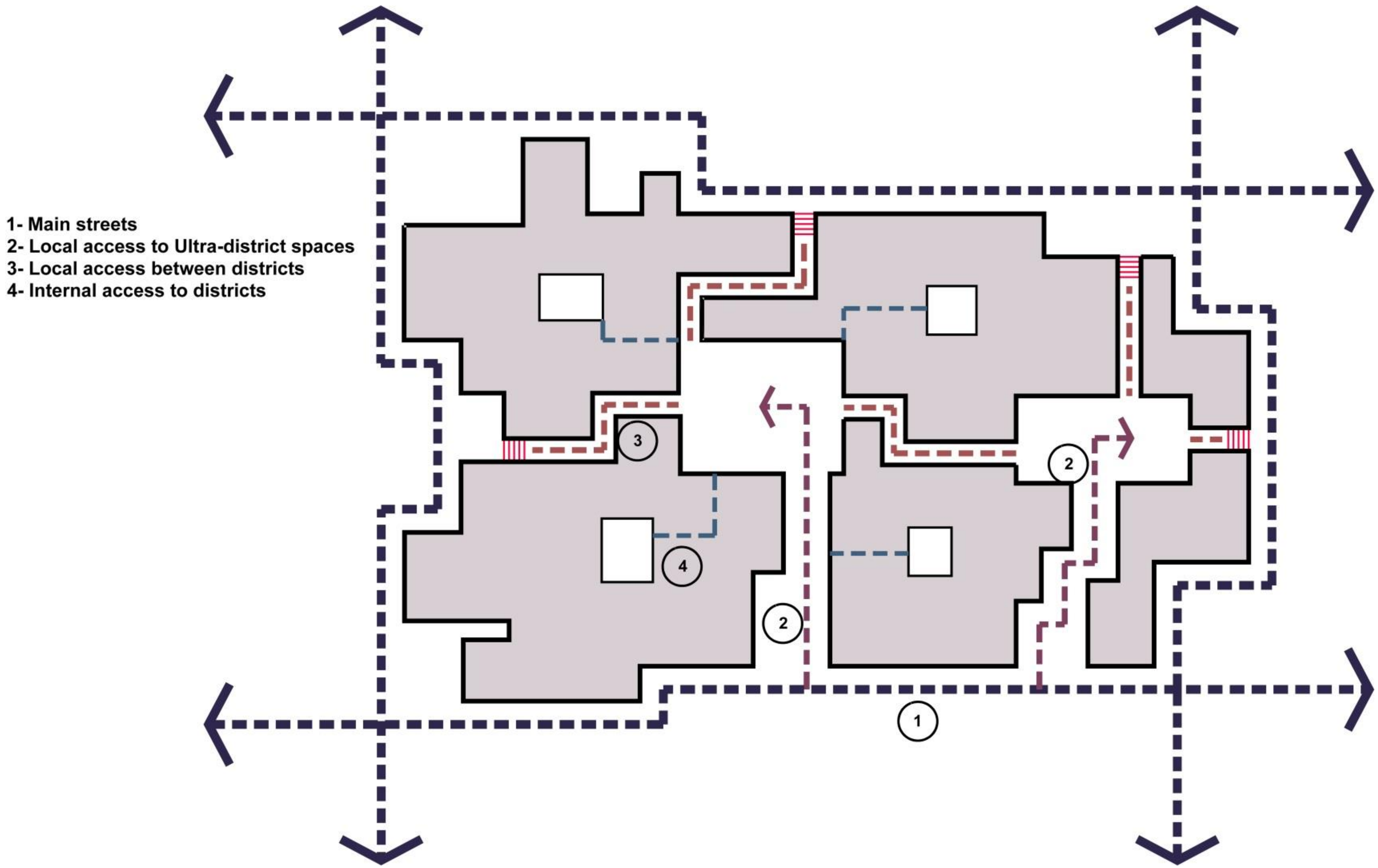


Figure 147: Graphic by author

Neighborhood scale:

7.7 Form and structure of the district:

It is difficult to define exact size and form of the proposed district. However inspiring from the historical districts' features in this dissertation, the best results of sustainability items were earned by districts with semi-linear and center focused shape in a special range of size (Figure 148).

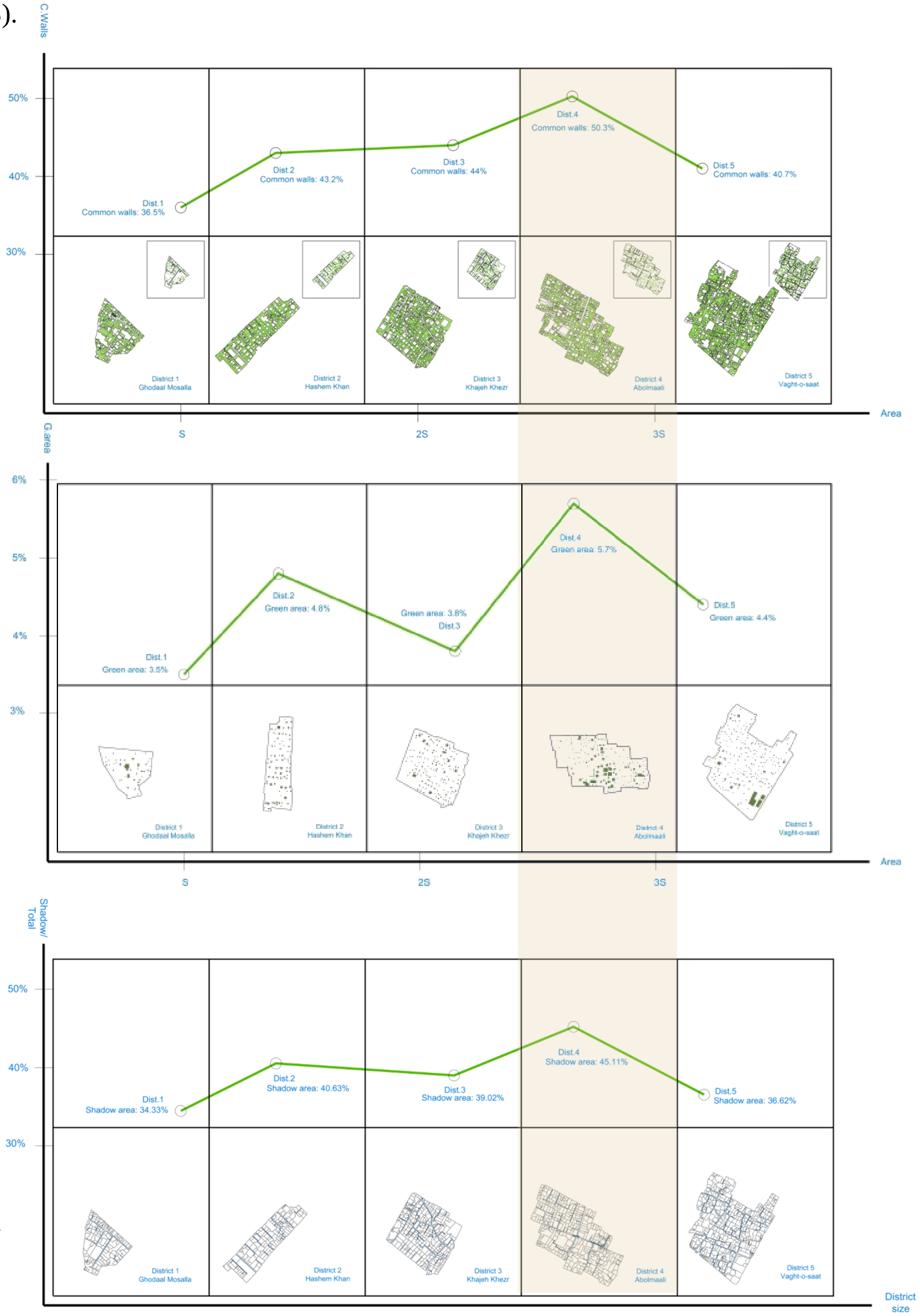


Figure 148: comparing historical results in some items. Graphic by author

The size and shape of the district affects some properties of the district such as the area of common walls between neighbors (Figure 149).

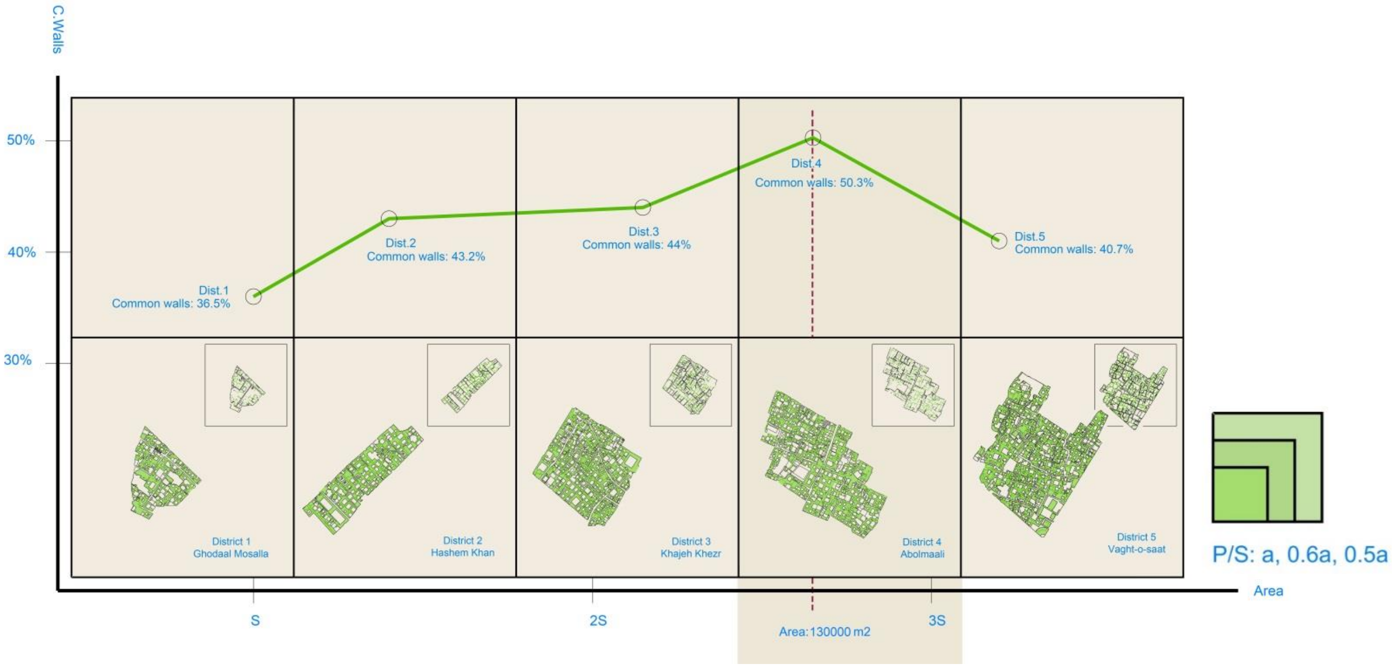


Figure 149: Graphic by author

According to a geometry rule, increasing the size of a square reduces its perimeter to area ratio (Figure 149, right side).

This means that in smaller case study districts, the ratio of surrounding walls to the size of the district is higher. The high amount of surrounding walls reduces the ratio of common walls to the external walls in each district (usually the surrounding wall of each district doesn't have connection with other districts and they are calculated as external walls). So according figure 149 the larger districts have more common walls because of the shorter length of surrounding walls in ratio to total walls of the district.

But in the very big districts such as Vaght district, another factor reduces the number of common walls: the large number of passageways to access different internal parts of the district. (The high number of passageways increases the amount of external walls facing the passageways).

On the other hand, the linear and semi-linear districts such as Abolmaali and Hashem Khan have better amount of this item because linear districts need fewer passageways for access to different parts of district.

The conclusion is that the bigger districts and semi-linear structured districts like Abolmaali perform better for increasing the amount of common walls (Figure 149).

A district like Abolmaaali performs better in other evaluation items too (Figure 148). This district and other linear districts have earned the highest points in this dissertation. Investigations show that Abolmaali is one of the oldest districts in Yazd that has saved its original conditions such as structure and forms.

After all, Abolmaali's size, form and structure can be a good pattern to inspire from, in designing a new district (Table 33).

Figure 150 shows Abolmaali district's features and structure.

Pattern district	Size	Form	Structure
Abolmaali	About 13 hectares	Semi-linear	Central & introverted

Table 33

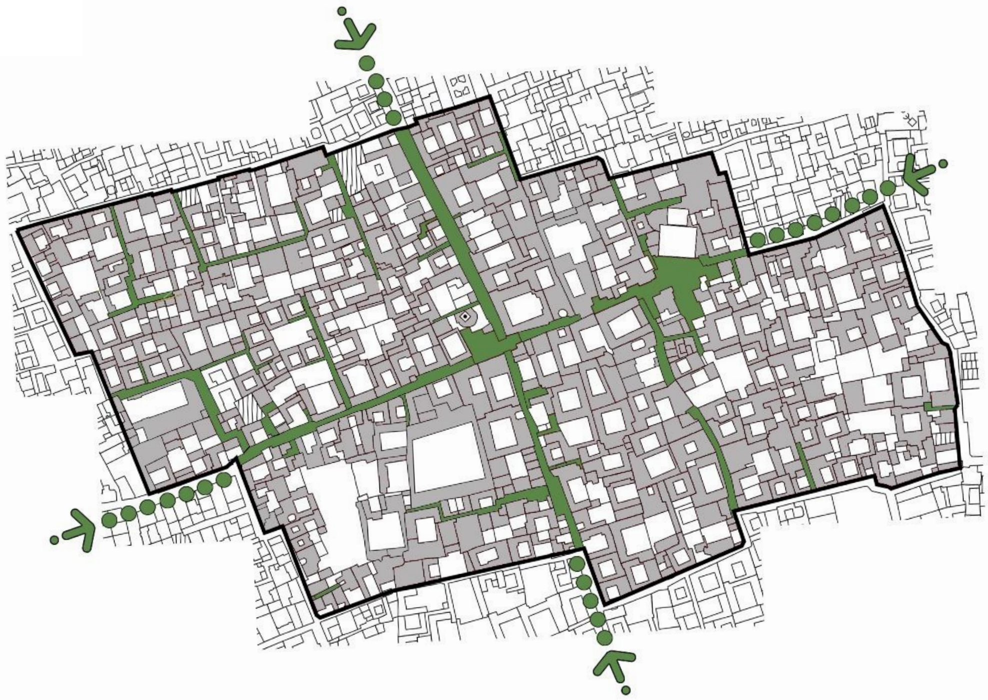


Figure 150: The structure of Abolmaali district. Graphic by author

According to figure 150, the main feature of Abolmaali (and other original districts) is an introverted organization with a district center that is defined by two crossed main passageways. In this structure houses are connected to the main passageways by means of dead-ended passageways that branch from mentioned crossed main passageways. Local facilities are located in the center of district. This is an introverted structure that everything including access, facilities etc. is supplied from the internal parts of district.

In the following part, this introverted organization feature will be discussed further by comparing different districts' patterns.

Defining structure of proposed district:

As mentioned in previous pages the good sample traditional district (Abolmaali) has an introverted structure. Following, the features of an introverted and an extroverted organization for the districts will be discussed.

Introverted district versus extroverted district:

Figure 119 illustrates the usual pattern of the structure for the contemporary Iranian cities and their districts. This pattern, influenced by the western styles, is proposed by some researches and designers for Iranian cities planning, and its negative effects can be observed in Iranian cities (Gharib 2008, 15).

Some features of this extroverted organization are explained in bellow:

a- Internal accesses to the district are supplied by surrounding collector and distributer streets around the district. Dead-end passageways branch from these outer streets. The center of district is specified for pedestrian routes.
b- District facilities such as shops and stores are located along the surrounding distributer streets (Figure 151).

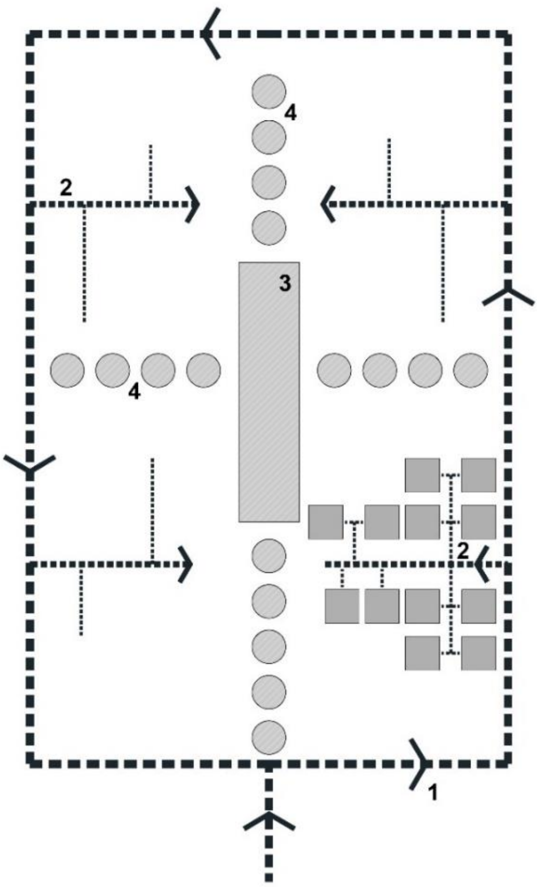


Figure 151: Extroverted district:

1- Collector and distributer streets
2- Secondary and dead-end passageways to the residential units
3- Pedestrian area
4- Pedestrian passageways

Graphic by author on basis of **(Gharib 2008)**

This mentioned pattern is beneficial considering the hierarchy of traffic system and saving the center of district for pedestrian area and routes.

While analyzing the Iranian historical districts shows that they have an inverse organization with more advantages such as concentrating local facilities and local accesses in the heart of the district and making more sense of belonging to the district and more social communication between the inhabitants.

Hence this research tries to propose an introverted district with features learnt from Iranian traditional cities, gained from analyzing Yazd historical districts such as Abolmaali.

This introverted district has features such as:

a- Internal access to the residential parts from inside of the district. These accesses are branched from two crossed main streets that pass through the center of district. Dead-ended passageways are connected to these main streets.
b- District facilities are located in the main plaza in the center of the district (Figure 152).

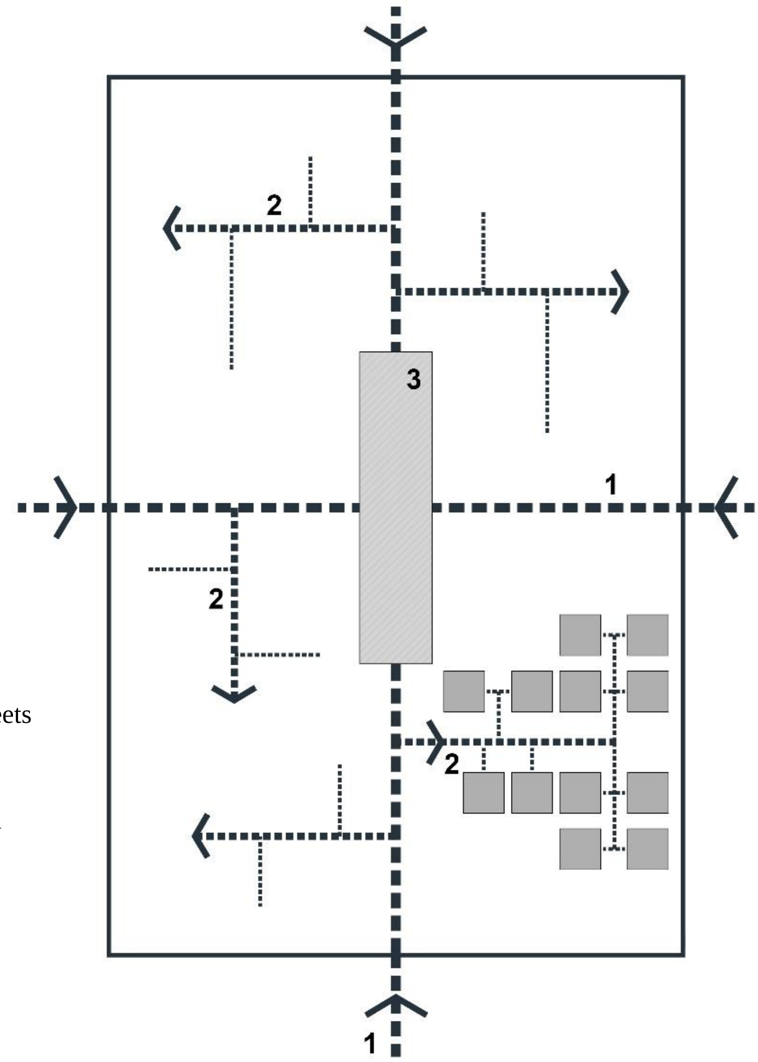


Figure 152: introverted district:

1- Internal collector and distributer streets
2- Secondary pedestrian and dead-end passageways to the residential units
3- Pedestrian area (facilities, shops and parking)

Graphic by author

On basis of the proposed structure in previous page, one sample district is designed by using discussed historical patterns and also new life standards. It is proposed with almost exact size and proportions (about 450x300 m² equal to the size of Abolmaali district). Features such as mobility and traffic system, hierarchy of access, compactness etc. are proposed as well (Figure 153).

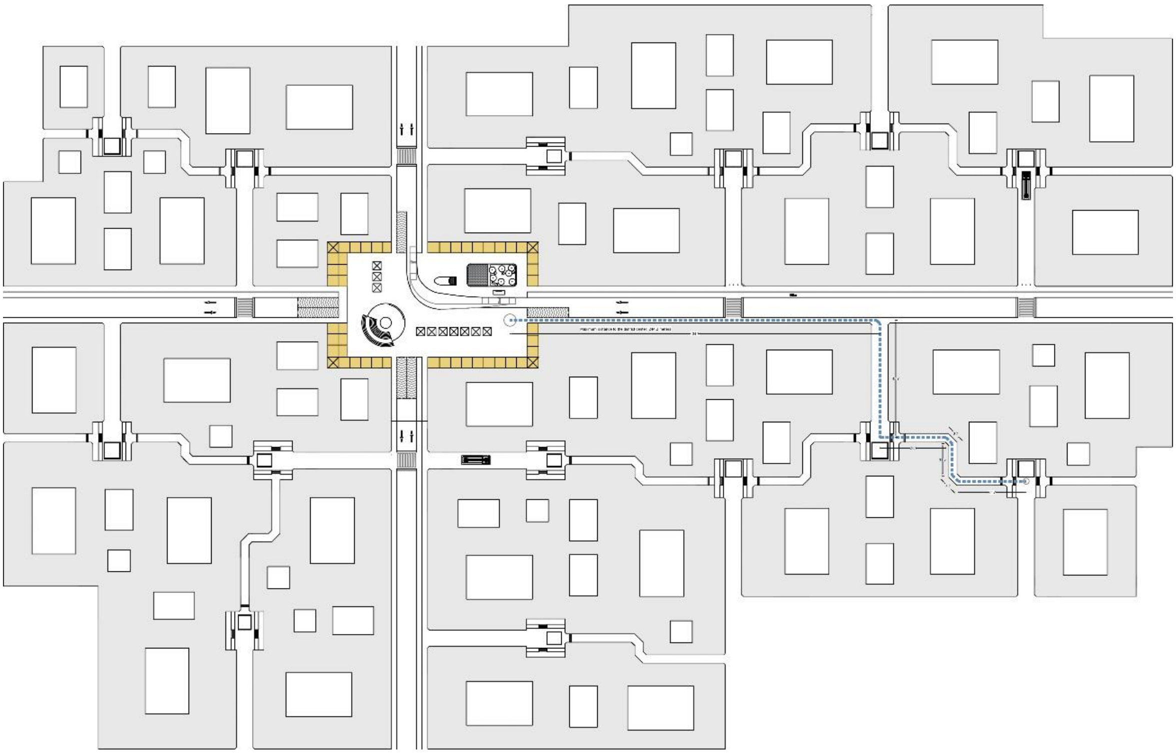


Figure 153: proposed district. Graphic by author

7.8 Mobility and traffic system:

In this part the system of access and hierarchy for the traffic system from the public to private residential parts are proposed (Figure 154).

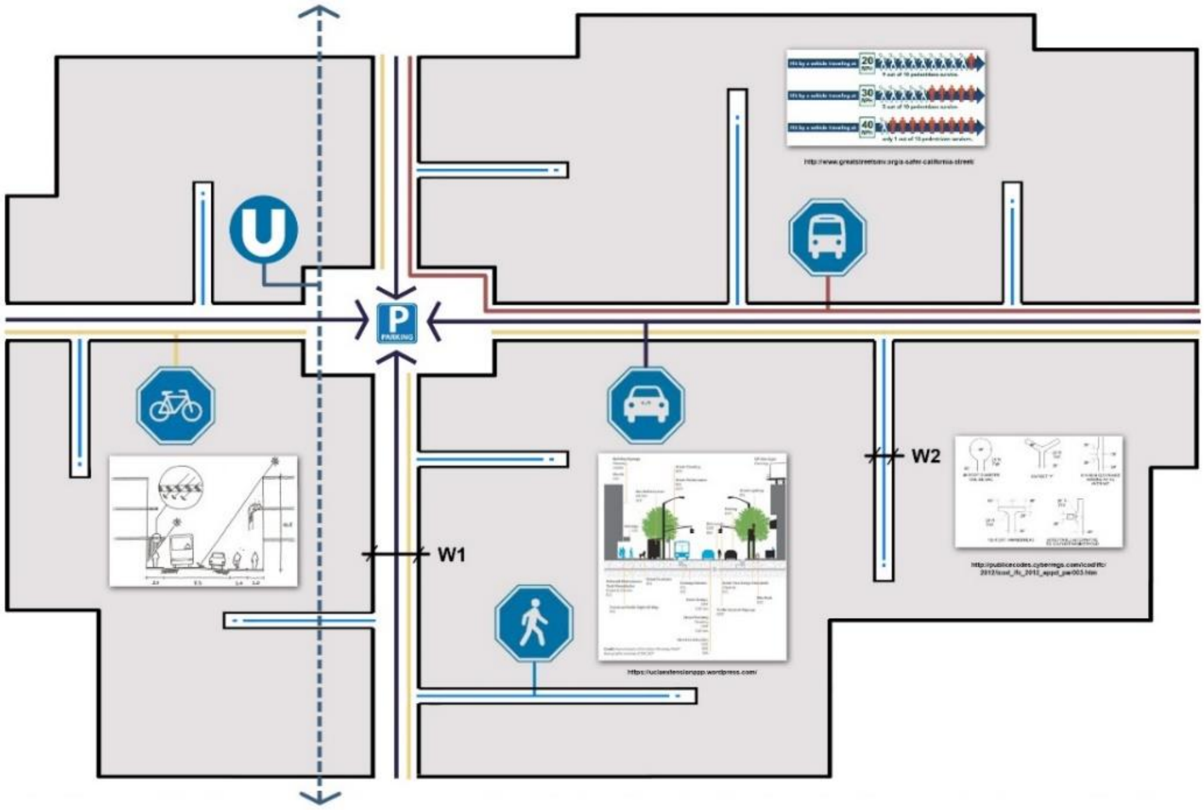


Figure 154: Graphic by author on basis of: **(UCLA 2015) (publicecodes 2015) (greatstreets 2015)**

There are some criteria and patterns for the hierarchy of traffic system to access the residential parts from the main streets in Iran for the neighborhood scale. As Gharib mentions, this hierarchy for the local accesses is classified as figure 155 shows:

- Public scale by means of the collector and distributer streets around the district (Nom. 5, Figure 123).
- Secondary dead-end and open streets (direct access to the residential units). (Num. 4, Figure 123).
- Secondary pedestrian passageways (by considering the car access). (Num. 3, Figure 123) (Gharib 2008).

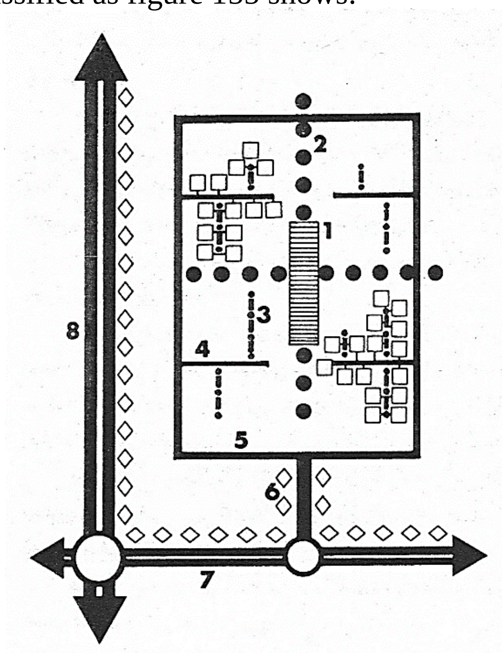


Figure 155: traffic system defined by Gharib. Image from: **(Gharib 2008, 15)**

Mentioned system in figure 155, copied from western organization, gives the priority to cars.

Another reference proposes one system considering the local social and cultural features in the hot arid regions of Iran: Tavassoli proposes an “access hierarchy” on basis of providing territory for the inhabitants by designing more dead-ended passageways and small squares between the neighbors as neighborhood centers (Tavassoli, Principles and Techniques of Urban Design in Iran 1997, 13) (Figure 156).

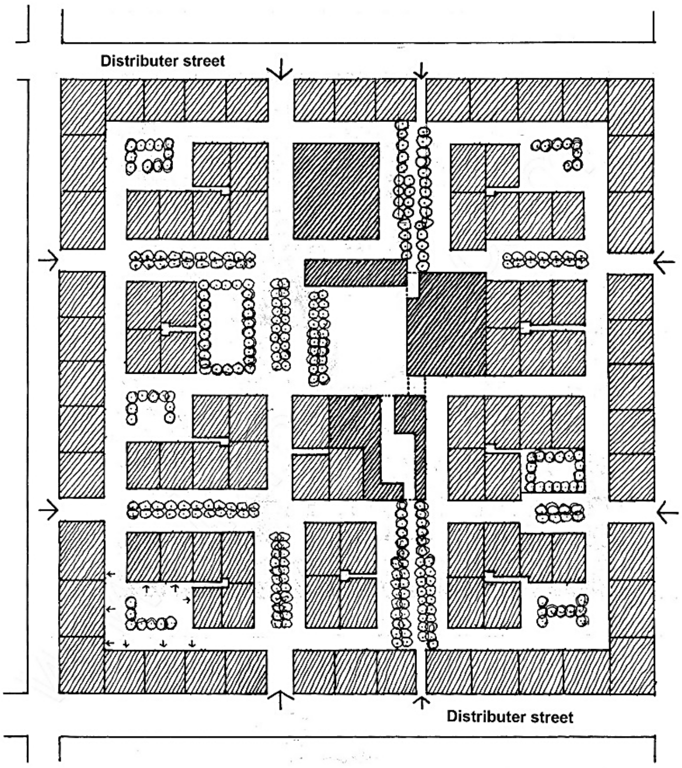


Figure 156: traffic system defined by Tavassoli. Image from: (Tavassoli, Principles and Techniques of Urban Design in Iran 1997, 13)

All of those mentioned systems are proposed on basis of priority of car access from main streets to each residential units with more or less pedestrian and dead-ended passageways.

While one of the most important criterion of sustainable design is reduction of car dependency and encouraging people to use public transportation and to have more physical activities by walking (LEED 2009). For this purpose designing the central parking lots in the district center near the public transportation stations can help people to have more walk distance and to select public transportation system. This system also preserves the residential units from problems created by cars such as air or sound pollution, safety issues, etc.

In addition, special climatic conditions of this region requires specific form and structure of streets and passageways. The historical parts of Yazd teach us to design narrow and indirect passageways for more shading and reduction of sand storm effects.

Therefore for proposing access and mobility system for Yazd, in addition to consideration of the standards of traffic system, the special features of local and historical urban design system as well as the criteria of sustainability should be intended.

Therefore, the proposed traffic system is defined on basis of the previously discussed introverted organization of the historical structure (Figure 157).

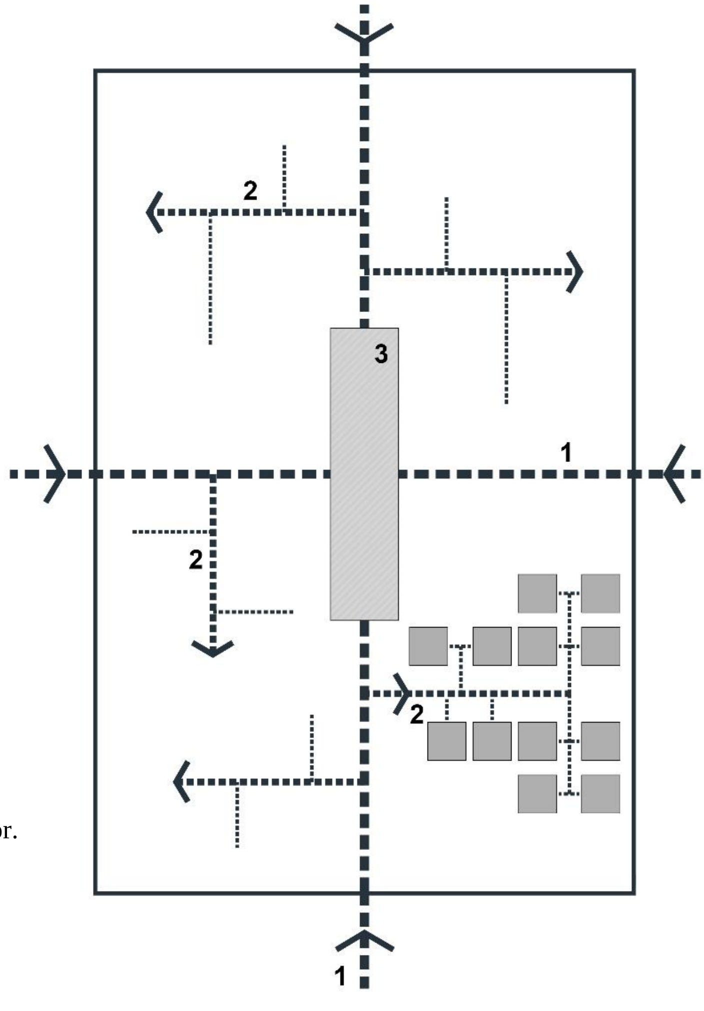


Figure 157: traffic system defined by author.
Graphic by author

Following, the proposed mobility system of this research by consideration of those mentioned features is introduced. For all of the streets and passageways, the climatic oriented design strategies such as making maximum shading by minimizing the width of streets and using some shelters for the sidewalks is considered (Figure 158, Sec. 1 & 2).

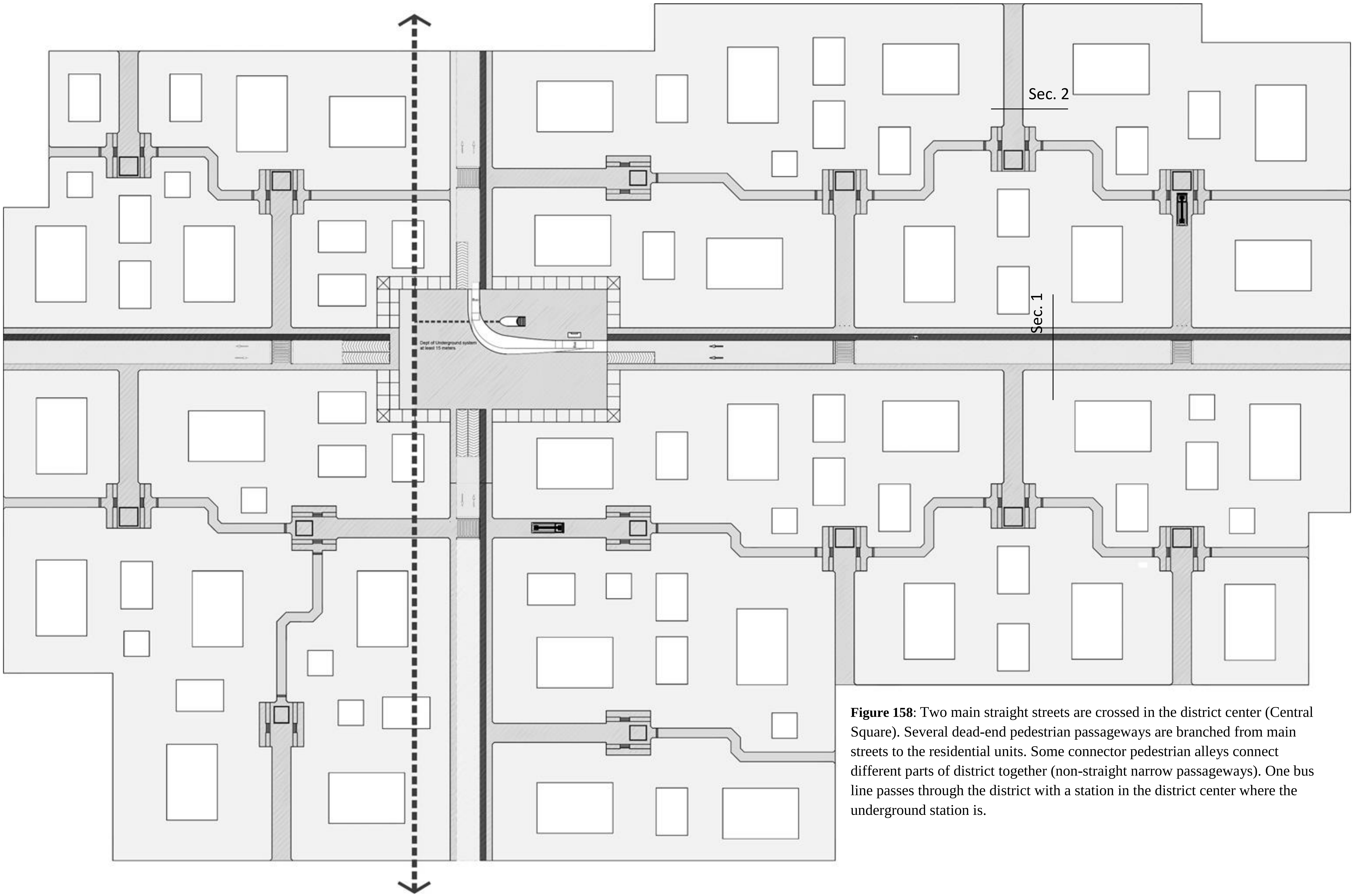
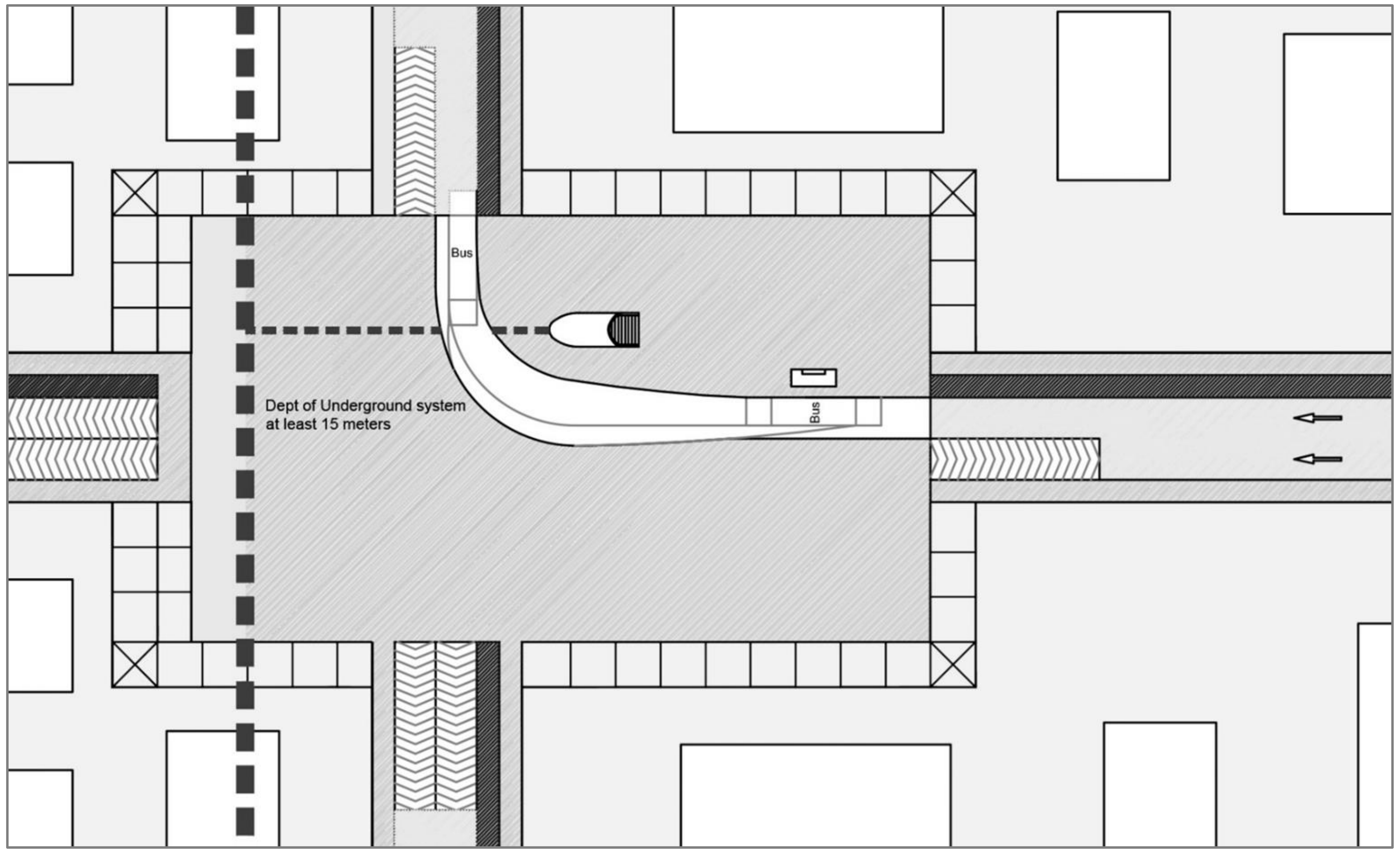
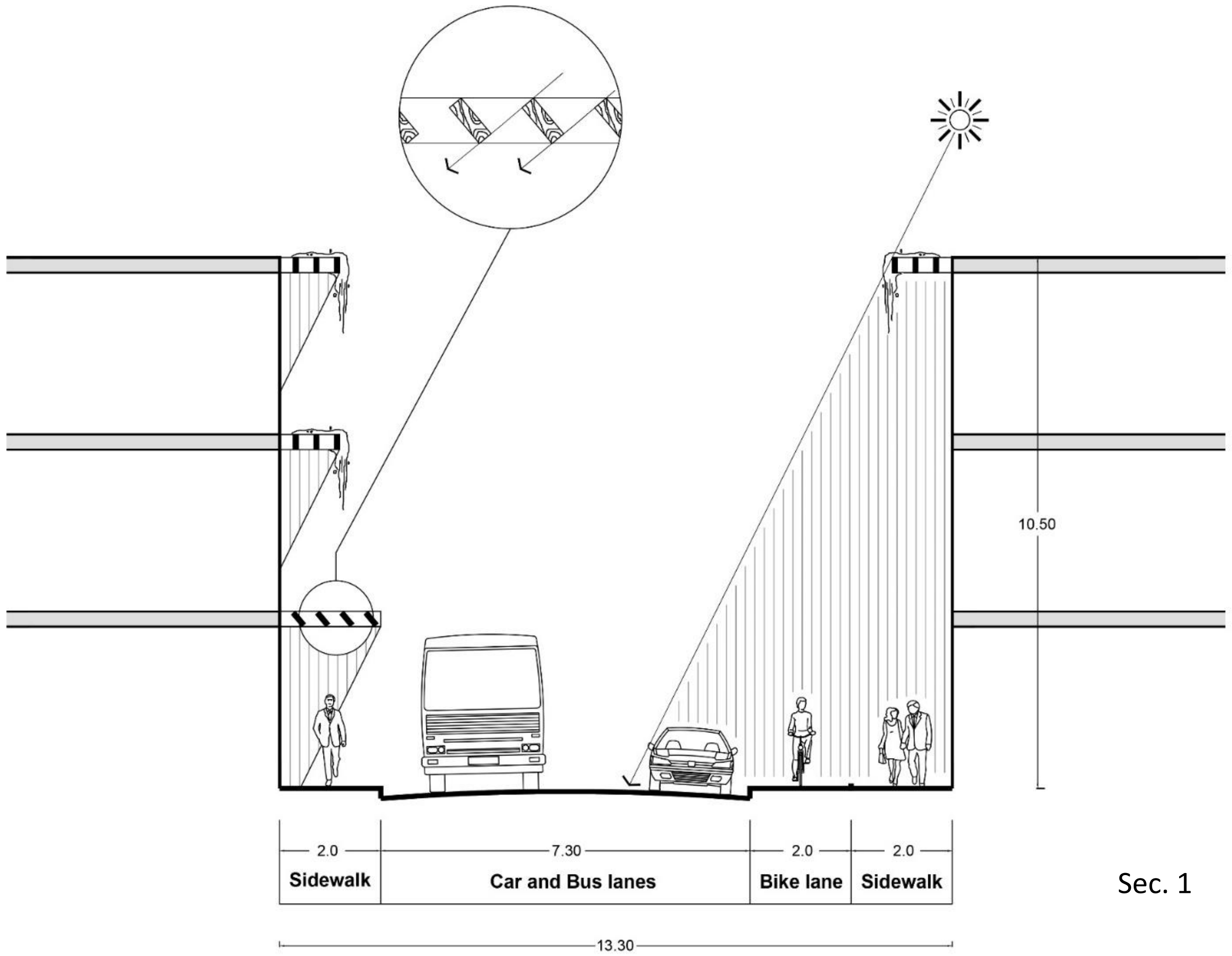


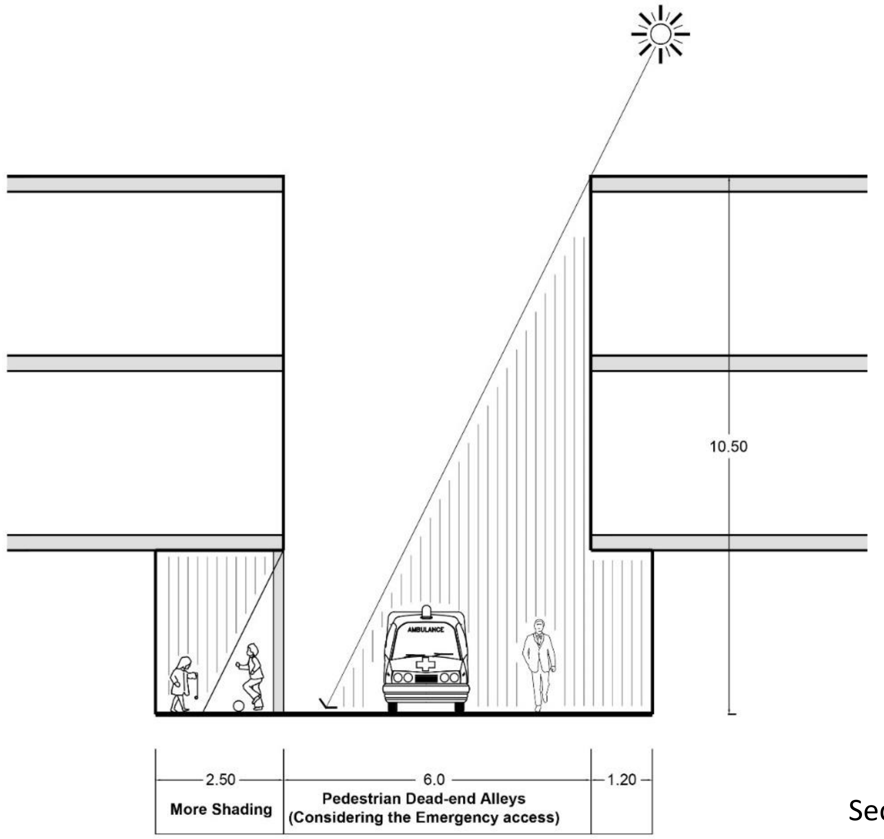
Figure 158: Two main straight streets are crossed in the district center (Central Square). Several dead-end pedestrian passageways are branched from main streets to the residential units. Some connector pedestrian alleys connect different parts of district together (non-straight narrow passageways). One bus line passes through the district with a station in the district center where the underground station is.



Zoomed in view from the district center and its public transportation system of figure 158.



Sec. 1



Sec. 2

In this system of traffic, besides usage of car system, the priority is given to public transportation and pedestrian routes. The internal car access to the center of districts is dead-ended ending in the underground parking lots in the district center. From this spot on, the access of residential parts is pedestrian routes by considering the possibility of emergency and security access (Figure 159).

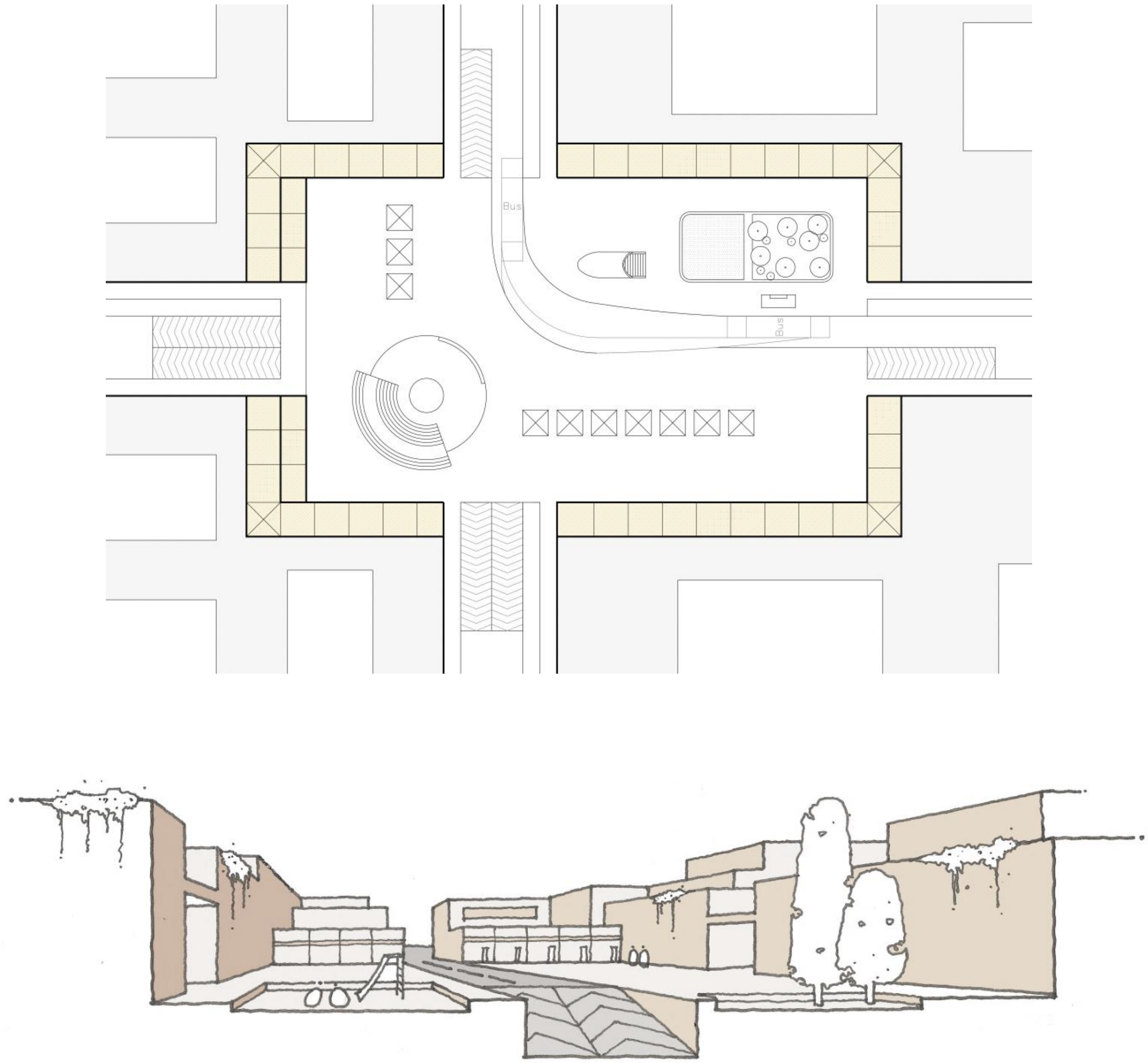


Figure 159: dead ended car access Terminated in the underground neighborhood parking**.** Graphic by author

7.9 Hierarchy and privacy: From public to private spaces:

Pattern for neighborhood centers and architectural structure (courtyard, connection between buildings, etc.)

As mentioned before, the structure of the proposed district is an introverted organization with two main streets that are connected together in the center of the district. Several dead-ended passageways connect the residential parts to the main streets. These passageways can be used as community centers between the inhabitants of surrounding buildings. There are several central courtyards with the dwelling units located around them. These courtyards are used as the first elements for organizing hierarchy of privacy. In other words, the neighborhood space between the neighbors is defined in these big courtyards. Second neighborhood space is at the end of dead-end passageways. Local streets of district have the third level of privacy regulation. At the end, the square in the center of the district has the role of bringing together the inhabitants of the district by providing local facilities and stores and Public Park (Figure 160)

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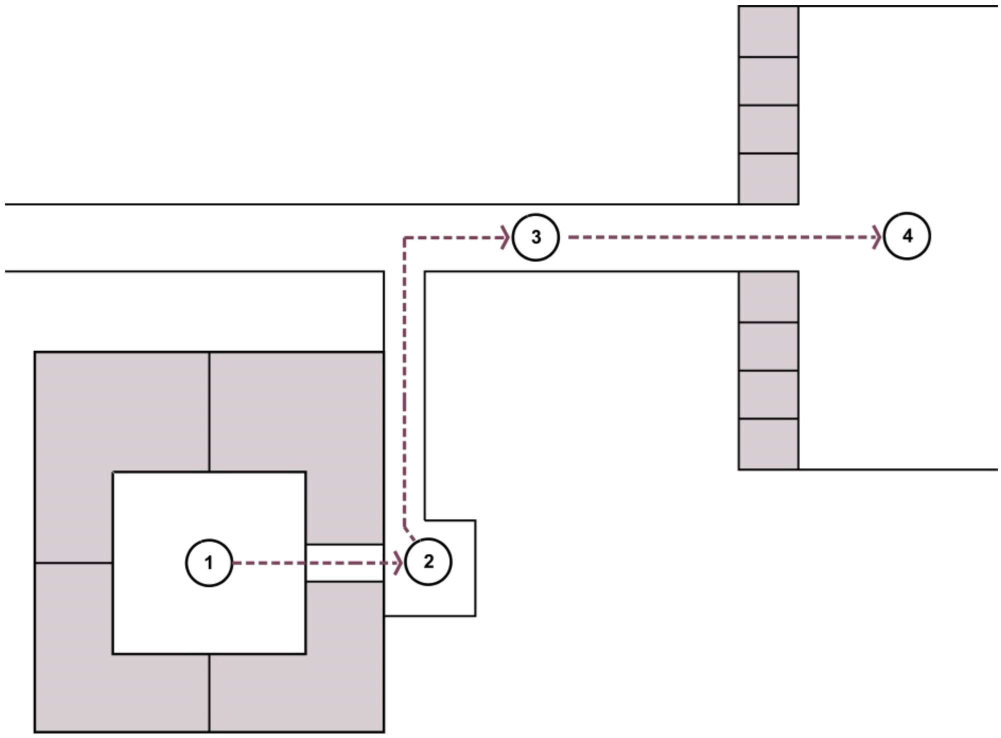


Figure 160: Hierarchy of privacy. Graphic by author

Figure 161 shows a schematic imagination of the neighborhood spaces at the end of dead-ended passageways. In this space as the first level of urban communication center some facilities such as children's playground, spaces for inhabitants to sit and chat, as well as green spaces are considered (Det.1). This pattern of neighborhood space is learned from the historical districts where the end of passageways have an important role for preparing social communications between the neighbors and making a secure space for children to play.

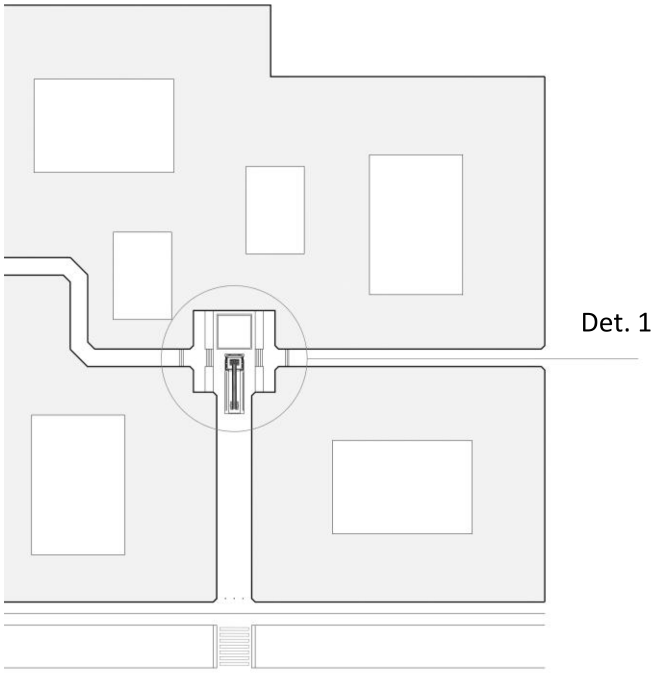
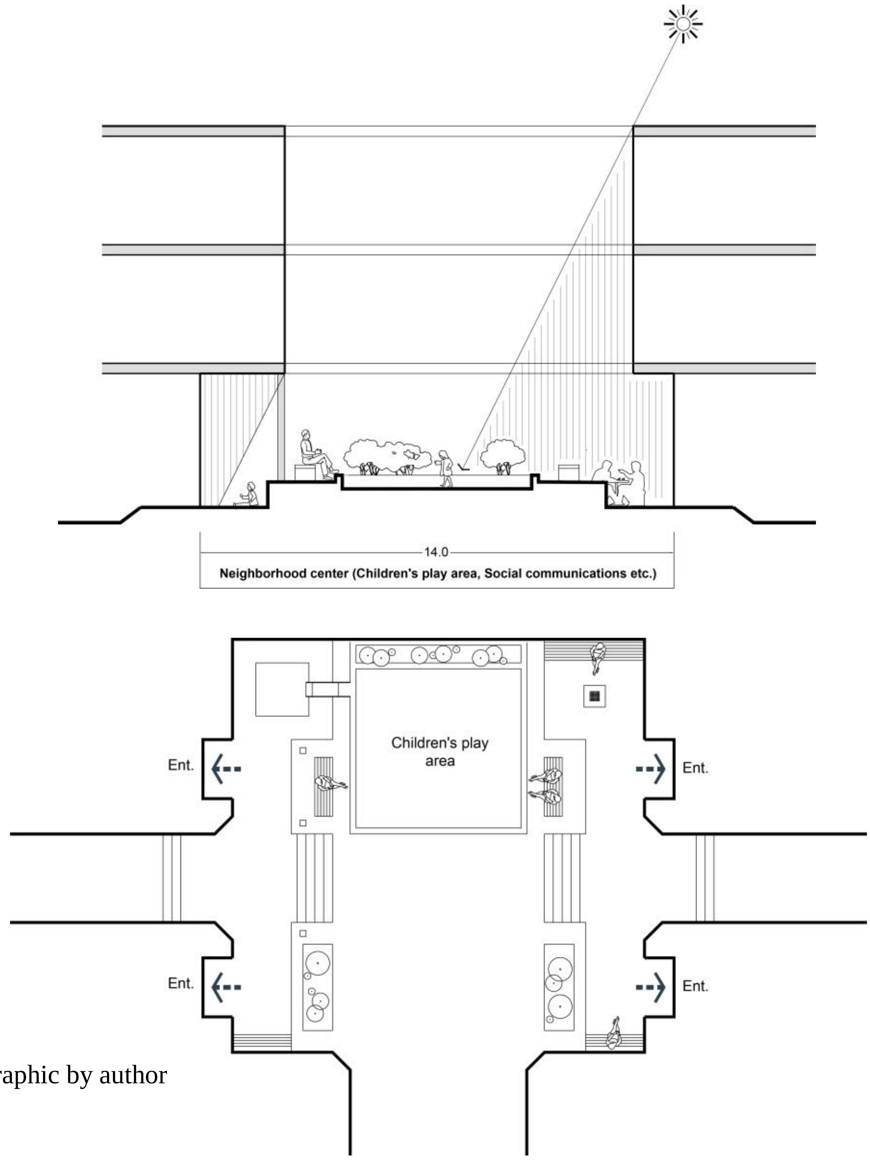


Figure 161: one dead-end passageway as the neighborhood space. Graphic by author



Det. 1, Graphic by author

Hierarchy for distribution of facilities (Mixed-use):

Analyses show that unlike the contemporary districts, all of the historical districts have at least 4 different functions in their centers serving as daily services and local facilities such as bazaar and mosque.

For the proposed district in its central square one bazaar with enough shops to cover the daily needs is considered. In addition, facilities such as kindergarten, primary school, Public Park and open air amphitheater as a communication center are considered (Figure 162).

According to Figure 162 the farthest spot of the proposed district has a walking distance of about 240 meters to the district center. This is less than the criterion defined by LEED (less than ¼ miles or 402 meters to the services and facilities)

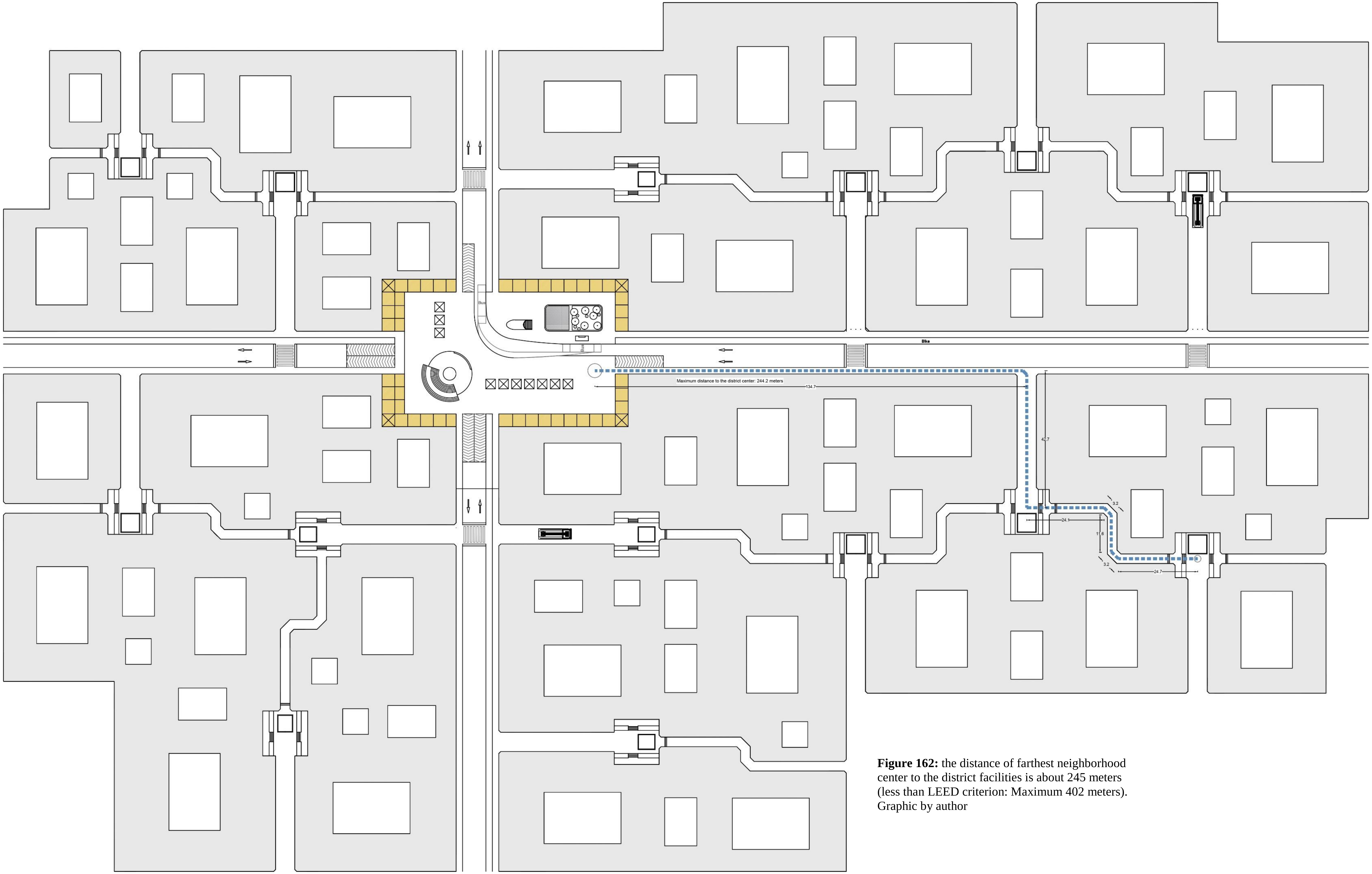


Figure 162: the distance of farthest neighborhood center to the district facilities is about 245 meters (less than LEED criterion: Maximum 402 meters). Graphic by author

Architectural structure:

According to figure 163, the houses in the proposed district are located around the courtyards with the maximum connections with the neighbors in different directions. This organization creates a compact urban texture with the maximum connection between the buildings and the number of common walls and floors are increased using this strategy, which is essential in this climatic zone.

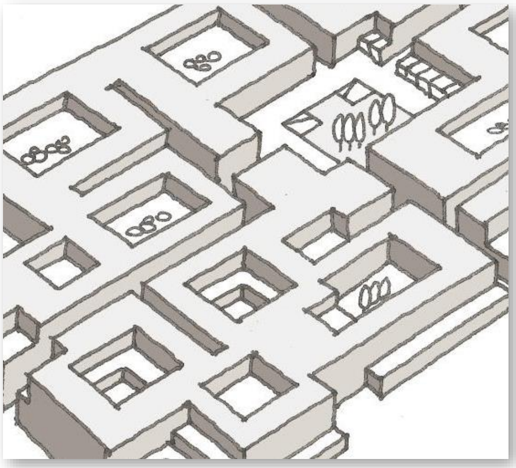


Figure 163: Graphic by author

More discussions about the architectural patterns and styles for the proposed district can be found in other document of this research, written by Afsaneh Soltani.

7.10 Compactness and Footprint:

According to the analysis, the compactness item should be at least 0.8 (FAR). Regarding the patterns of historical districts and also defined standard degree of compactness and footprint and considering the open spaces such as district center, passageways and courtyards, the density of proposed district is recommended (Figure 165).

The architectural document of this research (written by Afsaneh Soltani), recommends an overall height of 3 floors in addition to the underground level for the houses.

According to the defined criteria for compactness and the results of architectural document, and considering the size and form of proposed district, the amount of *footprint* and compactness are as follows:

- Proposed footprint: 47.7%

As figure 164 shows, the percentage of proposed *footprint* is close to the average *footprint* of historical districts. This is an acceptable result for more dense construction on basis of the high rate of footprints in the historical parts of the city.

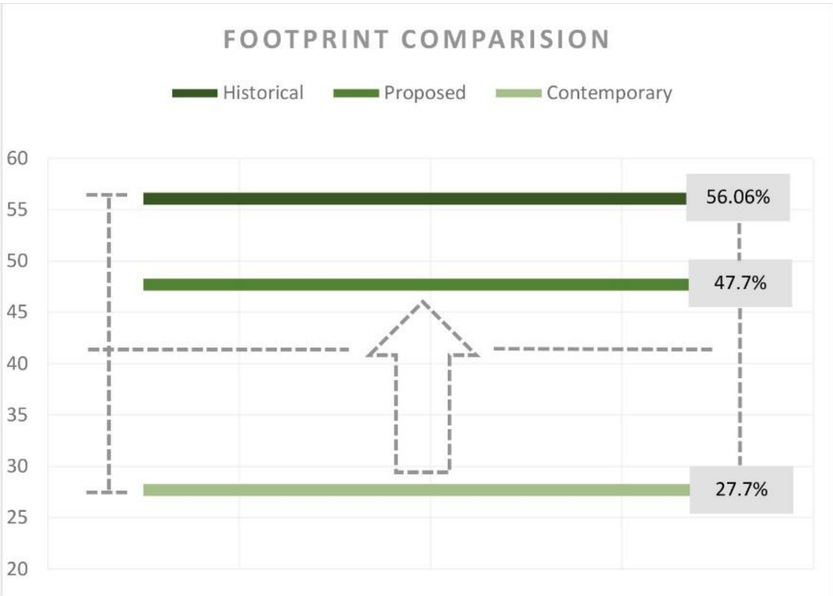
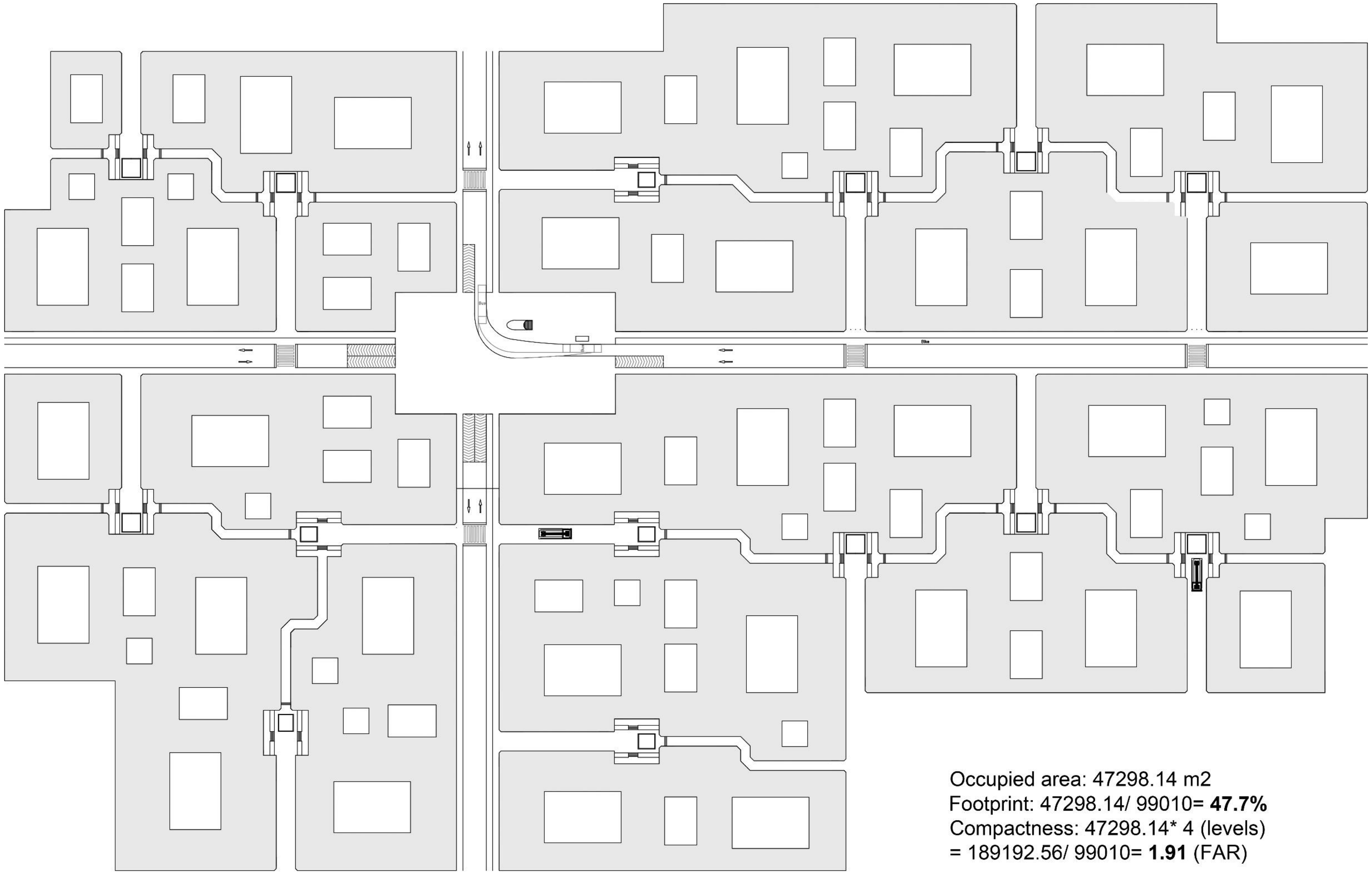


Figure 164: graphic by author

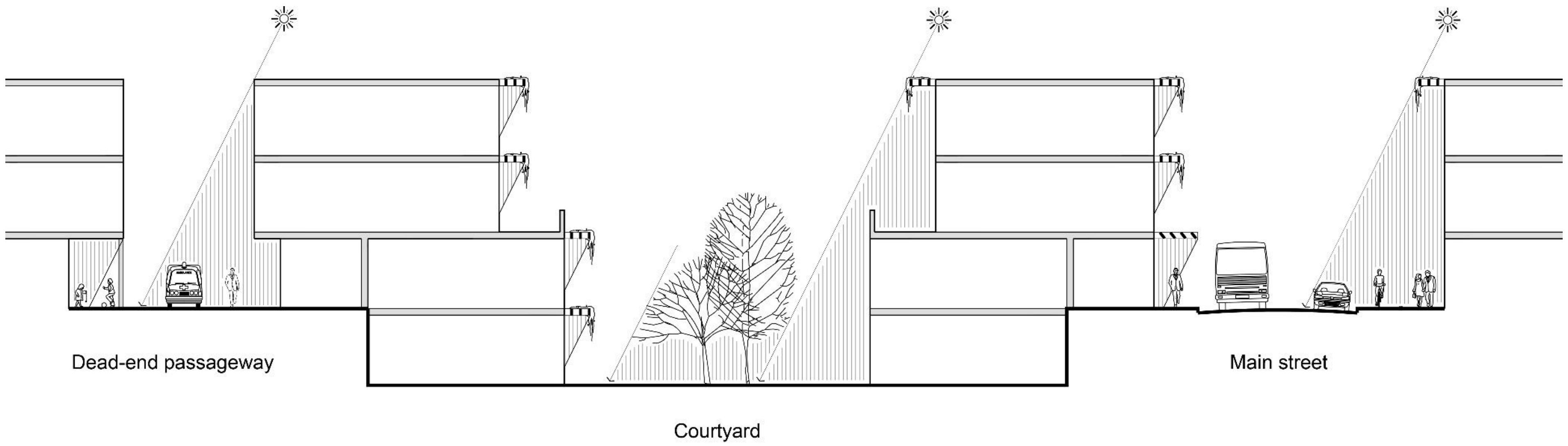
- Proposed compactness: 1.91 (FAR)

This result is more than two times the LEED's criterion.



Occupied area: 47298.14 m2
Footprint: 47298.14/ 99010= **47.7%**
Compactness: 47298.14* 4 (levels)
= 189192.56/ 99010= **1.91** (FAR)

Figure 165



7.11 Proportion and shape of passageways and shading:

The following schematic sections of passageways (Figure 166) are proposed considering LEED's proportions of the passageways[17] and also the usual proportions of the passageways in historical districts.

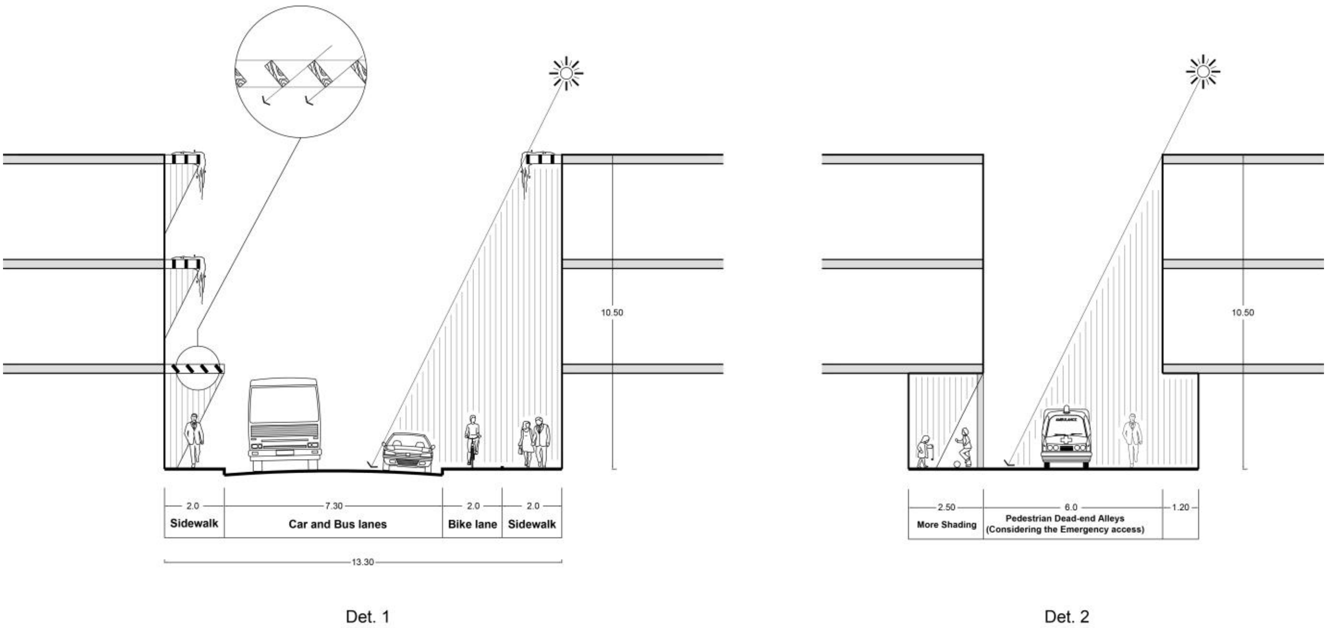


Figure 166: Graphic by author

Figure 134 left, proposes 1/1 proportions of length/width for the main passageways of district (street).

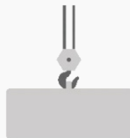
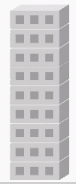
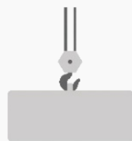
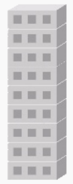
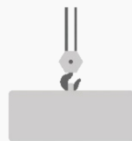
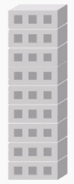
Figure 166 right, proposes the dead-ended passageways as pedestrian routes for access to the houses, with a narrower proportion than the main passageways. These proportions with minimum width and maximum height in addition to other strategies like terraces, result in more shading.

[17] Minimum building-height-to-street-width ratio of 1:1

7.12 Construction system, Materials and heat island effect:

As discussed before, adobe construction reveals benefits in terms of sustainability comparing with modern materials such as concrete. But as mentioned, adobe construction also has weaknesses such as low resistance against earthquake, limitation for the height of building and the required long time of construction.

This construction system needs to be reinforced by a second material. As table 34 shows three different material concrete, steel and wood are compared for reinforcement of clay construction in terms of sustainability. This analyze is divided into three periods: pre-construction, during construction and after construction.

	Pre-Construction			**Construction process**			**After Construction**	
Reinforcement Materials	Formation And production	Producing Pollution	Transfer	Construction Method	Height Limitation	Construction Pace	Earthquake Resistance	Reusability
Concrete								....
Steel								
Wood		....						

- Despite of concrete and steel, wood is formed and produced completely by nature

- Despite of concrete and steel, producing wood doesn't have pollution

- Nearest Factory: Mehriz: 45.7 Km
- Nearest factory: Navard Foolad Yazd Co.: 17 Km
- Nearest forest: Khatam 150 Km

(Google Maps 2015)

- Mechanical devices and expert workers are needed for all of those construction systems

- No limitation for midrise buildings

- Using concrete makes the construction slower than steel and wood

- All of them help to making resistance against earthquake

- In spite of concrete, wood and steel can be reused for new constructions and be recycled

Table 34

The results show that wood performs better in terms of sustainability for reinforcement of adobe:

	Pre-Construction			Construction process			After Construction	
Reinforcement Material	Formation And production	Producing Pollution	Transfer	Constructio n Method	Height Limitation	Constructio n Pace	Earthquake Resistance	Reusability
Concrete	More Required Energy	Air Pollution	Medium Distance	Non-Local Techniques	No Limitation	Slow	Resistant	Non-Reusable
Steel	More Required Energy	Air Pollution	Minimum Distance	Non-Local Techniques	No Limitation	Rapid	Resistant	Reusable
Wood	Less Required Energy	No Pollution	Maximu m Distance	Non-Local Techniques	No Limitation	Rapid	Resistant	Reusable

Table 35

According to the table 35, wood has the most advantages in terms of environmental sustainability, compared with concrete and steel, but there is limitation regarding this building material in the region; lack of wood resources in Yazd region. But there are some wood resources in different parts of Iran such as north part of the country and some regions in central parts of the country:

The forests on the south coast of the Caspian Sea and the northern slopes of the Alborz mountain range from sea level to 2800 m altitude . With an area of about 1900000 ha.

According to FAO[18] in the central Iran there are some sparse forests in Zagros Mountains with following characteristics:

"The main constituent of these forests is oak, *Quercus* spp. They stretch from north to south along the Zagros Mountains, extending as far as Shiraz. They grow under annual

[18] Food and agriculture organization of the united nations

precipitation between 450 and 1050 mm. They are subject to over-exploitation and degradation due to intensive human activities and overgrazing." (FAO 2015).

Figure 167 shows distributions of forest lands in Iran.

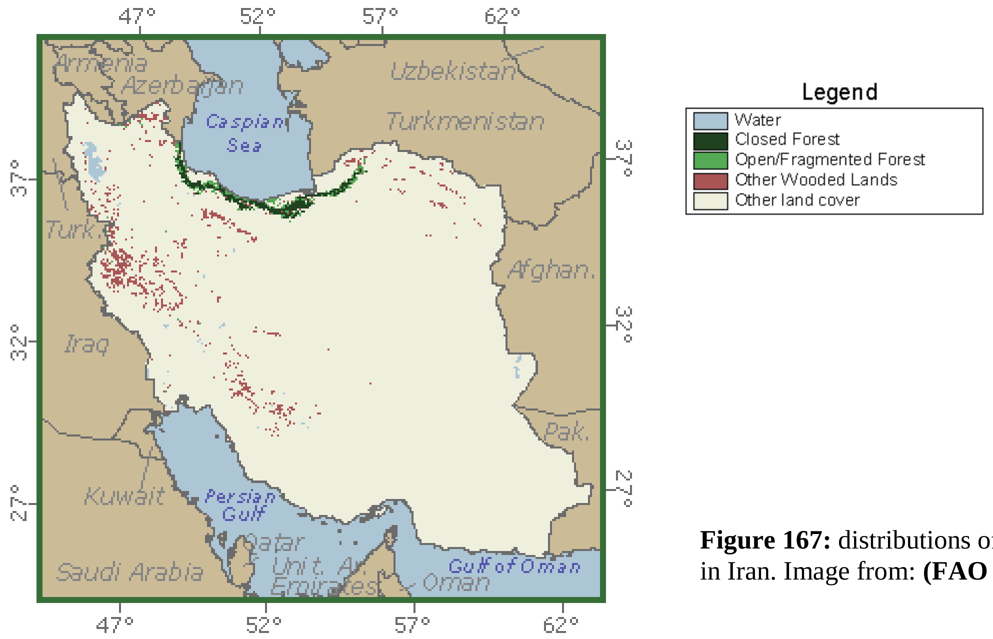


Figure 167: distributions of wooded lands in Iran. Image from: **(FAO 2015)**

According to UNEP[19] the forests in the central Iran don't cover even 10% of the surfaces (UN 2015) (Figure 168).

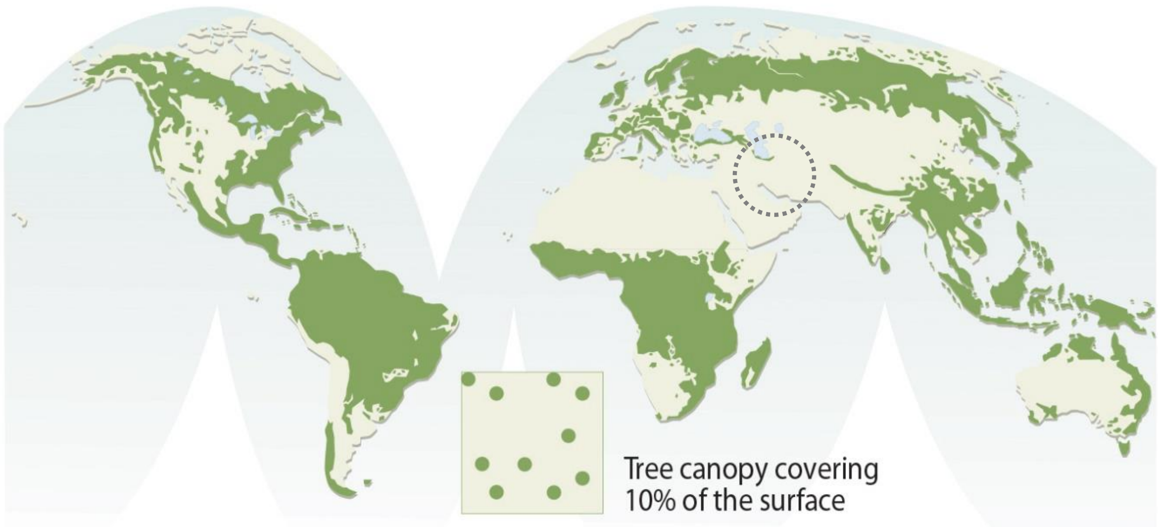


Figure 168: image from: **(UN 2015)**

[19] United Nations Environment Programme

Figure 169 shows the situation of oak forests in the Zagros Mountains.

Figure 169: Sparse and poor forests without enough wood for construction. Image from: **(IRNA 2015)**

On basis of FAO, many of these weak and poor forests are resulted from deforestation phenomenon in Iran (FAO 2015).

Therefore, the limitation of the wood resources in the central parts of Iran and present deforestation phenomenon can shift the first choice for the complementary reinforcement material for adobe, from wood to other materials at least for current time and short term use.

But the same reference (FAO) emphasizes there are some plans for planting forests in Iran: "In the last 25 years, programs were established to plant irrigated and non-irrigated areas to meet local needs for timber and environmental protection. By the year 1999, the total planted area reached 2221100 ha. The main purposes are to supply wood for forest industry and to minimize impacts on the natural forests of the country" (FAO 2015).

According to the programs for re-planting of Iran forest, and considering the sustainable advantages of wood, application of wood as a complementary building material can be proposed for long term (more information in the architectural document of this research written by Afsaneh Soltani).

Therefore, for the short term, according to table 35, steel can be used as reinforcement material in the second rank after wood, with more advantages in environmental sustainability compared with concrete.[20]
The existing good infrastructure of steel industry in Iran, and the high investment that has been put into this industry in past decades, confirms this choice.

A clay construction system reinforced by light steel is proposed for this research.

Figure 170 shows a view of the proposed construction system, with adobe as the main material, reinforced with light steel beams and columns.

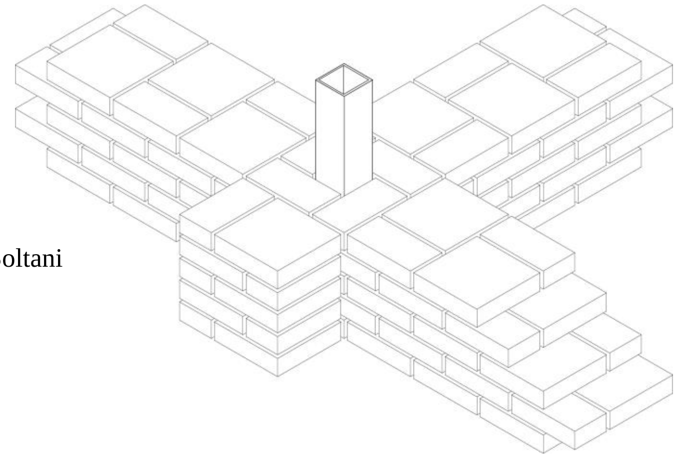


Figure 170: Graphic by Afsaneh Soltani

Heat island effect:

According part 7.3.3, chapter 7 application of Yazd traditional brick on the facades and surfaces with SRI 52 reduces the heat island effect. Recommended reinforced clay construction with the surfaces covered by the facade bricks for the walls, and brick paving for the roofs and passageways, are recommended for reducing the heat island effect by means of more solar reflection (Figure 171).

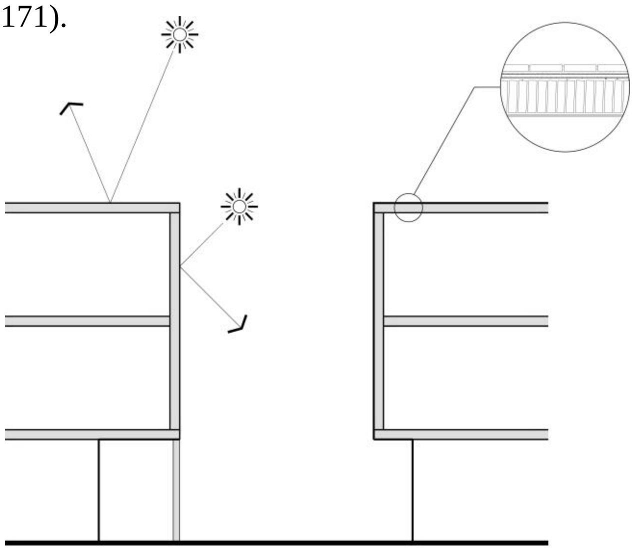


Figure 171: a schematic section from one of the proposed passageways covered its surfaces by brick. Graphic by author

[20] As Edwards argues, although the amount of embodied energy for formation and production of steel is about 20 times higher than that of concrete, but it must be considered that steel recycle costs much lower than concrete. As he mentions, more than 50% of the steel that is used in construction industries has been recycled from the steel previously used in existing buildings. Thus, due to this unlimited possibility for recycle of steel, its embodied energy is therefore shared with the coming generations. Therefore, steel is a wiser green material choice (Edwards, Rough Guide to Sustainability: A Design Primer 2005).

7.13 Green area:

For increasing the ratio of green area and following the criterion of this item defined previously in this research (at least 0.115 m2 per each square meter residential unit), In addition to green spaces and trees in the neighborhood courtyards, planting in the terraces facing the passageways is also recommended for the proposed district for more passive cooling and beautiful views (Figure 172).

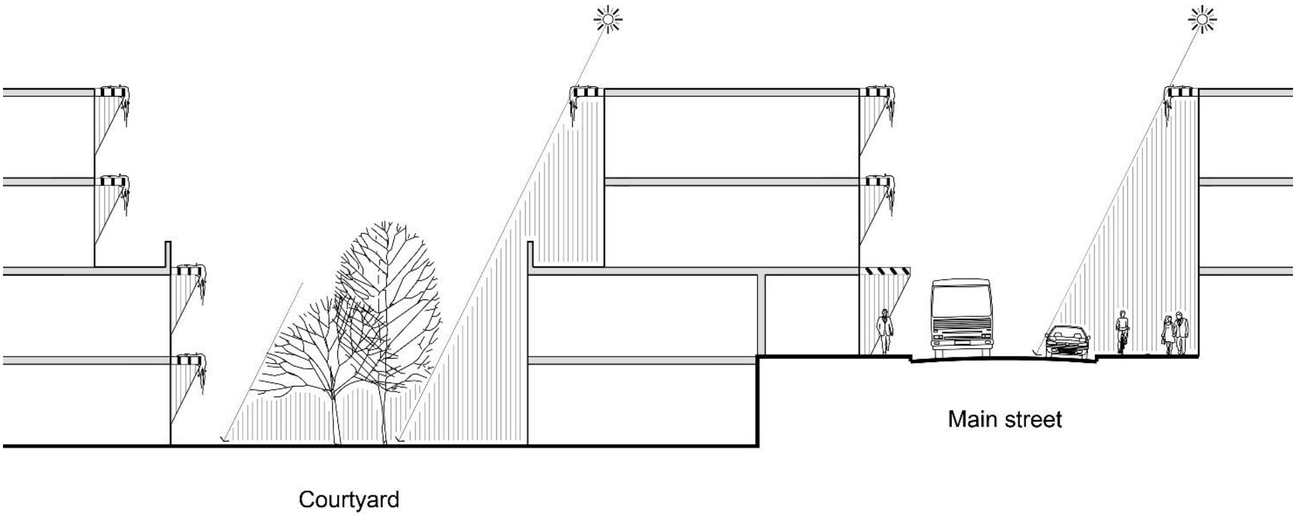


Figure 172: Graphic by author

7.14 Passive systems for water resource:

LEED evaluation system obligates to locate the project on a site served by existing water.

As mentioned before, in the historical parts of Yazd, *Qanāt* system is a passive system as a water resource.

This ancient system for water still exists in Yazd and covers the entire city, including the new parts.

This dissertation recommends locating the new districts near one of the *Qanāt* routes in the city and revitalization of *Qanāt* system as an **alternative resource** in addition to the existing modern water supply systems.

This is a potential of an ancient existing water supply system that needs to be repaired and reused as a secondary and alternative water source.

For this purpose one water reservoir (*cistern*), connected to the *Qanāt* canal, can be placed in the square of the district and its reserved water can be distributed to different spots of district for non-potable usages such as irrigation of green area and parks (Figure 173)

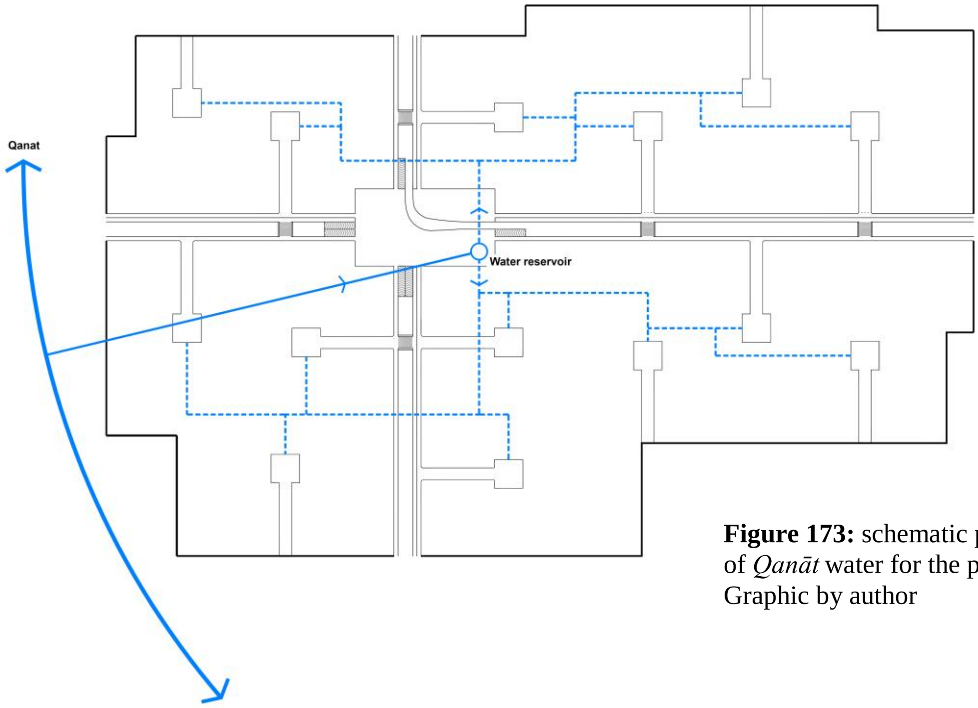


Figure 173: schematic plan for distribution of *Qanāt* water for the proposed district. Graphic by author

7.15 Garbage management:

As mentioned before, both historical and contemporary districts of Yazd suffer from lack of efficient system for garbage management. But there is some planning for the future in Yazd for managing garbage including separating solid wastes from the origin and recycling the garbage (Pasmandiran 2014).

This research recommends such strategies for short term. Improvement of the program to higher standards, inspiring from developed countries is demonstrated in figure 174.

Figure 174: Image from: **(Begin with the Bin 2016)**

Conclusion:

A Summary of results in this chapter is brought together in table 36. As mentioned before, these recommendations are some proposed solutions for designing an environmentally sustainable district on basis of inspirations and lessons from the historical districts of Yazd and with the aid of criteria from LEED evaluation system.

District's organization	**Interwoven organization with a flexible form and borders of districts**
Location	**Maximum 804 meters from district center to the first urban facilities**
Orientation	**20-45° rotation of urban fabric towards south-west**
Form and structure of the district	**Semi-linear by Central & introverted form with about 13 hectares area**
Hierarchy of facilities	**Maximum 402 meters to the district facilities**
Mobility and traffic system	**Using recommendations proposed in part 7.8, chapter 7 (Figure 158)**
Physical structure of the district	**Compactness: at least 1 (FAR), Proportion of the passageways: at least 1/1 (Height/Width), Using connected buildings with maximum common walls between dwelling units**
Materials and heat island effect	**Using traditional brick and clay construction (with SRI of 52) on the facades and surfaces**
Green area	**Designing at least 0.115 m2 per 1m2 of residential unit**
Passive systems for water resource	**revitalizing *Qanāt* system as an alternative and secondary water resource**
Garbage management	**Using programs such as separating solid wastes from the origin and recycling the garbage**

Table 36

As discussed, the investigated items in this dissertation do not cover all aspects of environmental sustainability items. They are some adaptive solutions learned from historical system.

Most recommendations are general recommendations of a design based method, illustrated by the aid of small sample sketches.

For more exact guidelines for environmental, social and economic items of sustainability that are useful for defining urban design rules in the cities like Yazd, wider comprehensive researches should be done with more detailed results at larger scales.

This research doesn't claim that it has achieved to exact guidelines for regulating urban design rules but it at least shows that there are several potentials in terms of sustainability in the historical parts of Yazd and they can be adapted with the contemporary life as some sustainable local solutions. These local sustainable solutions are ignored in current urban design rules in Iran since the modernizing cities was started in the recent decades. The results of this research can be used for the bigger researches such as defining criteria of sustainability in the hot and arid region of Iran on basis of the past experiences. These criteria strongly are needed to be surveyed and defined in the contemporary architecture and urban design in Iran and this research can be considered as an introduction to those national researches.

Also the primary results of this research prove that it is possible to combine the modern and standard methods like international rating systems with the historical patterns and solutions to make a local rating system for sustainability. This possibility has been showed and examined by analyzing some specified case studies by a combination of LEED items and some features and factors learned from the historical patterns.

LIST OF FIGURES:

LIST OF TABLES:

LIST OF CHARTS:

GLOSSARY:

- ***Eivān,*** A rectangular hall or space, usually vaulted, walled on three sides, with one end entirely open.

- ***Andarouni (Inner spaces),*** a complete unit in the house for the private use of family members even sometimes with a separate access to outside.

- ***Birouni (Exterior spaces),*** for non-family-member guests.

- ***Bād-gir (Wind catcher)***, the traditional Persian architectural element to create natural ventilation in buildings that come in various designs: unidirectional, bi-directional, and multi-directional.

- ***Cistern (āb anbār),*** the traditional reservoir or cistern of drinking water in Iranian antiquity.

- ***Footprint,*** the ratio of built area to total area of a district

- ***Madrasa,*** Traditional religious school

- ***Mahramiyat,*** religious privacy in Islam, to prevent the private spaces of a house from view or access of strangers or non-family members.

- ***Pardis,*** Persian traditional garden

- ***Qanāt,*** The traditional water system in Iran desert cities consisting of vertical shafts and horizontal water tunnel (with a slight slope) to transfer water from mountain sides to the city.

- ***Ron,*** The dominant orientation of urban fabric in a city.

- ***Sābāt,*** Vaulted roofs or rooms that cover parts of passageways in desert cities, to support the passengers with shade**.**

- ***Hashti (Vestibule),*** the entrance lobby of traditional houses with transition function to manage and control accessing to different parts of house with mostly octagon form in plan

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