Creating a Future for an Ancient Sustainable City, Yazd

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis.

This is the true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Sustainable architecture attempts to find a way to minimize the negative environmental impact of buildings by improving the use of energy and the efficiency of material used. As new and more affordable technologies emerge, solar-generated electricity and hot water, as well as passive and active systems of natural heating and cooling are becoming more widespread. Although advanced technology can provide some solutions, it may also be worth learning from energy-saving approaches of the past. This author believes that vernacular architecture can give us some clues to improve the environmental performance of tomorrow's architecture. A combination of our current understanding of ancient techniques in addition to current knowledge about building science may help us find unique and powerful solutions.

Ancient architecture used natural resources of energy to enhance the interior conditions of a building in the absence of modern cooling/heating systems. In this study, we review samples of architecture designed by such strategies; then, we move further to a specific example of sustainable features such as windcatchers, qanats, etc. located in Yazd, Iran. Windcatchers are the most remarkable well-adapted passive natural cooling and ventilation systems used in the harsh conditions in hot zones. In fact, the use of local materials and renewable energy resources in the most prominent feature of Yazd, the windcatchers, illustrate the harmony of human built-environments and nature.

This thesis focuses on hot, hot-arid and hot-humid climates in Iran and some of the Arab countries in the Persian Gulf region. It uses the vernacular architecture of Yazd as an excellent example of the area, both culturally and climatically. Although this region is the focus of this study, the fundamental approaches can be manipulated for use in other hot-climate locations as a method of sustainable design.

Literature reviews and analysis of case studies show that current Iranian designs do not achieve the best performance from an environmental aspect. It is proposed in this study that implementing vernacular architectural principles results in significant performance improvements over the current methods and offers a new architectural design language. In conclusion, a series of guidelines and successful strategies are presented to aid the designer of tomorrow's buildings.

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Dedication

I dedicate this thesis to my family members who have been part of this journey, especially to

My loving mother, for being my first and best teacher and the source of inspiration throughout my life… for her unconditional love, friendship and caring,

My devoted father, for his unconditional love, endless support throughout my life and encouragement for higher education,

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Table of Contents

Author's Declaration iii

Abstract v

Acknowledgements vii

Dedication ix

Table of Contents xi

List of Illustrations xv

Chapter I: Problems of an Old Rich City 1

1.1. Introduction 2

1.2. Problems of an Old Rich City 3

1.2.1. Yazd's Old Urban Fabric 3

1.2.2. Emerging of New Buildings in the Heart of Old Urban Fabric 5

1.2.3. New Urban Fabric 6

1.2. Thesis Outline 8

Chapter II: Climate Adaptive Architecture in Hot-arid Climates 12

2.1. Architecture and Human Comfort in Hot Climate Zones 13

2.2. Vernacular Architecture: Climate Adaptive Architecture 18

2.3. Urban Design in Hot Climates (Persian Gulf Area) 22

Chapter III: Passive Natural Cooling and Ventilation System: Strategies 26

3.1. Typical Housing Architecture in the Region 27

3.2. Thermal Mass 28

3.3. Managing the Sun: 29

3.3.1. Openings 29

3.3.2. Roof 31

3.3.3. Absorption, Reflection and Transmission 32

3.3.4. Shading 33

3.3.4.1. Self-Shading and Neighbors' Shading 33

3.3.4.2. Iwans: Semi Open Areas 35

3.3.4.3. Exterior Shading 35

3.4. Courtyards 36

3.5. Planting and Vegetation and Placing a Pool 38

3.6. Windcatchers 38

3.6.1. The Role of the Windcatcher in Hot-arid Regions 38

3.6.2. Categories Based on Functions 41

3.6.3. Orientation, Location and Form of Windcatchers 43

3.6.4. Structure and Ornaments 45

Chapter IV: Yazd and Climate Adaptive Architecture 47

4.1. Historical Context 48

4.2. Geographical and Climatic Context 51

4.2.1. Limitations 57

4.2.2. Opportunities 57

4.3. Yazd Architecture Adaptation to Climate 58

4.4. Traditional Layout of Yazd 60

4.5. Modern Layout: Comparison between the Historical Quarter and Suburbs 63

4.6. Modern Building Design 68

Chapter V: Yazd in the Modern World 72

5.1. Modern Desires/Needs and the Government's Responses 73

5.2. The importance of Preservation 74

5.2.1. Case Study I: The Historic Centre of Bruges, Belgium 76

5.2.2. Case Study II: The Historic Quarter of Suleymanie, Istanbul 79

5.2.3. Case Study III: Historic Cordoba, Spain 82

5.2.4. Preserving Old Yazd 85

5.2.5. The Study Area 87

5.2.6. Suggesting Solutions for Preserving Old Yazd 95

5.3. Appearance of Modernity in the Historic Contexts 106

5.3.1. New Buildings in Old Yazd 108

5.3.2. Suggesting Solutions for New Buildings in Old Yazd 109

5.4. The collision of Tradition and Modernity 113

5.4.1. New Buildings in New Yazd 115

5.4.2. Case Study I: Masdar City, Abu Dhabi 116

5.4.3. Case Study II: National Commercial Bank in Jeddah, Saudi Arabia 118

5.4.4. Case Study III: A Low Energy Residence in Aqaba, Jordan 120

5.4.5. Suggesting Solutions for New Buildings in Old Yazd 124

Chapter VI: Conclusions **127**

6.1. Design Summary for Preservation of the Historic Core 129

6.2. Design Summary for New Buildings in Historic Core 130

6.3. Design Summary for New Buildings in New Yazd 131

6.4. The contribution of the author 131

References 134

List of Illustrations

Figures	page	Description & Source
Figure 1.	6	Population growth in Yazd, redrawn by author *Source:* (Modarres, 2006)
Figure 2.	7	Ages of different areas and the inorganic growth of Yazd are shown *Source:* (Zanganeh Shahraki, et al., 2011)
Figure 3.	8	Parts of old, new and transition quarters for comparison in Yazd's urban fabric *Source:* (Google Maps, 2013)
Figure 4.	10	Very compact, connected and continuous urban fabric of Yazd in historical quarter, photo by Mehdi Khobrehdast *Source: http://mosque.mihanblog.com/post/56*
Figure 5.	10	Modern architecture; the new urban fabric in Yazd photo by Chris Belsten *Source:http://www.flickr.com/photos/cjb22222222/3078271186/in/set-72157611069782360/*
Figure 6.	14	Developed Bioclimatic Chart based on Olgyay's Bioclimatic Chart (and two other charts) *Source:* (Olgyay, 1963) *http://www.shadyattia.net/academic/BioclimaticDesign/Lecture%2006.html* *http://www.quora.com/Heating/How-do-you-heat-a-room-in-winter-without-a-*
Figure 7.	16	Examples of radiation, air temperature (MRT) and airflow on comfort, drawn by author
Figure 8.	18	Vernacular architecture in New Mexico *Source: http://www.earthenhand.com/why/*
Figure 9.	19	Material used in traditional buildings in New Mexico *Source: http://www.urbanplanet.org/forums/index.php/topic/30835-pictures-of-santa-fe-new-mexico/*
Figure 10.	19	Vernacular architecture in Yazd *Source: http://www.cyrustravel.com/page.aspx?id=12*

Figure 11.	20	Material used in traditional buildings in Yazd *Source: www.irangashttour.com*
Figure 12.	22	The ratio of mass over void in the historical core of Yazd, drawn by author
Figure 13.	26	Plan of a traditional courtyard house in Yazd, Golshan House; the dots show the bent entrance to the courtyards of the house, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 14.	28	Summer and winter rooms and suites in Gloshan house; winter suites are illustrated by blue and summer rooms are shown by red, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 15.	28	The left picture is a beautiful glasswork in Dolatabad Garden, photo by Ali Golshan; the right one is the typical windows in traditional Yazdi courtyard houses photo by Lilo *Source: http://www.payvand.com/news/11/jul/1018.html* *http:/www.lilo.aminus3.com/image/2008-07-13.html*
Figure 16.	29	Combination of dome and flat roofs in Yazdi traditional houses, photo by Reine *Source: http://minkmachine.reine.se/2010/11/a-journey-through-iran/*
Figure 17.	31	Absorption, transmission and reflection in 6mm clear glass, drawn by author
Figure 18.	31	Self-shading in a traditional courtyard house in Yazd, photo by Fereydun Masomian *Source:* (MKH, 2014)
Figure 19.	32	Self-shading in the afternoon/morning in a traditional courtyard house, Golshan House, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 20.	32	Self-shading in the afternoon/morning in a traditional courtyard house, Golshan House, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 21.	33	Traditional exterior shading in Cairo, Egypt *Source: http://www.touregypt.net/featurestories/baytsuhaymi.htm*

Figure 22.	35	Different views of traditional courtyards in Yazd, the left photos by author, the top right by Nicolas Rapp and the bottom right by Alex Wilkinson *Source: http://www.transworldexpedition.com/ http://www.gardenhistorysociety.org/post/agenda/the-gardens-of-persia/*
Figure 23.	36	The earliest forms of windcatchers in Hyderabad, Pakistan *Source: http://insideflows.org/project/ancient-wind-catchers-in-hyderabad/*
Figure 24.	37	Traditional windcatcher in Iran *Source: http://www.skyscrapercity.com/showthread.php?t=1571425*
Figure 25.	38	Ground floor plan of Golshan house; the orientation of the prevailing wind and the location of the wind tower is indicated, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 26.	38	Section of a traditional courtyard house, Golshan House, with a wind tower; air circulation is indicated with arrows, illustration by author *Source:http://www.tejaratgah.com/273b261bc000450843a28e827bed54b0-1.html*
Figure 27.	39	Transferring and evaporating air by means of windcatchers in hot-arid regions *Source:* (May & Reid, 2010)
Figure 28.	41	Typical plan of one directional windcatcher, drawn by author
Figure 29.	41	The typical plan of two directional windcatcher, drawn by author
Figure 30.	41	Typical plan of four directional windcatcher, photo by Alireza Javaheri *Source: http://www.panoramio.com/photo/84776641*
Figure 31.	42	Typical plan of eight directional windcatcher, drawn by author
Figure 32.	42	Eight directional windcatcher in the Dolatabad Garden, the tallest windcatcher in Yazd, photos by Mauro *Source: http://www.panoramio.com/user/7705189/tags/Bagh-e%20Dolat%20Abad*
Figure 33.	48	Development of Yazd city *Source:* (Google Maps, 2012), (Modarres, 2006)
Figure 34.	49	Location of Iran in Middle East *Source:* (Google Maps, 2012)

Figure 35.	50	Iran's province divisions, Yazd Province and Yazd city, illustration by author
Figure 36.	51	Temperature variations of °C of Yazd city; the red line illustrates the minimum; the black one shows the maximum redrawn by author *Source: http://www.world-climates.com/city-climate-yazd-iran-asia/ http://en.allmetsat.com/climate/saudi-arabia.php?code=40821*
Figure 37.	51	Monthly average number of hours of sunshine per day, redrawn by author *Source: http://en.allmetsat.com/climate/saudi-arabia.php?code=40821*
Figure 38.	52	Any kind of precipitation including drizzle, rain, hail, sleet or snow, redrawn by author *Source: http://en.allmetsat.com/climate/saudi-arabia.php?code=40821*
Figure 39.	52	Wind Speed (m/s) of the average daily: minimum illustrated by red, maximum by green, and average by black *Source: www.weatherspark.com/averages/32839/Yazd-Iran*
Figure 40.	53	Various percentages of wind direction over the entire year *Source: www.weatherspark.com/averages/32839/Yazd-Iran*
Figure 41.	53	"The fraction of time spent with the wind blowing from the various directions on a daily basis" *Source: www.weatherspark.com/averages/32839/Yazd-Iran*
Figure 42.	56	Compact, connected and continuous urban fabric of Yazd; a response to the harsh climate condition *Source: http://www.traveldirectors.com.au/tours/treasures-of-persia-and-the-caucasus*
Figure 43.	58	Old urban fabric of Yazd city; historical quarter. Amir Chakhmagh complex (the main square) in the heart of the historical quarter is distinguishable *Source:* (Google Maps, 2012)
Figure 44.	59	Narrow and irregular winding streets, photos by author
Figure 45.	59	Narrow and irregular covered winding alleys *Source: http://www.skyscrapercity.com/showthread.php?t=1571425*
Figure 46.	61	Visible dissimilarity in new and old urban fabric of Yazd *Source:* (Google Maps, 2013)
Figure 47.	62	Street map of Yazd in the mid-1990s, identifying selected street added or completed during last three decades *Source:* (Modarres, 2006)

Figure 48.	63	A boulevard in one of the new quarters of Yazd, photo by author
Figure 49.	63	Poor use of vegetation in wide modern streets with little shade, drawn by author
Figure 50.	64	Use of trees to provide shade for the pedestrians *Source: https://londontosydneybybike.wordpress.com/photos-iran/tehran-to-yazd-096/*
Figure 51.	64	The correct use of vegetation provides shade for the pedestrians' sidewalks, drawn by author
Figure 52.	65	Modern architecture in Yazd, photo by Mehrdad Tadjdidni *Source:http://www.trekearth.com/gallery/Middle_East/Iran/East/Yazd/Yazd/photo1276140.htm*
Figure 53.	67	New buildings in the new urban fabric of Yazd, photos by author
Figure 54.	72	The historic fabric of Bruges *Source:* (Wikipedia, 2014)
Figure 55.	73	The compact and dense urban fabric of historic Bruges *Source:* (Google Maps, 2014)
Figure 56.	73	The ring road around the historic city of Bruges *Source: ibid*
Figure 57.	74	Winding and narrow streets of Bruges, photos by Peter Collision *Source: www.flickr.comphotospcollison12524540535inphotostream*
Figure 58.	74	Winding streets of Bruges in the historic core *Source: http://www.asthebirdfliesblog.com/2014/01/Photos-of-Bruges-at-Christmas-in-Belgium.html#.U3AwxoFdWSp* *http://commons.wikimedia.org/wiki/File:Bruges_road.jpg*
Figure 59.	76	Narrow streets near the Suleymaniye Complex Source: *http://www.ibrahimpasha.com/assets/images/guide/fener.jpg*
Figure 60.	77	The dense urban fabric with the narrow streets and alleys *Source: http://www.ibrahimpasha.com/guide-architecture.html* *http://mandntakeistanbul.wordpress.com/author/ndk4yx/page/6/*
Figure 61.	78	The urban fabric of the historic district of Cordoba *Source:https://www.google.com/maps/place/C%C3%B3rdoba,+Spain/@37.8865057,4.7797217,15z/data=!4m2!3m1!1s0xd6cdf26f95e0aef:0x4df1d2e8108456c3*
Figure 62.	79	The urban fabric in the historic area

Source: https://veganwellbeing.wordpress.com/tag/cycling/
http://www.mikemurphy.nl/Cordoba.html

Figure 63. 79 The Jewish quarter with its narrow alleys
Source:http://www.experienciavivees.com/english/cordoba-program/cordoba-sevilla-natural-park-october-19-6-days-390/
http://www.sailblogs.com/member/sobellachronicles/?xjMsgID=107523

Figure 64. 80 Car access in the historic area
Source:https://impositivelysomewhere.wordpress.com/tag/mezquita-de-cordoba/
http://rnwoodward.blogspot.ca/2012_12_01_archive.html

Figure 65. 80 Tourist shops in the historic district in the irregular narrow streets
Source: http://thetravelaffair.net/travel-affairs/captivated-by-cordoba/
http://www.flickriver.com/photos/tags/touristshops/interesting/

Figure 66. 84 The historic core, the selected study area and the city limits are indicated in this map
Source: The photo is taken from the city hall of Yazd

Figure 67. 85 The function of the buildings, spaces and services are defined by means of colors in the historic core and the study area
Source: ibid

Figure 68. 86 Map of the transportation routes and the distance from the old housing
Source: ibid

Figure 69. 87 Aerial photo with the illustration of transportation routes in the study area
Source: ibid

Figure 70. 88 Aerial photo with the pedestrian routes shown
Source: ibid

Figure 71. 89 Aerial photo with the illustration of derelict and collapsed building sites in the study area
Source: ibid

Figure 72. 90 Aerial photo with the illustration of empty spaces/void in the study area
Source: ibid

Figure 73. 92 Parking (Pa) with its neighboring health service (H), Jami Mosque, covered bazaar and the close administration offices (Ad)
Source: ibid

Figure 74. 94 Expansion of the selected site for Parking a
Source: http://mosque.mihanblog.com/post/56

Figure 75.	95	The expansion of the parking a from another view *Source: The photo is taken from the city hall of Yazd*
Figure 76.	96	The smallest available ambulance, firefighter car and garbage truck *Source: http://www.cardekho.com/india-car-news/tata-motors-all-set-to-launch-new-mcv-buses-for-intercity-and-staff-transportation-9710.htm* (Wikipedia, 2011) *http://sweden.kcomposite.com/tiny-garbage-collection-truck/*
Figure 77.	97	Green Fields are chosen for functioning as parks, playgrounds and sport fields *Source: The photo is taken from the city hall of Yazd*
Figure 78.	98	The clinic and the adjacent parking lot (Pa) are shown in the picture *Source: ibid*
Figure 79.	99	The expansion of clinic site by adding the front empty space and the non-valuable shops *Source: ibid*
Figure 80.	100	The expansion of clinic site from another view *Source: http://mosque.mihanblog.com/post/56*
Figure 81.	101	The selected site for the school and the adjutant parking lot, Pc, are indicated *Source: The photo is taken from the city hall of Yazd*
Figure 82.	106	Recommended wall details for new buildings in old Yazd, drawn by author
Figure 83.	107	The chosen sites for the administration offices in the study area *Source: The photo is taken from the city hall of Yazd*
Figure 84.	108	The selected sites of administration offices and the close temporary parking lots (TP)/overflow parking for the clients *Source: ibid*
Figure 85.	113	The urban fabric of Masdar city *Source: http://masdarcity.ae/en/78/master-plan/*
Figure 86.	114	Modern sustainable features according to the fundamental vernacular architecture used in designing the city; the modern wind tower is shown in the left picture and the right picture illustrates the shading that is achieved by densely designed buildings *Source: http://masdarcity.ae/en/78/master-plan/*
Figure 87.	114	Exterior shading; a culturally accepted strategy for shading in the region

Source: http://masdarcity.ae/en/78/master-plan/

Figure 88. 115 Different views of National Commercial Bank in Jeddah, Saudi Arabia
Source: http://archnet.org/sites/483/publications/2712
http://www.relbanks.com/asia/saudi-arabia/national-commercial-bank
http://www.epdlp.com/edificio.php?id=143

Figure 89. 116 The sky-courtyards are shown in the left picture and the circular parking in the right
Source: http://www.jeddahpoint.com/balad-in-jeddah.html
http://abduzeedo.com/architect-day-som-skidmore-owings-merrill

Figure 90. 117 The low energy residence in Aqaba, Jordan
Source:http://www.archined.nl/en/features/aqabaresidenceenergyefficiencyinjordan/

Figure 91. 118 The main staircase is designed to work as a wind tower; view from inside and out
Source: ibid

Figure 92. 119 The section of the residence
Source: ibid

Figure 93. 119 The roof garden and the use of shading
Source: http://www.archi-mag.com/eng/aqaba_eng.php

Chapter I: Problems of an Old Rich City

1.1. Introduction

Sustainability in architecture, which is closely related to energy, climate and ecology, has been considered carefully in recent decades. An expanding world population, negative environmental impact, global warming, diminishing natural resources, etc., mean an uncertain future. Many architects have written books, newspaper and journal articles to address these problems so that future generations do not have to deal with them. Unfortunately, very few architects highlight the integral role that the now almost forgotten vernacular architecture (Dahl, 2010), which was very well-adapted to climate, played in previous generations.

In developing countries in the Middle East, such as Iran, there are a number of excellent examples of sustainability in historical vernacular architecture and in old urban texture. However, their governments do not consider sustainability important. Moreover, the modernization of Iran has led to accelerated urban growth and development in cities, having a direct impact on vernacular and traditional architecture. This phenomenon has changed the relationship between the built environment and the cultural values of society (Shamollahi, Selamat, & Jamluddin, 2012); Changing attitudes and demands are the evidence of this change. Mass migrations to the cities, moving from old areas to modern and developed areas of cities, have resulted in the abandonment of valuable historical quarters. The residents of the historic core are seeking for living in the developed comfortable areas to utilize modern transportation systems and construction technologies.

Iranian contemporary architecture has emulated modern architecture in terms of constructing high-rise buildings with modern materials—system forms, urban grid forms, wide and straight streets, and suburban and urban highways—without considering the benefits of the fundamental sustainable urban principles in the cities (Yousefi & Nejadkoorki, 2012). Today, it seems that the city planning and designing are based on vehicle use and requirements instead of human needs and comfort. Jane Jacobs pointed to the widespread influence of changing the approach to city planning, which may cause different problems in North American cities: “the automobile has been the chief destroyer of communities” (Jacobs, 2004). She stated that

> *The simple needs of automobiles are more easily understood and satisfied than the complex needs of cities, and a growing number of planners and designers have come to*

> *believe that if they can only solve the problems of traffic, they will have solved the major problem of cities. Cities have much more intricate economic and social concerns than automobile traffic. How can you know what to try with traffic until you know how the city itself works, and what else it needs to do with its streets? You can't.… The planners do not know what to do with automobiles in cities because they do not know how to plan for workable and vital cities anyhow—with or without automobiles* (Jacobs, 1961).

Modern cities are planned in order to give the automobile easy access, and the very basic needs of human comfort are being ignored or not taken seriously. A city's distinguishable urban identity, cultural identity and peoples' demands and needs are affected by the very familiar and complicated phenomenon of modernization.

1.2. Problems of an Old Rich City

Yazd, an extremely beautiful city in the heart of the Iranian plateau, embraces many historical and architectural wonders: irregular narrow and winding streets and alleys, several medieval mosques, religious schools, tombs, caravanserais[i] and special architectural elements such as qanats[ii], windcatchers[iii] and domed roofs. Yazd has always been known for its unique, dense and compressed urban fabric and adaptation to climate. The city, however, has gradually lost its cohesion in its physical and social context because of the rapid growth in population. The resulting urban expansion has caused various issues that are still unsolved. Yazd can be used as an example of the challenges facing most Iranian cities and their historic buildings. The following sections explore each of these problems.

1.2.1. Yazd's Old Urban Fabric

Sustainability in architecture can be defined as consuming fewer resources (material, energy, etc.) in the construction and operation of buildings and cities while releasing fewer pollutants and destroying fewer habitats. One approach to sustainability in architecture relies on natural forces to provide comfort and utility to buildings. The historical architecture of Yazd is a perfect example of the vernacular forms of architecture used in this approach. However, the wave of modernity has affected all aspects of this

[i] A roadside inn with a central courtyard where the travelers in the desert regions could rest.
[ii] Ancient underground water canal system.
[iii] A vernacular passive cooling system used in the Persian Gulf region.

historical city.

Today, different cities worldwide develop according to the global cultural features that impose western culture as the global culture. Therefore, these cities are very similar without a distinguishable urban identity. However, Yazd, as one of the oldest cities in Iran, has been affected by different historical influences and has always had a distinct urban identity and culture. Unfortunately, during the last century, the emergence of modernity and westernization significantly influenced both the cultural identity and social characteristics of the city. As a result, there was a major impact on the quickly disappearing local culture thereby destroying the sense of place. Due to the destruction of the sense of place and the inability of the city to maintain the vernacular monumental architecture, the identity and historical characteristics of the city will be sacrificed. Yazd's urban identity is shaped by historical monuments and a cultural heritage [iv] that should be inherited by the next generations. Since modernization and western city planning are being followed instead of traditional and vernacular urban orientations, unfortunately other ancient cities in developing countries similar to Yazd are gradually being demolished. The modernization and urban developments in the urban texture of Yazd will have a direct negative impact on Yazd's identity in the future. If the urban designers codify the principles of the previous fundamental climatic factors of the old area, Yazd's identity can be revitalized in new urban textures (Shamollahi, Selamat, & Jamluddin, 2012).

The rapid growth of technology has resulted in a social, economic and cultural change in people's expectations about life due to more urban facilities and services becoming available. People may believe that their demands for the modern lifestyle cannot be met in historical neighborhoods of the city. These historical areas are gradually being abandoned as a result. In addition, the unfeasibility of changes in the conventional infrastructure results in the gradual demolition of historical neighborhoods and the loss of cultural heritage (Abouei, 2006). Although attempts have been made to use complicated controlling systems in designing modern buildings in order to maximize occupants' comfort, it seems that instead, their level of discomfort has increased. These problems can be the result of failure in modern fundamental principles of architectural designs.

Rapid modernization of the historical quarters of cities has an impact on the lifestyles of residents. For instance, they need vehicles for various purposes; therefore, they need parking lots and easy access to

[iv] Cultural heritage is a term used for either physical artifacts such as objects and places or for ways of living, customs, folklore, practices, values, etc. defined by a community or society that are inherited from generation to generation. Cultural heritage embraces built environment (buildings, archaeological remains, etc.), artifacts (books, documents, objects, pictures, etc.), and natural environment (Wikipedia, 2012).

their homes in the historical part, which has narrow and irregular streets. Although the residents of these traditional buildings in historical quarters do not have access to modern facilities, most still enjoy the quality of living in these unique buildings; the lack of sound pollution, the calmness and peace in the large houses they share with family, privacy in their large houses with huge courtyards, plants and pools are more appealing features than living in a small, noisy flat or apartment, with no privacy. For tourists, the brick domed roofs, windcatchers, forms, designs and the traditional features of these houses are the main attraction to experience staying in these kinds of houses (Abouei, 2006).

Another problem is that the older buildings in the historical part are not as resistant to earthquake damage as modern buildings. Reinforcing historical monuments not only helps reduce the number of fatalities and amount of destruction, but also conserves the cultural heritage. Preservation of the cultural heritage buildings and historical monuments is not only a cultural necessity but also an economic and development requirement for Yazd. The consequence is economic growth by attracting tourists which results in development to the city (Okhovat, Almasifar, & Bemanian, 2011).

Climate adaptation designs in Yazd have some prominent architectural features such as the windcatcher, qanat, and cistern; all have been necessary due to the special climate of the region and built-in. Windcatcher, or wind tower, is a traditional ventilation and cooling system used in hot-arid and hot-humid climates that draws cool, fresh and clean air in and pushes the warm and polluted air out. It also provides humidity to the incoming air by means of a pond at the bottom end of the tower. Today, five hundred windcatchers on the roofs of Yazd's traditional houses in the historical area share the roof space with modern mechanical cooling and ventilating systems. The other feature, qanat, the water canal underneath the house that provides cold and fresh water during all the seasons can be accessed from the basement. There are 3,300 qanats in Yazd province; fortunately, 3000 are still in use. Since the number of inhabitants in the old urban fabric is decreasing and many of these architectural elements are not in use, they are falling into disrepair and risk removal or collapse. Furthermore, due to the industrial waste of local factories in the city, these valuable traditional underground services are gradually becoming polluted (Abouei, 2006).

1.2.2. Emerging of New Buildings in The Heart of Old Urban fabric

Studying the characteristics of the traditional architectural elements helps architects to understand the diverse applications and flexibility of combining the old facilities with modern ones into a hybrid system

to increase productivity and do the least damage to the surrounding environment. Moreover, the hybrid designs in the old core of the city act as the link between the historical quarter and the new developed areas, connecting the ancient cultural identity to the modern unknown culture and history to the mysterious future.

These types of design should embrace all aspects of vernacular principles and appropriate modern approaches. Unfortunately, very few are found as transition designs in city. Most of the new buildings in the old core neither consider following the vernacular principles of building design nor are compatible with the surrounding built environment.

1.2.3. New Urban Fabric

In the last few decades, there has been significant development and growth in the cities of Iran. According to the United Nations estimates, Iran's urban population will reach 80% of the total population in 2020 (Zanganeh Shahraki, et al., 2011), which is very close to Canada. Yazd, one of the provincial cities of Iran, is no exception. It has been reported that of the 60 million people who completed the last Iranian population survey in 1996, 37 million, or almost 61%, lived in cities. And within Yazd province, one of the most highly urbanized provinces in Iran, almost 75 percent of the population lives in cities. The city of Yazd has grown from a large town with a population of 63,000 in 1956 to a mid-size city [v] with 330,000 residents in 1996 and 582,682 residents in 2012 (Modarres, 2006) [Figure 1]. The area of the city has grown to accommodate new population.

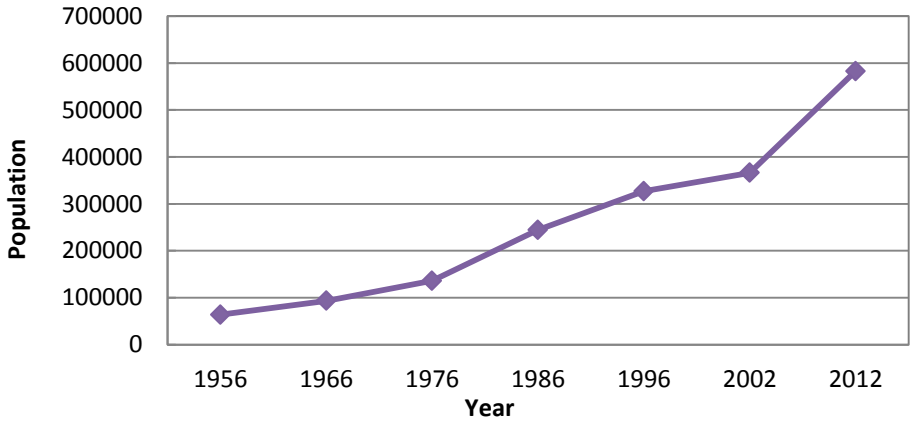

Figure 1. Population growth in Yazd, redrawn by author

[v] According to the Ministry of Housing and Urban Development of Iran, a city with the population of 100,000 to 500,000 is considered a medium-sized city (Zanganeh Shahraki, et al., 2011).

Yazd has experienced two different kinds of organic and inorganic growth in order to accommodate the growing population. The physical or organic growth is the result of changes in population and lifestyles, whereas the inorganic growth is the result of small villages, by different organizations in the south, west and east, becoming part of the city as it expands (Yousefi & Nejadkoorki, 2012). Currently, Yazd city is expanding towards the northwest and southeast. The result of this expansion, which is the consequence of the population growth, is an increase in the local traffic and the level of industrial activities in the surrounding areas (Nejadkoorki & Ziajahromi, 2011). Consequently, these connections increase the urban growth in an inorganic way. Today, the city has become five times larger than in the 1950s (Modarres, 2006)[Figure 2].

Some of the historical parts of the city are vacant, whereas the city limits are continuously expanding. This is causing an imbalance in population density in different areas, the destruction and gradual demolition of older neighborhoods and the steady departure of residents. Due to this rapid and sudden growth, it is not surprising that the historical part of Yazd today has been lost. Unfortunately, some of these neighborhoods have become home to immigrants and poor residents who cannot afford to maintain or repair these houses that are the most important parts of Iranian heritage in vernacular architecture.

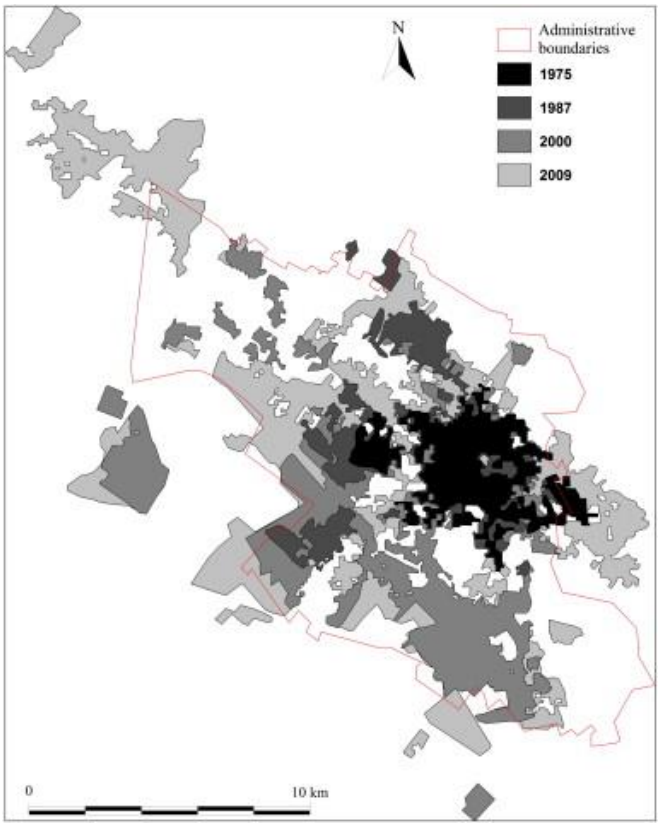

Figure 2. Ages of different areas and the inorganic growth of Yazd are shown

1.3. Thesis Outline

The most significant problems of this old rich city are the gradual destruction of the historical quarter and its valuable cultural heritage resulting from abandonment and depopulation. On the other hand, there is a disconnect between the old rich core and the developing areas in the new quarters of the city; the new buildings that have poor environmental performance, ugly tract housing and new regular suburban grid, which are inconsistent with local climate factors and history in terms of architecture and urban planning. These unanswered questions about these problems can be categorized in three sections that will be explored in the following chapters:

1. How to conserve, preserve and reinforce the old urban fabric, as a successful example of sustainability and environmentally friendly architecture. (OLD)
2. How new buildings in the old quarter should apply the vernacular, sustainable principles with a modern approach and interact with historical surroundings. (TRANSITION)
3. How the new urban fabric and building designs should be developed. (NEW) [Figure 3]

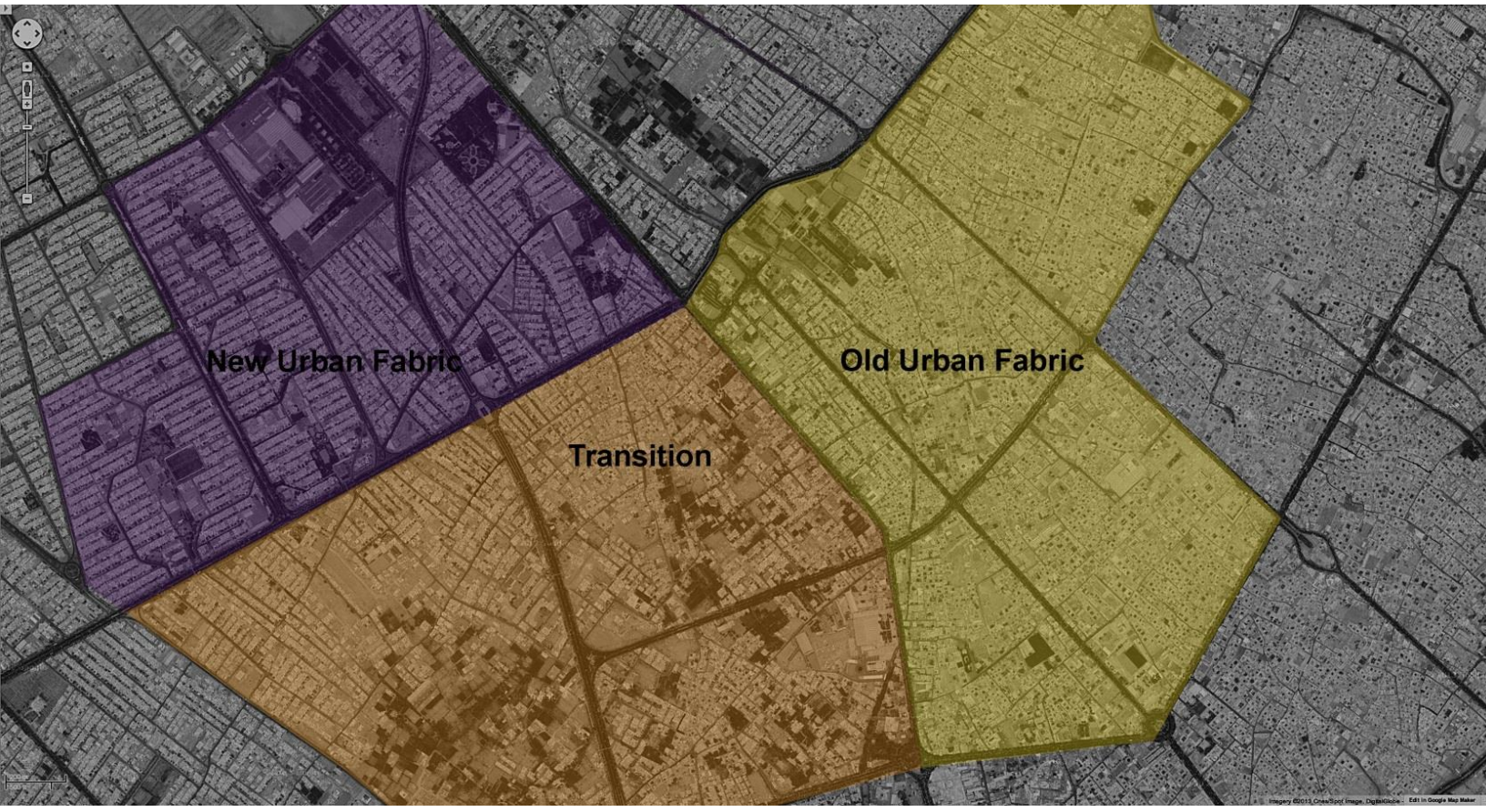

Figure 3. Parts of old, new and transition quarters for comparison in Yazd's urban fabric

This thesis focuses on the vernacular architecture found in hot-arid climates like in Iran and some of the Arab countries near the Persian Gulf. This thesis will use the vernacular architecture of Yazd as an example of the area, both culturally and climatically. Although this region is the focus of this study, the fundamental approaches can be manipulated for use in other hot-arid climate locations as a method of sustainable strategy.

Literature review and case studies are used to show that current Iranian designs do not achieve the best performance from an environmental perspective. As the modern Iranian design approach does not respect the needs of modern Iranians to the traditions, the existing architectural language, living environment, quality of human life, and the success of vernacular architecture.

A comparison between the old and new designs in nano, micro, meso and macro scales clearly shows the lack of sustainability concerns in designing modern buildings [Figure 5, 6]. This study proposes that an implementation of vernacular architectural principles would result in significant performance improvements over the current methods; it offers up a new architectural design language. A series of guidelines and successful strategies will be developed and presented to aid the designers of tomorrow's buildings.

Figure 4. Very compact, connected and continuous urban fabric of Yazd in historical quarter, photo by Mehdi Khobrehdast

Figure 5. Modern architecture; the new urban fabric in Yazd photo by Chris Belsten

Chapter II: Climate Adaptive Architecture in Hot-arid Climates

To understand how vernacular designs work it is necessary to briefly review the human comfort first. Second, it should be investigated how the traditional architects could link the human built environment with nature and cultural values.

2.1. Architecture and Human Comfort in Hot Climate Zones

Thermal comfort and climate-adaptive designs have always been very closely related. The ancient builders knew what the requirements for comfort were and how to adapt their designs to meet these conditions (Saberi, Saneei, & Javanbakht, 2002). One of the most significant goals of architecture has always been to provide a comfortable space to live. The term "comfort," as defined in the Oxford Dictionary, is "a state of physical ease and freedom from pain or constraint; things that contribute to physical ease and well-being." In Webster's Concise Dictionary, comfort is defined as "a state of ease and satisfaction of bodily wants" (Dahl, 2010). These definitions are very close to today's use and concept of this term.

Although the geographical location of the buildings plays an important role in people's perception of comfort, other factors have a direct impact on their definition of comfort level. Comfort temperature is not only the air temperature but more correctly refers to the operative temperature.

> *The operative temperature is a combination of the air temperature, the weighted average of all surface temperatures of a space (defined by the mean radiant temperature, MRT), and air velocity. At low air velocity, the operative temperature is the simple average of the MRT and air temperature* (Straube, 2009).

The human body has a core temperature of 37° C: if this temperature rises or falls more than 1 degree, serious health impacts begin. Under most conditions, heat must be lost to the environment regulate the body temperature.

Generally, heat transfer can occur by three different methods: thermal convection, thermal conduction and thermal radiation. With the same interior room temperature, even in the comfort zone, one person can be comfortable in one condition and another person uncomfortable in a slightly different condition.

To measure comfort accurately, environmental factors—such as air velocity, air temperature, mean radiant temperature (MRT), humidity—and personal factors, such as metabolic rate and clothing, should be taken into consideration. The relevance of these factors to the comfort level of the human body is expressed as follows:

Air Temperature is defined as the air surrounding the body and is in °C or °F.

Mean Radiant Temperature (MRT) is an equivalent temperature due to radiation from or to surfaces in their surrounding environment. As humans give off and absorb heat by radiation, a lower MRT will result in more heat loss from a person, and a higher MRT (or direct solar radiation) will result in heat gain or less heat loss by a person.

Air Velocity is defined as the speed of air which is measured by m/s and km/h. Since people are sensitive to air speed, it plays an important role in thermal comfort. If air flows over a person, heat loss by convection and evaporation cools them down.

Relative Humidity (RH) is "the ratio (expressed as a percentage) of the amount of moisture within the air to the maximum amount of moisture that the air could possibly contain at a specific temperature" (Building Science Corporation). Low RH air allows for faster evaporation from the human body (resulting in cooling) whereas high RH shows evaporation.

Clothing is very closely related to thermal comfort or discomfort as the addition or removal of layers of clothes changes the insulation level around the body. The insulation level provided by clothing is measured in units of Clo. Higher levels of insulation slows heat loss from the body, lower levels of clothing allows for increased heat loss.

Metabolic Rate is the heat rate which is produced inside the human body as a result of physical activity. Higher activity generates more heat, which may require more cooling.

The widely accepted definition of thermal comfort by ASHRAE, American Society of Heating, Refrigerating and Air-conditioning Engineers, ASHRAE Standard 55 is:
"Thermal Comfort is that condition of mind that expresses satisfaction with the thermal environment", it is acceptable when it "ensures the absence of damaging effects on health and ensures the satisfaction of at least 80% of the users of the building" (Dahl, 2010). It is commonly quoted that an acceptable

comfortable interior temperature for occupants is approximately 22°C ± 2°C (68 °F – 75 °F) and 20-60% relative humidity. This range of temperature and RH assumes a specific set of clothing, MRT equal to air temperature, sedentary office worker metabolic rate, and no air flow.

A more complete picture of comfort will include all of the important factors. To this end, a comfort chart was developed by combining information from *Design with Climate* by Victor Olgyay (Olgyay, 1963), (Quara, 2013) and (Bioclimatic Design, 2006) provide more information to better understand the comfort zone and comfortable condition [Figure 6]. In this chart, when the temperature is over 24°C, wind is needed to keep the comfort condition in balance; whereas when the temperature is lower than 20°C, more solar radiation is necessary to maintain the comfort level. When the temperature is 25°C or higher, faster air flow as well as shading are required. When the relative humidity (RH) is lower than 20% or more than 60%, conditions become uncomfortable. Thus, according to the local climate conditions, passive thermal design strategies (natural ventilation, high mass, high mass with night ventilation and evaporative cooling) can be considered to meet comfort desires.

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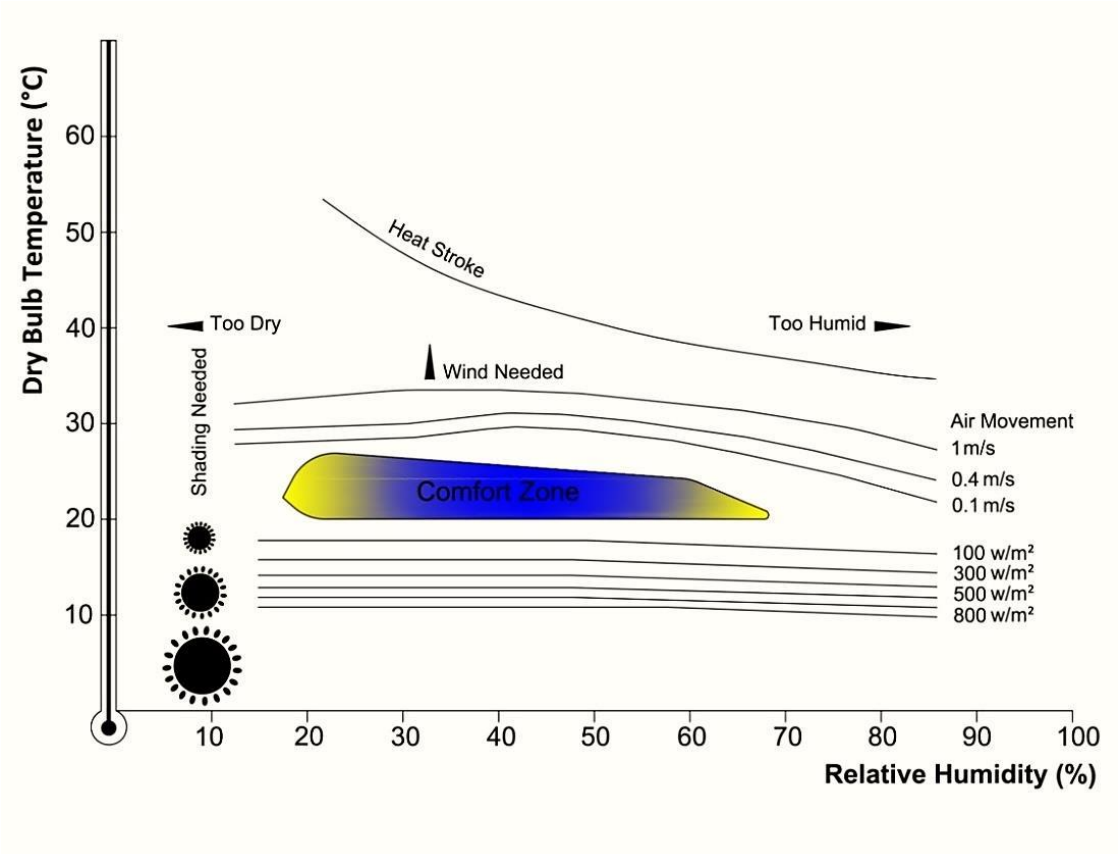

Figure 6. Developed Bioclimatic Chart based on Olgyay's Bioclimatic Chart (and two other charts)

Although Figure 8 shows the impact of air speed, RH and sun within a building or specific room, different air temperatures may result in different comfort levels depending on solar radiation to and from the room's surfaces, and to and from the occupants. Radiation through windows, radiation to cold walls or air flow caused by ceiling fans can modify the comfort zone.
To clarify, some examples explain these conditions of comfort based on simple physics laws and principles [Figure 7].

In Figure 7A, although the room air temperature in both conditions is 28°C, beyond the comfort zone, there is a significant difference in the overall feeling of comfort for these two occupants. The air movement (caused by ceiling fans) in addition to shading (due to overhangs) plays a major role in decreasing the 'feels like temperature', whereas the solar radiation through windows has a direct impact on increasing the overall discomfort.

In Figure 7B, even though the room air temperatures for both occupants are 24°C (in the comfort zone), shading decreased the direct impact of sun radiation on the overall feeling of comfort; one room feels like 24°C (still in comfort zone), whereas, the other feels like 28°C.

In Figure 7C, the heat is transferred from the inside to the outside through the window, and the occupant is not comfortable since he radiates the heat to the cold windows and walls (low MRT), hence the 'feels like temperature' has dropped from 22°C (in the comfort zone) to 19°C, whereas the other occupant is happy since the correct mass and insulation have been used.

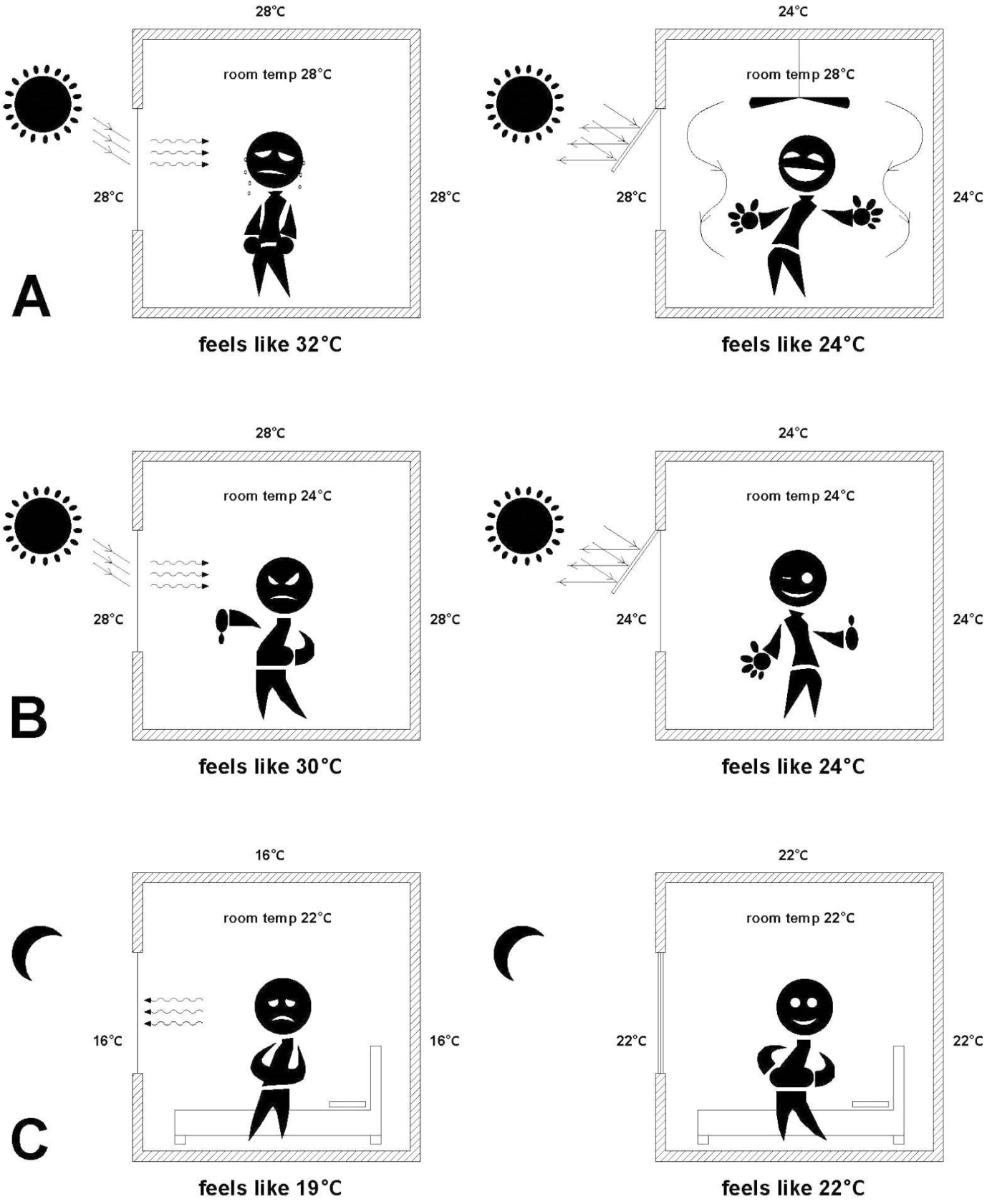

Figure 7. Examples of radiation, air temperature (MRT) and airflow on comfort, drawn by author

2.2. Vernacular Architecture: Climate-adaptive Architecture

Although attempts have been made to use energy intensive mechanical and complex control systems in designing modern buildings in order to maximize occupants' comfort, to some, it appears that the occupants' level of discomfort has actually increased (Abouei, 2006). The reason may be the differences in temperature, humidity, draught, light, sound etc. In contrast, in vernacular architecture, climatic adaptive design results in a high level of comfort for the occupants, with little or no mechanical equipment.

Without access to mechanical air conditioning, the ancient builders attempted to adapt their designs to the climatic conditions to provide the best comfort they could, relying only on the accessible resources of the region (climate responsive design). In particular, in the desert regions, due to the lack of energy resources and water, they were forced to build houses based on minimum energy consumption to enhance the interior conditions of a building in the absence of modern cooling systems. The available natural resources such as prevailing winds and day-night swings, etc. were used. These strategies may be used today to provide healthy, sustainable and comfortable living space for the occupants.

The interaction of use, control and climate is the key factor in vernacular architecture that has been neglected in contemporary architecture. A richer method of design can be achieved by a detailed study of climatic factors and the interaction of these factors with the human body and the building. A study of vernacular architecture proposes that understanding climatic adaption design is necessary to optimize natural resources in order to reach an actual level of sustainability in the built environment (Dahl, 2010).

Two thousand years ago, Vitruvius, a Roman architect, stated in his 6th book of *The Ten Books on Architecture*

> *If our designs for private houses are to be correct, we must at the outset note of the countries and climates in which they are built. One style of house seems appropriate to build in Egypt, another in Spain, a different kind in Pontus, one still different in Rome, and so on with lands and countries of other characteristics* (Dahl, 2010).

Architecture plays a role in connecting humans, climate and place. Vernacular architecture is based on the adaption to local conditions in different parts of the world (Dahl, 2010). Different factors can influence design, for instance, the availability of local materials to respond to the climate conditions, the religion or culture of people and the social character of that region.

It is interesting to note the similarity of materials used in Yazd and, for instance in other hot-dry regions such as New Mexico. Although they are located on different continents, very far from each other, both share very similar climatic conditions. This similarity in climatic conditions resulted in the same strategies and same use of available materials in both New Mexico [Figure 8, 9] and Yazd [Figure 10, 11] in order to provide occupants with a comfortable living space.

Figure 8. Vernacular architecture in New Mexico

The harmony of the human built environment with nature, cultural values and the climatic conditions of cities in different zones is definitely visible in the sustainable design strategies of the traditional architecture in these zones (TolouBehbood, Taleghani, & Heidari, 2010).

Figure 9. Material used in traditional buildings in New Mexico

Figure 10. Vernacular architecture in Yazd

Figure 11. Material used in traditional buildings in Yazd

In vernacular architecture, successful solutions to the problem of climate were not based on a scientific way of thinking. Designs were based on countless accidents (experiment based) by different generations of traditional builders who learned to use what worked and to ignore what did not. For many centuries, the traditional architects were completely dependent on natural energy resources and available local materials to form their built environment, and they learned how to interact with their climate. They created and added sets of principles for the next generations based on all these accidents and experiments. These principles are about the process of the whole and in detailed designs are based on the availability of resources, choice of materials, consideration of climate, site selection, orientation of buildings, culture of the place, method of design, etc. (Fathy, 1986).

Hassan Fathy in his book, Natural Energy and Vernacular Architecture, states that

> *In the environment of continuously changing pressure, wind movement, temperature, humidity, cloud cover, an architect places a fix building. Such a rigid structure is intended to provide comfortable internal environment over a wide range of these external*

variables. How can a rigid man-made object respond to these changes? Shouldn't it be like a living organism which continuously adapts itself to the flux of its environment?

As mentioned previously, cultural values play an important role in traditional designs. The vernacular architecture in Yazd and Cairo, Egypt, both share more or less similar climatic conditions in addition to the same cultural values, resulting in some of the same strategies in the traditional designs of houses. An introverted architecture in these two cities is based not only on the climatic conditions but also on the need for privacy; for instance, the location of the entrance to the house is designed to prevent a straight view from the outside; the courtyard is inside the house instead of outside; iwans or openings such as windows are designed to face the inside courtyard, etc. (Dahl, 2010).

2.3. Urban Design in Hot Climates (Persian Gulf Area)

Expanding awareness of the vernacular architecture of existing inherited cities of the past not only enriches the contemporary climate adaptive architecture but also expresses the need for preservation of these cultural heritages (Okhovat, Almasifar, & Bemanian, 2011). Contemporary designs in hot-arid zones still have much to learn from the past.

Modernization has had a major impact on urban forms in the hot zones in Persian Gulf cities. In order to become modernized, these cities have replicated the western symbols of modernity such as high-rise buildings with modern materials and systems, urban grid forms, wide and straight streets, etc. Since the compatibility of the materials, forms and designs with climatic context is not considered, this phenomenon is out of sync with the history of the region (Ben-Hamouche, 2008).

The overall layout of old cities was based primarily on the climate characteristics of their zones and defense strategies against their enemies during wars. The urban textures in hot climates, in particular in hot-arid regions, were built very densely in order to protect the occupants from the harsh climatic conditions. In fact, urban density was and is a key factor in traditional city planning as a response to hot-arid climatic conditions. Almost all cities in hot-arid zones have prominent key components such as narrow irregular winding streets that surrounded connected residences with tall walls resulting in high density, courtyards with large gardens and pools, and use of materials with high thermal mass, etc.
Yazd, Kashan (Iran), Cairo (Egypt), Manama (Bahrain), etc., are shaped by very dense and continuous urban fabric surrounded by narrow and irregular alleys. In Yazd and Kashan, in particular, buildings are

connected tightly together and oriented based on the direction of the sun and prevailing wind. A typical building plan for these kinds of houses, categorized as introverted architecture style, is a private central courtyard surrounded by one or two storey buildings. The local materials are mostly earth and unbaked bricks depending on the availability. The builders usually used the earth excavated for foundations and below grade space. Most of these principles of the old urban fabric of Yazd and Kashan are similar to other desert cities in the Middle East.

One of the most interesting and prominent characteristics of these cities is the relationship between mass and void. The domination of mass over void at the city level is noticeable [Figure 12]. The ratio of mass over the voids of the houses is also very similar. On a city scale, void embraces open public areas, streets and alleys, central courtyards of the houses, etc., and on a residential scale, void includes all the openings such as windows, doors, etc. onto the mass of the walls (Ben-Hamouche, 2008).

Generally, the urban texture of old cities in the Middle East was shaped by main components such as mosques, bazaars, palaces, maidans (squares), hammams (public baths), madrasahs (religious schools) and courtyard houses.

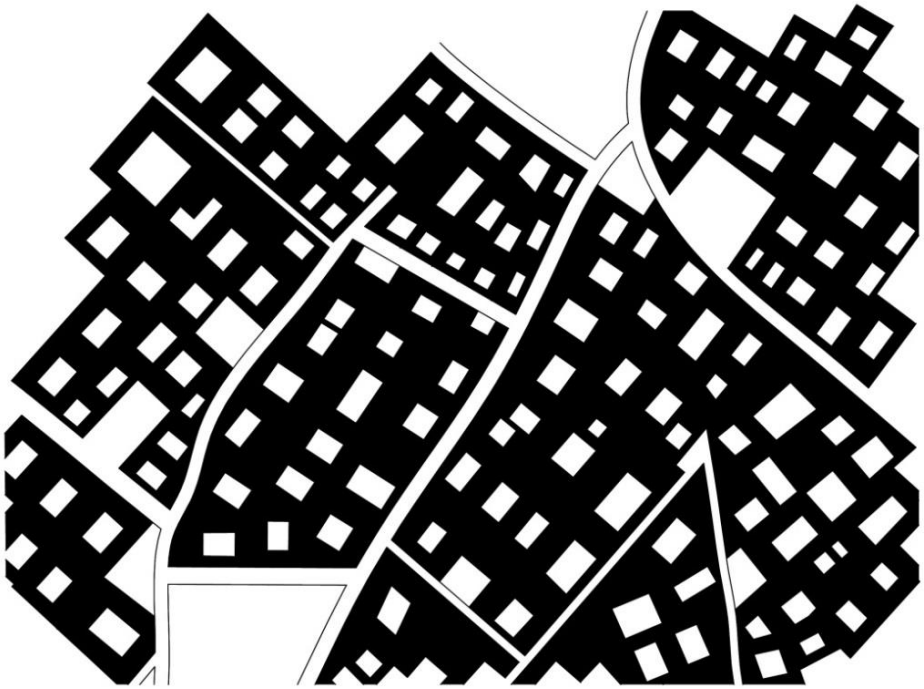

Figure 12. The ratio of mass over void in the historical core of Yazd, drawn by author

After the Arab invasions of the Middle East countries, the structure of the cities transformed to meet Islamic requirements. Usually the mosque was built in the centre which was connected to the main traditional bazaar, palace, madrasah and hammam, and the remaining components were located around this core. This pattern is combined with the climatic conditions to form the old cities of this particular region (Sharifi & Murayama, 2013).

Chapter III: Passive Natural Cooling and Ventilation Systems: Strategies

Diverse strategies in Persian vernacular architecture have been used on different scales in order to meet all the needs and requirements of the inhabitants:

- In a building/residence: orientation of the building, seasonal migration, use of windcatchers, courtyards, vegetation, pools, mass, basements;
- In a neighborhood: narrow, irregular winding covered alleys; and
- In a city: orientation of the city, ratio of mass to voids, uniformity in the use of materials, gardens around the compact cities.

Since the compact urban texture of Yazd includes various combinations of sustainable features that operate as an interconnected chain, it is very difficult to consider any of the sustainable pieces independently. However, in order to get an idea of their mutual functions, some of these features will be examined in this chapter and the following one.

This chapter reviews the most important strategies used in hot-arid cities (in the Middle East) such as Yazd with regard to building scale. The neighborhood and city scales will be discussed in the next chapter.

3.1. Typical Housing Architecture in the Region

The typical Yazdi houses are courtyard housing. The courtyard is a private space, which contains a pool and a small garden, and is the main space that the openings face; all the doors and windows, directly or indirectly, open only to the courtyard. In the Persian Gulf area, in order to provide visual privacy for the houses, the only opening on the outside is the entrance door that is located in a place which protects the female residents from the eyes of male strangers and blocks a direct view from the outside. Visual privacy, which is a direct result of cultural values and religious standards, has a great importance in traditional courtyard housing. In some cities i.e., Cairo, Egypt, the outside openings are fully covered with exterior shading which blocks the view from outside. The houses are surrounded by high, thick and mostly blank walls with rare openings above eye level on the exterior and a bent passage from the

entrance to the courtyard or a stopping space called a hashti [vi] to prevent passersby from looking in [Figure 13] (Memarian & Brown, 2006), (Sadoughianzadeh, 2013).

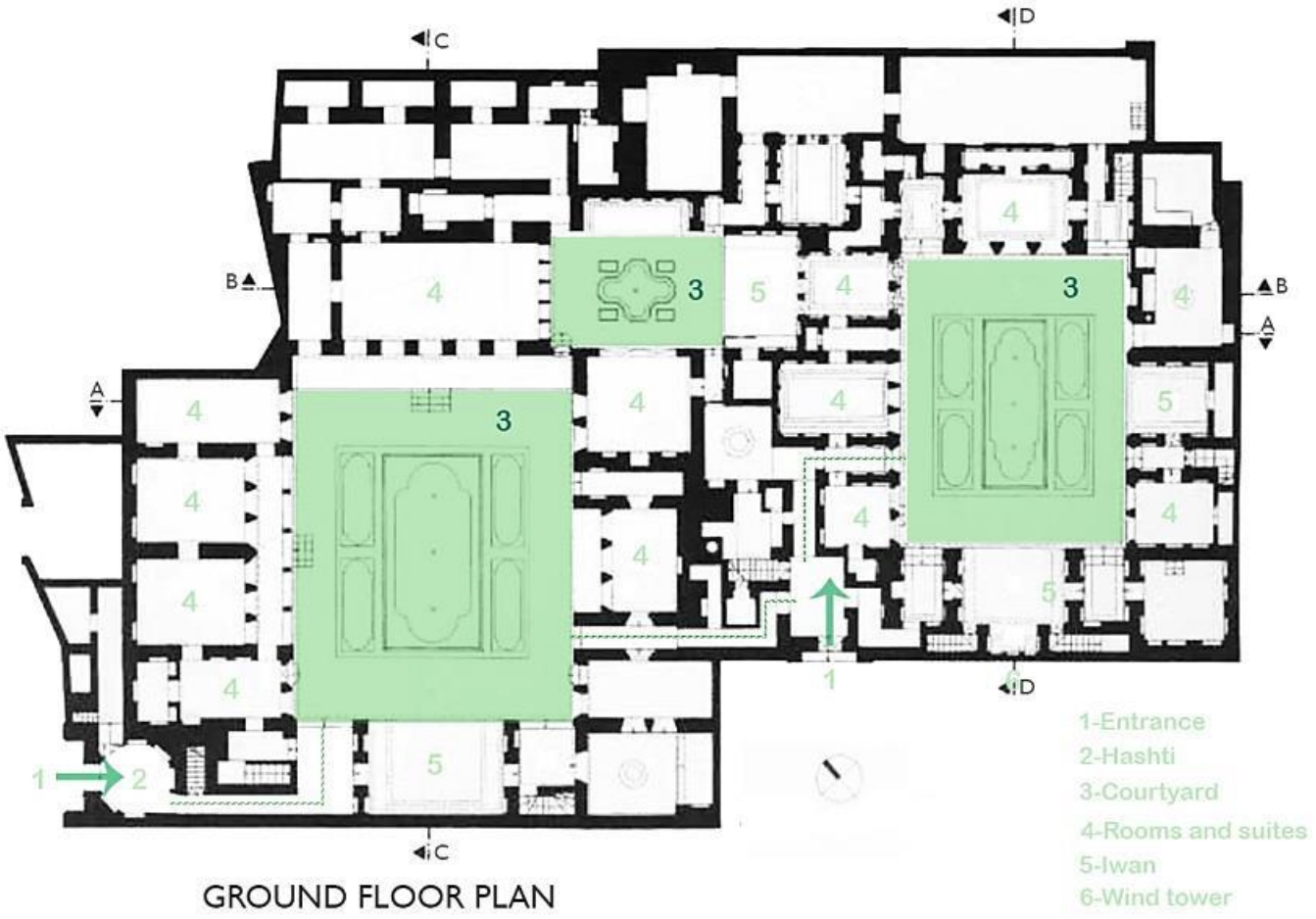

Figure 13. Plan of a traditional courtyard house in Yazd, Golshan House; the dots show the bent entrance to the courtyards of the house, illustration by author

3.2. Thermal Mass

Since there is a significant temperature swing between day and night in desert cities and thermal mass plays a vital role in the performance of buildings, this strategy is widely used in the cities of the region.

[vi] A small enclosed foyer or a stopping space, called hashti, which usually leads to the home's courtyard by a series of curved and narrow corridors to prevent strangers from looking in.

Thermal mass describes the inherent capacity of materials to absorb, store and release heat. Thermal mass strategy in building design, either passive or active, defines how the mass of buildings reacts and modifies the temperature while temperature fluctuates between day and night. When the interior temperature drops (during the night), these materials release the heat absorbed and stored from the sun during the day to the interior and the exterior: warming up the surroundings, and hence, increasing the comfort of the occupants (Sustainability Articles, 2013).

In traditional mass walls, e.g. the adobe or unbaked brick walls in old Yazdi buildings, “heat flow was controlled by the thermal storage capacity of the massive walls, not just by virtue of the materials’ thermal conductivity like the specialized insulation layers commonly used in modern building assemblies.” These types of walls that were used for thousands of years not only carried the structural loads but also performed as an acceptable enclosure. The mass and thickness of walls could control heat, vapor, water and airflow; although the control of airflow through windows and doors was poorly managed, the walls were airtight (Struabe, 2010). Due to the building responsive design in Yazdi buildings, the walls were sheltered by other buildings so that the water/rain control was managed before reaching the inner surface of the buildings and causing damage. Using thick walls of materials such as mud brick, clay and adobe that have high thermal capacity was a traditional solution for temperature fluctuations in buildings in a hot-arid climate such as Yazd (Monshizade, 2008).

3.3. Managing the Sun:

3.3.1. Openings

The overall orientation of the courtyard houses in most Iranian cities is north-east/south-west. The main winter suites or rooms are located on the north-east or north-west sides, whereas the main summer rooms are located on the south-east or south-west sides of the house. In winter, the rooms receive sunlight from the north-east openings, whereas, in summer, the rooms on the south-west side are located in the shade [Figure 14]. A seasonal movement occurs between rooms or suites in a courtyard house so that the occupants are comfortable throughout the year. It is true, though, that in winter, inhabitants move to the rooms with few openings in the corners and during the day, they use the larger, south-facing rooms (Memarian & Brown, 2006).

Typically, the window openings in the courtyard houses in Yazd are deep, tall and narrow with a thick wooden mullion. These tall and narrow window openings minimize the solar heat gain. Frequently, the upper parts of the windows are designed with beautiful colorful glassworks [Figure 15].

Figure 14. Summer and winter rooms and suites in Gloshan house; winter suites are illustrated by blue and summer rooms are shown by red, illustration by author

Figure 15. The left picture is a beautiful glasswork in Dolatabad Garden, photo by Ali Golshan; the right one is the typical windows in traditional Yazdi courtyard houses photo by Lilo

3.3.2. Roofs

Traditional architects used various forms for roofs of the residences to minimize the solar heat gain. One of these techniques is dome techniques and vaults. The dome roofs and vaults are used to reduce solar gain while speeding up the heat loss of the room through the top hole (Monshizade, 2008). In hot-arid region cities such as Yazd, a combination of flat and dome roofs is used for residences. Dome roofs have been used to cover large areas in buildings such as mosques, churches, shrines, bazaars, etc. Due to the excellent thermal performance of dome roofs, they have been used in various buildings and on different scales. By inserting a hole in the top of the dome roof, passive cooling can be achieved by the negative pressure over the dome letting the air flow from openings toward the roof hole. The air flow decreases the inside temperature of the roof and consequently, less heat is transferred by convection and radiation to the interior space (Faghih & Bahadori, 2011) [Figure 16].

As well as structural applications, dome roofs have been used in Iran to achieve natural ventilation and passive cooling. The combined use of windcatchers and dome roofs can result in a pressure difference between the air entering the space from the wind tower and the air rising and exiting from the dome roof hole, ultimately causing natural air flow. The geometrical shape of dome roofs increases the wind velocity over them and results in an increase in “the convection heat transfer coefficient”. It is worth noting that the heat transfer from dome roofs is greater than from flat roofs. When the wind flows over the dome roofs, some of the heat is removed and the rest transferred by conduction through the roof (Faghih & Bahadori, 2011).

Figure 16. Combination of dome and flat roofs in Yazdi traditional houses, photo by Reine

The opinions of various researchers about comparing the temperature in dome roof buildings and flat roof buildings need to be investigated. Konya showed in his research that the temperature of dome roof buildings is lower than of buildings with flat roofs, and Mainstone believes that the lower temperature in dome roof buildings is related to the "higher ground and reflected radiation heat loss", whereas Olgay stated that the reason for the lower temperature in dome roof buildings is lower absorption of solar radiation (Faghih & Bahadori, 2011).

3.3.3. Absorption, Reflection and Transmission

The amount of sun radiation that is absorbed, reflected and/or transmitted depends on the colour of the surface. Different components of a building such as walls, windows and roofs are able to absorb, reflect and/or transmit various amounts of electromagnetic light; wherever absorption occurs, heat energy is produced. Dark colours absorb better than light colours so, dark materials become hotter.

> *In all cases, absorption depends on the electromagnetic frequency of the light being transmitted (i.e. the colour) and the nature of the atoms of the object. If they are complementary, light will be absorbed; if they are not, then the light will be reflected or transmitted. In most cases, these processes occur simultaneously and to varying degrees, since light is usually transmitted at various frequencies. Most objects will selectively absorb light while also transmitting and/or reflecting some of it* (Williams, 2011).

In hot-arid regions in the Persian Gulf area, especially in Yazd, the material used for traditional buildings is adobe and unbaked brick, with a layer of clay and straw. The outer layer on walls and roofs reflects most solar radiation and a small amount is absorbed and then released to both exterior and interior spaces. A brilliant white would be a better color to reflect solar heat; however, this traditionally was achieved through the use of pure lime coating but such materials were not locally available as they require pure carbonate limestone to produce. It is also important to recognize that white surfaces will become covered with the light yellow dust of the surrounding landscape, without rain to wash them clean.

Traditional glass used in windows, of course, absorbs only a small percentage of the sun's energy, passing most of it directly to the inside. For instance, 6mm clear glass transmits almost 91% of the radiation, absorbs 4-5% and reflects 2-4% [Figure 17].

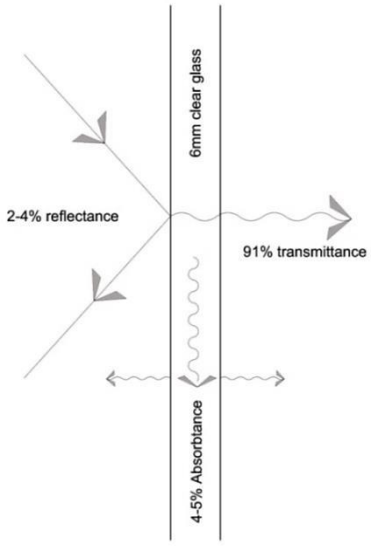

Figure 17. Absorption, transmission and reflection in 6mm clear glass, drawn by author

3.3.4. Shading

Thermal mass and reflective surfaces help reduce heat gain from the sun, but shading is even more effective when possible.

3.3.4.1. Self-Shading and Neighbors' Shading

The houses in this region are surrounded by high shared walls, which provide shady areas for both the neighboring courtyards and/or probably the courtyard and the narrow adjacent streets and alleys [Figure 18-20]. The compact neighborhoods and cityscape decrease the area exposed to solar radiation and heat gain.

Figure 18. Self-shading in a traditional courtyard house in Yazd, photo by Fereydun Masomian

Figure 19. Self-shading in the afternoon/morning in a traditional courtyard house, Golshan House, illustration by author

The residents of traditional courtyard houses choose how to spend their time during the day according to the climate conditions. The spaces in shadow/shade, north-east and south-east, and the underground spaces are used to avoid heat during the hot days. The underground level generally has a lower temperature than the upper level. During the winter, residents choose the south rooms to receive the solar gain in order to reduce the fossil energy for heat (Monshizade, 2008).

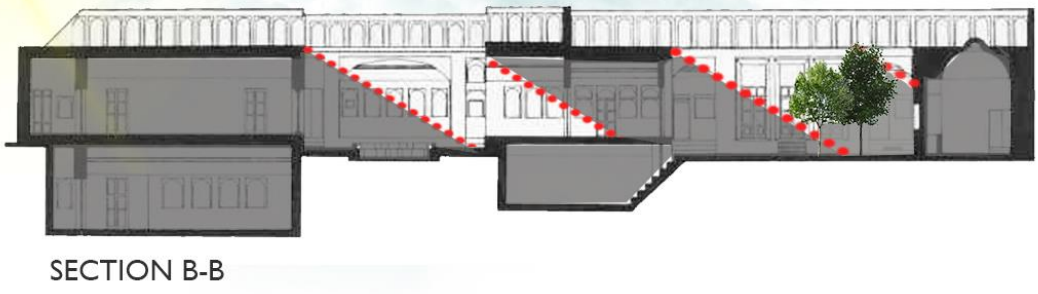

Figure 20. Self-shading in the afternoon/morning in a traditional courtyard house, Golshan House, illustration by author

3.3.4.2. Iwans: Semi Open Areas

Iwans are the vaulted semi open areas (walled on three sides), which face onto the courtyard of a residence or mosque and provide a shady and cooler living area during the day.

3.3.4.3.. Exterior Shading

Most of the residences in this region, especially in Arab cities, have always had shading on their exterior opening, which prevents strangers from looking into the interior of the residences [Figure 21].

Figure 21. Traditional exterior shading in Cairo, Egypt

Today, substitution of a double façade with various exterior shading systems, which are culturally widely accepted and provide both privacy and shading for the occupants are developing in the Persian Gulf area. There are varieties of forms of exterior screens which “range from being constructed of heavy materials whose thermal mass is used to absorb heat, to lighter metals that can use fine cutting techniques, to screens that employ advanced fabrics.” There is a good example of exterior shading in new buildings in Masdar City, which is “a very clear hybrid façade system where the inner layer is glazed and the exterior precast screen uses traditional Islamic patterns….The thermal capacity of the screen is intended to decrease heat transmission to the cool interiors.” (Boake, 2014)

3.4. Courtyards

Courtyard housing strategies in Iranian and Arab cities in hot-arid regions can be investigated from different points of view such as cultural, religious, climatic, economic and social. “The traditional courtyard house was a well-balanced organism where social cultural factors integrated with architectural/environmental ones.” (Edwards, Sibley, Hakmi, & Land, 2006)

According to historical evidence, courtyards have existed in Iran for 8000 years; however, their functions and types are different from one area to another: defining boundaries of properties, circulating air, creating a cool place. In hot-arid cities, the traditional courtyard plan is rectangular with rooms on two or four sides where members of extended or single families live (Karimi, 2012).

In typical Iranian courtyards, since the architecture of houses is introverted and inward-looking in the compact urban fabrics in some cities such as Yazd, Shiraz, Isfahan, the function of courtyards includes broader criteria. Providing privacy for the residents is a key factor in this kind of architecture (Memarian & Brown, 2006).

Central courtyard structure in both shape (geometry and element designs) and developing methods (technology and materials) are strongly in accordance with both local and climate considerations (Dehghan, Naghizadeh, & Nasrabadi, 2011). Variations in the climate have resulted in various responses in the architecture of the courtyard houses. The existence of a courtyard in hot-arid cities is an architectural response to the harsh climate of the region (Memarian & Brown, 2006). A number of strategies are combined with the use of courtyards to maintain comfort for the residence such as constructing basements, designing semi open spaces, using windcatchers, migrating seasonally planting vegetation. The main role of a traditional central courtyard is “to exploit the buoyancy of the heated air to force ventilation through the smaller strategically-placed windows” (Edwards, Sibley, Hakmi, & Land, 2006).

The form of residential houses, which have a courtyard that contains a garden and a pool in the centre and openings only facing the courtyard, is an example of inward looking architecture. The design of the building is aimed to maximize passive potential to warm the residence in maximum penetration of the sun in winters and minimize it in summers by using passive cooling strategies (Monshizade, 2008)[Figure 22].

Figure 22. Different views of traditional courtyards in Yazd, the left photos by author, the top right by Nicolas Rapp and the bottom right by Alex Wilkinson

3.5. Planting Vegetation and Placing a Pool

Placing a pool in the centre of the courtyard, planting vegetation around it and locating a windcatcher(s) in the corner(s) of the house aid in climatic modification (Edwards, Sibley, Hakmi, & Land, 2006). In the afternoons, the interior spaces as well as the water surface of the pool, the plants and trees located at the centre of the courtyard get cool by means of the windcatcher that conducts the air to the space.

Crofts in the courtyards are generally filled with those kinds of trees that need less water, such as pomegranate, fig, pistachio and grape. These trees not only provide fruits but also reduce the air dryness and provide shade (Dehghan, Naghizadeh, & Nasrabadi, 2011).

3.6. Windcatchers

3.6.1. The Role of the Windcatcher in Hot-arid Regions

Since electricity production is the major source of carbon emissions, air conditioning and mechanical ventilation systems consume a significant proportion of a building's energy demand; the negative impact on the environment can be dramatically reduced by using low energy natural ventilation and cooling systems. Wind as a renewable driving force can provide fresh and healthy indoor thermal comfort by means of windcatchers, solar chimneys, etc. Over the past three thousand years, wind tower systems or windcatchers, from the very primitive to the complicated, have been the major cooling systems used in the Persian Gulf region to improve thermal comfort inside buildings (Saadatian, Haw, Sopian, & Soulaiman, 2012) [Figure 23].

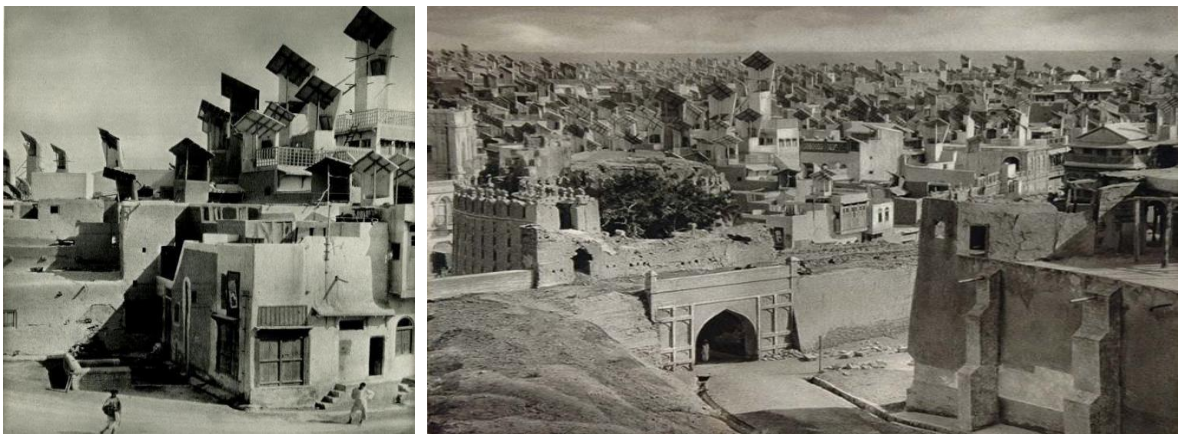

Figure 23. The earliest forms of windcatchers in Hyderabad, Pakistan

These ancient passive cooling and ventilation systems have been found in hot, hot-arid and hot-humid regions, particularly in Persian Gulf area countries such as Iran [Figure 24], Bahrain, the Emirates, etc. and North African countries such as Egypt. Windcatchers have different shapes and names from Pakistan to North Africa. The windcatcher is called *baadgir* in Iran, Iraq and the Persian Gulf area, *malqaf* in Egypt, *bating* in Syria and *mungh* or *hawa-dani* in Pakistan.

Figure 24. Traditional windcatcher in Iran

Windcatchers are traditional tower-like structures projected through the top of roofs of buildings with openings toward the favorable prevailing wind to catch the warm wind, cool it down and transmit it to interior space to provide thermal comfort for occupants.

The air flow occurs either due to the wind blowing or the temperature difference between the interior and exterior of the building. When the wind blows, the result is positive pressure on the windward side and negative pressure on the side of the windcatcher. In windless conditions, the windcatchers operate like a chimney or air trap according to the stack effect; hot and less dense air rises and outflows from the windcatcher's openings (Ahmadikia, Moradi, & Hojjati, 2012)[Figure 25, 26].

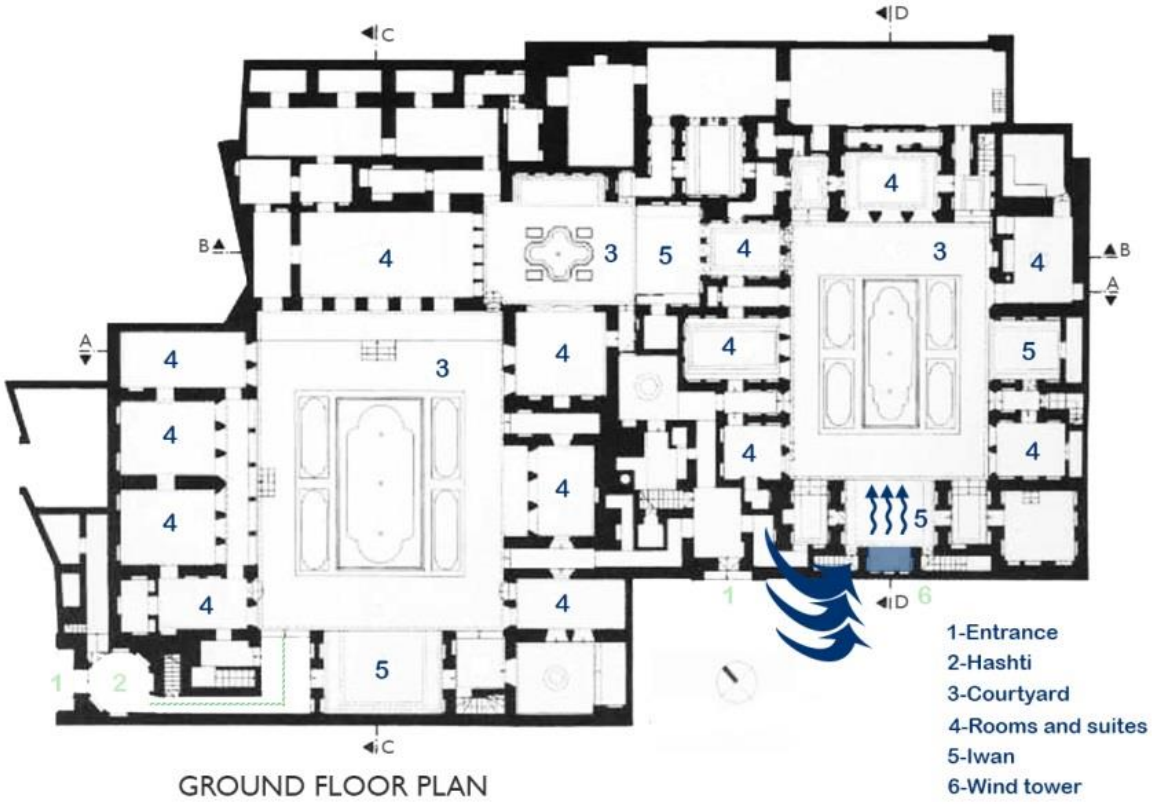

Figure 25. Ground floor plan of Golshan house; the orientation of the prevailing wind and the location of the wind tower is indicated, illustration by author

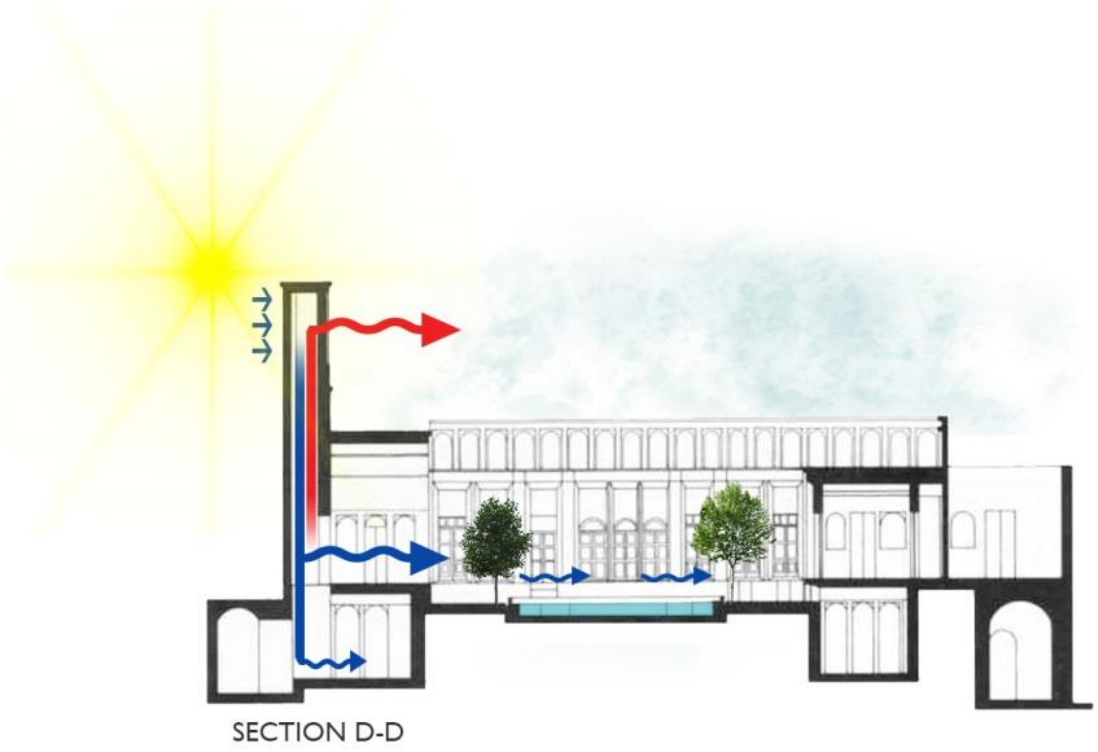

Figure 26. Section of a traditional courtyard house, Golshan House, with a wind tower; air circulation is indicated with arrows, illustration by author

3.6.2. Categories Based on Function

The main function of a wind tower system is to bring fresh air into a building and send the hot and polluted air out. The functional system of a windcatcher can be divided into three parts:

- Convection
- Air transfer
- Evaporation

Some of the windcatchers cool the building through air transfer only, whereas some others both transfer and evaporate air (Kianersi & Ahmadi, 2012) [Figure 27]. In general, the windcatchers are multi-functional in operation according to the wind velocity and direction, the intensity of sun radiation and the air temperature. However, the operations of windcatchers are slightly different based on their use in specific regions, hot-humid or hot-arid climates. In hot-arid areas, in particular in desert climates because of the low relative humidity, ponds or underground water reservoirs are an additional major section that provides required humidity to the warm incoming air and cools it down through evaporation.

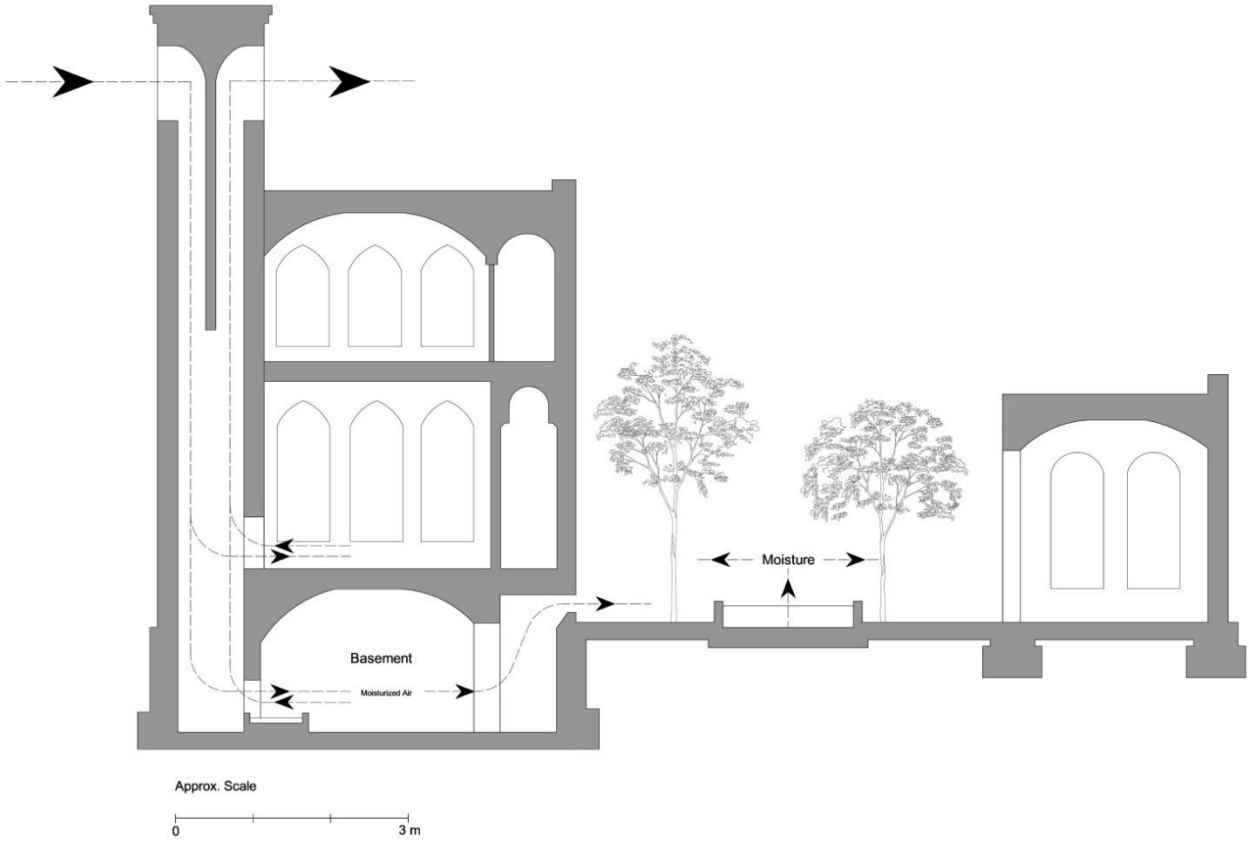

Figure 27.Transferring and evaporating air by means of windcatchers in hot-arid regions

Considering the fact that there is a significant temperature fluctuation between day and night in desert climates, thermal mass plays a fundamental role in the operation of the windcatchers. The heat, which is absorbed and stored during the day by mud bricks, will be released at night. If the wind blows during the night, the incoming cool air becomes warm while passing the tower internal walls; if there is no wind at night, the tower, which has a higher temperature than the surrounding air, acts like a chimney and draws the warm, less dense air upward to let it exit from the tower's openings. The next day, when the warm wind blows, the air is cooled while contacting the internal walls of the tower that become cooled over the previous night and the cooled air flows into the space. If there is no wind during the day, the interior warm air, which rises to escape through the tower, cools down while making contact with the internal walls and becomes denser and cooler, and, therefore, is pushed down. This process continues to circulate the interior ambient air.

Windcatchers have aesthetic and functional parts. In the most developed Persian windcatchers in hot-arid climates, four different categories of components can be identified. (Kianersi & Ahmadi, 2012):

1. The **Shelf** is the top part of the windcatcher that transfers the air to the body. The ornaments and shapes of this part may vary (the aesthetic function).
2. The **Stem Body** is the part that is located between the roof and the shelf.
3. The **Blades** are elements made of clay and brick to divide the air vent into the smaller vents.
    - **Main Blade**, the center wall, is located in the vent to divide it into smaller vents until the bottom end.
    - **Secondary Blades** are located between the main blade and the vent walls and do not continue to the bottom.
4. The **Eyelets** are the space or the holes between two blades that allow air flow

3.6.3. Orientation, Location and Form of Windcatchers

Generally speaking, the windcatchers are oriented primarily according to the prevailing desired wind(s), designed plan and orientation of the building. The names of different types of windcatchers are derived from the directions of openings, e.g., uni-directional, bi-directional and multi-directional (four directional or eight directional towers). In Yazd, since the desired wind is from the north and the northwest, uni-directional windcatchers face these specific directions and have only one or two vents. A

1988 survey shows that only 3% of windcatchers in Yazd are uni-directional (Maleki B. A., 2011)[Figure 28].

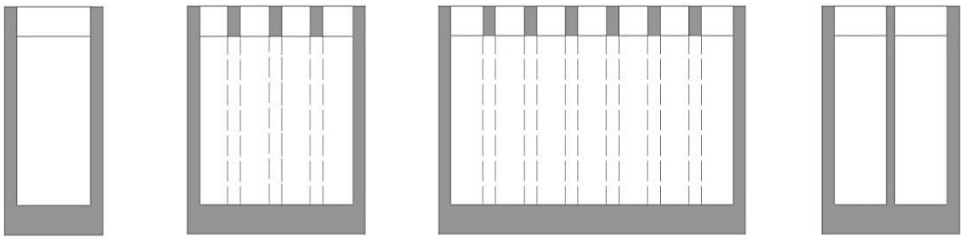

Figure 28. Typical plan of one directional windcatcher, drawn by author

Two directional or bi-directional windcatchers, as the name implies, have two openings with the division of the main blade, a centre wall inside the tower. The openings usually face the north and the south (north-south). The survey reveals that 17% of windcatchers in Yazd are bi-directional [Figure 29].

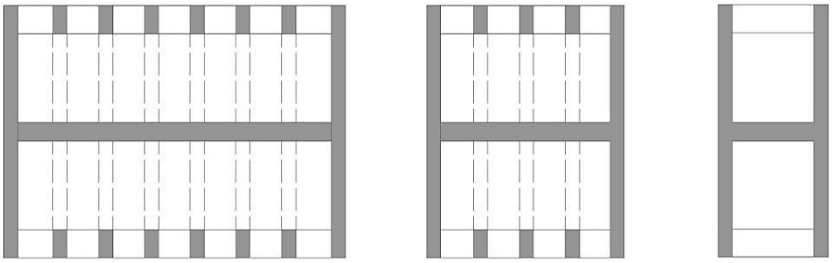

Figure 29. The typical plan of two directional windcatcher, drawn by author

The most popular windcatchers are four directional according to the survey. More than half of the windcatchers in hot-arid regions are four sided, divided into four vents by two additional main blades [Figure 30].

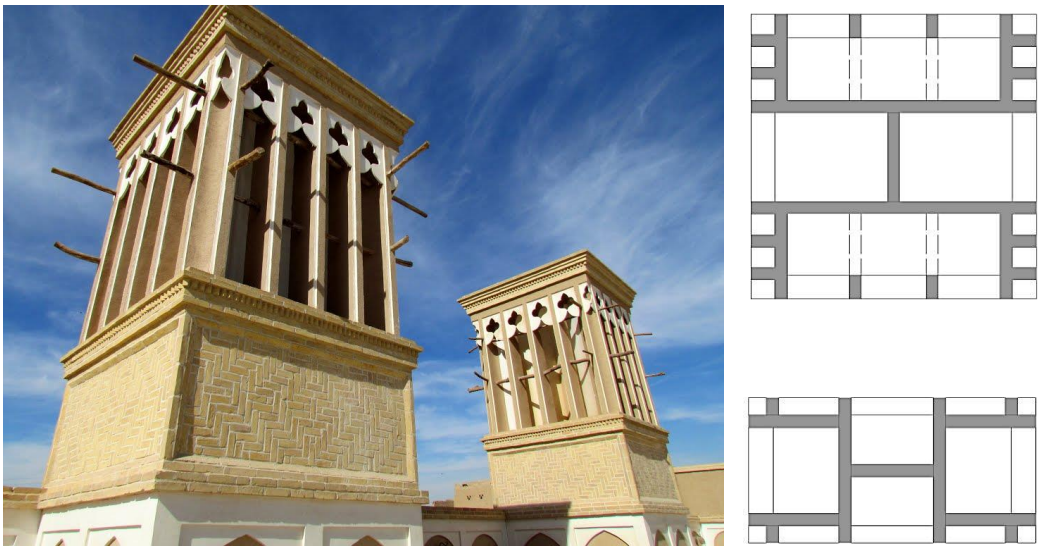

Figure 30. Typical plan of four directional windcatcher, photo by Alireza Javaheri

The eight directional towers or octagonal windcatchers are commonly used in cisterns and water reservoirs in Yazd. These kinds represent only 2% of the windcatchers in Yazd. The most famous one is in the Dolatabad Garden [Figure 31, 32].

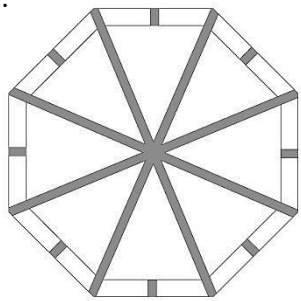

Figure 31. Typical plan of eight directional windcatcher, drawn by author

Figure 32. Eight directional windcatcher in the Dolatabad Garden, the tallest windcatcher in Yazd, photos by Mauro

The location of windcatchers may vary as follows:

- The location is behind the hall in a symmetrical axis
- The location is in the corner of the courtyard connected to the hall through pond space
- The location is in the north corner of Yazdi houses (since the prevailing desired wind is from the north and the northwest)

Any of the mentioned locations and directions can have a major impact on the cooling function of the whole system (Kianersi & Ahmadi, 2012).

3.6.4. Structure and Ornaments

The structure of the wind tower consists of sun dried or baked mud brick, which is covered with mud plaster with chopped straw in it, and reinforced with small wood beams. Timber beams are used in order to fasten the structure together to increase the shear resistance and also support the internal partitions in different levels of the tower. Timber beams stick out from the tower, which can be used as a ladder for maintenance and cleaning (Maleki B. A., 2011).

The shape, dimension, height, decoration and elaboration of the wind towers vary. They may relate to the space they serve and the station, class and wealth of the house owner (Forouzanmehr, 2012). Some of these ornamental features of the wind towers are made with adobe and some are made with plaster decoration or brick works at the top of the tower. In fact, the form of ornamentations was the signature of the architect who used various form based on his preferences. These features were not based on any climate condition or functionality but the cultural reflection (Maleki B. A., 2011).

In the following chapters, the historical and geographical contexts of Yazd city as well as the climate adaptive architecture from the old days until the present will be explored.

Chapter IV: Yazd & Climate Adaptive Architecture

4.1. Historical Context

Iran, a vast country with diverse climatic conditions, various ethnic groups and cultures, with a long history of different dynasties and their realms, has witnessed different stages of growth and decay. These complex features have a direct impact on the traditional to modern architecture in this country. Yazd, one of the oldest cities in Iran, which has still kept its own historical quarter despite all the invasions of Iran, has experienced various stages of development in architecture in different eras. This rich old city has been able to preserve its ancient religion, traditions, culture and unique style of architecture throughout its history. However, the pressure of modern developments has put the culture and history of Yazd at risk, just as in many other Middle Eastern cities with less historical significance. The name of this city is mentioned in various famous books such as *Travels of Marco Polo* (1272) and *Masalik and Mamalik* [vii] (Wikipedia, 2012).

The historic core of Yazd has undergone various expansions and has grown during different periods. According to historical records, during the Achaemenid dynasty (the first Persian Empire from 550 to 330 BC), the city of Yazd was called Isatis (or Ysatis). Another historical report, by Iraj Afshar, indicates that the development of Yazd goes back to the period of Alexander the Great who built Alexander Prison in Kasah city as Yazd was called at that time. Based on another historical report by the same author, the name of Yazd is probably derived from the name of a Sassanid Emperor, Yazdgerd, in whose realm the city witnessed major growth (Khademzadeh, 2004).

During different dynasties, Yazd was always regarded as a safe haven due to its distance from the different capitals of Iran, remote desert location and difficulty of approach. After the Arab invasion of Persia, during the third Caliph of Islam in the seventh century AD, this city was felled by Muslim troops. Since Yazd was an important Zoroastrian center during the Sassanid and later dynasties, most of the Zoroastrians fled to this safe city from different parts of Persia. For a long time, Yazd remained Zoroastrian by paying a levy to the Islamic central government (Wikipedia, 2012). Today, only ten percent of the city's population is Zoroastrians who still follow their original religion. A famous Zoroastrian Fire Temple in the city has kept a traditional fire burning continuously for more than 1300 years.

[vii] Masalik and Mamalik or the *Book of Roads and Kingdoms* is a famous book by the geographer Ibn Khordadbeh that was written in the 9th century and contains maps and descriptions on the major trade roads of the Muslim world at that time.

During the eleventh century AD, expansions and developments of Yazd, with the construction of gates and castles around the city, converted it to a prominent and prestigious city with a new identity. (Khademzadeh, 2004) The traditional city forms and architecture in addition to the inaccessibility of its geographical location kept this old city immune from major battles and the destruction of war. When Genghis Khan invaded Persia in 1200 AD, he destroyed and set fire to almost all cities on his way to the capital but because of its record of peace and security, Yazd was spared and became a safe place for scientists, artists and intellectuals (Wikipedia, 2012).

In the fourteenth century, when the Mozzafarids were in power, the city began to expand toward the west and southwest. A new city wall with seven gates and various new buildings were built in this period as well (Khademzadeh, 2004).

In the fifteenth century, with the rule of the Safavids, a period that was a glorious age in Persian architecture, unlike other cities of Iran (such as Isfahan, Shiraz, and Tabriz that were flourishing), Yazd did not develop much. The city centre, which was shaped around the Amir Chakhmagh Complex (consisting of the mosque, bazaar and water basin), remained in the same place, and new neighborhoods were added to the city on the other side of the existing city wall toward the west and southwest (Khademzadeh, 2004).

During later dynasties such as Zands and Qajars, Yazd expanded toward the south with the construction of various building types such as schools, baths, etc. Although, in 1815, a new city wall was constructed to enclose the entire city, it could not stop the development of Yazd towards the south and southwest. (Khademzadeh, 2004) Throughout the reign of the Qajars, the first stage of Persian modern architecture began to appear as a result of growing communication between Iran and European countries (Diba & Dehbashi, 2004).

With the rise of Pahlavi, Reza Shah (the king) wanted to create a modern Iran similar to what Mustafa Ataturk had done in Turkey at that time. The Shah made significant infrastructural reforms all over the country to change the look of the cities and even the people. The education, economy, culture, civil projects were all influenced by the West: constructing of wide streets in cities, changing buildings and neighborhoods, building new stores, introducing new types of entertainment and public spaces, such as cinemas, parks, clubs, developing transportation systems (Karimi, 2012) and forcing people to adopt nontraditional clothing and life styles, such as the removal of the hijab. The government that had a major role in the city planning and civil projects had asked western architects and contractors to design

and execute new buildings and plans in Iranian cities. Thus, the traditional designs of buildings changed considerably in this period. Symbols of Persian forms and features were not found in this type of architecture (Diba & Dehbashi, 2004).

With the rise of Mohammad Reza Pahlavi in 1941, many commercial, residential and governmental buildings were built with no consideration of climatic factors in many cities such as Tehran, Kashan, Tabriz, Mashhad, as well as Yazd (Diba & Dehbashi, 2004). Although, the historical core of Yazd was kept intact, the city development accelerated again. The focus was more on the new developing areas [Figure 33].

After the Second World War, the desire of Iranians to transform traditional residences to modern western housing began. Unfortunately, cheaper and faster constructions without any Persian ornaments, a lack of a variety of materials and use of new ones by the developers began at that time and has continued until today. Briefly, the unpleasant 'build-and-sell' (poor quality of architecture) combined with western modern designs was the major style of this period. Although there were some examples in some cities of prominent architecture by famous Persian architects, the typical architectural style of that era was influenced by this approach to building (Diba & Dehbashi, 2004). These transformations, injected "modern" into people's lifestyle and had a major impact on the crisis of cultural identity. Therefore, most of the intellectuals opposed this approach by the Shah and the government. One of the famous Iranian writers, Jalal Al Ahmad, who was a critic of the new imported modern lifestyle, wrote in his book, A Plague from the West (Karimi, 2012)

> *We are like strangers to ourselves…in our food and dress, our home, our manners,… and most dangerous to our culture.*

After 1979, by the Islamic Revolution in Iran, the new government showed more interest in Islamic identity instead of westernization, which was the symbol of Pahlavi. Rapid population growth, migration of villagers to cities, new social and economic situations and the aftermath of an eight-year war with Iraq (1980 to 1988), caused anarchy and chaos in the architecture of Iran. Copying and importing foreign architecture without any adaptation to the context was dominant in the country. Although the irregular growth of Yazd was the main factor that resulted in a lack of urban management, replacing vernacular architects by the developers and contractors who were not trained and familiar with aesthetics in Iranian architecture played a major role in this phenomenon. The priorities of the new government were the informal and rural areas and rapid and cheap housing (Derakhshani, 2011). Lack of regulations and

rules in building design and different points of view resulted in worthless architecture that only copied western versions especially residential high rises (Diba & Dehbashi, 2004).

Figure 33. Development of Yazd city

The use of the term “western architecture” in Iran refers to the international style used in the 1950s and 1960s, which respected neither the place nor the purpose of the building; this style was not compatible with climate, culture or the available resources of the site. However, during the last few decades, this approach has been completely disregarded and replaced with a new approach toward sustainable and environmentally responsive designs based on the climatic conditions and energy efficiency.

If western architecture could be considered not as a model to copy but as an achievement of the human architectural heritage, Iranians could benefit from the western ways of thinking and technology. They could incorporate them into their own architectural heritage and adapt them to the climatic conditions and therefore introduce a truly contemporary Iranian architectural language (Diba & Dehbashi, 2004).

The geography and climate characteristics are major influences on the urban and architectural design in Yazd; thus, they are considered next.

4.2. Geographical and climatic Context

Iran is a vast country, the second largest country in the Middle East and the eighteenth in the world. This country is located between the Persian Gulf and the Oman Sea in the south, and the Caspian Sea in the North. The expansion from North to South resulted in variety of climate conditions: hot-arid, hot humid, cold-arid and Mediterranean [Figure 34].

Figure 34. Location of Iran in Middle East

Kavir Desert and Kavir-e-Lout are two deserts located in the central part of Iran and occupy one seventh of the country. These barren regions with desert climate characteristics have a direct impact on the nearby cities and areas. Yazd province is situated in the central part of Iran [Figure 35]. This province has

a partial border with the Kavir Desert in the north, Khorasan province in the northeast, Kerman province in the south, Isfahan province in the west and a small border with Semnan province in the northwest. Two high mountains, Shirkuh and Kharaneq, form a wide, arid valley in this region that creates very dry, hot summers and very dry and relatively cold winters (Abouei, 2006). Yazd province has climate characteristics that make it one of the hottest and driest provinces of Iran:

- dusty winds
- Low rainfall, annual precipitation of about 60 mm and evapotranspiration more than 3500 mm (Dastorani, Bavani, Pourmohammadi, & Rahimian, 2011), resulting in low humidity and shortage of water
- Low plant coverage
- Very high temperature fluctuations between day and night (similar to other desert climates e.g. Las Vegas (Nevada), Phoenix (Arizona), Riyadh (Saudi Arabia), etc.)
- Wide seasonal temperature swings: in the hottest months of the year, the temperature in the north and northeast areas of the province reach an intolerable 50° Celsius, whereas, in the coolest months, in western areas, in Shirkooh and Barfkhaneh mountains, the temperature drops to about -20° Celsius (Abouei, 2006).

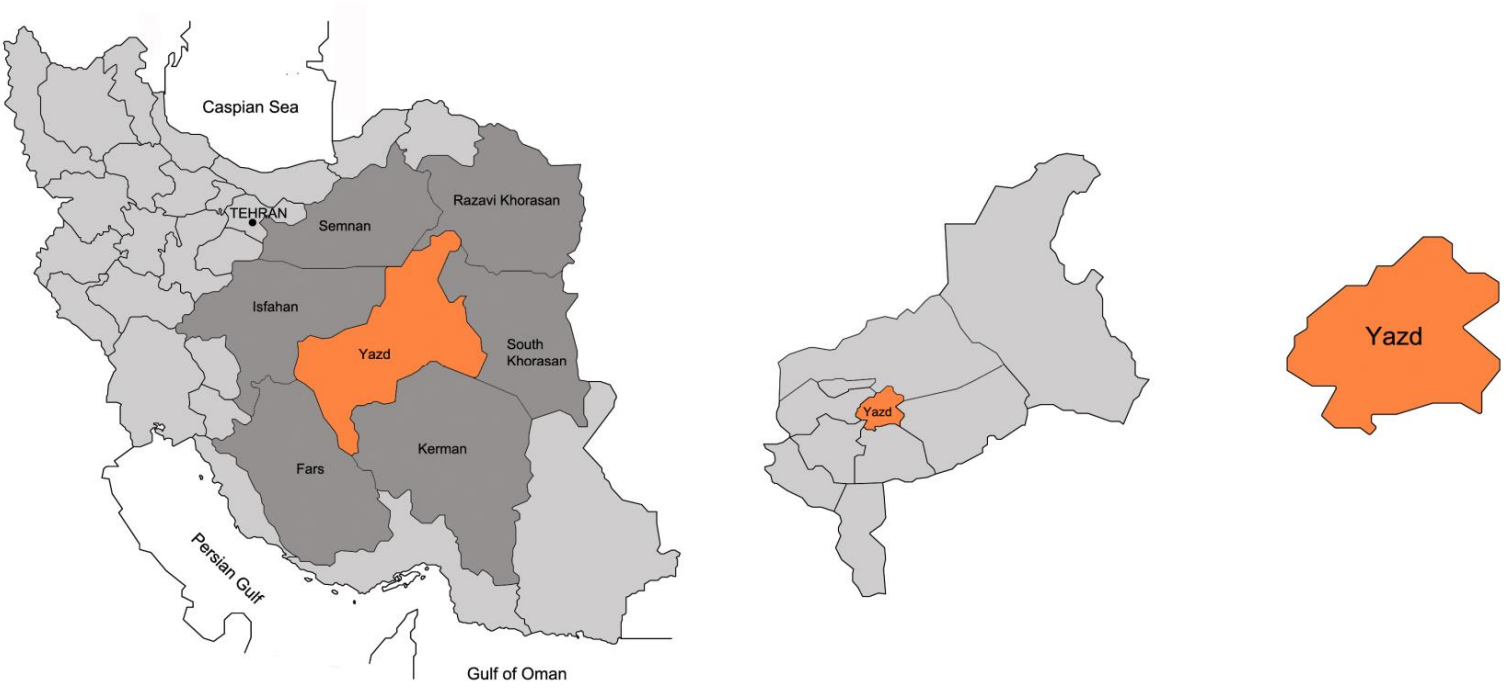

Figure 35. Iran's province divisions, Yazd Province and Yazd city, illustration by author

Yazd city, capital of Yazd province, like all other cities and towns in this province, is located in the desert region in the central part of Iran. As weather reports and graphs indicate, the maximum temperature in the hottest month of the year, mid-July, is almost 40°C whereas the minimum temperature in the coldest month of the year, February, is almost 0°C [Figure 36]. The day and night temperature in Yazd vary significantly. It is too hot during the day and cool (or sometimes cold) at night.

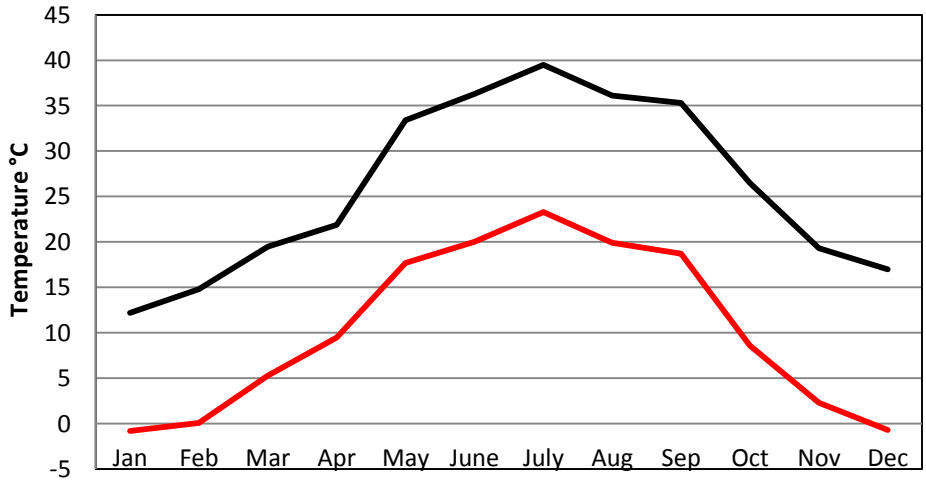

Figure 36. Temperature variations of °C of Yazd city; the red line illustrates the minimum; the black one shows the maximum redrawn by author

For building designs, in particular sustainable and vernacular architecture, a deeper understanding of climate is often necessary. Hence, information about variations in temperatures, speed and frequency of desired and undesired wind, number of hours of sunshine per day [Figure 37], precipitation [Figure 38], relative humidity, etc. are useful. In the interaction between building design and climatic conditions, both limitations and possibilities should be considered carefully.

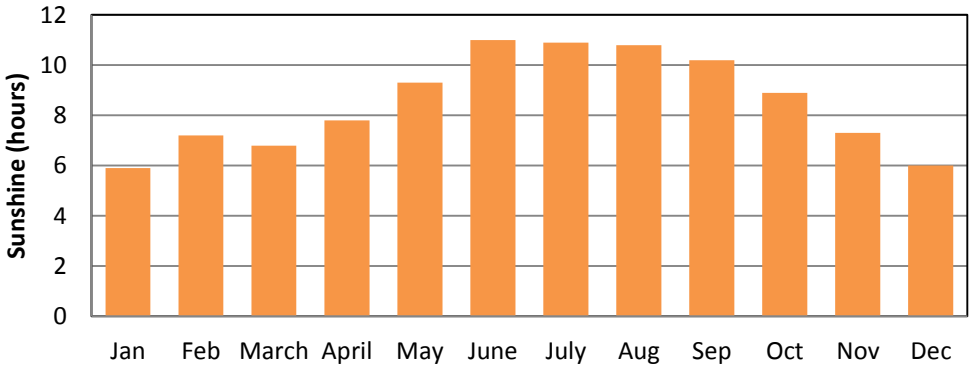

Figure 37. Monthly average number of hours of sunshine per day, redrawn by author

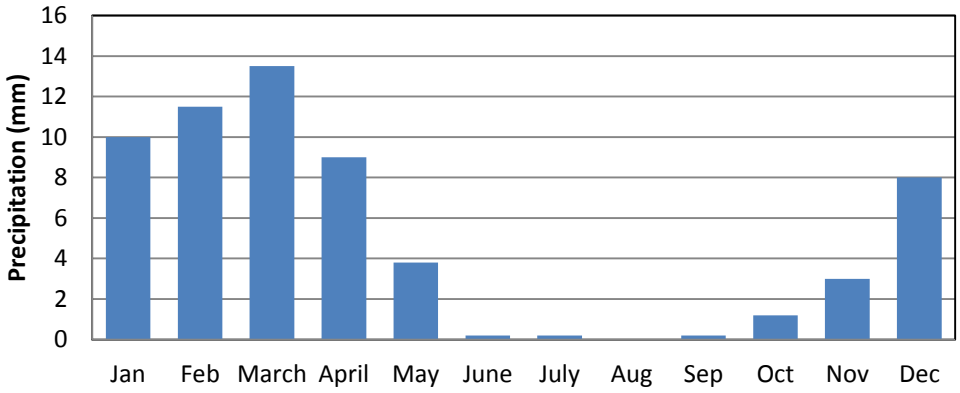

Figure 38. Any kind of precipitation including drizzle, rain, hail, sleet or snow, redrawn by author

Wind speeds vary from a calm breeze, 0 m/s to 7 m/s, to, on rare occasions, a strong breeze greater than 12 m/s. The highest average wind speed of 3 m/s (light breeze) happens in June, when the average daily maximum wind speed is 6 m/s (moderate breeze); the average number of hours of sunshine is 11; and the average precipitation is approximately zero. The lowest average wind speed of 2 m/s (light breeze) occurs in December, when the average daily maximum wind speed is 4 m/s (gentle breeze), the average number of hours of sunshine is 6 and the average precipitation is 8 mm (Weather Spark, n.d.) [Figure 39].

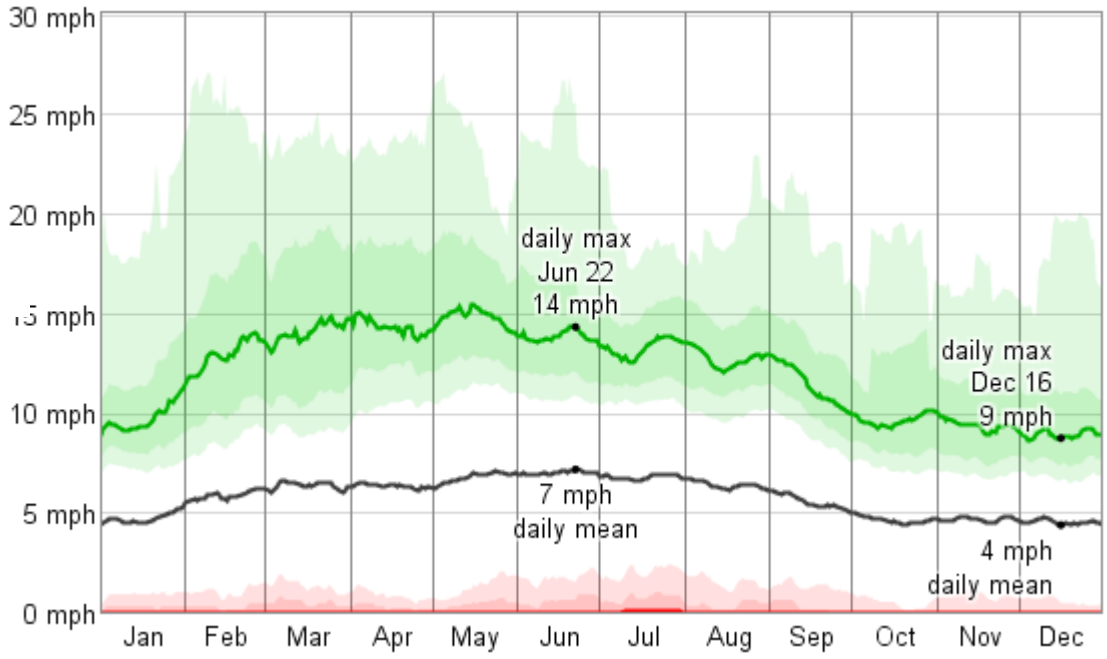

Figure 39. Wind Speed (m/s) of the average daily: minimum illustrated by red, maximum by green, and average by black

In a year, the wind direction is from the *west,* 16% of the time, similarly from the *northwest,* almost 16% of the time and from the *southeast,* 13% of the time. The wind direction from the northeast is the least often: 2% of the time [Figure 40, 41].

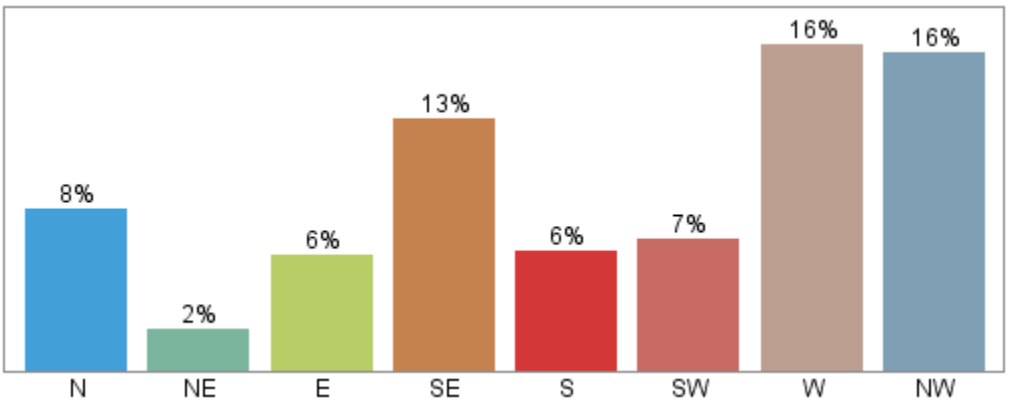

Figure 40. Various percentages of wind direction over the entire year

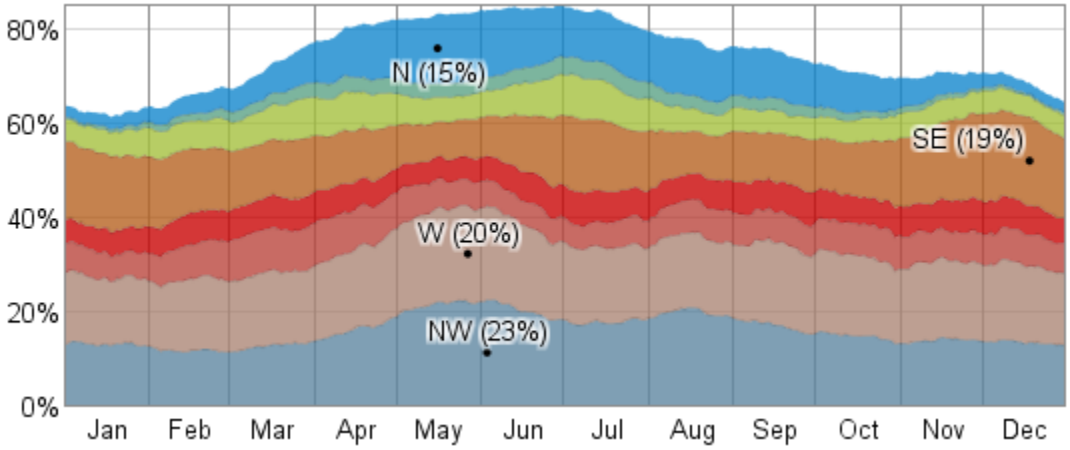

Figure 41. "The fraction of time spent with the wind blowing from the various directions on a daily basis"

Typically, the climate-adaptive architecture designs should be based on the worst time of the year, available resources and constraints. The resources of a hot-dry desert city are wind, sand/dirt and sun whereas the limitations include shortage of water, hot-dry weather and very low humidity, etc. Notably, Yazd's vernacular architecture has followed climate-adaptive rules, resulting in the city being a prominent example of this type of architecture. Taking these factors into consideration, the ancient builders tried to make the interior of the buildings more pleasant and comfortable considering the

climate by choosing suitable orientations, by organizing space and by including different architectural features.

4.2.1. Limitations

Considering the fact that Yazd has very special climate characteristics according to its location in the hot-arid zone, there have always been limitations for the builders and for the occupants.

- Insufficient precipitation resulting in low humidity and shortage of water
- Hot climate and sunlight
- Very high temperature fluctuations between day and night
- Dusty and sandy winds from the two near deserts
- Insufficient herbal coverage

Although these problems and limitations have always existed, the ancient builders attempted to use the available natural resources to respond to the harsh climate conditions based on their countless experiments and accidents.

4.2.2. Opportunities

The ancient architects learned how to address the problems in order to moderate the harsh climate condition by:

- Using water reservoirs and qanats (underground water canals) to provide chilled water
- Ventilating and increasing humidity to the interior space by means of a wind tower system
- Locating openings in specific places with particular sizes to reduce heat gain
- Using thermal mass
- Opening up the openings of the windcatchers facing the desirable wind and closing the other openings to avoid dusty and undesired winds.
- Planting trees and bushes and placing a pool in the middle of courtyards in order to provide shading and humidity

4.3. Yazd Architecture Adaptation to Climate

Iranian vernacular architecture, which is still unknown in the West, has always been successful in the ingenious use of renewable energy resources such as wind, sun, etc. Without having to consume additional power to enhance comfort and performance of the buildings, it decreases costs and reduces ecological damage (Kianersi & Ahmadi, 2012). The techniques and specific strategies used are the ancient builders' response to the hot-arid climatic conditions [Figure 42].

A comparison of harmony of the human built environment with nature, cultural values and the climatic conditions of the vernacular architecture in Yazd to the architecture of today in that region proves that the traditional designs and strategies were more compatible with complicated climatic factors and provided comfortable living space. These strategies can be divided into four categories:

- **Macro scale** (Macro climate responsive design) that can be defined as scale of the city and the urban fabric. It includes the orientation of the city, enclosed urban environment, the irregular and narrow streets and alleys, the distance between the buildings and neighborhoods, etc.
- **Meso scale** (Meso climate responsive design) that defines specific site features such as wind tower systems or windcatchers, air traps, iwans, riwaqs or arcades, qanats etc. that can modify the climate of each building.
- **Micro scale** (Micro climate responsive design) as the subset of the macro climate responsive design focuses more on the site and the building itself. This category includes building form, building envelope, self-efficiency in materials, etc.
- **Nano scale** (Nano climate responsive design) that defines the characteristics of the building materials used such as U-value (TolouBehbood, Taleghani, & Heidari, 2010).

Figure 42. Compact, connected and continuous urban fabric of Yazd; a response to the harsh climate condition

Traditional Yazdi builders applied all these four categories to their climate responsive designs resulting in the old city of Yazd. As mentioned previously, one approach to sustainability in architecture relies on natural forces to provide comfort and utility to buildings. The historical architecture of Yazd is a perfect example of the vernacular forms of architecture used in this approach. In addition to the design of the residences in hot-arid regions, some other strategies were used by the occupants in order to respond to the harsh climate. For instance, an internal seasonal migration took place; often, the northern rooms were used in the summer and the southern rooms in winter. During the summer, since the ground level rooms were heated, most of the time, iwans were used as living space in the evening and rooftops for sleeping at night. In the morning, the ground level rooms have lost their heat and become fresh and cool (Ben-Hamouche, 2008).

Comparative analysis of the traditional urban design with the new urban patterns helps us to learn from the past and understand the failures and successes to be able to use what worked and to ignore what did not, and then, apply the knowledge of the scholars and experts in those successful areas to create a hybrid system that can meet the demands of modern life as well as respect this complicated and ingenious climate responsive architecture.

4.4. Traditional Layout of Yazd

Most historical urbanists have divided Persian urban planning into two categories: pre-Islamic (from 9th century B.C to 7th century A.D) and post-Islamic periods. After the Arab invasion, a new style of urban planning emerged to meet the Islamic requirements. It was a combination of pre-Islamic and Islamic impressions. The cities were composed of integrated components. The mosque was usually built in the centre, which was connected to the main traditional bazaar, palace, madrasah (religious school) and hammam (public bath) of the city, and the remaining components were located around this core (Sharifi & Murayama, 2013). In general, the overall layout of the city in all dimensions, with its hierarchy principles and consideration of climate for the comfort of private users, occupants of residences, or public users, pedestrians, created a uniform environmentally friendly city.

In the old urban pattern, the paths were designed according to the pedestrians' needs in addition to providing comfort. In fact, the mass and voids were planned to provide shady outdoor areas and shelters for the pedestrians in the harsh climate conditions.

> *Traditional urban areas had a compact and mixed used pattern, were well-connected through a network of pedestrian paths and local characteristics, safety measurements were also considered in the design process. Combination of these qualities made the traditional city successful in achieving needs such as accessibility, equality, housing, employment, privacy, social relations, collective actions, etc. which are regarded as necessary for achievement of social sustainability* (Sharifi & Murayama, 2013).

The old city fabric of Yazd shows traditional courtyard houses woven together to create a harmonized and complicated urban texture. Yazd has the largest uninterrupted historic urban fabric in Iran [Figure 43]. There are various features and strategies in Yazd's vernacular architecture and urban texture:

Figure 43. Old urban fabric of Yazd city; historical quarter. Amir Chakhmagh complex (the main square) in the heart of the historical quarter is distinguishable

- Very compact, connected and continuous urban fabric
- Orientation of the city based on climatic factors
- Buildings positioned in a suitable wind direction
- Use of appropriate local materials
- Walls with high thermal capacity
- Central courtyards with pools and plants
- Organization and hierarchy of space
- Use of domed roofs
- Windcatchers to provide ventilation and a cooling system
- Connected water canals from the underground level of the residences
- Compatible direction of streets based on the desirable wind
- Narrow and irregular streets [Figure 44, 45]
- Covered alleys (Sabaats)
- Residences below alley level, etc.

Figure 44. Narrow and irregular winding streets, photos by author

Figure 45. Narrow and irregular covered winding alleys

4.5. Modern Layout: Comparison between the Historical Quarter and Suburbs

New, successful urbanists pay attention to various aspects of urban design such as sense of location, civic places, appropriate density, community identity, affordable housing, neighborhoods, citizen responsibility, safety and security, local values, public transportation, reduced automobile dependency and economic health, etc. (Leccese & McCormick, 2013). In a historical city like Yazd, urbanists are also inspired by the traditional urban design to respect the historic patterns for a cohesive design for urban society.

Today, urban planning in Yazd appears inconsistent with the climatic factors and the designs fail to meet environmentally friendly requirements. As mentioned previously, the urban fabric in the historic quarter is entirely different from the new urban fabric. Since the old urban texture was designed and constructed based on climatic considerations, the characteristics and shapes of elements, buildings, streets and alleys are closely related to climatic principles, whereas in the new urban fabric, which is not compatible with climatic factors, few sustainable elements or constructions can be found. Climatic considerations create unity and cohesion on nano, micro, meso and macro scales of construction; however, this harmony is not visible in the new areas of the city. Glaring inconsistencies in the city planning of the new urban fabric are a result of the lack of a comprehensive urban plan to address the ongoing rapid growth of Yazd [Figure 46].

Although the builders have had a perfect example of micro scale responsive design to emulate, they have not considered it important to follow this pattern: the scale and the urban fabric, which include orientation of the city, urban environment, street and alley forms, distances between the buildings and proximity of neighborhoods, etc.

The micro scale is only a copy of Western urban planning based on easy access to automobile without considering pedestrians, whereas in ancient times, the main focus of a design was to provide comfortable, easy access for people. The new areas are designed as follows:

- Chaotic orientations of the city
- Western urban grid forms
- Very wide and straight streets
- Suburban and urban highways

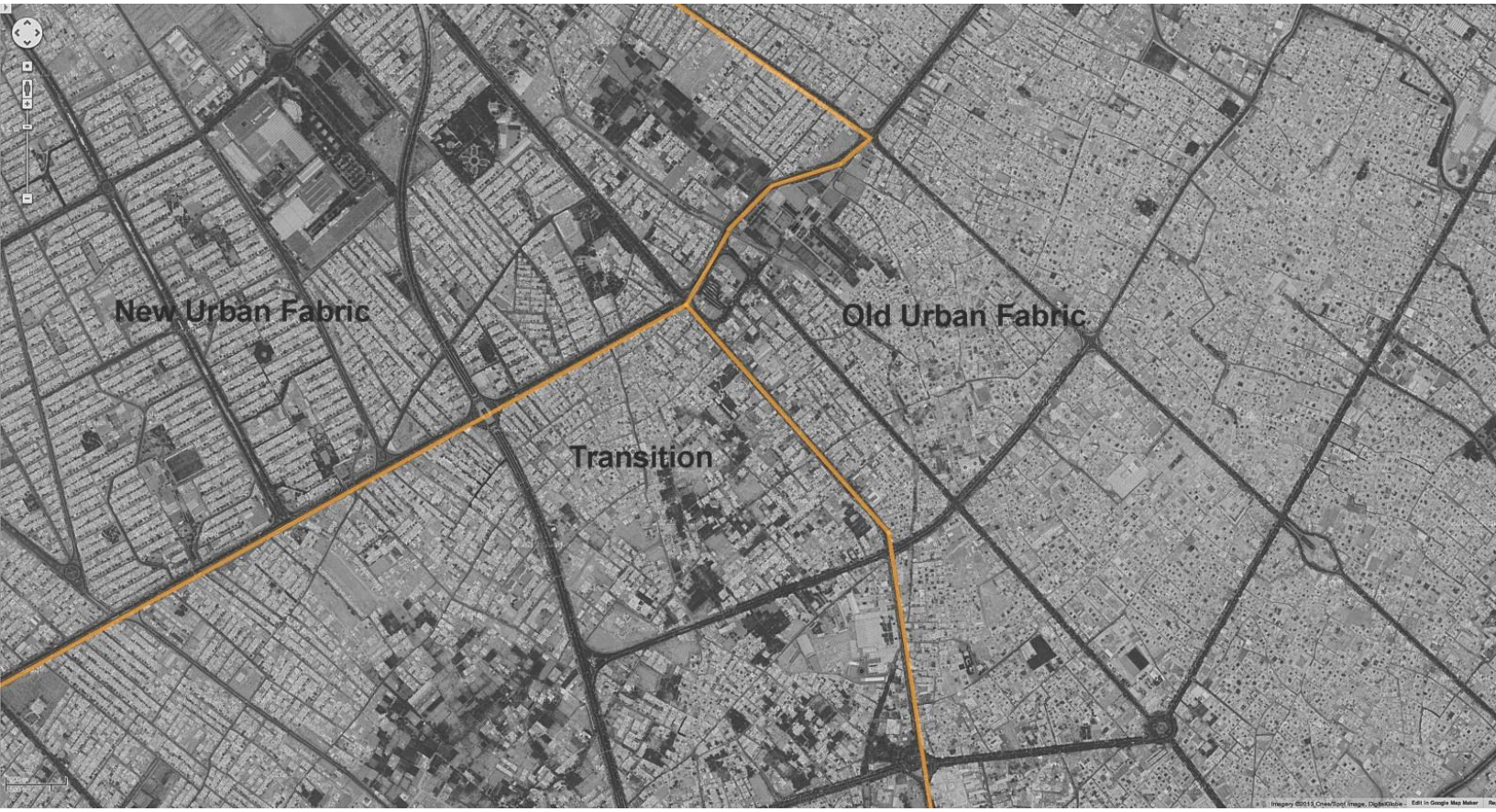

Figure 46. Visible dissimilarity in new and old urban fabric of Yazd

None of the designs considers the benefits of the fundamental sustainable urban principles used in the old city:

- Appropriate orientation of the city
- Narrower streets and alleys with high walls to provide shady passages
- Enclosed urban environment
- Proper distance between the buildings and proximity of neighborhoods

As mentioned in the historical context, Reza Shah's modernization program was related to significant infrastructural reforms in the country to transform the economy, culture and politics of the Iranian society. The government that played a major role in city planning and civil projects asked the western architects and contractors to design and execute new buildings and plans in cities. The civil projects were entirely influenced by the West: constructing of wide streets in cities, changing in buildings and neighborhoods, building new stores along the streets, introducing new public spaces and developing transportation systems (Karimi, 2012).

The major change in the look of the cities was the new street network to provide accommodation for automobile use. As a result, the integrated and cohesive urban structure of the cities began to disappear. Consequently, the functionality of the traditional components of the city was lost. The traditional bazaar was neither the central axis of the urban structure nor the main commercial centre. The dimension of the maidan changed, and it no longer functioned as a gathering public space; it was converted to a small square for automobile movements. After the establishment of the modern education system and construction of private baths in houses, the religious school and public baths lost their functions as well (Sharifi & Murayama, 2013).

Unlike the traditional street network, unfortunately, the priority is no longer the environmental comfort principles for humans; the modern street grid is only oriented toward automobile easy access and transportation. Today, a very basic problem of the new urban fabric is related to the street planning in this city [Figure 47].

Figure 47. Street map of Yazd in the mid-1990s, identifying selected street added or completed during last three decades

The goal of urban planning should be to decrease the negative environmental impacts on all scales. However, in the new areas of the city, the streets and boulevards with planting in the middle, are designed only for aesthetic reasons and do not consider providing environmental comfort for the pedestrians [Figure 48, 49]. Simply planting vegetation to provide enough shade can have a significant environmental impact [Figure 50, 51].

Figure 48. A boulevard in one of the new quarters of Yazd, photo by author

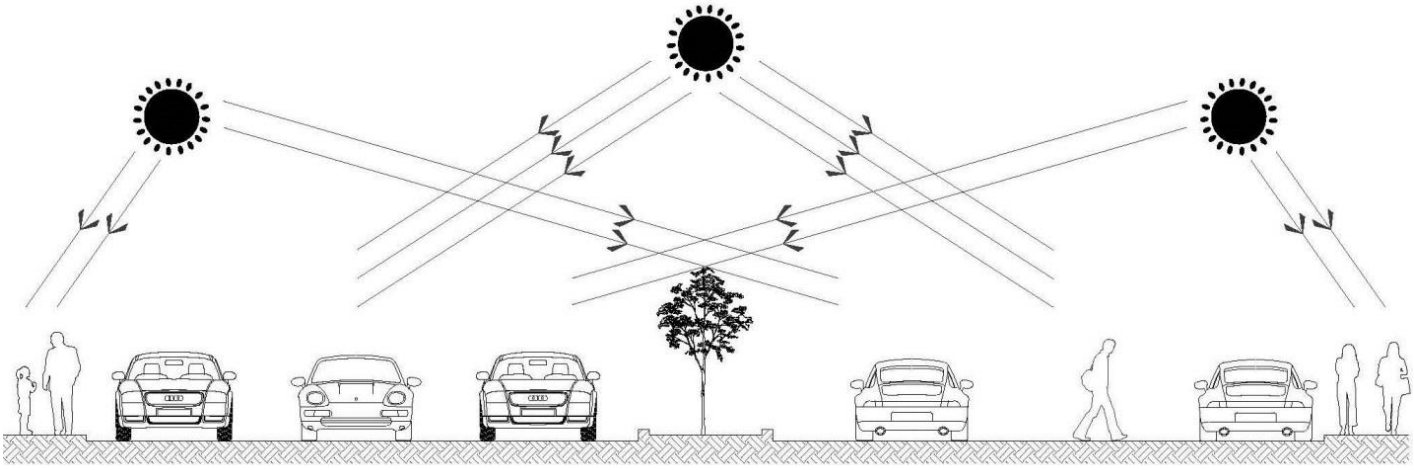

Figure 49. Poor use of vegetation in wide modern streets with little shade, drawn by author

It is worth noting that the main streets in the historic core are designed and oriented based on the desired wind. Even though the street in Figure 50 is not narrow, the correct use of planting aims to provide enough shade for the pedestrians on hot summer days.

Figure 50. Use of trees to provide shade for the pedestrians

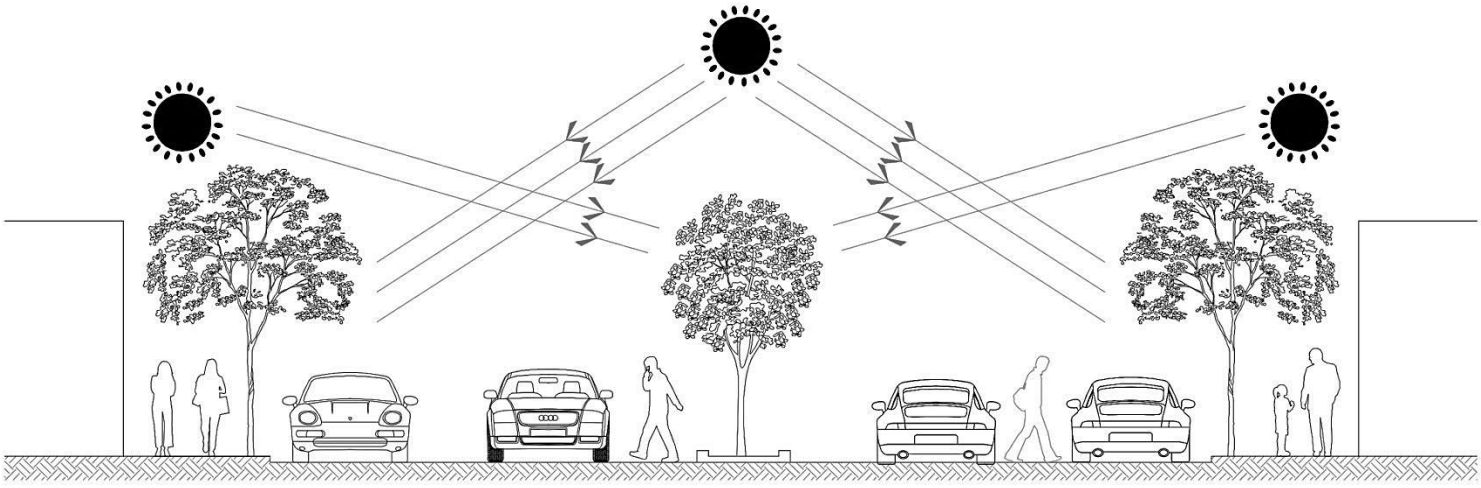

Figure 51. The correct use of vegetation provides shade for the pedestrians' sidewalks, drawn by author

4.6. Modern Design

The fast growth of Yazd to accommodate rural migration, from Pahlavi II until today, resulting from Reza Shah's land reforms in 1960, has created a strong demand for housing. The solution that the government has found is an approach of 'build-and-sell': cheaper and faster constructions, with modern amenities but without accommodating the unique local climate and culture considerations. Unlike the successful vernacular architecture in Yazd, modern architecture does not respect the local environment and tradition. With this approach, this historical city is moving toward an unknown future.

The tract apartments and buildings with modern materials that do not incorporate or reflect the local history of Yazd are the evidence of "modern development" (Modarres, 2006). Yazd, similar to other provincial cities of the country, has copied the only western influences that were evident in Tehran, the capital. Hence, the western influences emerged as poor secondhand copies [Figure 52].

Figure 52. Modern architecture in Yazd, photo by Mehrdad Tadjdidni

In modern residential buildings in the new urban fabric, the courtyard became smaller or has been eliminated; the low walls of the courtyards are not able to provide shade and protect the building against sunlight and wind. Using flat bitumen roofs, thin walls with poor thermal resistance, the colours and the materials (e.g. highly glazed), results in an increase in the interior temperature of the building in summer and a decrease in winter: the temperatures are extremes, either too hot or too cold. Consequently, the residents need to use fossil fuel heaters to provide enough heat during the winter and mechanical cooling systems to provide cool air in the summer. Hence, the occupants need to use massive amounts of energy to provide thermal comfort.

These approaches to constructing buildings do not follow the vernacular architecture principles and respect neither the site and its local history nor the climate conditions [Figure 53]. Hence, the urban morphology and traditional architecture of Yazd have been gradually lost and replaced by poor quality modern buildings. In consequence, this replacement results in the loss of the city's cultural identity and its soul.

Ali Modarres states in *Modernizing Yazd* that "As prisoners of modernism, Yazdis live in a present void of their past, oblivious to environmental and social problems emerging on their urban horizon."

Figure 53. New buildings in the new urban fabric of Yazd, photos by author

Chapter V: Yazd and the Modernized World

5.1. Modern Desires/Needs and the Government's Responses

Modernization and development have dominated all people's lives and created the perception that they should make the leap from tradition toward modernity. The recent rapid advancements in technology have resulted in a dramatic change in people's economic, social and cultural desires and expectations. Contemporary people's personal and urban lives, their attitudes, needs and definitions of comfort have been influenced by this wave of modernity so they have opted to make a change for a "better life". Unfortunately, this "better life" has not always led to a more comfortable, economic and healthy one in harmony with their cultural, traditional and social roots and Yazdi people are no exception.

After 60 years of modernity, the approach of constructing cheaply and quickly with modern amenities but with no environmental innovations that respect neither the site and its local history, nor the climate conditions, has been applied to the developed and developing areas. The results are poorly insulated, unshaded, air conditioned new tract buildings, some highly glazed, that need to use massive amounts of energy to provide thermal comfort. This section investigates the following questions:

Why and how have the urban morphology and traditional architecture of Yazd been gradually lost and replaced by poor quality modern buildings in the developed areas?

What approach should the government and architects take?

The ongoing growth of Yazd and its trajectory, and the desire for the familiar yet complicated phenomenon of modernization, are threatening the vitality of the culture and tradition of the city (Samizay, 2012). Negative population growth in the historic fabric indicates that the residents' departure from this area is due to various problems such as the lack of facilities and amenities and services and the time-worn urban texture of the area.

Although the owners of stores in the historic bazaar and traditional families still live in the historic quarter, opponents of living in the historic core, in particular the young people, believe that the historic quarter of the city is unable to meet their desire for a modern lifestyle. The time-worn buildings and cityscape in the historic core are not appealing to the youth; hence, living in the older quarters and older types of buildings is no longer popular. Some people believe the material used, e.g. adobe and unbaked brick, in these kinds of buildings are symbols of an old and backward era. Modern materials and systems

are preferred even if they are not appropriate for the climatic conditions. Since the 2003 earthquake in Bam some people have been concerned whether the old buildings in the historic quarter were constructed safely. Others might care about the lack of modern amenities such as internet access, electric power, electronic devices, gas, plumbing, air conditioning systems, easy access to automobiles and private parking.

Even though today, the residents of the traditional buildings choose to deal with various problems, the residents in new areas of Yazd are facing countless comfort problems. In reality, they do not realize that modern materials with low thermal capacity and buildings with inappropriately designed openings, lack of overhangs and shade, poor insulation and inappropriate orientations of buildings also have a major impact on their level of comfort.

Due to their dissatisfaction with the inadequate facilities and services in the historic setting to meet their needs, many young people have moved to the new and developed areas. On the other hand, rapid industrialization and employment markets in a growing city such as Yazd have caused the rural laborers to migrate to urban areas, resulting in an increase in the population and size of the cities. The response of the Yazdi government to fast growth in population was a western housing model of four to five-storey blocks (Diba K. , 1980).

The lack of modern services and facilities in the historic core causes the residents to move to the newly developed areas; the residents from the historic core need housing; the migration to the developed areas results in depopulation of the historic core; the depopulation results in the failure and collapse of the abandoned buildings; new buildings need to be constructed in the historic setting but they are not in harmony with the existing buildings and the story continues…

5.2. The Importance of Preservation

Humans have always been very curious about their past and its mysteries. Today, interest in the preservation of cultural heritage has become more prominent. In fact, by preserving cultural heritage, people can not only connect to their past but also pass this connection on to future generations. Attention to the preservation of the cultural heritage that is a key part of the historical identity of a city

would guarantee a better present and a better future for the city (Beheshti, 2004). Therefore, urban and cultural identity as well as people's demands for housing should be given careful consideration.

Since historic buildings, both vernacular and formally designed ones, contribute to the cultural identity of a nation and local pride, they are valued.

> *The physical survivals of our past are to be valued and protected for their own sake, as a central part of our cultural heritage and our sense of national identity. They are an irreplaceable record which contributes, through formal education and in many other ways, to our understanding of both the present and the past. Their presence adds to the quality of our lives, by enhancing the familiar and cherished local sense and sustaining the sense of local distinctiveness which is so important an aspect of our towns, villages and countrywide. The historic environment is also of immense importance for leisure and recreation* (Jokilehto, 1998).

According to Luigi Piccinato's approach to conservation and innovation in historic settings (1934), the conservation of a building can easily lead to innovation by changing the traditional use of the old buildings and introducing a new function for the old buildings related to tourism, commerce, education or administration (Jokilehto, 1998).

> *Tensions exist between the purpose of preservation and the need for recreation. The first, simulated by the awareness of conservation, causes public alarm when residents see a beloved structure or site threatened by aggressive modernism. The second, directed by demands of progress and visions of the future, is relentless significantly; both sides of the debates are valid. A civilized environment should accommodate conservation and development in order to sustain continuity and rational discourse between architectural forms. The crux of the argument is how to prevent buildings from standing in opposition and producing a chaotic effect on the urban setting. The implication is clear, that conflicts between design ideologies are undermining, not enhancing, the quality of life in crowded human settlements* (Warren, Worthington, & Taylor, 1998).

Iranians are not the only people in the world who inherited historical cities. In order to preserve their cultural heritage, people in Europe's historical cities are concerned about conserving historical buildings, so they keep the buildings' envelopes and renovate the interior instead of destroying the old buildings

and constructing new ones. They should be aware that their desire for modernity has a direct impact on the conservation of their cultural heritage.

Since the historic core of Yazd has been nominated as a World Heritage Site, all organizations and individuals should attempt to revitalize this heritage. This revitalization is possible; since the Second World War, there have been many examples of well-preserved medieval cities in Europe that have maintained their historic fabric and cultural identity over the centuries. Some of the well-preserved cities are the historic centre of Bruges, Belgium; the historic centre of Prague, Czech Republic; Regensburg and Bamberg, Germany; York, England and many other examples all of which are UNESCO World Heritage Sites. With this prestigious title, Yazd would be on the international map along with these cities and would attract numerous tourists.

In order to analyze, compare and underline the principles these cities share with Yazd, some related case studies are used. These case studies are used in different layers of comparison such as similarity in culture/history, built environment, climate, urban fabric/density and the shared religious or political aspects.

5.2.1. Case Study I: The Historic Centre of Bruges, Belgium

Figure 54. The historic fabric of Bruges

Bruges is a compact and dense city with a unique and intact medieval architectural style, which has been preserved over the centuries. Since 2000, this historic city has been designated as a “UNESCO World Heritage Site” (Wikipedia, 2014) [Figure 55, 56]. Like all other historic cities, it was not easy to integrate the new developments into the historic texture. In Bruges, achieving a balance between the

combination of new functions and preservation of medieval heritage has been very difficult; the preservation of old buildings has taken precedence over the renovations, and only the buildings that have collapsed or are near collapsing are allowed to be replaced by new ones (Anonymous, Bruges, World Heritage City, n.d.). Therefore, the well-preserved historic, dense urban fabric of Bruges with its winding narrow streets can be a good example for the renewal of the historic core of Yazd and also can be used as a successful example for a well-balanced integration of new buildings within a historic setting.

Figure 55. The ring road around the historic city of Bruges

Figure 56. The compact and dense urban fabric of historic Bruges

During the wave of modernity that took over Europe in the 1960s, the historic heritage in Bruges was disregarded; new and different architectural styles and scales that were not compatible with the historic setting began to appear. After 1970, the conversion of historic elements into modern features with consistency/compatibility of materials and volumes with the medieval buildings became the main focus; the inspiration was based on the guidelines that the city council had declared. In 1971, the Municipal Department for Heritage Conservation and Urban Renewal which consisted of architects and historians who were to follow/screen restoration, to establish urban development policies, building permits and scientific research, and to hold the exhibitions and competitions in the city, was created. Attempts were made to preserve the historic appearance of the medieval city with its winding streets and canals while meeting citizens' requirements for modern life [Figure 57, 58] (Anonymous, Bruges, World Heritage City).

Figure 57.Winding and narrow streets of Bruges, photos by Peter Collision

Figure 58. Winding streets of Bruges in the historic core

In order to deal with traffic, a ring road around the historic core was built and the use of cars in that area was restricted; gradually, the city became bicycle-friendly, more public parking was added and the public transportation system promoted. The government provided funding and encouraged the new residents and the old owners of the traditional houses to restore their properties. Gradually, the appearance of the city became appealing again and the number of tourists, who were and are the main sources of income, increased. From the 1970s until today, the strict municipal bylaws and regulations continue to maintain the harmony of the historic urban fabric of Bruges (Anonymous, Bruges, World Heritage City, n.d.). In 2002, all these efforts resulted in the election of Bruges as the "European Capital of Culture", which annually attracts two million tourists (Wikipedia, 2014).

5.2.2. Case Study II: Historic quarter of Suleymaniye, Istanbul

Although Istanbul and Yazd are different in climate conditions, they share more or less the same political climates. These two neighboring countries (Turkey and Iran) also share a long history, similar culture and religion, which are evident in their architecture. The dense urban fabric in Istanbul with narrow streets and alleys, which people and government have recently tried to preserve, can be used in Yazd as a recent neighboring example.

Suleymaniye is one of the historic quarters of Istanbul where the governmental class of the Ottoman Empire lived in the seventeenth century. The name of this quarter is derived from the Suleymaniye mosque complex. This quarter is located on the third hill of the seven hills of Istanbul, where various architectural monuments were built during the period of the Ottoman Empire (Anonymous, 2004) [Figure 59].

In the 20th century, through industrialization and the development of Istanbul, worker immigrants and their families became the main residents of this quarter. The residents are either workers in the manufacturing companies, in marginal businesses or have no job. As might be expected, the social and cultural layout of the quarter witnessed a dramatic change (Gulersoy, Tezer, Yigiter, Koramaz, & Gunay, n.d.).

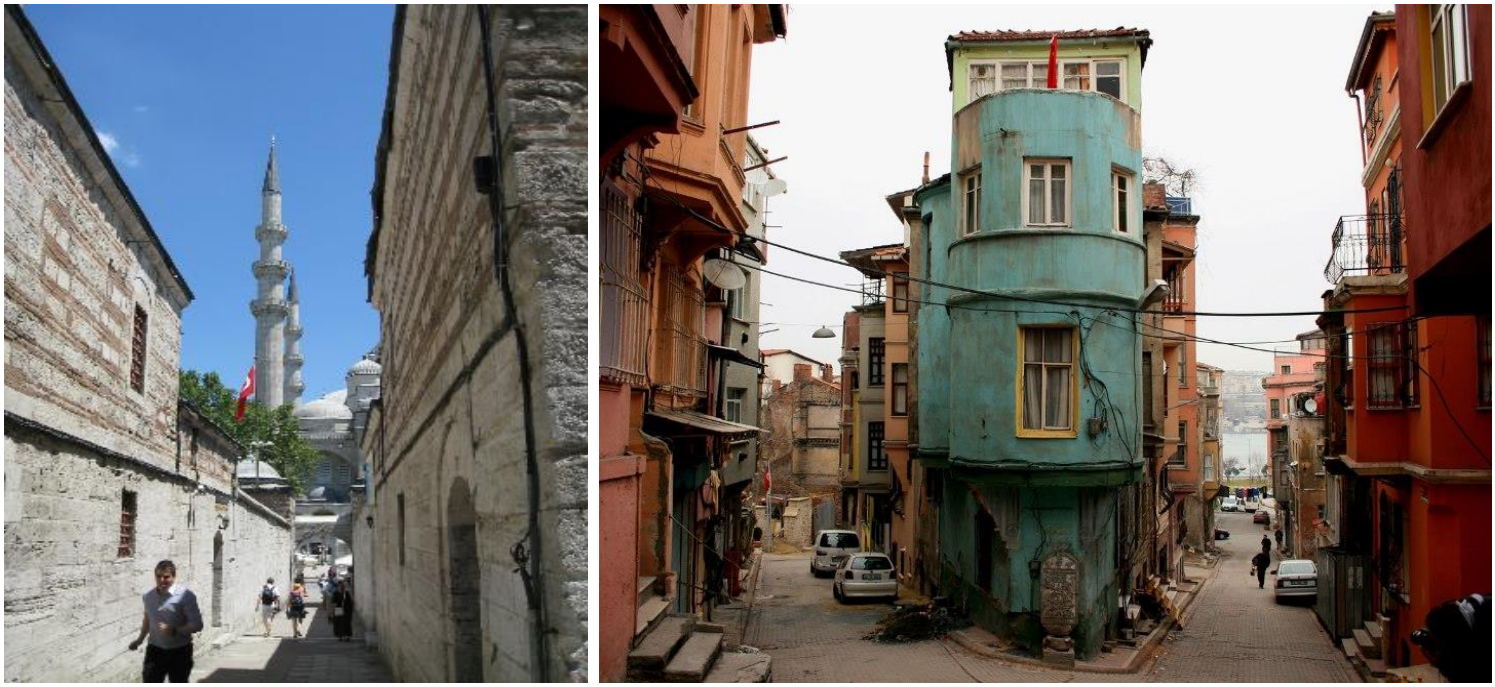

Figure 59. Narrow streets near the Suleymaniye Complex

The urban fabric of this historic area is very dense with narrow cobblestone streets and compact 3-storey high buildings. Since this quarter is one of the major attractions for tourists, an LRT is provided to service the tourists and the residents of the quarter. Although car access is allowed, most of the streets are one-way due to their width [Figure 60].

Although there is only a small number of inhabitants in this quarter who have truly any idea about Suleymaniye, most of them think the solution to this problem would be urban renewal through replacement of the historic buildings which are small and cramped with modern multi storey buildings (Gulersoy, Tezer, Yigiter, Koramaz, & Gunay, n.d.). It does seem, however, that most of the youth in Istanbul are truly aware of the environmental and cultural impact of these developments where modern structures replace the historic areas. The recent (2013-2014) social protests which initially formed to protest against the urban development plan in Taksim Gezi Park is a good evidence of their awareness of the importance of these kinds of issues.

Fortunately, Istanbul University is located in the core of this historic area and had a direct impact on restructuring the social and cultural layout. The socially active environment that students brought back to this quarter revitalized it (Gulersoy, Tezer, Yigiter, Koramaz, & Gunay, n.d.). Restaurants, a hospital, the university and the Suleymaniye complex itself can be major reviving factors in this historic area.

Figure 60. The dense urban fabric with the narrow streets and alleys

The year 2000 was a turning point in improving urban infrastructure and housing organization and regeneration in the historic fabric of Istanbul. Due to the value of the cultural heritage of these historic quarters and the main attraction of tourists, the government considers regeneration and conservation of the historic core very important. During the past five years, the renewal and preservation of these quarters have been discussed broadly in the public domain: conferences, seminars, articles, etc. (Dincer, n.d.). A comprehensive plan and the cooperation of people in conserving their heritage are the key elements in achieving the best results for revitalizing this quarter.

5.2.3. Case Study III: Historic Cordoba, Spain

Cordoba is a city in southern Spain, in Andalusia, which has a rich history from the period of the Byzantine Empire and even after it was captured by the Muslim army in 711. (Wikipedia, 2014) It will always have the footprints of its Roman, Muslim and Christian rulers left on the city layout (Reed, 2005-2008) [Figure 61].

Figure 61. The urban fabric of the historic district of Cordoba

Cordoba shares a similar dense historic urban fabric and climate with Yazd. This city has hot summers with a daily average of 36.2 °C (the highest average among the European countries) and cool summer nights. This European city with some shared architectural principles with Yazd is one of the best and most successful examples of well-preserved cities that can be used in the preservation of historic Yazd.

Cordoba's historic centre was declared a UNESCO World Heritage site in 1994. The medieval plan and the irregular layout and narrow streets of the historic centre of Cordoba are well-preserved. The historic landmarks of Cordoba consist of various styles of architecture of different eras: Moorish minarets and the Almodovar Gate, the Roman relics, the Christian monuments and churches, the great mosque-cathedral, the Jewish synagogue and other architectural elements which have been conserved very well and are considered to be symbols of a golden age and coexistence between cultures and religions, a reality which we would like to be a model for our era (Guichard, 2006) [Figure 62].

Figure 62. The urban fabric in the historic area

After the Napoleon invasion of Spain in the 19th century, new changes were applied to the urban fabric. The old tower and gates were destroyed to pave the path for new streets and developments; however, some of these historic gates and towers still remain (Reed, 2005-2008).

Figure 63. The Jewish quarter with its narrow alleys

Generally, the urban fabric in the historic district in Cordoba is compact and dense with mostly 2-storey buildings and irregular narrow streets. There is an old Jewish quarter near the cathedral that has many irregular narrow cobblestone streets (Wikipedia, 2014) [Figure 63], which are mostly used by pedestrians; car access is mostly banned in the main historic districts. The renovated traditional houses, which have been converted to hotels, cafes and small tourist shops have changed the dominant white facades of the buildings to colorful stops and are always full of tourists [Figure 64, 65].

Figure 64. Car access in the historic area

Figure 65. Tourist shops in the historic district in the irregular narrow streets

5.2.4. Preserving Old Yazd

The culture has its own body and spirit. The body of a culture is the historical relics or, in other words, the physical evidence that are remains from the past such as the artifacts, buildings and monuments, whereas the spirit of a culture shapes the cultural identity of nationhood (Beheshti, 2004). However, unfortunately, the body of the culture and these historic structures are under the risk of inappropriate restoration and poor conservation in Yazd.

Although Yazd with its large variety of historic monuments and sites has retained its ancient cultural heritage throughout its history, today, the city is dealing with depopulation of its historical urban fabric, which is a direct consequence of an accelerated modern technology that has changed people's economic and social expectations and, ultimately, caused migration to the modern areas and abandonment of the historical core. The historical core is now facing the risk of the gradual demolition of its historical mud brick buildings, windcatchers, qanats and other traditional features as the consequence of this depopulation. Since the number of inhabitants in the old urban fabric is decreasing and many of these architectural elements are not in use, they are falling into disrepair and risk removal or collapse. These features can only be rescued and preserved if public awareness increases (Abouei, 2006).

To encourage occupancy of the historic core and hence guarantee its future survival, either people's expectations need to be modified by means of education or the management strategies in the historic core and its buildings need to change. Although both changes are difficult to be performed, both approaches have been considered in this section.

This ancient city is dealing with various problems. Some of these existing problems are not related only to residents, planners and architects; they are related to the governmental structure and the hierarchy for decision making and urban management. Today, there are five different organizations that are involved in major decisions: Yazd City Hall, City Hall of the Historic Area, Islamic Council of Yazd City, Ministry of Housing and Urban Development, and Cultural Heritage, Handcrafts and Tourism Organization of Iran. On the other hand, people are not aware of the value of their cultural heritage and the historic relics. So, they do not care about the collapse or destruction of the traditional buildings especially when they can afford to live in a more comfortable and modern house. If the people's awareness does not increase, the success of revitalization of the historic core will be impossible.

Although in Yazd, the government has not taken any steps to increase the awareness of people, unfortunately, the architects have not taken any significant action either. Although a few examples exist they are only related to the renovation of some old buildings, which, are used primarily as traditional restaurants, hotels and guesthouses for tourists. Since the maintenance and costs of preservation of the cultural heritage often outweigh the environmental quality and performance, they are neglected by the government. However, the restoration and revitalization of the house of Malek-O-Tojjar, a historic residential building in the bazaar area, into a hotel (guest house) in 2000, was a good step to take for increasing awareness of the neighboring residents, but it was and is not enough.

Another problem that has affected the historic core of Yazd is the lack of investigation of either the public sector or the private sector investors; this is related to the lack of security and safety in the historic core and also a decrease in the cost of lands in that area.

Moreover, the investigation shows that most residents in the historic core consist of old people or heads of families with their families. Most of the youth and active labor force population have immigrated to the new and developed area; therefore, some of the historical houses are without any residents and this depopulation changed the boom of the historic core (Ahmadpour & Shamaee, 2001). Some of these buildings are rented or occupied by immigrant labourers or poor and deprived people who do not feel responsibility or interest for conserving and preserving these residences. On the other hand, some other buildings that are close to destruction became the centre of crime and misdeeds. (Ebrahimi, Saraei, & Biranvand, 2008) As a result, the old city has become unsafe and lacks security.

Different levels of governmental organizations, planners, architects and Yazdi people who admire their cultural heritage must collaborate and cooperate to take some steps for revitalizing the historic core and the valuable existing buildings, instead of abandoning or destroying them. It is necessary to try to reinforce, conserve and reuse them. For achieving this goal, there should be one coordinated organization to have authority to manage the historic core and be responsible for complaints, expectations and concerns about any shortage of facilities and services.

5.2.5. The Study Area

The bound area of the historic urban fabric of Yazd which is 743 ha lies between Rajaee Ave. and 10th of Farvardin St. in the south, Dolat Abad and Saeedi Blv in the West, Basij and Daheh Fajr Blv. in the East and Fahadan St. and Seraj Alley in the North. The population of this historic core according to the 2004 population census is 72000 with the density of 60 person/ha. In Figure 66, the selected study area of the historic urban fabric, the historic core and the city limits in 2000 are indicated. The selected study area can be used as a sample which can represent most of the old quarters of the historic urban fabric. The transportation and pedestrian routes are also indicated in the aerial photos from the study area [Figure 66-70].

Many buildings which are near to collapse or completely destroyed are found in the study area, it is possible to use these buildings for different purposes such as schools, health services and clinics, and government administrative services. Some unused and empty spaces are also found in the study area, and these can be used to provide the services that the residents and neighborhoods may need from parking lots to parks, green spaces and sport fields [Figure 71-72].

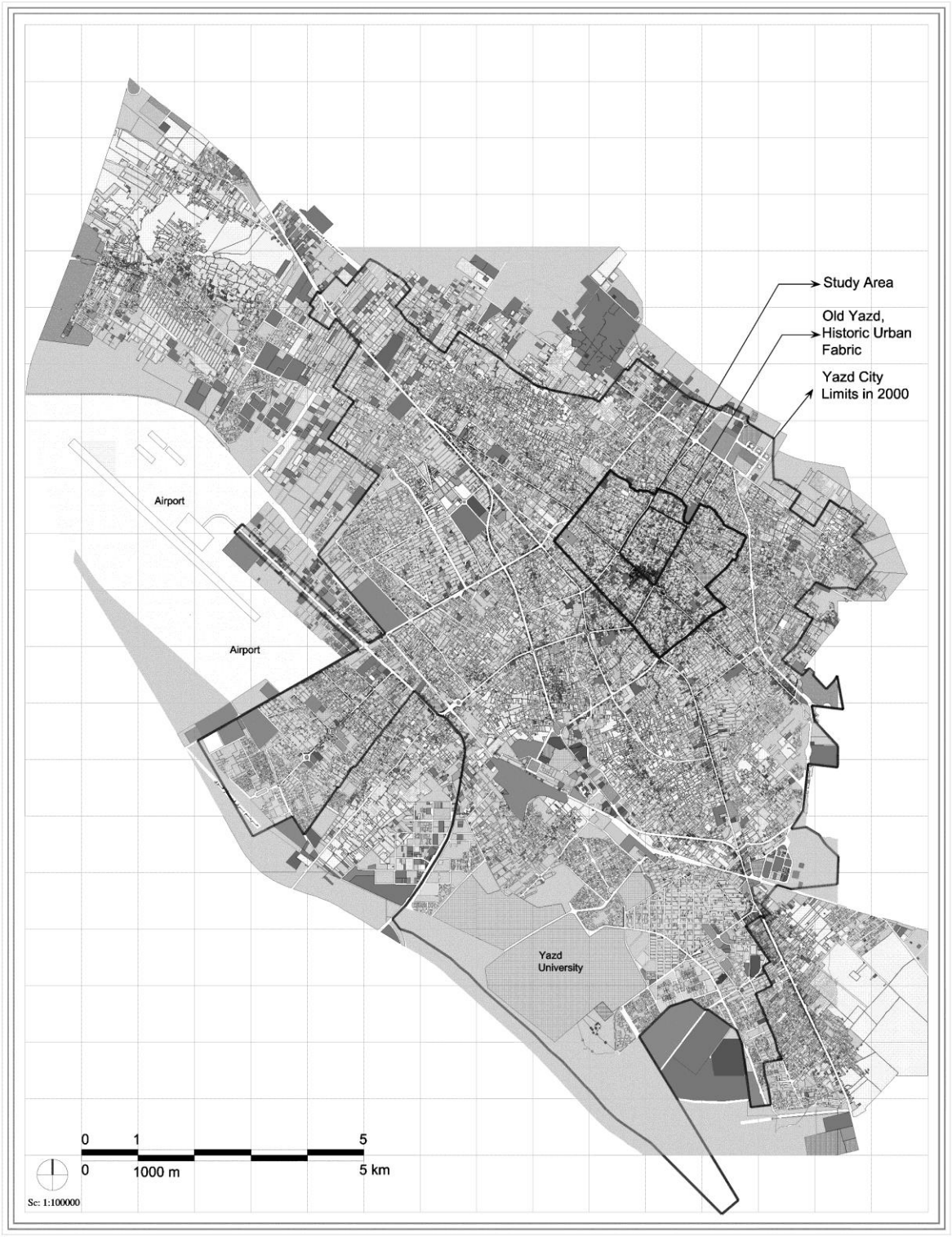

Figure 66. The historic core, the selected study area and the city limits are indicated in this map

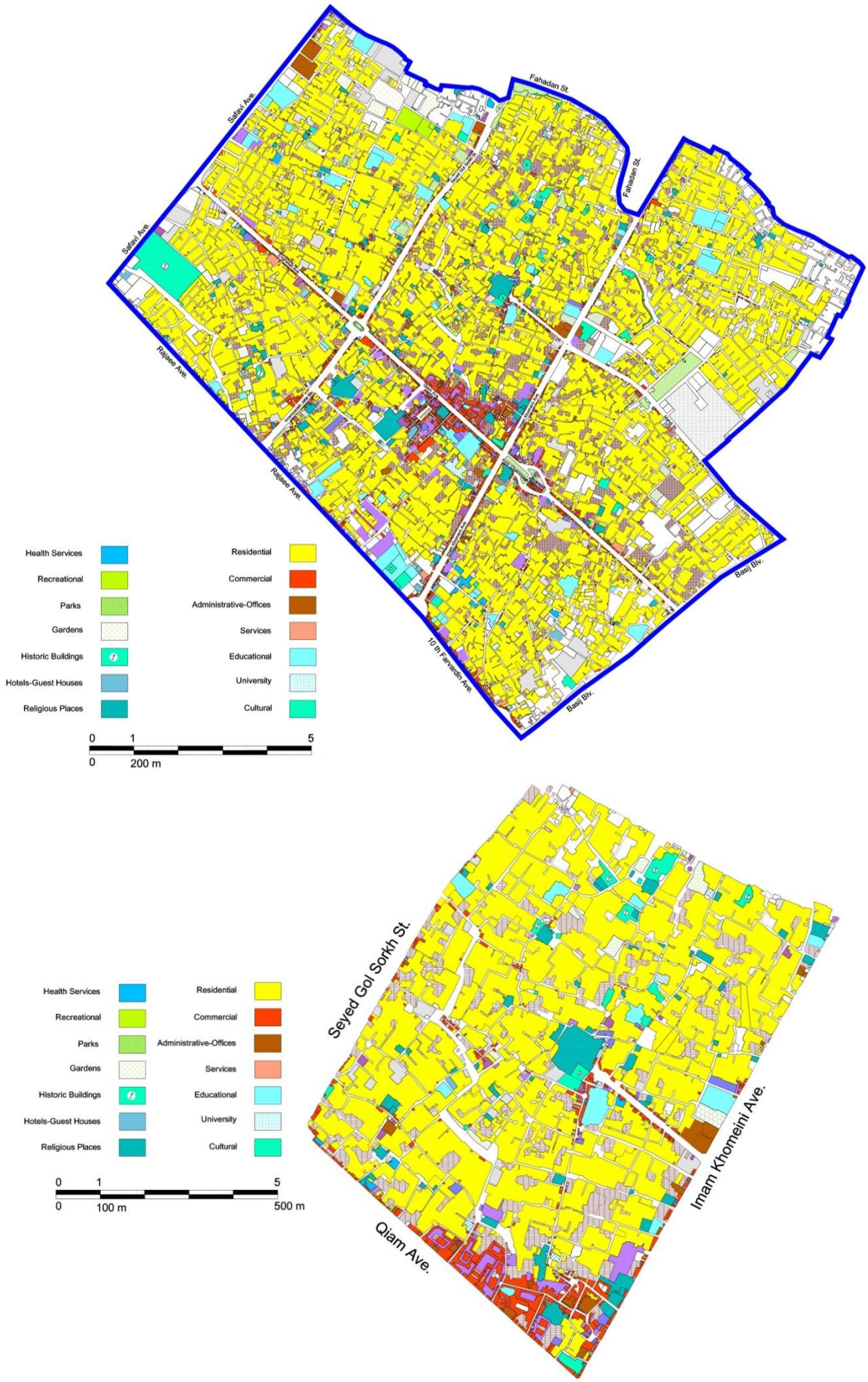

Figure 67. The function of the buildings, spaces and services are defined by means of colors in the historic core and the study area, the first map shows the historic quarter while the second map illustrates the study area

Figure 68. Map of the transportation routes and the distance from the old housing, the first map shows the historic quarter while the second map illustrates the study area

Figure 69. Aerial photo with the illustration of transportation routes in the study area

Figure 70. Aerial photo with the pedestrian routes shown

Figure 71. Aerial photo with the illustration of derelict and collapsed building sites in the study area

Figure 72. Aerial photo with the illustration of empty spaces/void in the study area

5.2.6. Suggesting Solutions for Preserving Old Yazd

- **Educate Yazdi residents about the historic value of old Yazd:** educating people can be achieved by domestic media, schools, billboards, etc. to highlight the value of the historic setting and increase the awareness of Yazdi people about gradual demolition of the historic core and ask for their cooperation to prevent it.

- **Prohibit demolition of historically valuable buildings; encourage renovation:** None of the significant vernacular architectural buildings or details should be demolished; instead, people should try to keep the old features such as windcatchers and qanats systems working to revitalize the historic core. The classification of buildings as historic relics, which are non-valuable, time-worn, or which need reinforcement or renovation only would be the direct responsibility of the coordinated organization or committee chosen by five Yazdi governmental organizations. If some of the non-valuable buildings are known and selected, they can be destroyed or changed in function in order to accommodate some of the necessary services of the neighborhoods.

    - Note 1: In the study area, some of the shops and residences are considered non-valuable based on their appearance.

    - Note 2: Parking sites are selected from the empty spaces or completely collapsed building sites.

- **Improve Public Transportation:** private car access to the historic core should be banned partially (in rush hours) or completely in specific areas**;** instead, the public transportation system should be improved to meet people's needs for transport.

- **Provide Public Parking:** if car access is banned in some areas, residents, the employers and retailers will need parking lots to park their cars close to their homes, companies and stores and they'll have to walk the rest of the way to work. The empty spaces can be used as parking lots for neighborhoods. The capacity of the recommended parking spaces may vary according to the area of the site in the study area.

- Note 1: All the parking locations are selected not only to serve the residents but also to service the near-by administration employees during the day.

- Note 2: Sites for parking lots are carefully selected according to the area of the site, close access to the main roads and the needs of each block or neighborhood, whether for the residents of those neighborhoods, the shopkeepers, the employee or tourists. [Figure 73].

Figure 73. Parking (Pa) with its neighboring health service (H), Jami Mosque, covered bazaar and the close administration offices (Ad)

- Note 3: Ideally, the parking garages will consist of three to four levels to maximize density. Because the overall height of the parking garage should not surpass the dominant height of the historic core which is approximately four to five meters (a level and a half), at least two levels would have to be underground. It is also possible that the qanat network may limit the depth.

- Note 4: Parking lot a (Pa) is selected based on the needs of the Jami mosque, the adjacent bazaar, the selected site for the neighboring health service/clinic, the residents and the employees of the administration offices for parking lots.

- Note 5: In order to expand the parking (Pa) sites to service more people, the small shops in front of the parking site, which are not considered valuable or included in the historic plan can be destroyed and their space can be added to the selected parking site [Figure 74, 75].

- Note 6: The location of parking b (Pb) is selected according to the pedestrian entrance to the bazaar as well as the other general considerations for parking lots; e.g. the needs of the adjacent neighborhood.

- Note 7: the location of parking c (Pc) is selected in order to service the neighboring school as well as the neighboring offices and residences.

Figure 74. Expansion of the selected site for Parking a

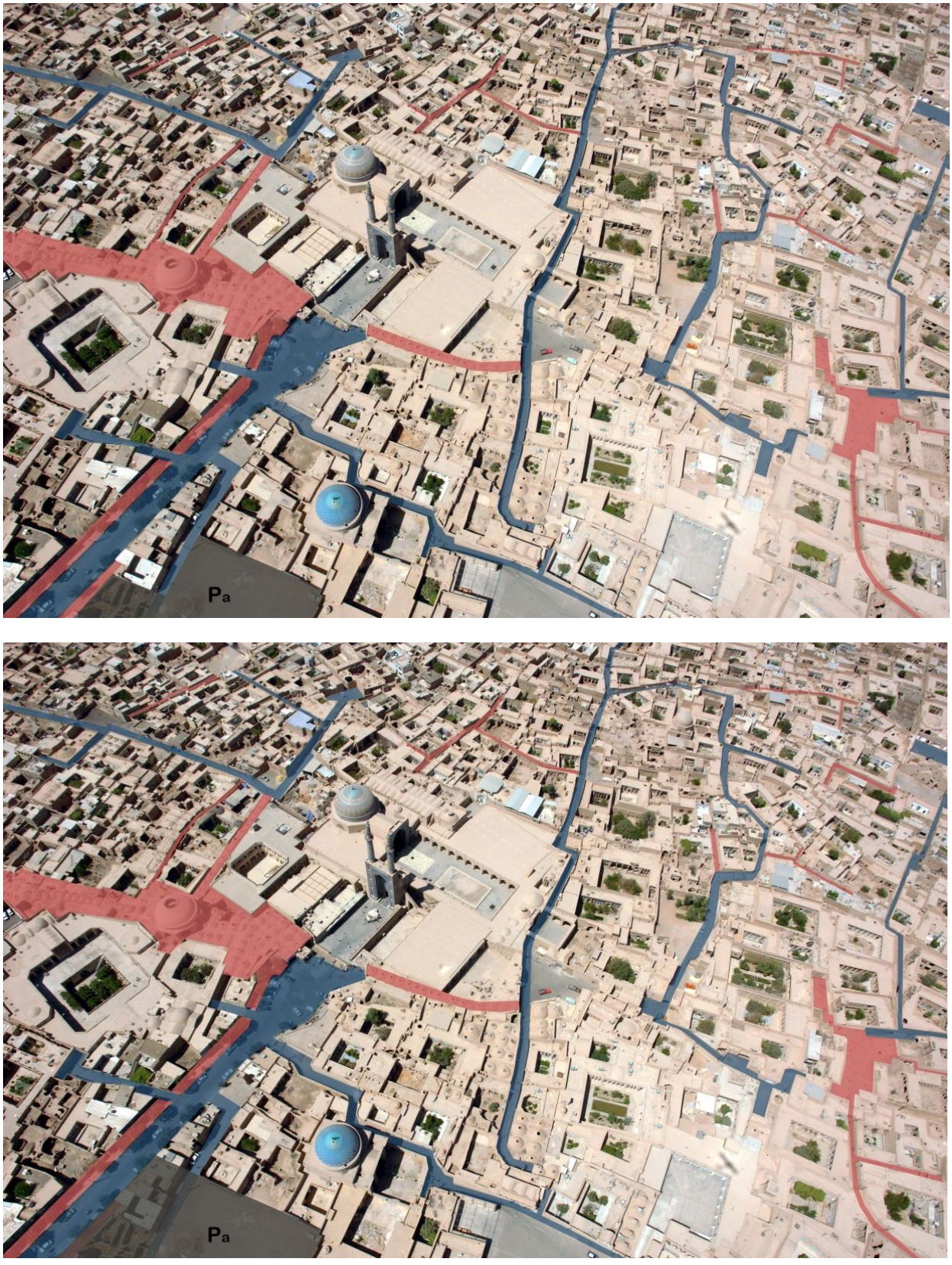

Figure 75. The expansion of the parking a from another view

Improve access to the historic core: Since the streets and alleys of the historic core of Yazd are tighter even than historic cities such as York in the UK or Bruges in Belgium, a special solution needs to be provided to solve the problem of ambulances, firefighter vehicles and garbage trucks having access to the historic core of the city. One of the recommendations would be establishing specific sizes for trucks, ambulances or firefighter cars that are used in the historic section so that they easily can move through the alleys which are both narrow and low (especially in covered alleys)[Figure 76].

Figure 76. The smallest available ambulance, firefighter car and garbage truck

- Note 1: making all the local routes in the historic core one-way or limiting vehicles to residents only in order to control the traffic flow in the historic core would also help improve access and movement within the core.

- Note 2: Changing the asphalt streets and alleys to cobblestone pavers would be beneficial due to its durability as well as for aesthetic reasons.

- **Upgrade amenities:** the rusted and time-worn plumbing networks for gas, water and wastewater should be completely or partially replaced by a new network. The sewage and wastewater systems should be redesigned and reconstructed very carefully in order to prevent any problem of mixing pure water of qanats with the wastewater. High speed internet in the historic areas and free Wi-Fi in public spaces and coffee shops can be provided to attract youth.

- **Provide enough facilities for the youth and children:** there is lack of green spaces, parks, playgrounds and sport fields in this part of the city. As mentioned previously, the empty spaces can be used for these purposes according to the needs of the neighborhoods.

- Note 1: The existence of green space (parks and sports fields) is a must; this shady cool space acts like a breathing space for this compact and dense core of the city. Furthermore, it would definitely change the appearance of the study area [Figure 77].

- Note 2: Almost all of the sites for this purpose are chosen from smaller empty spaces in the study area. Specifying parking for a sports field, park or a combination would be based on the needs and area of the spaces.

Figure 77. Green Fields are chosen for functioning as parks, playgrounds and sport fields

- **Provide enough medical facilities:** the residents in the historic core are suffering from a lack of clinical services. Some of the old buildings can be specified for these purposes. The buildings

which are very near to collapse or destroyed buildings are be used as the site for these purposes in the study area.

- Note 1: The location of the health service/clinic is based on access to the main roads. It would definitely serve the patients much better than being in a location where the main accesses are tight. Moreover, the adjacent parking can service the staff and people who accompany patients [Figure 78].

Figure 78. The clinic and the adjacent parking lot (Pa) are shown in the picture

- Note 2: The site of the clinic is chosen from derelict and worn-out building sites. Non-historically-valuable shops and an empty space in front of the chosen site can be added

to it. There is a building in the middle of the site which seems to be in fairly good shape. If this building is considered as a historic relic, it should not be destroyed if it is a regular house; it is probably worth destroying it in order to achieve a public goal: a well-equipped health care centre [Figure 79, 80].

Figure 79. The expansion of clinic site by adding the front empty space and the non-valuable shops

Figure 80. The expansion of clinic site from another view

- **Provide the required educational services:** The lack of a girls' school in the historic core is a problem for the families. To solve this problem, a site consisting of several derelict buildings is chosen to construct a girls' school in the study area [Figure 81].

  - Note: Parking c (Pc) is located very close to the school. It is a facility which the school staff and the parents can use.

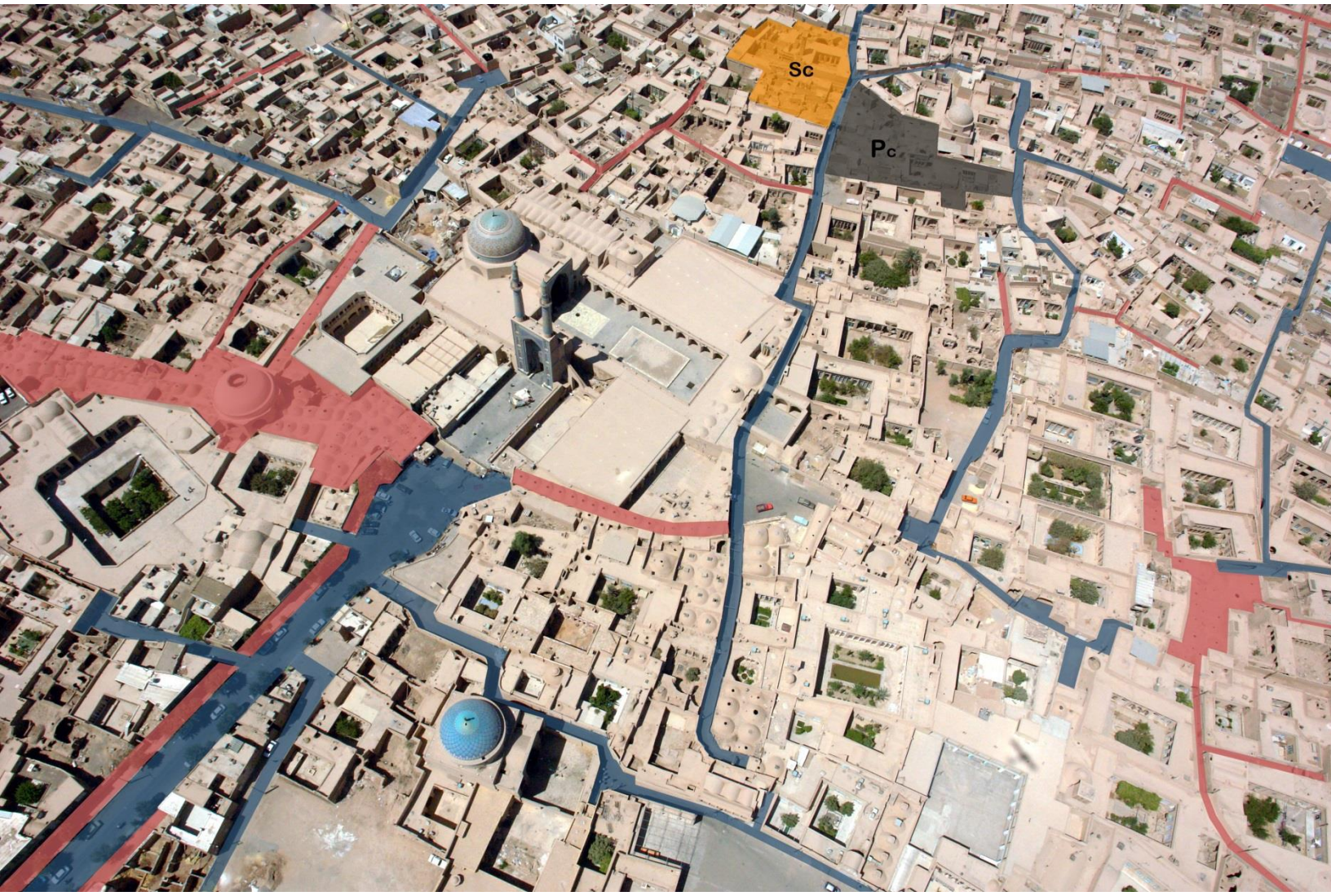

Figure 81. The selected site for the school and the adjutant parking lot, Pc, are indicated

- **Provide governmental Financial Aid:** structures and foundations of historic buildings need to be reinforced; hence, public or governmental sector investors should provide short or long term mortgages and loans for renovation, conservation and preservation of historic buildings.

- **Solve the problem of security:** the demolished and partially-destroyed buildings have become unsecure and dangerous places in neighborhoods which have converted to places for crime and criminals. This problem should be solved as soon as possible to bring back the safety to these neighborhoods. Since the private sector investor stopped investment in this area because of the lack of security and safety, the private sector investor will be active again once the government provides security.

- **Change the functionality of the abandoned residences:** in order to revitalize these residences, a variety of new functions can be specified for the old buildings to reuse them, such as governmental offices, private office, clinics, museums, etc. Shifting the important governmental offices to this area can play a key role in reviving the historic core.

- **Provide neighborhood 24/7 services:** a janitor or a watchman can be employed by the government for each neighborhood to provide security and safety while helping to keep the neighborhood clean.

- **Increase the citizens' and government's income:** If the city were revitalized, both the private and public sectors would benefit when the number of tourists increases. Based on the city's economic growth, the hotels, shops, public museums and other organizations would have more income and this growth would increase the government's income when the citizens and organizations pay their taxes. The city would then have a chance to flourish as it once did in the old days.

5.3. Appearance of Modernity in Historic Contexts

Yazd is not unique in facing challenges in the appearance of new buildings in historic settings; North American and European cities have also experienced the same challenges. With the rise of modern technology and new urban planning in the 19th century, the appearance of new buildings in historic contexts and traditional towns, new developments became an issue for discussions in various journals in several countries such as Germany, England, France and Belgium. In the aftermath of the First World War, the buildings in old areas were destroyed. Although some effort had been put into rebuilding these historic areas, the supporters of the Modern Movement in architecture were opposed to any use of

previous styles in contemporary constructions. Later, due to the massive destruction of the Second World War, a growing conservation movement led by John Ruskin and William Morris became widely accepted in the first decades of the 20th century. A longing for the past as well as an eagerness for the modern urban planning and building design were considered more seriously. In several countries, various guidelines were established to control new buildings in historic settings; however, some countries were strict about using traditional materials and keeping the old architectural styles (Jokilehto, 1998).

Historic towns and cities became more important due to the 1972 UNESCO World Heritage Convention. The convention did not specify any principles; however, the Management Guidelines for World Cultural Heritage Sites by ICCROM[viii] were published to clarify conservation planning in historic fabrics:

> *The building of new structures should not be an excuse for demolishing old ones. New construction may, however, be necessary to re-establish functional and architectural and architectural continuity, and in cases where empty lots might be hazardous to or further decay surrounding buildings* (Jokilehto, 1998).

It is important to consider that what is built today has a direct impact on future generations. People do not see a new building in isolation; they use it in its context. Therefore, successful new buildings are those ones which integrate with their local context by using local materials and techniques (Velluet, 1998). Hassan Fathy believed that science can help humans develop the use of natural energy resources far beyond what has been achieved in vernacular architecture if the architects can fulfill two requirements: “a systematic application of science and a comprehensive comparison of modern and traditional structure” (Fathy, 1986). In addition to these requirements, the traditional solutions must be respected. This attempt not only enriches architecture but also enhances cultural and ecological quality.

Designing new buildings in historic settings requires very careful consideration. The major concern should be respect for the architectural style in the historic context; the harmony of the neighborhood should be retained and the appropriate mass or volume of the building as well as the scale considered. Furthermore, materials should be used wisely to avoid a visual disruption of the existing historical, dominant materials in the setting (Jagger, 1998). Some general principles for designing new buildings in historic settings follow:

[viii] Centre for the Study of the Preservation and Restoration of Cultural Property

- "Use of architectural style appropriate to place and time
- Volume and massing consonant with the established form
- Colour, scale and texture comparable with the historic environment
- Usage that does not disrupt the established context" (Warren, Worthington, & Taylor, 1998)

> *In general it is better that old buildings are not set apart, but are woven into the fabric of the living and working community. This can be done, provided that the new buildings are carefully designed to respect their setting, follow fundamental architectural principles of scale, height, massing and alignment and use appropriate materials. This does not mean that new buildings have to copy their older neighbors in detail…. Good design can help promote sustainable development, improve the quality of the existing environment, attract business and investment; and reinforce civic pride and a sense of place. It can help to secure continued public acceptance of necessary new development* (Velluet, 1998).

5.3.1. New Buildings in Old Yazd

During the last century, the modern building practices in Iran disregarded the significance of culture and environment on human comfort by using cheap and non-renewable materials and excessive technology and industrialization instead of benefiting from the source of inspiration: the existing traditional and vernacular responsive designs. During many years of architectural practices, these proven principles were used and ultimately resulted in the current sophisticated building forms. Therefore, a set of planning strategies is needed for the design principles to conserve the cultural and environmental heritage that formulates the principles to generate the cultural matrix and lifestyle of the 21st century (Kazimee, 2012).

The architects and urban planners should carefully analyze the old and existing fragments of the city to be able to integrate them in a coherent overall structure. Unfortunately, there are many buildings in the historic core of Yazd that are designed and executed without considering any of the basic principles of design in the historic settings, which deface and affect either the beautiful skyline of the historic core by their heights or the old setting by inappropriate use of architectural style in the area.

The lack of an archetype of either new modern sustainable designs or properly restored old buildings that can provide comfort with very simple principles while meeting modern needs, respecting local culture and imposing less on the natural environment should be a real concern for the architects.

5.3.2. Suggesting Solutions for New Buildings in Old Yazd

- **Colour, texture and material used in building facades:** The visual unity of the city fabric of Yazd is shaped by local materials: clay and mud bricks. Therefore, the colour and texture of the materials should be in harmony with the old setting.

- **Massing, volume, height and form:** these characteristics of buildings should also be considered carefully to prevent any interruption in the historic context.

- **Architectural style:** The architectural style should be compatible with the environment and climatic conditions. The available vernacular architecture is the best resource and paradigm for new designs, which can be a combination of the old principles and new technologies.

- **Culture:** The new designs should respect the cultural and religious values of the area. The introverted architecture of the courtyard houses was the concern for the vernacular architecture of old Yazd; as a result, new housing should follow this rule as well, but offices and shops can be more open to the outside.

- **Specific construction of structure and walls:** For the structure and walls of new buildings some examples are designated to respect the old setting of Yazd and to follow architectural principles [Figure 82].

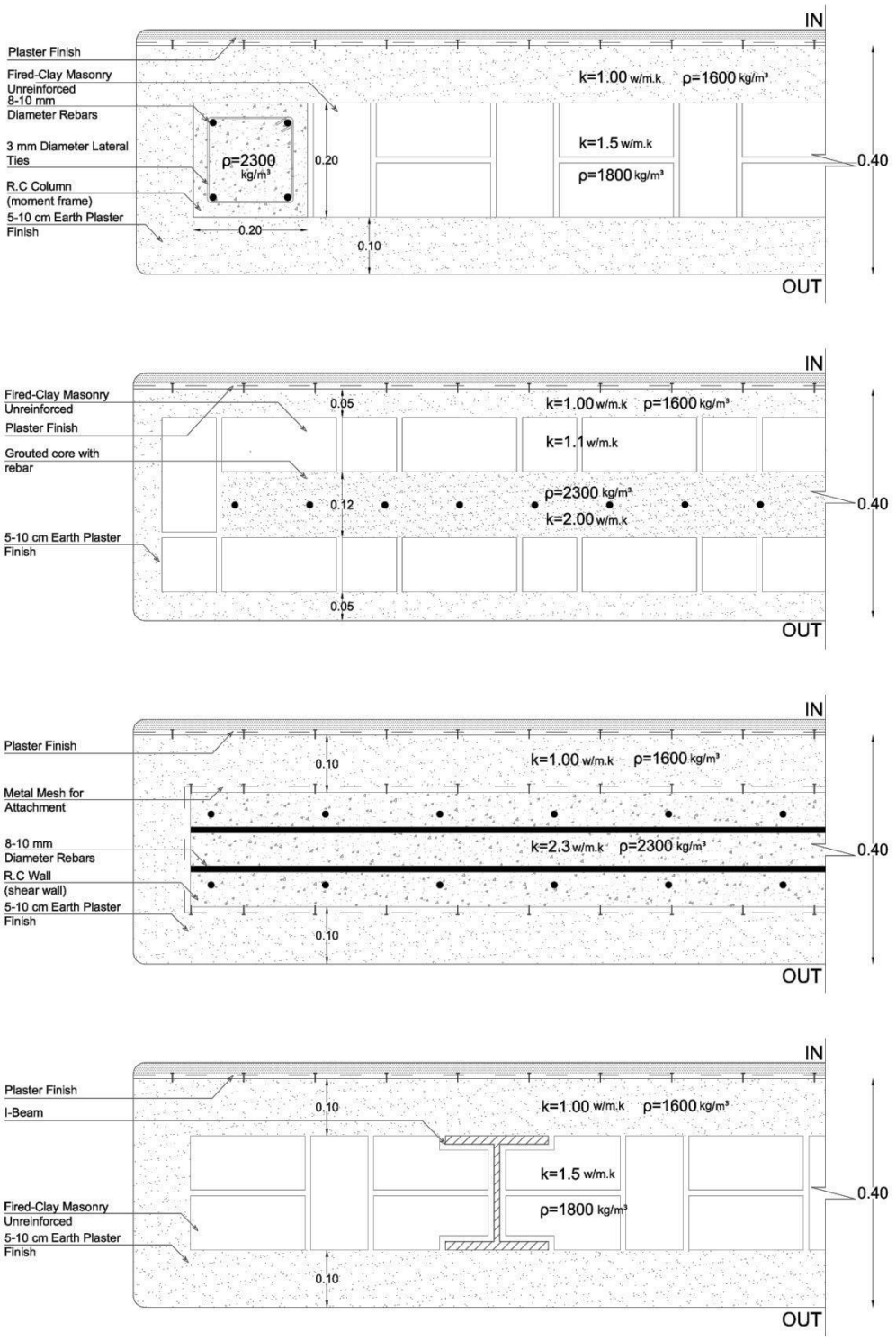

Figure 82. Recommended wall details for new buildings in old Yazd, drawn by author

- **Relocation of buildings:** Important governmental buildings can be relocated to the historic setting to encourage reuse and rebuilding in the historic core based on the principles of the coordinated organization or committee. Shifting the important governmental offices to this study area can play a key role in reviving the historic core.

  - Note 1: The recommended sites for these administration offices would be time-worn and derelict building sites or large empty spaces [Figure 83].

Figure 83. The chosen sites for the administration offices in the study area

- Note 2: Some overflow parking lots could be chosen very close to most of these administration offices to serve the clients better. These temporary parking lots can be used by the neighbors after working hours [Figure 84].

Figure 84. The selected sites of administration offices and the close temporary parking lots (TP)/overflow parking for the clients

- **Architects, city planners, people and the government as well as the Yazdi residents should cooperate in not demolishing any historic relics.**

- **Build new schools:** since the youth and children are a significant number of the populations who live in the new areas, there is a lack of schools in the old part of the city to service the children of these areas.

- **Provide and build medical services:** since people suffer from the lack of medical services and clinics in this part of the city, enough services should be provided.

5.4. The Collision of Tradition and Modernity

Iranian society has witnessed a challenging transition of massive social and cultural change: from a traditional society to a modern social system. These socio-economic and cultural changes appeared in the middle of the 19th century with increasing communications with the West and capitalism, and accelerated during the secular government of Pahlavi (Sadoughianzadeh, 2013). The evolution of the last century can provide an understanding of the contemporary architecture of Iran. Iran, like all other developing countries, is still experiencing a rupture with its traditions and achievements of the past and the modern world (Diba D. , 1991).

Mohammad Reza Shah, who was educated in Switzerland was familiar with new Western values, attempted to change the image of Iran to a modern Iran. The socio-cultural values began to change from 1955 to 1978 (Diba D. , 1991). Since Iran was Western oriented in the 1970s, any western import was considered desirable by the majority of Iranians. Thus, the architects became discouraged and did not search for the solutions to the problems in vernacular and traditional architecture; they preferred the alien models, which were appropriate neither to the cultural nor to the social context, but appealing to the people (Diba K. , 1980). The rapid process of modernization has affected the architectural form and function, transformed the traditional architecture and replaced it with the new forms in Iranian cities

> *Besides the socio-cultural impact and side-effects of the worldwide modernism and as their spatial manifestation, the spatial structure of the city and the building form, the country's Introvert arrangements have mostly changed to some sort of the Extrovert. In different parts of the country, especially in the urban areas, the architectural forms has more and more come to absorb features resembling those of the International Style of Modern Architecture and thus to lessen the more traditional traits* (Sadoughianzadeh, 2013).

As Darab Diba states, the cubic form of architecture with travertine, light steel structures, picture windows, flat roofs and thin walls became a dominant model in big cities. This style (build and sell) became a reliable investment and business for some builders who “became the masters of the cities”. Diba believes that the new, modern apartments reproduce modern western concepts, which reflect the low-rent buildings constructed after the Second World War in Europe. The repetitive apartment blocks mar the appearance of the city and overshadow any traditional features and landmarks. He adds that “the current context of regulations, trafficking of influence, quantity- based evaluations, property speculation, excessive cost of sites, lack of labor and supporting technology, all act against the appearance of human, healthy, high quality architecture“. He believes that the reason for lack of recent excellent quality architecture can be found in socio-political factors as well as the level of technology and labor skills. Hossein Sheikh Zeyneddin, a prominent architect and theoretician, believes that the failure in today’s architecture is related to economic chaos and cultural transformation (Diba D. , 1991).

> *The over-exposure to Western institutions and attendant value systems proved to be culturally detrimental. A loss of cultural identity and the prevalence of social anomie became inevitable. Modern Western society is rooted in a materialistic value system, and there is continuous interaction and feedback within this total structure. The importation and formation of such institutions in Iran lacked cultural relevance and moral support; a sense of cultural schism and conflict could not help but develop. The newly emerging materialistic value systems seemed confusing and corrupt, and when they interacted with Islamic culture they proved to be inadaptable* (Diba K. , 1980).

Today, concrete and steel with brick cladding are the materials frequently used for structures. Steel can be erected quickly and saves more space than concrete. However, poor quality steel due to unregulated manufacturing does not often meet international building code standards. Compared to steel structures, concrete structures although they need precautions and more detailed site planning, are better constructed in Iran. Architects rarely use exposed concrete as a finish due to its poor appearance, so they cover the façade with stone or brick (Diba D. , 1991).

Kamran Diba belives that the architects should pay a great deal of attention to their own culture, local architectural history, religious, social and aesthetic considerations, in addition to the "international"

ideology of building. He clarifies that architects and planners are part of the lack of cultural awareness in Iranian society

> *Bureaucracy and big business tend to minimize the role and power of the architect, until he becomes essentially powerless. Architects should be the true representatives of the user; society should be more aware of the inherent power of the architect/ planner, and of his role in the formation of our environment. In societies where a lack of cultural awareness prevails, planners and designers should be subsidized by the government, thereby ensuring that precious resources are channeled in a direction which creates environments sympathetic to culture, tradition and humanity. As long as architects are manipulated by big business and pushed around by government bureaucracies, we cannot hope for better quality in our communities and urban centers* (Diba K. , 1980).

5.4.1. New Buildings in New Yazd

Although in the Middle East countries, there is a valuable heritage of almost forgotten traditional architecture with unique strategies, techniques and elements, there are only a few governments such as Saudi Arabia, Dubai, Abu Dhabi, Qatar and Morocco who are attempting to establish energy codes for developing climate responsive designs with the cooperation of both local and foreign architects and experts (Elgendy, 2012). Unfortunately, the Iranian government does not consider this approach important and has not made it a priority of the country.

With the rising of modernity in Yazd, the repetitive apartment blocks in four to five-storey heights either by light steel structures or with poor quality concrete with punched windows, flat roofs and thin walls became a typical model in building investments. Poorly designed and executed cubic forms of architecture without considering the culture, local architectural history, religious, social and aesthetic factors resulted in an amalgamation of copying styles. The rich and valuable vernacular architecture could be combined with high technology and scientific methods to decrease the environmental impact while increasing the thermal comfort for designing new buildings in the new urban fabric of Yazd; but, unfortunately, it was disregarded.

Inconsistent and disharmonic expansion in the new areas of Yazd shaped an unbalanced urban texture. The irregular development of New Yazd resulted in uncontrolled construction of buildings in margins, which are mostly vacant. Although the reports show that in 2001, there were more than 1300 hectares of unused and abandoned lands inside the New Yazd, this impolitic method of construction has led to the conversion of even margins/sideline farming and mineral lands to building sites. As a result, the population has moved to the sidelines and the central parts of the city are depopulated. The population density in Yazd in 1996 was 37person/hectare; this number for the old fabric in the same year was 68.6 and for the new Yazd was 33.7person/hectare, which indicates the uncontrolled expansion of the city. Wide access streets and highways, unused and abandoned lands and dispersed and scattered constructions in the margins of new areas are the reason for lower density in New Yazd (Ahmadpour & Shamaee, 2001).

There are some excellent examples of using traditional methods in a new high-tech cityscape and of increasing performance while decreasing the negative environmental impact. Yazd can also follow its own vernacular principles with an approach of creating a high-tech cityscape in new Yazd such as Masdar City, National Commercial Bank in Jeddah and the first low energy house in Jordan.

5.4.2. Case Study I: Masdar City, Abu Dhabi

Masdar City is a new example of a sustainable planned city and an arcology[ix] project in Abu Dhabi, United Arab Emirates, which the Iranian government and architects can use as a model for the new developing Yazd. It deftly combines vernacular architecture and high-tech principles in creating a livable city. Masdar, designed by the architectural firm Foster and Partners is intended to be a sustainable zero-carbon environment, entirely dependent on renewable energy resources with zero waste (Wikipedia, 2011). By applying the latest technologies and saving costs and resources, the purpose of this project is to create a sustainable urban fabric in planning, designing and operating [Figure 85]. This project is being completed according to the fundamental vernacular architecture, which is focused on the local culture and architectural history of the region, and combined with the use of high-tech and renewable energy to

[ix] "**Arcology**, a portmanteau of "architecture" and "ecology", is a set of architectural design principles for enormous habitats (hyper structures) of extremely high human population density. These largely hypothetical structures would contain a variety of residential, commercial, and agricultural facilities and minimize individual human environmental impact."

design low-rise and high-density buildings (Elgendy, Masder City Masterplan Reviewed, 2010). These principles embrace the macro, meso, micro and nano scale in design [Figure 86, 87].

Figure 85. The urban fabric of Masdar city

Figure 86. Modern sustainable features according to the fundamental vernacular architecture used in designing the city; the modern wind tower is shown in the left picture and the right picture illustrates the shading that is achieved by densely designed buildings

The planners intended to integrate renewable technologies and recycled materials in order to design a more sustainable and high performance cityscape. The green concrete used in Masdar is a type of an industrial waste, ground granulated blasted slag; it replaces conventional cement by reducing the carbon content up to 30-40% while enhancing performance and strength. The recycled reinforcing bars and recycled aluminum content used for the inner façade are examples of the recycled materials used in Masdar City. Water-based paints are also used to minimize ecological damage (Masdar City, 2011).

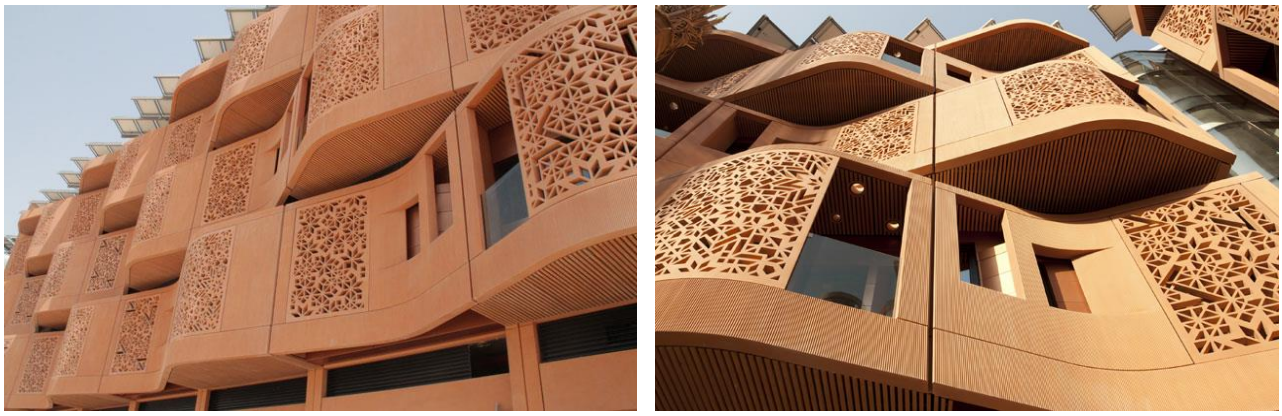

Figure 87. Exterior shading; a culturally accepted strategy for shading in the region

This project is successful not only because of its technological aspects, zero-carbon impact or entire dependency on renewable energy resources with zero waste; the success is being able to change the collision of tradition and modernity to a successful combination of both that respects both sides. As mentioned earlier, this project can be used as an excellent example for new buildings in the new urban fabric of Yazd.

5.4.3. Case Study II: National Commercial Bank in Jeddah, Saudi Arabia

The majority of the building forms that have been imported to the Middle East are unsuited to the culture and climate. This phenomenon that is clearly apparent in high-rise buildings with high levels of glazing, inappropriate orientation and site planning, has caused a massive energy use for cooling (Clair, 2009) and Yazd is no exception. Quick urbanization growth in recent decades resulted in more and more high-rises in the developing cities. Although the negative environmental impact of high-rise buildings has become more serious, the huge economic profit of high-rises outweighs these consequences especially when the land prices have accelerated (Xu, Zhang, & Xie, 2006).

The National Commercial Bank HQ in Jeddah, which was designed by Gordon Bunshaft in 1982, is designed according to ecological methods. The ecological design of high-rises should be based on climate, energy saving, passive design and ecological considerations. (Xu, Zhang, & Xie, 2006) When the vernacular architecture is completed according to the climatic factors and the ecological designs are based on the same factors, this design is an integrated design which combines both ecological and vernacular aspects [Figure 88].

Figure 88. Different views of National Commercial Bank in Jeddah, Saudi Arabia

The triangular tower for the National Commercial Bank in Jeddah is designed in 27-storeys with a 6-storey circular plan parking garage next to it. The total area for 2000 employees is 56300 sqm. (ArchNet, n.d.) The deep hole within the mass of the building with the consideration of solar gain on the exterior façade, the design of the sky-courtyards so that all the window openings face into the courtyard rather than towards exterior facades, insulated stone for the facades, the maximum use of available natural resources such as daylighting and wind, and the other factors in designing this high-rise building emphasize its adaptation to climate (Xu, Zhang, & Xie, 2006) [Figure 89]

One of the most significant strategies employed in this high-rise was the use of sky-courtyards (aerial courtyards), which had a direct impact on reducing the cooling loads by having glazing face into these sky-courtyards. (Clair, 2009)

Considering the fact that the climate in Jeddah is very close to Yazd, this method of design in National Commercial Bank can be used as an effective method of designing high rises in Yazd and other similar climates.

Figure 89. The sky-courtyards are shown in the left picture and the circular parking in the right

5.4.4. Case Study III: A Low Energy Residence in Aqaba, Jordan

Due to rising energy (oil and gas) prices, Jordan, the country which does not have many natural resources and imports most of its energy requirements from neighboring countries, has implemented an approach of designing sustainable buildings to save energy. This policy has become the focus of the government (Visser, 2009). Unfortunately, Yazdi government did not consider this approach the focus of the government. Therefore, most of the residential or commercial buildings are not climate and environmentally responsive, thus, do not follow energy saving principles. Although designing a single building in the new urban fabric of Yazd does not solve any problems, it can be used as a successful model and a positive step to take for raising awareness of residents to enhance energy efficiency.

Aqaba is a city located in the southern part of Jordan. The temperature in the summer is 40C and winters are very mild (Visser, 2009), more or less similar to Yazd. The low energy residence in Aqaba is designed according to a combination of passive low energy strategies and efficient active systems using the approach of environmentally-responsive design. Choosing appropriate planning and orientation, shading and landscaping as well as new passive strategies such as wall and roof insulation are all combined to reduce solar heat gain in the building (Elgendy, 2010) [Figure 90].

Figure 90. The low energy residence in Aqaba, Jordan

The layout of the house is arranged so that the spaces that are seldom used (such as corridors and washrooms) are located on the south-west side, which is the hottest area of the residence. These areas act like a buffer zone to keep the main spaces such as bedrooms and living spaces cool. The main staircase is designed to work as a wind tower in the house (Visser, 2009) [Figure 91].

Figure 91. The main staircase is designed to work as a wind tower; view from inside and out

The combination of modern insulation and thermal mass approach is used to increase energy saving. Although it was very uncommon in Jordan to insulate the roof and floor to wall connections to prevent thermal bridge, it is now used in this residence to increase energy saving (Visser, 2009). The wall cavities of the north facing walls of bedrooms are filled with sand and finished with straw and plaster in order to maximize the energy efficiency (Visser, 2009) [Figure 92].

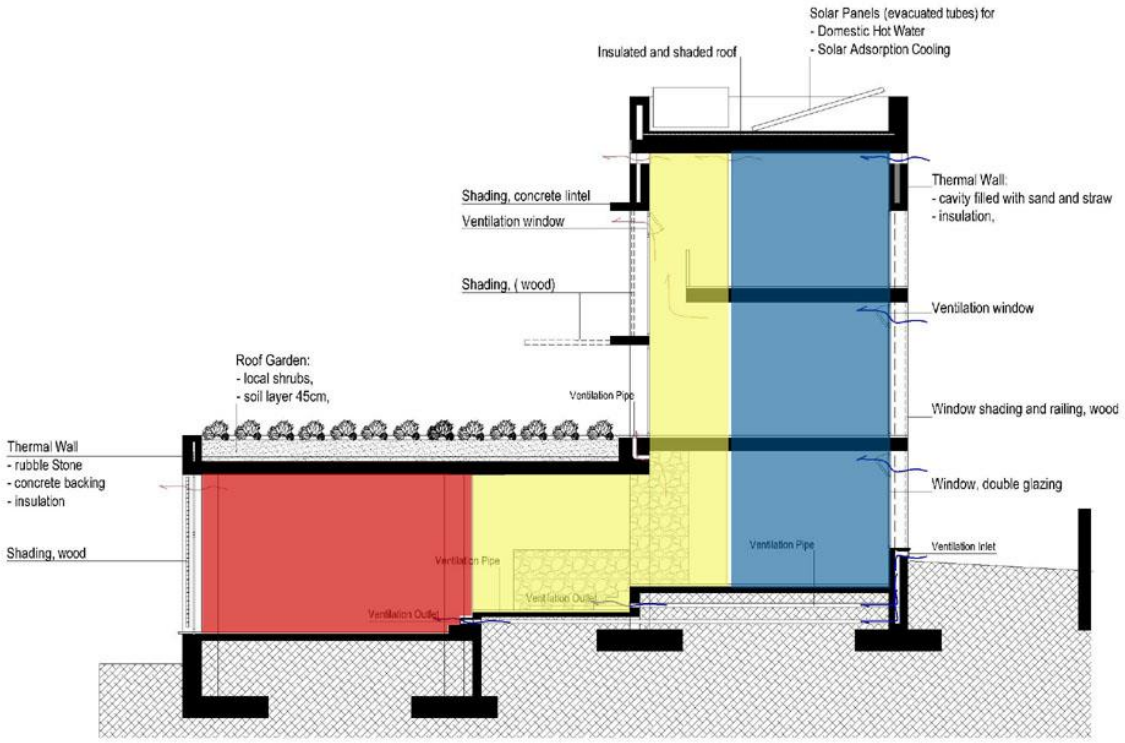

Figure 92. The section of the residence

Natural ventilation, evaporative cooling (for outdoor spaces) and solar cooling systems (for indoor spaces) are also applied in designing this residence in order to decrease energy use (Elgendy, 2010). The garden soil (40-cm-deep) of the roof garden has a high heat capacity and its water-efficient plants and trees that need only a small amount of irrigation provide shade (Visser, 2009) [Figure 93].

Water saving is a vital issue in Jordan, which is one of the poorest countries in terms of water resources. As the architect explains, this residence is equipped with a dual plumbing system: one for pure water for

Figure 93. The roof garden and the use of shading

showers and sinks and the other one for filtered waste water for the garden irrigation (Visser, 2009).

5.4.5. Suggesting Solutions for New Buildings in New Yazd

- **Orientation of the buildings:** the city should be oriented, designed and developed based on gaining maximum efficiency at the lowest cost in a way that minimizes solar gain and maximizes the use of cooling winds during the day.
- **Low rise and high density buildings:** the ratio of the building height to the road/street width should be considered carefully to provide enough shade for the pedestrians. If the heights of the buildings are not more than 5 storeys, the ground area around the buildings decreases and ultimately the density (unit/ha) increases which is a key factor for an environmentally sensitive design in a hot-arid region.
- **Pedestrian friendly:** designing narrow, shaded streets and walkways similar to the old days, encourages the residents to walk; however, convenient transportation should be provided.
- **Public space:** spaces between buildings can be designed as parks to invite the public to enjoy the outdoors while being shaded and cooled by the use of tall trees and benefiting from the height of the neighboring buildings.
- **Locally available and sustainable materials:** recycled or reclaimed local construction waste such as clay plasters, renders and mortars; fired clay blocks for external walls, and unfired clay blocks for internal partitions can be used to reduce costs and encourage the use of sustainable materials. Reflection and colours of the materials should be considered carefully as well.
- **Windcatchers:** modern windtowers can be used as passive ventilation systems in either the public spaces or in private residences.
- **High quality building insulation:** enclosures with high levels of insulation and good airtightness should be built to save energy and reduce operating costs. Thermal mass will often be beneficial but it is not rigid.
- **Use of shade:** shade reduces solar gain on buildings, while increasing natural light, thereby reducing the demand for internal lighting and cooling.

- **Exterior shading:** culturally widely accepted strategy for providing both privacy and shading for the residents.

- **Courtyards:** the courtyard as an architectural response to the harsh climate of the region in hot-arid cities is combined with different strategies to maintain comfort for the occupants and can be used in different sizes and shapes and also on different levels.

Chapter VI: Conclusion

Even with its many different layers of problems in population, economics and urban growth, as well as the problems of preserving its cultural heritage, Yazd is still one of the most beautiful cities of the region which has kept its traditional urban fabric mostly intact. However, like all other developing cities in the Middle East, it is also dealing with multiple issues of today's modern world.

In the last few decades, most of the building forms, exactly similar to the international style in the 1950s and 1960s in the west, have been imported to the Middle East region without considering compatibility with the climate of the region. The rapid process of modernization has affected the architectural form and function, transformed the traditional architecture and replaced it with the new alien forms in Iranian cities as well. It has led to accelerated urban growth and development in cities, having a direct impact on vernacular and traditional architecture.

This phenomenon also has gradually changed the relationship between the built environment and the cultural values of society. Gradually, the socio-cultural values also have begun to change during this period. The collision of tradition and modernity combined with the lack of a conscious transition from a traditional approach to a modern one is not a problem of Yazd only but almost all of the cities in developing countries.

The phenomenon of modernization is being continuously developed on the other side of the world, in Europe and North America due to the shortage/lack of energy resources, in the 1970s and 1980s, the architects and designers became more concerned and focused on designing energy efficient buildings and cities. The approach of combination of modern technology and high performance materials with environmentally responsive designs and climate adaptive architecture became highlighted. However, in the Middle East, which had a long history and a heritage of vernacular and climate adaptive architecture, this approach was completely ignored until very recently.

During the last century, the modern building practices in Iran disregarded the significance of culture and environment on human comfort by using cheap and non-renewable materials and excessive technology and industrialization to accommodate the growing population instead of benefiting from the traditional sources of inspiration. Consequently, these transformations, injected "modern" into people's lifestyle and had a major impact on the crisis of cultural identity. With this approach, this historical city is moving toward an unknown future. Although nobody can stop this trend or ask people not to be modernized or not to use complicated technologies in their lives, the speed of this cultural crisis can be slowed (or

probably stopped) only by educating people. This education can be achieved by domestic media, schools, billboards, etc.

Even though it is impossible to solve all the problems in the short term, a comprehensive long term plan by the government with the cooperation and collaboration of the Yazdi people, architects and urban planners to draw a better future for this rich ancient developing city should be considered. This plan should cover repairing and renovating the historic structures and preventing the demolition of valuable historic relics in the historic core. Developing standard principles for designs of appropriate new buildings that do not disrupt the traditional context on any scale would be the next step to take.

In order to conserve the historic quarter, as well as provide a standard level of comfort in either the new or old urban fabric, the government should develop and implement two different approaches. The first is to undertake a comprehensive plan to prepare facilities/services for the renovation and repair of the buildings in the historic quarter using appropriate techniques and modern materials so that the buildings are convenient and comfortable for occupants. This approach can establish the culture of preservation and conservation of inherited historic buildings as well as increase the level of residents' comfort. The second is related to the construction of buildings in the new urban context, which are neither compatible with climatic considerations and vernacular sustainable methods, nor satisfactory for occupants to maintain appropriate standard levels of living, convenience, and comfort. A comprehensive strategy for comfort levels and sustainable designs in the construction of new buildings should be discussed. In this wide-ranging plan, a hybrid system of vernacular and modern principles should be carefully considered in either the new or old areas.

6.1. Design Summary for Preservation of the Historic Core:

For achieving the goal of reviving the traditional urban texture of Yazd, some recommendations are provided, which are based on the today's needs in historic core of Yazd. These suggested solutions can be changed by time, situations and governmental approach. The Yazdi Government plays a vital role in providing financial aid, continuous security for neighborhoods, educational services, enough medical facilities and upgrades to amenities, improved access to the historic core and the education of Yazdi residents about the value of their cultural heritage and the necessity of their cooperation and understanding in order to revitalize this historic core. The proposed list of principles for preservation of the historic core is as follows:

- Educate Yazdi residents about the historic value of old Yazd
- Prohibit demolition of historically valuable buildings; encourage renovation
- Improve Public Transportation
- Provide Public Parking
- Improve access to the historic core
- Upgrade amenities
- Provide enough facilities for the youth and children
- Provide enough medical facilities
- Provide the required educational services
- Provide governmental Financial Aid
- Solve the problem of security
- Change the functionality of the abandoned residences
- Provide neighborhood 24/7 services
- Increase the citizens' and government's income

6.2. Design Summary for New Buildings in Historic Core:

In order to successfully design appropriate new buildings which are woven into the historic fabric without disruption of the traditional context on any scale, these recommendations are provided. Although designing a single new modern sustainable design in the historic urban fabric of Yazd does not solve any problems, but it can be used as an archetype for the whole area. It also can prevent defacing and affecting either the beautiful skyline of the historic core by their heights or by inappropriate use of architectural style and materials.

However, achieving this goal is not possible without the cooperation of architects, city planners, the government and the Yazdi residents to design and execute buildings which respect the cultural and religious values of the area and are compatible with climatic considerations. The proposed set of principles for designing new buildings in the historic setting is listed below:

- Colour, texture and material used in building facades
- Massing, volume, height and form
- Architectural style
- Culture:

- Specific construction of structure and walls
- Architects, city planners, people and the government as well as the Yazdi residents should cooperate in not demolishing any historic relics.
- Build new schools
- Provide and build medical services

6.3. Design Summary for New Buildings in New Yazd:

To avoid inconsistent and disharmonic expansion in the new areas of Yazd, which has resulted in an unbalanced urban texture and uncontrolled construction of repetitive cubic blocks in margins, and also an amalgamation of copying styles without considering the climate, culture and the local architectural history, these recommendations are provided. The source of inspiration for these recommendations would be the combination of the valuable heritage of almost forgotten traditional architecture and climate responsive principles including new building technology and science which must be implemented in the historic core ; everything, from the shape and orientation of buildings to the use of available systainable materials and high quality building insulation must be considered. The list of the proposed principles for designing new buildings in new Yazd is as follows:

- Orientation of the buildings
- Low rise and high density buildings
- Pedestrian friendly
- Public space
- Locally available and sustainable materials
- Windcatchers
- High quality building insulation
- Use of shade
- Exterior shading
- Courtyards

6.4. The contribution of the author:

The contribution of the author of this thesis was to investigate the existing problems and to recommend the possible ideal solutions in the face of the massive social and cultural change which has resulted in

the construction of buildings which are an amalgamation of foreign styles and forms. However, even though these sets of principles are very basic they need more detailed study; there must also be consultation with local architects, urban planners and construction professionals to be more comprehensive and practical. Although the National Building Code is more about safety, energy and technical provisions for the design and construction of new buildings, these recommendations can be used as an appendix for the alteration, change of use and demolition of existing historic or non-historic buildings.

References

(2011). Retrieved from Wikipedia: http://en.wikipedia.org/wiki/Fire_apparatus

Abouei, R. (2006). Conservation of Badgirs and Qanats in Yazd, Central Iran. *The 23th on Passive and Low Energy Architecture.* Geneva, Switzerland. Retrieved September 6-8, 2006

Achieving a balance between historic preservation and urban development: proceedings. (1994). Strasbourg, France: Council of Europe Press.

Ahmadikia, H., Moradi, A., & Hojjati, M. (2012). Performance Analysis of A Wondcatcher With Water Spray. *International Journal of Green Energy, 9*, 160-173.

Ahmadpour, A., & Shamaee, A. (2001). The Physical Developement of Yazd and its Influence on the Formation of the Population in the Old Urban Fabric. *Social Science Newsletter , 18*, pp. 3-32. Retrieved 2014

Amirkhani, A., Zamani, E., Saidian, A., & Khademi, M. (2010). Wind Catchers: Remarkable Example of Iranian Sustainable Architecture. *Journal of Sustainable Developement, 3*(2).

Anonymous. (2004). *WORKSHOP ON ARCHITECTURAL HERITAGE TODAY: WORKSHOP ON SULEYMANIYE AREA AND MOSTAR .* Istanbul: Architectural Heritage Today.

Anonymous. (2008, December). Designing Commercial Building with Natural Ventilation. *Energy Design Resource e-News*(61).

Anonymous. (n.d.). *Bruges, World Heritage City.* Retrieved April 2014, from https://www.brugge.be/files/uploads/document/werelderfgoedstad-unesco-brugge-engels-3.pdf

Anonymous. (n.d.). *Bruges, World Heritage City.* Retrieved April 2014, from https://www.brugge.be/files/uploads/document/werelderfgoedstad-unesco-brugge-engels-3.pdf

ArchNet. (n.d.). Retrieved 2014, from http://www.archnet.org/sites/483

Azami, A. (2005). Badgir in Traditional Iranian Architecture . *International Conference on Passive and Low Energy Cooling for the Built Environment.* Santorini, Greece.

Beheshti, S. M. (2004). The Art of Revitalisation. In P. Jodido, *Iran: Architecture for Changing Society* (pp. 21-26).

Ben-Hamouche, M. (2008). Climate, Cities and Sustainability in the Arabian Region: Compactness As A New Paragigm In Urban Design and Planning. *Arch Net-UAR: International Journal of Architectural Research, 2*(2), 196-208.

Bioclimatic Design. (2006). Retrieved 2013, from http://www.shadyattia.net/academic/BioclimaticDesign/Lecture%2006.html

Bloom, J., & Blair, S. (1997). *Islamic Arts.* London: Phaidon Press.

Boake, T. M. (2014, March 2). *Mashrabiya Reinvented: Double Façades, Persian Gulf Style* . Retrieved March 2014, from Construct Arabia: http://www.constructarabia.com/the-insider/mashrabiya-reinvented-double-facades-persian-gulf-style/

Building Science Corporation. (n.d.). Retrieved 2012, from www.buildingscience.com

Charlesworth, E. R., & Adams, R. (2011). *The EcoEdge: urgent design challenges in building sustainable cities.* London: Routledge.

Cherry, N., & Nagel, K. (2009). *Grid/street/place: essential elements of sustainable urban district.* Chicago: American Planning Association Planners Press.

Clair, P. S. (2009). Low-Energy Design in the United Arab– Buildings Design Principles. *BEDP Environment Design Guide*, 1-10.

Cohen, N. (2001). *Urban planning conservation and preservation.* New York: McGraw-Hill.

Dahl, T. (2010). *Climate and Architecture.* Milton Park, Abingdon, Oxon: Routledge.

Dastorani, M., Bavani, A. M., Pourmohammadi, S., & Rahimian, M. (2011, December). Assessment of Potential Climate Change Impact on Drought Indicators (Case Study: Yazdstation, Central Iran). *Desert, 16*, 159-167.

Dayarante, R. (n.d.). *Vernacular in Transition: The Traditional and the Hybrid Architecture of Bahrain.* Retrieved from Academia.edu: http://uob.academia.edu/RanjithDayaratne

Dayaratne, R. (n.d.). *Vernacular in Transition: The Traditional and the Hybrid Architecture of Bahrain.* Retrieved 2013, from Academia Website: www.academia.edu

Dehghan, A., Naghizadeh, M., & Nasrabadi, A. T. (2011). Central Courtyard: Iranian Strategy to Achieve Local Sustainable Architecture. *The American-Eurasian Network for Scientific Information (AENSI), 5*(9), 2900-2905.

Derakhshani, F. (2011). Longing and Contemporaniety, Iran, New Froms of Self-Expression. In L. F. Galiano, *Atlas: Architecture of the 21th century. Africa and Middle East.* Fundación BBVA.

Diba, D. (1991). Regional Report: Iran and Contemporary Architecture. (H.-U. Khan, Ed.) *Mimar 38*, 20-25.

Diba, D., & Dehbashi, M. (2004). Trends in Modern Iranian Architecture. In *Iran: Architecture for Changing Societies* (pp. 31-37). Retrieved 2013

Diba, K. (1980). The Recent Housing Boom in Iran- Lessons to Remember. *Housing: Process and Physical Form*, 38-40.

Dincer, I. (n.d.). The Dilemma of Cultural Heritage- Urban Renewal: Istanbul, Suleymanye and Fener-Balat. *14th International Planning History Society Conference.* Istanbul.

Documentation on historic cities in the Middle East: selected from presentations at the International Making Cities Livable Conferences. (1996). Carmel, Calif.: IMCL Council.

Ebrahimi, S., Saraei, M. H., & Biranvand, M. (2008). An Investigation on the Effective Factors on Old Urban Distressed Areas of Yazd. *The First Conference on Regeneration and Revitalization of Urban Area.* Retrieved 2014

Edwards, B. (2006). *Courtyard housing: past, present and future.* Abingdon, England: Taylor & Francis.

Edwards, B., Sibley, M., Hakmi, M., & Land, P. (2006). *Courtyard Housing: Past, Present & Future.* Taylor & Francis.

Elgendy, K. (2010). *Masder City Masterplan Reviewed*. Retrieved from Carboun: Advocating Sustainable Cities in the Middle East: http://www.carboun.com/?s=master+city+masterplan+reviewed

Elgendy, K. (2010). *The First Low Energy House in Jordan*. Retrieved from Carboun: Advocating Sustainable Cities in the Middle East: http://www.carboun.com/sustainable-design/the-first-low-energy-house-in-jordan/

Elgendy, K. (2012). *A Review of Sustainable Design in the Middle East*. Retrieved from Carboun: Advocating Sustainable Cities in the Middle East: http://www.carboun.com/sustainable-design/sustainability-in-the-desert/

Faghih, A. K., & Bahadori, M. N. (2011). Thermal Performance Evaluation of Domed Roofs. *World Renewable Energy Congress*, (pp. 8-13). Sweden.

Fathy, H. (1986). *Natural Energy and Vernacular Architecture: Principles and examples with references to hot arid climate.* Chicago: The University of Chicago Press.

Forouzanmehr, A. (2012, November). The Windcatcher: User's precipitation of A Vernacular Passive Cooling System. *Architectural Science Review, 55*(4), 250-258.

Givoni, B. (1998). *Climate considerations in building and urban design.* New York: Van Nostrand Reinhold.

Google Maps. (2012). Retrieved from https://www.google.com/maps/place/Yazd/@31.8828338,54.3568099,10930m/data=!3m1!1e3!4m2!3m1!1s0x3fa61993035b2a91:0x5d92a19dd7d4a10c

Google Maps. (2013). Retrieved from https://www.google.com/maps/place/Yazd/@31.8795584,54.338808,12z/data=!3m1!4b1!4m2!3m1!1s0x3fa61993035b2a91:0x5d92a19dd7d4a10c

Google Maps. (2014). Retrieved from https://www.google.com/maps/place/Bruges/@51.2606668,3.2221451,11z/data=!3m1!4b1!4m2!3m1!1s0x47c350d0c11e420d:0x1aa2f35ac8834df7

Guichard, P. (2006). *From the Arab conquest to the Reconquest: the splendour and fragility of Al-Andalus.* Granada, Spain: Junta de Andalucia, Consejeria de Cultura.

Gulersoy, N. Z., Tezer, A., Yigiter, R., Koramaz, K., & Gunay, Z. (n.d.). *Istanbul Historic Peninsula Conservation Study: Social Structure Analysis in Suleymanie.* Istanbul: Istanbul Technical University, Faculty of Architecture.

Haas, T. (2012). *Sustainable urbanism and beyond: rethinking cities for the future.* New York: Rizzoli.

Hillenbrand, R. (1994). *Islamic architecture: form, function, and meaning.* New York: Columbia University Press.

Hillenbrand, R. (1999). *Islamic Art and Architecture.* New York: Thames and Hudson.

Hoag, J. D. (1977). *Islamic Architecture.* New York: H.N.Abrams.

Jacobs, J. (1961). *The death and life of great American cities.* New York: Random House.

Jacobs, J. (2004). *Dark Age Ahead.* New York: Random House.

Jagger, M. (1998). The Planner's Perspective: a view from the front. In J. Warren, J. Worthington, & S. Taylor, *Context: New Buildings in Historic Settings* (pp. 71-82). Oxford: Architectural Press.

Jodidio, P. (2011). *The Aga Khan Historic Cities Programme: strategies for urban renewal.* Munich: Prestel.

Jokilehto, J. (1998). Organizations, Charters and World Movement: an overview. In J. Warren, J. Worthington, & S. Taylor, *Context: New Buildings in Historic Settings* (pp. 40-50). Oxford: Architectural Press.

Karimi, P. (2012). Dwelling, Dispute, and the Space of Modern Iran. In J. Massey, *Governing by Design: Architecture, Economy, and Politics in the 20th Century* (pp. 119-139). University of Pittsburgh Press.

Kasprisin, R. J. (2011). *Urban design: the composition of complexity.* Milton Park, Abingdon, Oxon: Routledge.

Kazemi, A. G., & Shirvani, A. H. (2011). An Overview of Some Vernacular Techniques in Iranian Sustainable Architecturein Reference to Cisterns and Ice Houses. *Journal of Sustainable Developement, 4*(1), 264-270. Retrieved from www.ccsenet.org/jsd

Kazimee, B. A. (2012). *Heritage and Sustainability in the Islamic Built Environment.* Southhampton, UK: WIT Press.

Khademzadeh, M. H. (2004). Continuity and Change in the City of Yazd. In P. Jodidio, *Iran: Architecture for Changing Society* (pp. 27-30).

Kianersi, M., & Ahmadi, F. (2012). Some Tips of Sustainable Evidence Conforming to Traditional Iranian Architecture(Wind Tower,Watering Place). *International Journal of Sustainable Development , 5*(1).

Krieg, J. C., & Sappington, N. (1999). *Desert landscape architecture.* Boca Raton, Fla: CRC Press.

Kriege, J. C., & Sappington, N. (1999). *Desert landscape architecture.* Boca Raton, Fla: CRC Press.

Leccese, M., & McCormick, K. (2013). *Charter of the New Urbanism .* New York: McGraw-Hill Professional.

Longstreth, R. W. (2011). *Sustainability and Historic Preservation: Toward a Holistic View.* Delware Press.

Lyall, J. (1998). Pulling teeth and filling cavities. In J. Warren, J. Worthington, & S. Taylor, *Context: New Buildings in Historic Settings* (pp. 154-164). Oxford: Architectural Press .

Maleki, B. A. (2011). Traditional Sustainable Solution in Iranian Desert Architecture to Solve the Energy Problem. *International Journal on Technical and Physical Problems of Engineering, IJTPE, 3*(6), 84-91.

Maleki, B. A. (2011, September). Wind Catcher: Passive and Low Energy Cooling Systems in Iranian Vernacular Architecture. *International Journal on Technical and Physical Problems of Engineering, 3*(3), 130-137.

Masdar City. (2011). Retrieved 2013

May, J., & Reid, A. (2010). Iranian Desert Towns. In J. May, & A. Reid, *Buildings Without Architects.* New York: Rizzoli International Publications.

Meiger, M. (2010). *Sustainable urban design: examples and perspectives = Duurzame stedenbouw : voorbeelden en perspectieven : the next step.* Wageningen: Blauwdruk.

Memarian, G., & Brown, F. (2006). The Shared Charactrestics of Iranian and Arab Courtyard Houses. In B. Edwards, & M. H. Magda Sibley, *Courtyard Housing: Past, Present & Future* (pp. 21-30).

MKH. (2014). Retrieved 2014, from Deutsche Welle (Persian): http://www.dw.de/%DA%AF%D8%B4%D8%AA%DB%8C-%D8%AF%D8%B1-%DB%8C%D8%B2%D8%AF-%D8%B4%D9%87%D8%B1-%D8%A8%D8%A7%D8%AF%DA%AF%DB%8C%D8%B1%D9%87%D8%A7-%D9%88-%D8%AF%D9%88%DA%86%D8%B1%D8%AE%D9%87%D9%87%D8%A7/g-17465062

Modarres, A. (2006). *Modernizing Yazd: Selective Historical Memory and the Fate of Vernacular Architecture.* Costa Mesa, California: Mazda Publishers.

Monreal, L. (2011). The future of Historic Cities. In P. Jodidio, *The Aga Khan Historic Cities Programme: strategies for urban renewal* (pp. 12-21). Munich: Prestel .

Monshizade, A. (2008). The Desert City As an Ancient Lining Example of Ecocity, Case Study:Yazd. *7th International Ecocity Conference.* San Francisco.

Moughtin, C., Signoretta, P., & Moughtin, K. M. (2009). *Urban design: health and the therapeutic environment.* Amsterdam: Elsevier/Architectural Press.

Nejadkoorki, F., & Ziajahromi, S. (2011). Zonal Air Pollution Study in Yazd, Iran. *Middle-East Journal of Scientific Research , 9*(4), 437-441.

Okhovat, H., Almasifar, N., & Bemanian, M. (2011). A research on Historical and Cultural Buildings in Iranian Vernacular Architecture. *ACE: Architecture, City and Environment, 6*, 37-58.

Olgyay, V. (1963). *Design With Climate: Bioclimatic Approach to Architectural Regionalism.*

Quara. (2013, Jan). Retrieved 2013, from http://www.quora.com/Heating/How-do-you-heat-a-room-in-winter-without-a-heater/answer/Rodrigo-Tello-1/comment/1593899

Ragette, F. (2003). *Traditional domestic architecture of the Arab Region.* Stuttgart: Edition Axel Menges.

Reed, T. (2005-2008). Retrieved from InfoCordoba: Discover the Delights of Cordoba, Spain: http://www.infocordoba.com/spain/andalusia/cordoba/city_walls.htm

Reine. (2010). *A journey through Iran*. Retrieved from Mink Machine: http://minkmachine.reine.se/2010/11/a-journey-through-iran/

Robinson, D. (2011). *Computer modelling for sustainable urban design: physical principles, methods and applications.* London: Earthscan.

Saadatian, O., Haw, L. C., Sopian, K., & Soulaiman, M. (2012). Review of Windcatcher Technologies. *Renewable and Sustainable Energy Reviews, 16*(3), 1477-1495.

Saberi, O., Saneei, P., & Javanbakht, A. (2002). Thermal Comfort in Architecture. *Iranian Universities Conference*, (pp. 1-11).

Sadoughianzadeh, M. (2013, October-December). Gender Structure and spatial Organization: Iranian Traditional Spaces. *SAGE Open*, 1-12. Retrieved 2014

Samizay, R. (2012). Spatial heritage of sustainable urbanism in Yazd, Iran. In B. A. Kazimee, *Heritage and Sustainability in the Islamic Built Environment* (pp. 127-149). Southhampton, UK: Wit Press.

Scott, A., & Joseph, E. (2012). *Renewtown: adaptive urbanism and the low carbon community.* Abingdon, Oxon: Routledge.

Shamollahi, B., Selamat, N., & Jamluddin, S. (2012). The Role of Physical Structure of Yazd City in Its Urban Identity. *Business and Society, 167*, 515-517.

Sharifi, A., & Murayama, A. (2013). Changes in the Traditional Urban Form and the Social Sustainability of Contemporary Cities: A Case Study of Iranian Cities. *Habitat International, 38*, 126-134. Retrieved 2013, from www.elsevier.com/locate/habitatint

Straube, J. (2009). *Insight: The Perfect HVAC*. Retrieved 2011, from BuildingScience.com: www.buildingscience.com

Straube, J. F., & Brunett, E. (2005). *Building Science for Building Enclosures.* Westford, Mass.: Building Science Press.

Struabe, J. (2010). *Insight Historical Developement of the Building Enclosure*. Retrieved 2013, from Building Science Corporation: http://www.buildingscience.com/documents/insights/bsi-042-historical-development-building-enclosure/?searchterm=thermal%20mass

Sustainability Articles. (2013). Retrieved 2013, from Architectus: http://www.architectus.com.au/sustainability/articles/thermal-mass

TolouBehbood, K., Taleghani, M., & Heidari, S. (2010). Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan. *Emirates Journal for Engineering Research, 15*(2), 85-91.

Vakili-Ardebili, A., & Boussabaine, A. H. (2006). Quality Concept in Persian Precedent. *The 23rd Conference on Passive and Low Energy Architecture.* Geneva, Switzerland.

Velluet, P. (1998). The National Interest. In J. Warren, J. Worthington, & S. Taylor, *Context: New Buildings in Historic Settings* (pp. 51-60). Oxford: Architectural Press.

Visser, F. (2009). *Aqaba Residence Energy Efficiency in Jordan*. Retrieved from ArchiNed: http://www.archined.nl/en/features/aqabaresidenceenergyefficiencyinjordan/

Warren, J. (1998). The Historic Context: principles and philosophies. In J. Warren, J. Worthington, & S. Taylor, *Context: New Building in Historic Settings* (pp. 8-17). Oxford: Architectural Press.

Warren, J., Worthington, J., & Taylor, S. (1998). *Context: New Buildings in Historic Settings.* Oxford: Architectural Press.

Weather Spark. (n.d.). Retrieved from www.weatherspark.com/averages/32839/Yazd-Iran

Wikipedia. (2011). Retrieved from http://en.wikipedia.org/wiki/Masdar_City

Wikipedia. (2012). Retrieved 2012, from http://en.wikipedia.org/wiki/Yazd

Wikipedia. (2012). Retrieved from http://en.wikipedia.org/wiki/Cultural_heritage

Wikipedia. (2014, April). Retrieved from http://en.wikipedia.org/wiki/Bruges

Wikipedia. (2014). Retrieved from http://en.wikipedia.org/wiki/C%C3%B3rdoba,_Andalusia

Williams, M. (2011). *University Today*. Retrieved from http://www.universetoday.com/87943/absorption-of-light/

Xu, F., Zhang, G., & Xie, M. (2006). The Emphasis on Ecological Design for High-rise Buildings. *The Sixth International Conference for Enhanced Building Operations: Renewable Energy Resources and a Greener Future*, *VIII-4-4.* Shenzhen, China.

Yousefi, E., & Nejadkoorki, F. (2012, September 10-12). The Study of The Environment in Old and Modern Forms (Case Study of Yazd, Iran). *International Conference on Applied Life Sciences (ICALS).* Turkey.

Zanganeh Shahraki, S., Sauri, D., Serra, P., Modugno, S., Sefoldini, F., & Pourahmad, A. (2011). Urban Sprawl Pattern and Land-use Change Detection in Yazd, Iran. *Habitat International, 35*, 521-528.

http://archnet.org/library/sites/sites.jsp?letter=&country_code=&place_id=&type=&style=Safavid&usage=&century=&decade=&order_by=site&showdescription=1

http://whc.unesco.org/en/tentativelists/5191/

http://nptel.iitm.ac.in/syllabus/syllabus.php?subjectId=112105129