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Re-Designing Contemporary City Blocks : Designing In Favour Of Energy Conservation For A City In Desert: Kerman, Iran

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RE-DESIGNING CONTEMPORARY CITY BLOCKS:
DESIGNING IN FAVOUR OF ENERGY CONSERVATION FOR A CITY IN DESERT: KERMAN, IRAN

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Abstract

Re-designing contemporary city blocks:

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In Iran, urban block morphology has changed as a result of the architectural focus shifting away from traditional concerns such as climate-and-energy sensitivity onto issues such as land use, transportation and finance. Current architectural practice while has completely overlooked the architecture of the past, failed to improve the quality of life.

The hot, arid climate in combination with non-responsive urban building designs has resulted in high energy consumption to keep occupants comfortable. Although it is possible to overcome many of the negative effects of an inefficient design by the use of mechanical systems, this thesis through an architectural response, explores the role of climate sensitive strategies, practiced in the traditional architecture, in recognizing the importance of energy conservation. While it is only at the urban scale that energy-saving strategies could effectively tackle problems, the applicability of these principles will be studied at a neighbourhood scale.

Acknowledgments

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Paria

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Chapter One: Introduction

1.1 Introduction

The awareness that buildings in hot regions should be compatible with climate is one of the most significant energy-sensitive principles (Emmanuel, 2005). It is stated that the main consumers of energy are residential buildings, where the majority of energy used in hot-arid climates goes towards space cooling for the occupants comfort (Lentz, 2010). While traditional modes of adapting the built environment to climate in this region became obsolete in the urban fabric, the demand to rethink the conventional wisdom of energy efficient design in high population densities of the cities with changes to climate qualities and also inhabitants' lifestyles seems necessary. At the same time it is also of great concern to challenge the international style of architecture emerged in Iranian cities decades ago in creating a modern indigenous architecture, using climate characteristics of each region as a starting point.

As a result, the three-way relationship between environment, energy and urban architecture can be considered as one of the dominant and overwhelming challenges in the cities of today. However, this relationship has been induced by rapid growth of population and urban densities, and so far had received little attention in urban design and planning.

This thesis aims to lay out the problems regarding present-day energy consumption and inefficient architecture of hot-arid climates in Iran and points the possibilities of mitigating these changes through design and planning options.

1.2 Problem Summary

- **Energy shortage and increasing amount of energy consumption**

- **Carbon dioxide emission**: In the modern society, the possibility of global warming and the increase in the amount of carbon dioxide, sulphur dioxide, lead, hydrocarbon and nitrous oxide emissions are becoming an ever increasing threat. As it is widely known, the primary cause of this warming is green gases produced thorough combustion of fossil fuels that is most common in energy production and usage. The main consumers of fossil fuels are residential buildings, where the majority of energy used in hot-arid climates goes towards space cooling for the occupants comfort (Lentz, 2010).

- **Non-responsive contemporary architecture**: Energy waste in contemporary buildings in Iran due to poor envelope design and exclusion of passive strategies.

- **Non-responsive contemporary urban design**: Due to recent changes in the urban density and street networks of contemporary urban context, controlling micro-climate of neighbourhoods and local challenges such as dusty winds becomes impossible and results in decreasing the health, safety and comfort of outdoors.
  Orienting long rows of building masses towards south which is a common accepted proposal to achieve maximum solar radiation in winters and to minimize summer heat gains, lead in developing uncomfortable areas between building blocks (i.e. paths and yards) while these paths in winters would remain in a long-time shade as well as long-time radiation in summers.

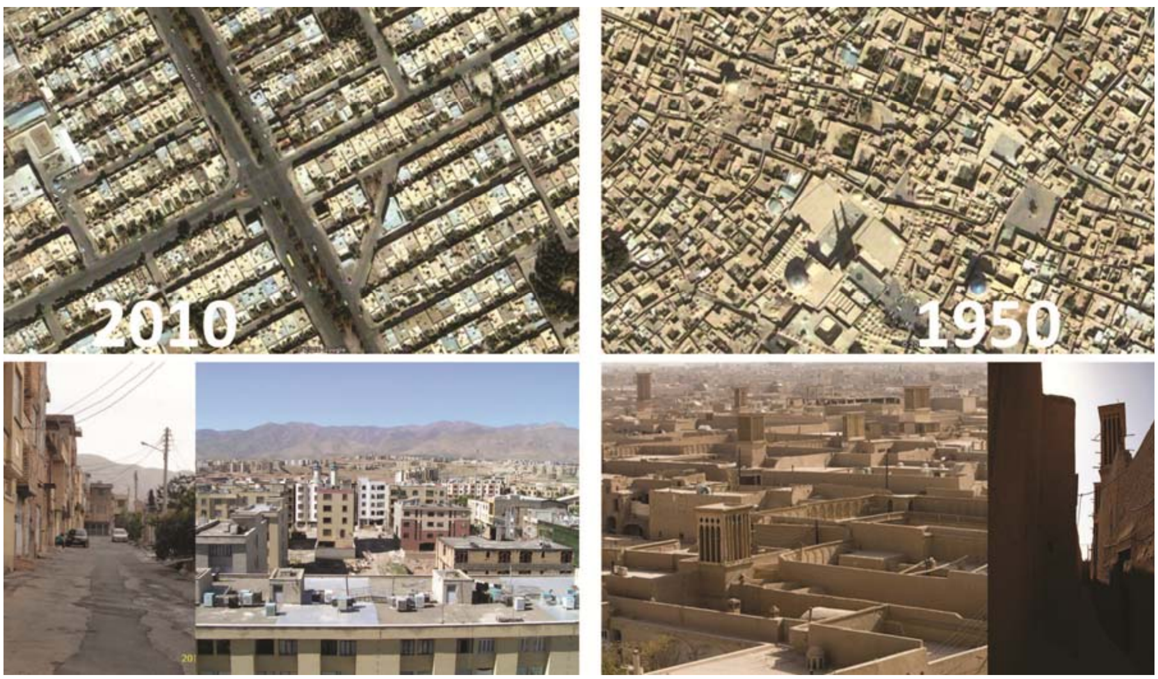


Figure.1 Comparison between contemporary and traditional Architecture and Urban design in Iran. Source: Author

1.3 Possible Solutions

It has been suggested that renewable sources of energy could effectively replace products of the fossil fuel industry, thus solving environmental problems. However, this proposal has inherent problems, for instance, the high cost involved and the lack of technology appropriate for urban-scale applications.

In Iran, the present economy and political circumstances do not allow for utilizing high cost technologies of renewables in the urban context in order to help the energy demand of the cities.

Stefan Behling and Gerard Evenden of Foster and Partners were interviewed regarding energy-optimized architecture. They explained that their designs, as they lowered energy consumption, would result in lifestyle changes. Behling pointed out that consumption is a natural outcome of demand, and that demand in turn arises from design. He gives the comparison that demand for petrol results from car design and that car design is in turn a response to city planning.

In the same way, architects can design buildings, infrastructures and urban developments with an eye to energy demand. In view of the fact that the building industry consumes 44% of the world's energy (Holm, Kjeldsen, Kallahauge &Rank, 2009) it is clear that architects must take responsibility for controlling energy demand. Their designs must not only ensure reduced energy consumption but also be adaptable to accommodate future technology.

In Iran, my country of origin, the sun has had an extraordinary influence on every aspect of life, including architecture, energy demand, and culture. Solar considerations have profoundly affected design and urban decisions. Persian architects were renowned for knowing the mystery of the sun.

Architects in the old days of ancient Iran were called "MEHRAZ" that is based on two words of "MEHR" (the sun) and "RAZ" (the secret). Therefore, in Iran architect was the one who knows the secret of the sun (Samimi, 2007).

In line with this tradition, the intelligent urban design would provide external and internal comfort as it incorporates solar features. Optimized energy-conscious architecture and urban planning must consider solar orientation and building proportions as well as environmental alternatives, and develop these from a concept to implementation. This thesis attempts to put forward a new vision of the sun, climate and architectural geometry.

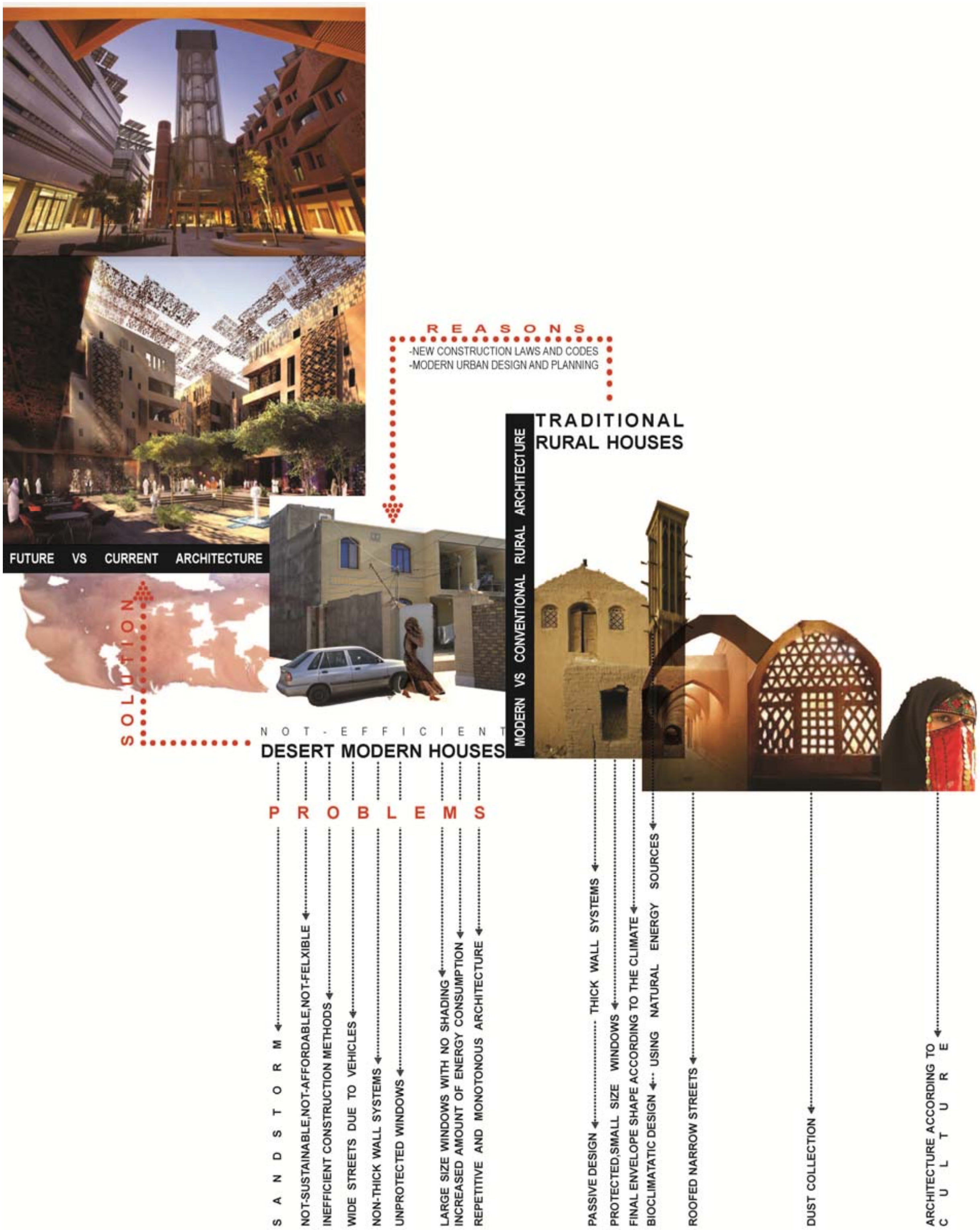


Figure 2: The Problem Statement. Source: Author

1.4 Research Questions

- Is it possible to enhance the level of comfort in the urban open spaces through developing an optimized form for the street networks and building arrangements at a city block scale?
- If traditional strategies in architecture used for several decades in Iran were energy efficient and could provide comfort for the indoor and outdoor spaces, then how these traditional principles can be transformed to be utilized in contemporary buildings?

The thesis Hypothesis:
To propose the most optimized and energy efficient urban block with street network and building forms in the current situation of Iranian cities with hot arid climate.

1.5 Project Goals

The aim of this research is to enhance the microclimate of neighbourhoods by proposing an effective design for the city blocks in response to their environment. This goal is achieved through the following:

- Extensive overview of the condition of the existing buildings and energy consumption in Iran.
- Understanding the pragmatic sustainable solutions to develop energy efficient buildings and verifying the most effective bioclimatic design strategy in hot arid regions.
- Investigating the practical methods of applying the traditional Iranian techniques of creating low-energy housing into the new apartment building lifestyle.
- Re-designing a typical city block in hot arid climate of Iran utilizing the possible passive techniques of past into the contemporary urban morphology.
- Implementing a solar computer simulation programme in order to investigate the effectiveness of the proposed design in regard to the rate of comfort in urban spaces.
- Applying the corrections to the design proposal based on the simulation results.

Chapter Two: Background Information

2. Iran, at a glance

2.1 Geography and climate of Iran

Iran with an area of approximately 1,648,000 square kilometres is divided into four main climatic regions (Ghobadian, Taghi & Ghodsi, 2008):

- Temperate climate in northern shores
- Cold climate in mountain and high plateau
- Hot and dry climate in central plateau
- Hot and humid climate in southern shores

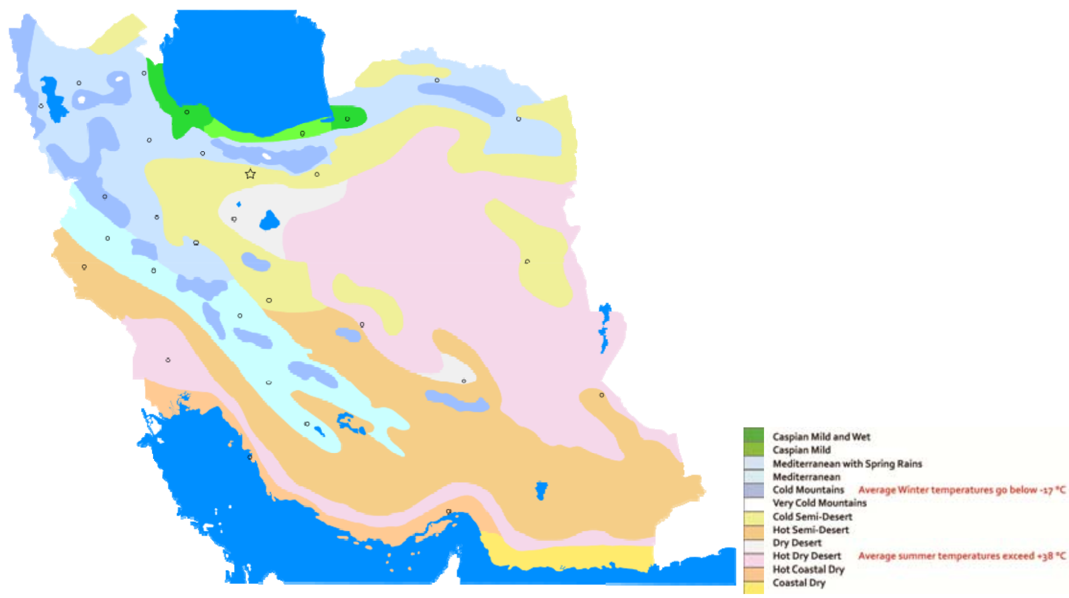


Figure 3: Climate map of Iran
Sourcehttp://fa.wikipedia.org/wiki/%D9%BE%D8%B1%D9%88%D9%86%D8%AF%D9%87:Iran-climate-map.svg

As shown in the figure above, hot and dry climate is covered most parts of Iran that both heating and cooling energy is needed in these regions due to relatively cold winters and hot summers.

Climatic Conditions of Hot-Dry Regions of Iran

Warm and dry summers, hard and cold winters, high differences between day and night temperatures, dusty winds, very low precipitation, air humidity and herbal cover are the most significant outstanding climatic specifications for the hot-dry parts of Iran.

The average maximum temperature of the cities in this region in summer is 30-35°C and an average daytime temperature is 24°C. Solar radiation is very strong, and in June and July it may reach 7.7 kWh/m^2 per day on a horizontal surface. In the summer, ambient relative humidity is very low, between 20 percent and 40 percent during most of the day, but it rises considerably during the night, when the ambient temperature drops sharply, to reach 90 percent. Summer daily temperature fluctuation is about 18°C, and the average temperature is within the range of thermal comfort.

In winter the average temperature in January is -1 to +13°C and the average minimum daily temperature is +5°C. The temperature at night often drops below freezing (0°C). The intensity of solar radiation during the winter is considerable and can reach 3.3 kWh/m^2 per day on a horizontal surface, and about 4.6 kWh/m^2 per day on a south-facing vertical surface. Precipitation ranges from 120-125 mm (Peregrine, Ember, 2003).

2.2 Energy Situation in Iran

Iran is among the richest countries with regard to fossil fuel resources and is a founding member of the organization of the Petroleum Exporting Countries (OPEC). Natural gas, gasoline, oil, gas oil and fuel oil are the main resources of energy in Iran.

Iran's population is growing steadily. According to statistics there are more than 20 million residential buildings around the country (http://ifco.ir/english/index.asp). The growing population as well as the increasing rate of urbanization will lead to an increase in domestic energy demand (http://www.eia.gov/).

According to Iran's Ministry of Energy in 2006, the residential sector consumed approximately 33.2% of the produced electricity, more than any other sector (http://www.sardabir.com/?p=21601).

Energy consumption per square meter of a building equals 30 cubic meters of gas per year, compared to 5.5 cubic meters in European cities. Currently a building in Iran consumes on average 310 kWh/m^2 (Hyde, 2008). According to the Ministry of Energy, 60,000 MW of electricity must be generated by 2015 to meet the growing demand.

2.3 Iranian Governmental Energy Policy

In Iran more than one-third of the entire country's energy is allocated to its six billion dollars a year construction sector. However, considerable amount of energy is wasted. Presence of oil resources, hidden and overt state subsidies, violations of national building regulations and lack of cultural awareness have all combined to create indifference to the value of energy. As a result, the majority of buildings constructed in Iran lack the technical criteria to avoid energy waste (Dariushi, 2006).

Furthermore, applying traditional construction methods in modern buildings led to a significant reduction (up to 30 years) in the life expectancy of buildings and more waste of energy. Current methods and styles of construction and architecture are neither developed nor traditional (http://www.sardabir.com/?p=21601).

In response to these problems, the Organization of Optimizing Energy Consumption provided guidelines and also set forth “The Iranian National Building Regulations” to reduce energy consumption in buildings by means of changes in design, selection of standard materials according to climate, proper methods of construction and the operation of heating and cooling equipment. Thermal regulation was added to the national building codes in 1992; when adhered to, its regulations can reduce up to 30% of energy waste in buildings. Unfortunately, the first draft of the Building Thermal Regulation Code was based on the German code and didn’t take into consideration important parameters of the energy conservation level such as climate (Torabian, Miraghaderi, Akhoundi, 2008). In 2000 climate zones were determined based on heating and cooling degree-days and these changes were put into the building code (Fayaz, Mohamad Kari, 2006).

In Iran, a 5 cm thick layer of polystyrene insulation is applied for all external walls that is proposed by the national building code and the U-value achieved by using this thickness of insulation is 0.7 W/ m^2K. The main portion of insulation cost is its installation cost, and the thicker the insulation, the more expensive the cost of insulation would be (Saberi et al., 2006).

2.4 Process of Urban Transformation in Iran

Generally, the process of urban evolution has two main driving forces: internal existing and external prevailing causes. Internal existing causes comprise a country’s progress and development over a long-term period and include governmental, social, and economic conditions. External prevailing causes are constantly in flux and do not allow for adaptation; in this category are wars and natural disasters (Tafahomi, Lamit, Bushri, n.d.).

In Iran, the acceptance of Modernism and International Style resulted in critical changes in social, economic and political patterns. Widespread destruction of existing urban textures and the non-compatible behaviour of people to modern urban spaces were some of their external manifestations. Whereas in Europe Modernism had successfully emphasized urban spaces and their role in daily life, in Iran urban spaces became less popular; also the hierarchy of districts, streets and squares collapsed.

Public urban spaces that had once been places for gathering, integrating and observing were much less frequented after the arrival of Modernism. Nowadays streets, nodes and other urban spaces are considered only as corridors, means of getting from one place to another. One of the reasons that results in ignoring urban spaces as places for gathering and social events is creating not-thermally comfortable and not-properly oriented streets that were made considerably wide to ease car traffic as can be seen in figure 4.

Figure 4: Streetscape, Iran
Source:
http://www.trekearth.com/gallery/Middle_East/Iran/East/Yazd/Yazd/photo1221661.htm

The revolution in Modernism began with the construction of streets in Iran. The presence of more vehicles and the need for thoroughfare routes and high-speed roads intensified street networks. The imposition of Euclidian geometry on the streets had the effect of breaking internal connections between districts and people.

The districts that had been destroyed were replaced by newly designed neighbourhoods, but these lacked substantive identity, form and function, hierarchical order, open gathering spaces and connection paths. Roadsides became more important and the new apartment buildings (the most common residential form in big cities) became prevalent and changed the aspect of the city.

In the transition period of the 1920s to 1960s, neighbourhoods lost their mixed-use features, changing from financial and social districts into mainly residential ones. Also, restrictions placed on the dimensions of urban plots limited what could be built on them (Shayesteh, Steadman, 2005). The dimension and shape of plots constrained housing types by offering limited relations to enclosure, access and daylighting. New urban regulations specified that all buildings (high-rise, mid-rise and low-rise) should cover only 60% of a plot, leaving 40% for open space. These constraints greatly affected spatial organization of housing as well as urban design (Mirmoghtadaee, 2009).

In order to show morphological transformations of districts in Iran, a sample area of three Tehran boroughs 500 meters by 500 meters was selected. In figure 5, one can clearly see the transformation in terms of size, floor plan area, frontage width, ratio of built to open space, density and street network (Shayesteh, Steadman, 2005). The evolution of typology of dwelling arrangements is also abstractly represented.

In borough 12 the traditional fabric was maintained and therefore courtyard typology is predominant. Courtyard housing is also found in borough 11 but in borough 2 it has been completely replaced by row houses.

Figure 5: Floor plan area. Top: Borough 12, middle: Borough 11, bottom: Borough 2. Source: Shayesteh & Steadman, (2005).

Chapter Three: Methodology and Research Analysis Technique

3. Summary of the Proposed Methodology

To accomplish the thesis process, the following process had been followed:

1. Investigating the traditional passive strategies in architectural elements that have been successfully implemented over centuries to control the effects of harsh climate and to provide indoor comfort.
2. Re-thinking and re-designing the most successful climate-conscious strategies of the traditional architecture to be adapted to modern life style and attempting to apply them to a larger scale: i.e. urban block;
3. Verification of the early design proposal by SOLARCHVISION simulation program to identify the rate of comfort in each moment.
4. Refinement of the urban block design, from macro to medium to micro scale.

3.1 Technical Information on Energy Efficient strategies in Architecture

In the last decades of the 20th century a new perspective on the objectives and methods of environmental and energy control in buildings emerged. It emphasized finding ways to reduce demands on fossil fuel energy sources and mechanical power, and to replace them. In the book "Design with Climate", Victor Olgyay investigated the relation between climate and architecture with the goal of controlling energy demand; he proposed a model of 'interlocking fields of climate balance' (Figure 6).

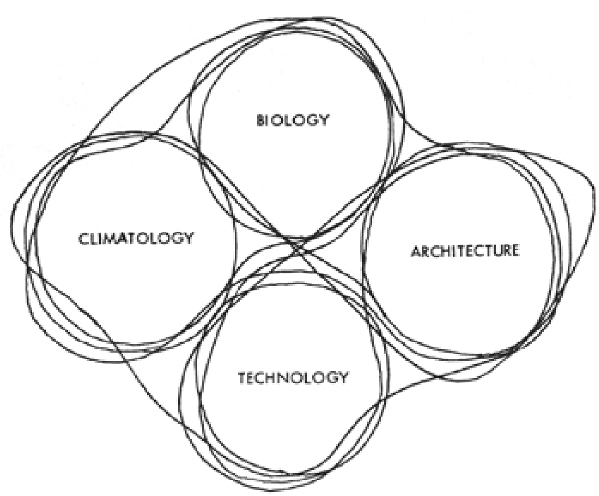


Figure 6: 'Interlocking Fields of climate balance', Victor Olgyay

Source: http://architecture.mit.edu/class/nature/student_projects/2007/rsr/context.html

In this model Olgyay distinguishes between architecture and technology (mechanical services), in the process of environmental control.

In another simple diagram he showed that how the manipulation of environmental conditions and microclimatology might significantly reduce the demands placed upon the mechanical plant.

'Bioclimatic architecture', a term introduced by Olgyay, describes a trend in architectural design that sets out to work with rather than against nature. This "bioclimatic design" seeks to utilize climatic conditions to produce dwellings or building elements and devices that would maintain the comfort of residents.

Bioclimatic design brought together the disciplines of human physiology, climatology and building physics. Research into bioclimatic issues has gradually taken the form of passive low energy architecture research (PLEA) (Hyde, 2008).

3.1.1 Passive Cooling

Passive cooling is a low-energy-intensive method of keeping buildings comfortably cool that relies on architectural design. Heat avoidance techniques and natural cooling, when incorporated into a structure, minimize energy consumption and improve indoor comfort level (Wright, 1996).

In the hot, arid climate of Iran passive strategies were of critical importance to architecture and urban design and were utilized by native architects.

In traditional buildings passive cooling was a method that relied on innovations in the built form, self-efficiency in building materials and optical and thermo-physical properties of the building envelope to eject heat, ventilate the air to keep it cool and control sunlight (*Tolou Behbood, Taleghani, & Heidari, 2010*). Other means of passive cooling technology that came into use include insulating materials, air infiltration, radiant heat transfer barriers below the roof, innovative window designs and high-performance glass that slows heat flow.These strategies were categorized in three levels as shown in table below:

Scales	**Climate Responsive Design Strategies**
MACRO	Distance between buildings; Enclosed urban environment; Narrow and irregular streets
MEDIUM	Building form- Building envelope- Self-Efficiency in materials; Optical and Thermo-physical properties of the building envelope
MICRO	Module Unite; Eyvan and Revak; Wind catcher (Air trap)

Table 1: Classification of climatic responsive strategies of Iranian traditional architecture
Source: redrawn from Tolou Behbood et al., 2010.

3.1.2 Macro-Scale Climate Responsive Design Strategies and their Effects

In desert regions of Iran, the main outdoor environmental stresses by the climate to the people staying outside are as follows:

- High heat stress of summer days due to high ambient air temperature and intense solar radiation
- High glare from sunlight (direct and reflected)
- Dust storms, mainly in the afternoons
- Cold winds in winter season

According to these outdoor environmental problems, the urban design details in hot dry climates should aim in lessening the harsh situation (Givoni, 1998).

Distances between Buildings: Neighbourhoods used to be planned in a way to shorten the distances for walking people and playing children. In addition, the streets were narrow enough in order to provide shady areas in streets and courtyards during the day which results a cooler environment in summers and a warmer environment in winters.

Figure 7: The distance between the buildings in traditional cities of Iran
Source: http://bia2bama.loxtarin.com/p.php?page=10
http://blog.travelpod.com/travel-photo/lucky/15/1274442968/2_yazd.jpg/tpod.html
http://www.followtheway.info/trips/iran-6-yazd-arid-and-luminous/

Narrow-Irregular Streets: Since hot-dry regions commonly have dusty strong winds during daytime, direct building ventilation is not desirable. Conversely, in the evenings ventilation is essential for indoor comfort. Therefore, providing potentials for evening and night ventilations is at the main concern (Tolou Behbood et al., 2010).

In order to drop wind speed, neighbourhoods with high density, narrow irregular streets, and similar building heights were constructed. In this case a sharp drop in the wind speed would happen below the roofs' level. Having a low speed wind in hot dry regions can be considered a positive point on one hand due to reduction of sand distribution in the neighbourhoods, and it can be considered a negative point due to difficulties in providing indoor ventilation especially when the ambient wind speed is very low.

For controlling dust storm, according to planning policies, the density of the built-up area should avoid un-built lands and protect other lands that can be realistically keep as landscape areas (Givoni, 1998).

Figure 8: Narrow and irregular street in compact texture of a city in Iran
Source: Tolou Behbood et al., 2010.

Enclosed Urban Environment: The structure of the cities in desert with sand storms were made enclosed in order to prevent the high velocity of storms from penetrating to the street level. As a result the air inside the town becomes more static and compatible to human's comfort than air outside the city and could lessen the negative effects of strong speedy winds in spreading solid particles to the air.

Figure 9: Enclosed streets. Source: http://www.gooseontheloose.com/diary/diary17.htm
http://www.trekearth.com/gallery/Middle_East/Iran/East/Yazd/Yazd/photo1269158.htm
http://blog.travelpod.com/travel-photo/ranizo/1/1259356687/one-of-yazd-many-laneways.jpg/tpod.html

3.1.3 Medium-Scale Climate Responsive Strategies

Originally in Iran, people used to have nomadic communities and therefore moving was an intrinsic feature of their behaviour, culture and architecture. Not only they used to move from place to place in summer and winter to take the best advantage of local climates, but also they change their location in their own static house, from north rooms to south rooms according to the sun's path. Therefore, the layout of their houses played an important role in their daily lives.

Building Form and Layout: the direct impact of a building's layout is related to the envelope's surface area and the ratio of the building's envelope's surface area to its volume or floor area verifies the relative exposure of the building to the sun radiation and also it determines its exposure to the ambient air (Hyde, 2008).

From the energy expenditure point of view, the more compact the building's plan, the smaller the energy expenditure. Because for a given volume or floor area of a building, a more compact plan will result in a smaller exposed surface area of the walls and the roof which result in a significant reduction in heat exchange by conduction between the building and the ambient air. In this case, in hot seasons and hours, due to smaller surface area less energy is needed for air conditioning. On the contrary, in houses with spread plans and more exposed envelope, heat gain or loss is greater and energy expenditure is larger, but we should consider that in this type of buildings the potential for cross-ventilation is better. The larger the area of external walls, the more opportunities would be there for openings which will catch the wind from different directions. But we should take into account this fact that for buildings in hot dry climates, having a better ventilation and daylighting are not considered as advantages for a building due to dust winds and excessive natural light which are common in this type of climates. Cubic forms can help the building to reduce their exposure surface area to hot weather than more linear forms of the buildings (Hyde, 2008).

Contemporary Typological Housing Sets in Hot Arid Climates

In the book "Bioclimatic Housing", Vahid Ghobadian (2008) declares that different building types exhibit different thermal performance characteristics in hot- dry climates. As he suggested, all building typologies should extended along the east-west axis. In addition, the house plan should be directed towards south so that all apartments could have direct access to sunlight from the south side. Although all typology of houses exists in Iran, according to the topic of this thesis low-rise buildings will not be discussed.

Multi-Storey Apartment Buildings

Double-Loaded Corridor Apartment Buildings

Double-loaded corridor buildings not only minimize the heat gain during the daytime and have poor solar exposure for approximately half of the apartments, but also they lack high ventilation especially during the night hours. Thus from the summer comfort aspect, this typology is not suitable in hot climates and requires mechanical devices for the whole-house.

Single-Loaded Corridor Apartment Buildings

If single-loaded corridor buildings are oriented properly in a way that the corridor is open in summer and is located on the leeward side of the building, they may be considered as an appropriate solution in hot dry climates. As a result of this orientation, cross ventilation would happen when door and windows in the corridor wall are left open. In societies where comfort is sacrificed for privacy, this typology is not recommended.

3.1.4 Micro-Scale Climate Responsive Strategies

This section presents a number of building elements that facilitate and control the relation between climate and indoor condition of buildings. These building elements can naturally engage with the built solids of a city in cooling down the temperature and conserve energy. The medium of architecture in modern era is replacing technology in providing a physically and psychologically comfortable modern structure in order to respond the social needs (Fathy, 1986).

The following is an illustration of three selected elements in the traditional architecture of Iran which were used in hot arid regions.

Dome and Vault Roofs

Domes and vaults are used as covering roof for public or private places in hot arid climates. They have been proved as useful elements in natural ventilation and passive cooling. Vault is an elongated arc and dome is a special type of vault constructed on a circular, elliptical, or polygonal plan (Curl, 2006).

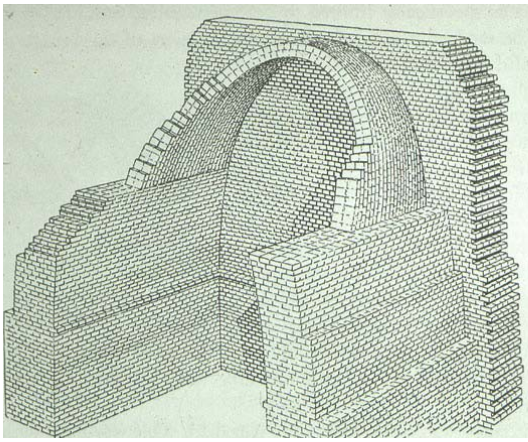
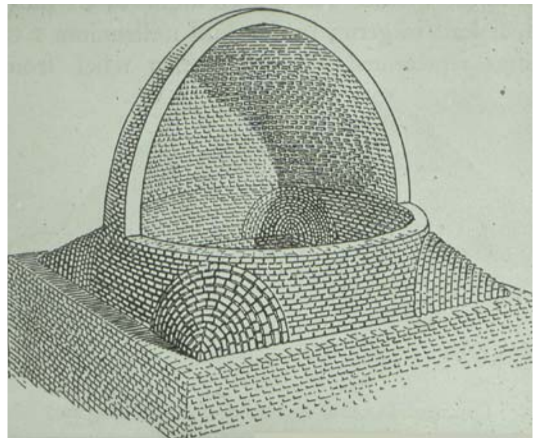
 

Figure 10, 11: Iranian Vault (left) and Dome (right)
Source: http://krc.orient.ox.ac.uk/krc/index.php/image-archive?func=detail&id=11706#joomimg http://krc.orient.ox.ac.uk/krc/index.php/image-archive?func=detail&id=11707

Besides the structural reasons, the dome and vault shape roofing in this region have some critical thermo-physical reasons as well. Having convex and unbalanced surface, curved shapes could influence the intensity of sun rays. The angle sunbeam on dome or ached roofs and therefore their impact is different from one point to another, and a part of it always remains in shade during morning and afternoon and as a result they could be a suitable shape for releasing and emitting sunbeams and waves during night and it helps to the night cooling.

It is common that roofs are paved with square shape bricks called paved bricks which can cause the change in sun radiation intensity and radiation angle in the period between early in the morning and late afternoons.

Based on "Venturi effect" which is a concept that demonstrates how pressure differentials can produce air movement, when air flows over a dome or vault surface, it speeds up at the apex of the curve and as a result its pressure drops, creating an area of low pressure. If there is an opening in the peak of the dome or vault, hot air that has collected under the peak will be sucked out by the lower pressure moving air outside (figure 12).

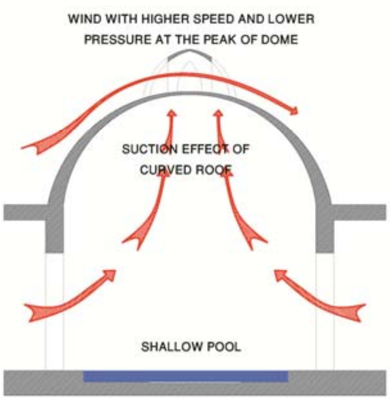


Figure 12: (right) Air flow pattern over a domed roof
Source: Redrawn from: Tolou Behbood et al., 2010.
Figure 13: (Left) Bulbous glasses on a domed roof, Hama, Syria, Source: Bahrami, 2006.

In a comparison between a flat roof covering and a dome covering, it is concluded that, while the heat gain from solar radiation is almost the same for both types of roofs, the amount of heat loss by convection is higher in dome shape roof than that on a flat roof. This comparison showed that the dome is an appropriate choice for hot areas.

In order to create effective ventilation system in dome or vaulted roofs, locating openings in proper positions is needed. Providing natural light for spaces under domes in hot regions could also be created through the use of several small holes on the roof and cover them with bulbous glass (figure 13).

Wind Catcher

Passive ventilation strategies of the traditional Iranian house influenced the design of the iconic wind towers that harness solar energy and wind power to passively produce air flow in the layers of a building. These high-rise shafts can make it possible to capture wind above the buildings, where it is cooler and less windy and direct it to the rooms below. Since the velocity of wind increases height above the ground, wind catchers opening could be smaller than windows at ground level. The number of openings and the direction of them should be chosen based on a wind rose analysis for months the building requires cooling (Brown & Dekay, 2001).

Difficulty in combining the functions of an ordinary window which include providing light, view and ventilation in hot arid climates results in separating them. Large windows while provide sufficient lighting and outside view, they can increase strong and offensive glare as well as sandy air movement inside the living spaces.

The value of wind-catcher is more obvious in ventilating air when it significantly reduces the sand and dust so prevalent in hot arid regions. The captured wind from higher levels contains less solid materials than the lower heights, and also much of the sand entered the shaft would be dumped at the bottom of it.

A specific type of wind-catcher in Iran and the countries of Gulf called *Badgir* that has one shaft with the top opening on four sides to catch the breezes from any direction. The shaft has two partitions placed diagonally across each other down the length of the shaft and extends down to a level that let the breeze to reach rooms of the building directly (figure 14).

In the design proposal of re-designing a climate-sensitive city block, two badgirs are considered on two sides of the block in order to work like the old badgir and catch wind from all the directions and the proposed shaft is attempted to be height enough to trap air from high levels and direct them to the low levels that let the breeze to pass over the water bodies.

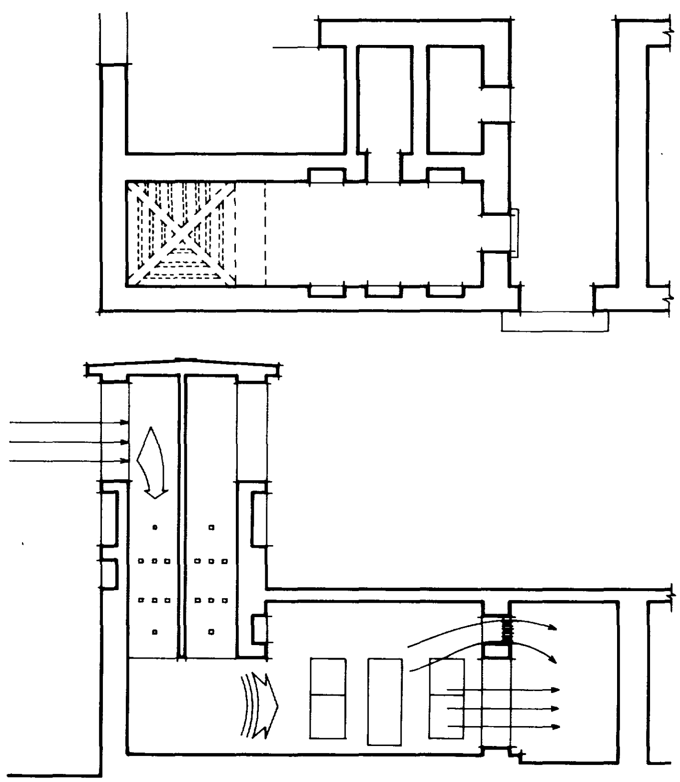
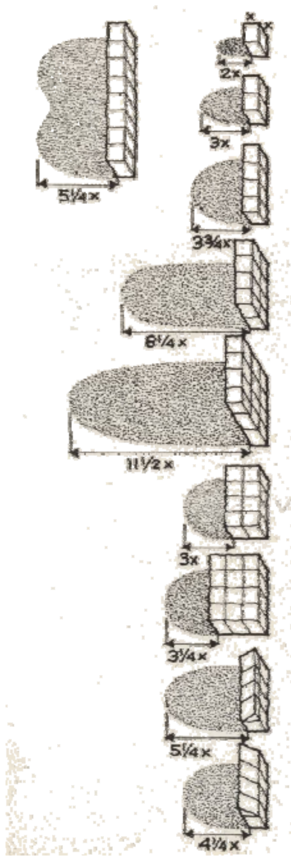


Figure 14: Plan and Section of Badgir. Source: Fathy, (1986)

In general, as wind blows against a structure an area of high pressure would be created on the windward side and a low pressure zone to the leeward side which depending on the wind velocity this low pressure zone continues to a certain distance beyond the building. The length of the low-pressure zone for normal wind velocities is shown in figure 15, 16.



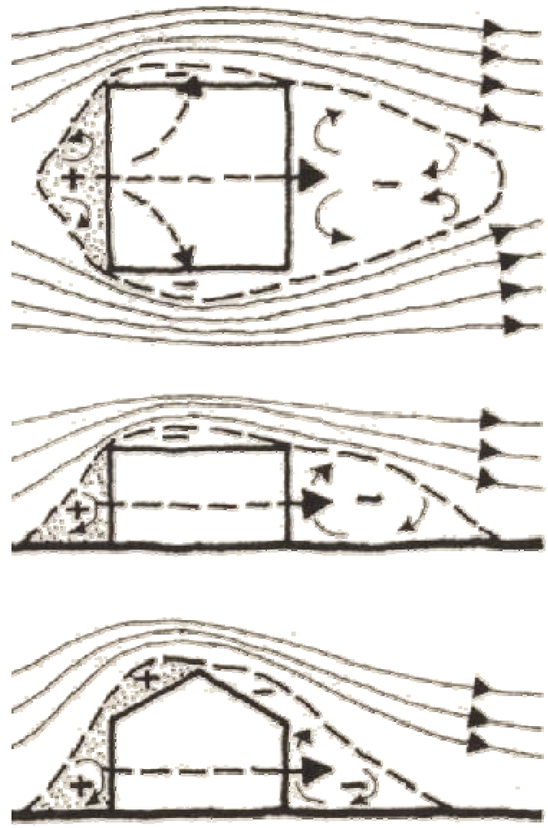


Figure 15: Left: Air flow around and over a building showing pressure and suction zones
Figure 16: Right: The extent of the low pressure zone depends on the height of the building rather than its width. Source: Konya, (1980)

In order to create a complete ventilation system in a building, a typical wind-catcher should operate as part of a complete system as shown in figure 17. As shown, two shafts are needed in order to capture and also draw out the air through suction. The system depends on the air movement by pressure differential and also by convection that produce the stack effect.

Due to the increased air pressure at the entrance of the wind-catcher caused by the wind, cool breeze could be channelled down into the interior. Inside the building the air slows down, and would flow and rise into the upper levels and escape through the *mashrabiya* (The Arabic term for a type of window enclosed with carved wood latticework). Wind blowing over the central dome shape roof can be accelerated due to low pressure air at the peak and the air beneath the dome can escape and would continuously replaced by the internal air. Therefore, a complete circulation can happen (Konya, 1980).

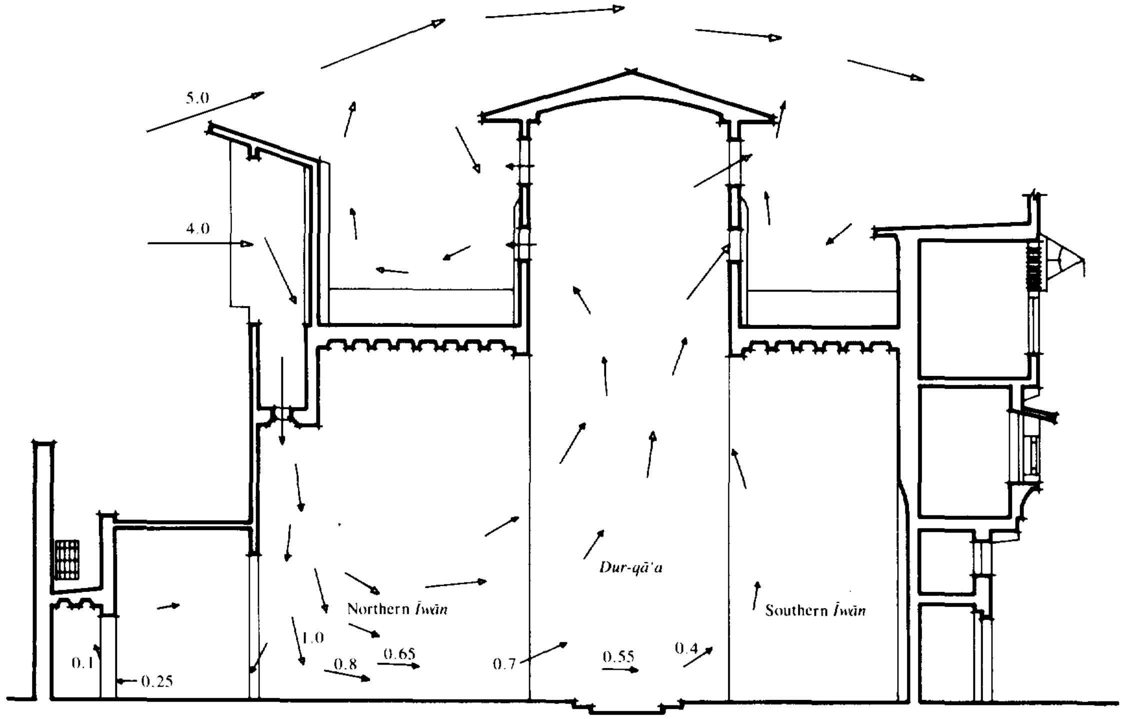


Figure 17: Wind-catcher, source: Fathy, (1986)

The taller the wind catcher, the greater the negative pressure over it. But the height factor of the wind tower should be weight up against aesthetic concerns and planning restrictions as well.

In apartment buildings if wind tower could be combined with the lift motor room with considerations it could provide the interior of the units with cross ventilation.

Ideal Position of the Openings

- The ideal position for harnessing winds from all directions is the centre of the building. Because a wind tower is at its maximum efficiency at the windward of the roof where the negative pressure is the greatest.
- The ideal position for the inlet openings is along the windward façade where the positive pressure is at its maximum level. However, it is better to have a complex building-management system that can open and close windows/vents or to have openings on all facades if there is a change of wind direction (Battle McCarthy Consulting Engineers, 1999).

Water Edges:

In hot arid climates water evaporating into the air can be significantly lessen the air temperature. The factors affect the rate of evaporation are the surface area of the water, the velocity of the wind, the relative humidity of the air, and the water temperature. Beside these factors, designers have the most control over the surface area of the water and the location of the ponds or fountains relative to the wind direction and the spaces to be cooled.

It is calculated from experiments that under the average wind velocity and temperature conditions, the expected cooling rate from an exposed water body of about 1 m^2 (11ft2), would be 200 W (682 Btu/hr) (Brown & Dekay, 2001).

In hot arid regions if breeze could be channelled over pools or water sprays before they enter buildings, they can ensure that cooled and humidified air enters the interiors. To be efficient, and in order to reduce water evaporation in hot-arid climates with high intensity of direct solar radiation, the pool should be contained between walls on two or three sides (Konya, 1980). A spray pond has an additional advantage over a still pool of the same size that it not only can cool the air but also can wash it: water droplets can stick to dust particles in the air and therefore can no longer remain suspension.

The *Bahai Temple* in New Delhi, India, designed by the Iranian architect Fariburz Sahba, localized the cooling affect in courts by trapping cool air through nine sunken pools and directing the taken air to the basement level (figure 18). The air is then drawn into the central atrium and sucked out through the vent located in the top of the structure. Fans are also used when required (Brown & Dekay, 2001).

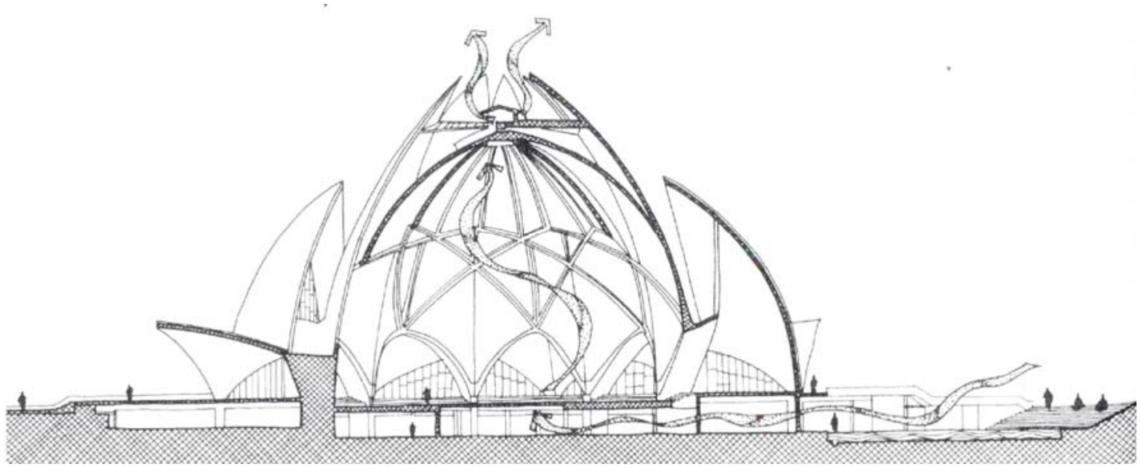


Figure 18: Bahai temple, New Delhi, India, Section, Source: Brown & Dekay, 2001.

3.1.5 Case Study No. 1

A Successful Case Implementing Traditional Elements

Boroujerdi House, Kashan, Iran

Building type:	Semi-dethatched, courtyard
Year of construction:	1875-1876
Architect:	Ali Maryam

Considered as a typical traditional "four season" house in hot arid climate of Iran, Boroujerdi house is a good example of a climate-sensitive house in Iran and economically and socially was and still is appropriate for this location. The energy consumed for construction, and occupation is at the minimum level.

The architect of this house in the macro scale considered the location and the orientation of the house and is surrounded by other buildings to allow the house to get minimum heat from its parameters.

In the medium scale, the linear form of the building, the central yard and two deep Eyvans create shady and cool interior spaces. Moreover, this building is built totally by mud and other vernacular materials such as wood.

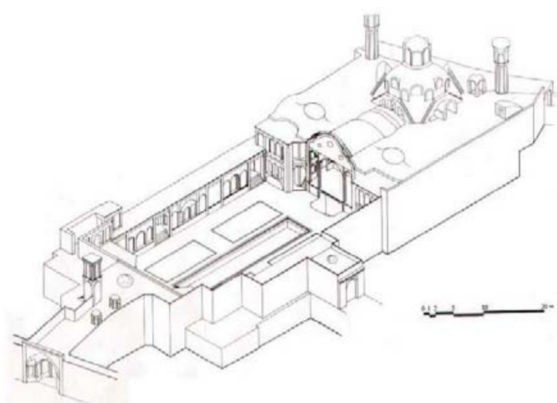


Figure 19: Isometric view, Boroujerdi house
Source: Tolou Behbood et al., 2010.

Figure 20: South Facade, Boroujerdi house
Source:
http://www.flickr.com/photos/roham/3489896042/

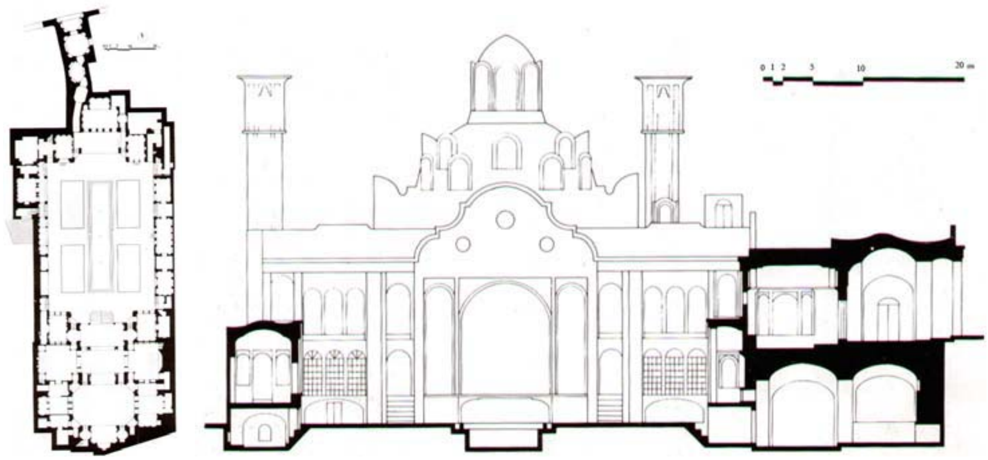
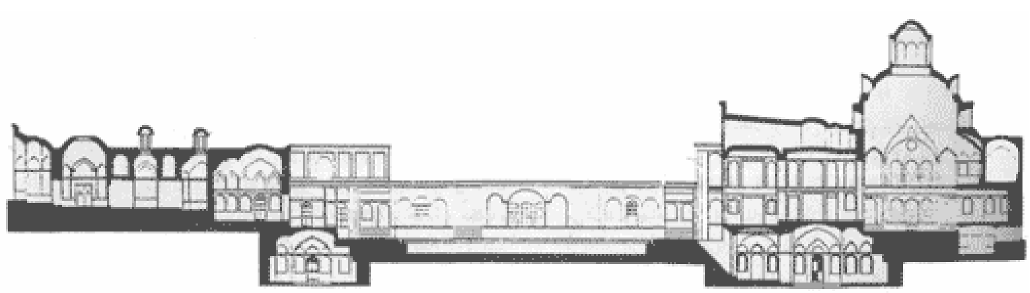


Figure 21: Plan and front view, Boroujerdi house
Source: Tolou Behbood et al., 2010.

Finally in the micro scale, smart combination of domed roof, wind-catcher and fountain is an instrumental use which could effectively create better thermal comfort for inhabitants of building.

The importance of this historical house is in its unique wind catchers which are made of stone, sun-baked brick and a composition of clay, straw and mortar. Three single wind-catchers with almost 40 meters heights in combination with a unique shape wind-catcher on the summer quarter of the house could trap hot breeze and maximize cooling ventilation by evaporative cooling.

In this inward looking house, the summer rooms have higher ceilings equivalent to two regular floors than rooms used in winter period (figure 22). The higher levels for ceilings are achieved through dome shape roof which supplies better thermal comfort by providing more space for stratification of air that allows the occupants to inhabit the cooler lower levels (Lechner, 2009). By using vent at top of the dome roofs in boroujerdi house, proper light without direct penetration of sun rays can also be provided.



Winter quarter   Summer quarter

Figure 22: Difference in the height of ceilings for thermal comfort at the summer and winter quarter, Kashan, Iran. Source: Foudazi & M'Rithaa, n.d.

This smart combination of micro elements (wind-catcher, dome roof and fountain) becomes an inspiration in developing a modern eco-air-conditioning system in the design phase of this thesis. In a schematic design, in order to provide natural ventilation for a group of buildings in a city block a secondary envelope was designed to cover the surfaces of the buildings and to assimilate the aerodynamics of wind-catchers (figure27). This concept does not appear in the final design proposal of this thesis due to limitations in studying the success of creating natural ventilation in a larger scale through secondary elements.

3.1.6 Case Study No. 2

An Unsuccessful Case Applying Traditional Principles

Hashtgerd new town, Tehran, Iran

Hashtgerd, the new town, located north-west of Tehran, is one of the sub-projects of "Young cities project", a German-Iranian Research Project that seeks to find strategies for the development of low carbon "energy-efficient" and resilient housing districts in semi-arid climates. The case study, a 35 ha area located on the southern part of Hashtgerd NW, is the main demonstration ground slated to be developed as a low-carbon neighbourhood using passive strategies for 8,000 inhabitants in 2,000 residential units (Future Megacities in Balance-Session A7). The aim of the project include: Investigating climate-sensitive urban form, integrated planning of the energy infrastructure systems and semi-and de-centralized energy infrastructure systems.

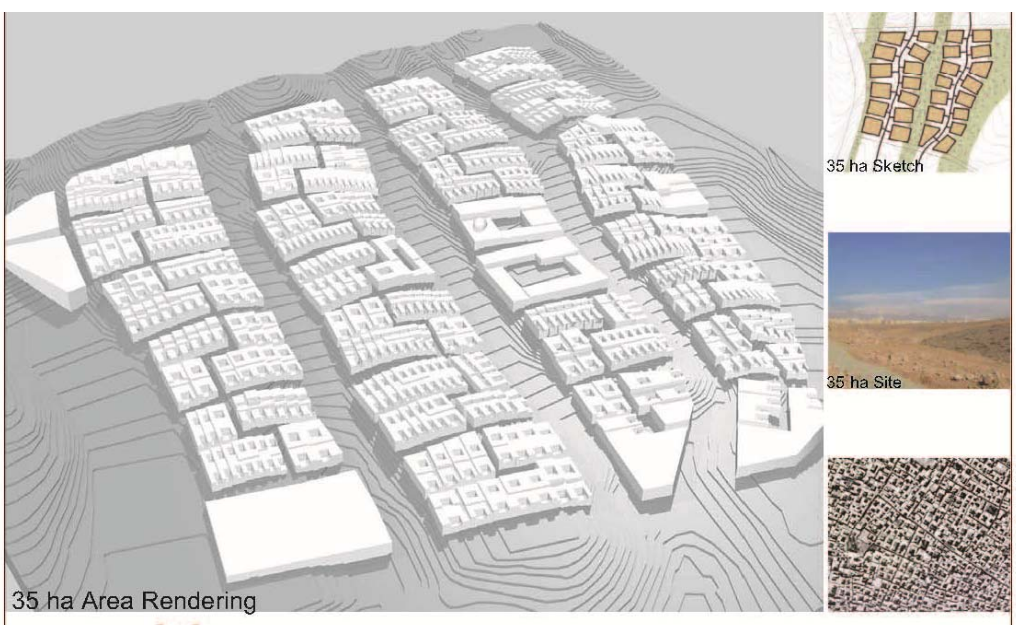


Figure 23: Low Carbon Urban Form. Source: Nytsch & Seeling, (n.d.)

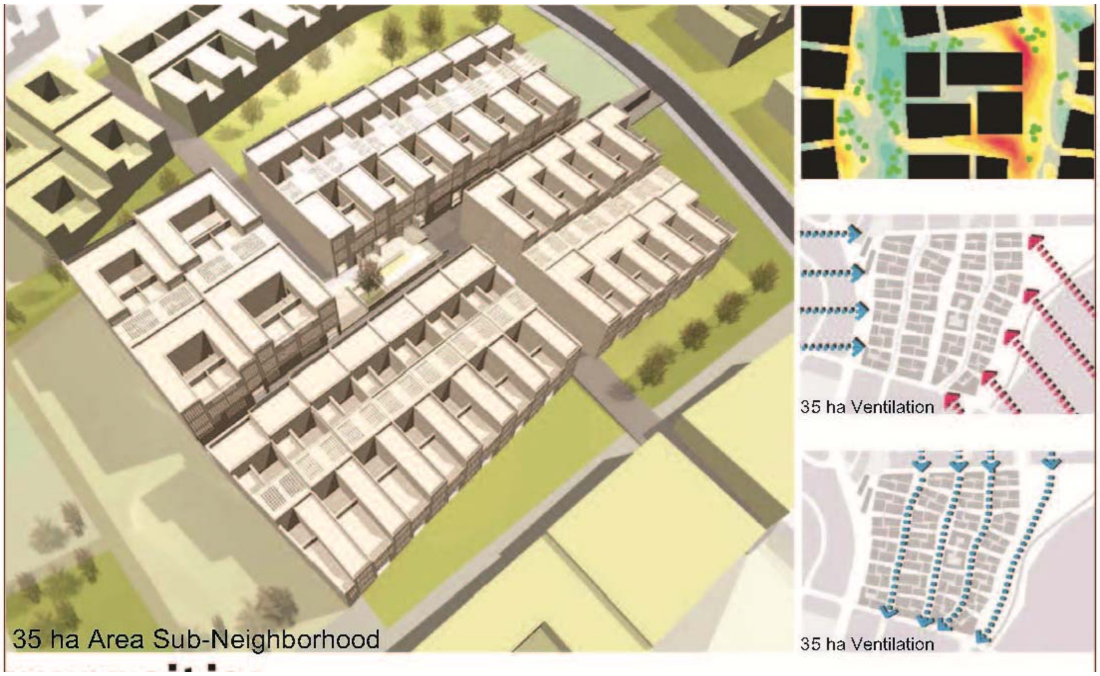


Figure 24: Climate-Sensitive Urban Design. Source: Nytsch & Seeling, (n.d.)

A design priority was to revitalize spatial and energetic qualities by referencing traditional Iranian spatial, urban and functional logics. According to these principles, a low-rise, high-density urban form with a clear hierarchy of public, semi-private and private spaces was proposed. Twenty-eight compact clusters were arranged in four rows and oriented north-south.

Resembling traditional courtyard housing, each cluster consisted of a central courtyard surrounded by four building groups; this created a clear spatial hierarchy for blocks. This modern courtyard housing intended to combine the advantages of introversion (social and cultural aspects), compactness and orientation. Based on this proposal, elements of traditional Iranian housing architecture were combined with modern design to achieve maximum energy and resource efficiency (Nytsch & Seeling, n.d.).

It was predicted that the predominant north-south orientation of this built project would result in reducing the cooling demand up to 23%. Moreover, the compact building arrangements was expected to create shadows on neighbouring buildings that would lessen the demand for cooling up to 6%. Ventilation was provided by grouping the buildings according to wind direction so that cooler north-south winds would channel through the site whereas hot and dusty winds from the south-east would be blocked.

Unfortunately, the resulting typology of courtyard housing with narrow streets and the developed urban design created temperature problems for the whole year cycle.

In figure 26, the simulation model of the soil temperature of the sub-grid of Hashtgerd NW analyzed by the micro-climate model ENVI-met is shown. The input data for this model include: solar radiation, vertical profile of the wind, soil moisture, air temperature and relative humidity. According to it, the semi-public courtyards and streets oriented east-west have the maximum soil temperature, so they are deficient in providing comfortable outdoor spaces in regard to sun radiation and natural ventilation. Although the streets between the volumes are narrow, their temperature is high in summers and the agglomeration of buildings creates shadow in winter.

It could be concluded from this case study that nor the width of the streets neither the combination of volume masses in resembling traditional courtyards are enough in creating thermally comfortable urban spaces. For alleviating this condition, the mentioned low-energy, passive strategies should be added to the correct orientation of the streets in order to create thermally comfortable outdoor spaces.

In the design proposal of this thesis, the first design criteria is finding the most appropriate orientation for the internal streets of a city block while all the main streets of the designated city are oriented north-east to south-west direction in order to cast shadow for the most hours of a day.

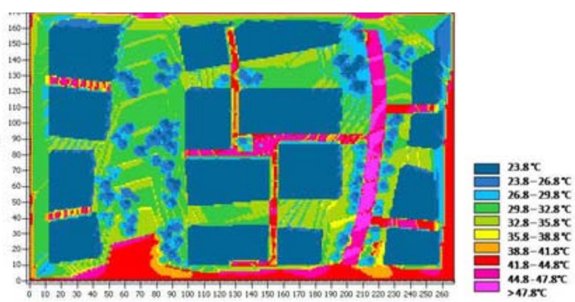


Figure 25: Low Carbon Urban Form. Source: http://www.youngcities.de/pilot-projects.html
Figure 26: Image of soil temperature simulation of the sub-grid of Hashtgerd, 15.07.2005. Source: http://www.youngcities.de/151.html

3.2 Applicability of Traditional Passive Strategies into Modern Design

In this section the applicability of traditional elements and principles to contemporary building design will be investigated through three conceptual designs. Adapting traditional natural ventilation systems such as wind-catchers and shade canopies for use in modern buildings can be considered as an alternative to improve their energy efficiency.

Hassan Fathy in his book "Natural energy and vernacular architecture" (1986), argued that forms that traditionally evolve in hot arid climates are based on natural concepts and create comfort, beauty, social and physical functionality for their occupants. Contemporary buildings that use modern materials while ignoring environmental context, on the other hand, can be in general problematic.

While change is inevitable and new forms and materials are coming into use, not every convenient modern form or material will be suitable for long-term application. The eagerness to be modern and the rush to abandon traditional age-old solutions to climate challenges has resulted in a failure to evaluate possible substitute materials or forms and has even led to forgetting the concepts behind traditional techniques. If the language of traditional ideas could be translated into modern forms the result could transcend both the contemporary and the conventional and allow for the development of a type of architecture that is responsive to its environmental context.

3.2.1 Conceptual Design 1: Developing of a Typical City Block Using Principles of a Wind Catcher

As previously discussed, the effectiveness of natural ventilation depends upon air movement, air changes caused by differences in temperature, and wind direction (Konya, 1980). In desert areas of central Iran, breezes flow in various directions. In summer breeze flows north and north-east. Therefore, in developing the design of a typical city block, the buildings are suggested to be grouped in a way to form spaces that could result in creating natural ventilating in hot days of summer and function like a wind catcher. While the buildings are oriented south-west to north-east, a second envelope layer is proposed in order to cover the façade and roofs of the cluster and to capture and funnel the prevalent wind and direct it to lower levels (figure 27).

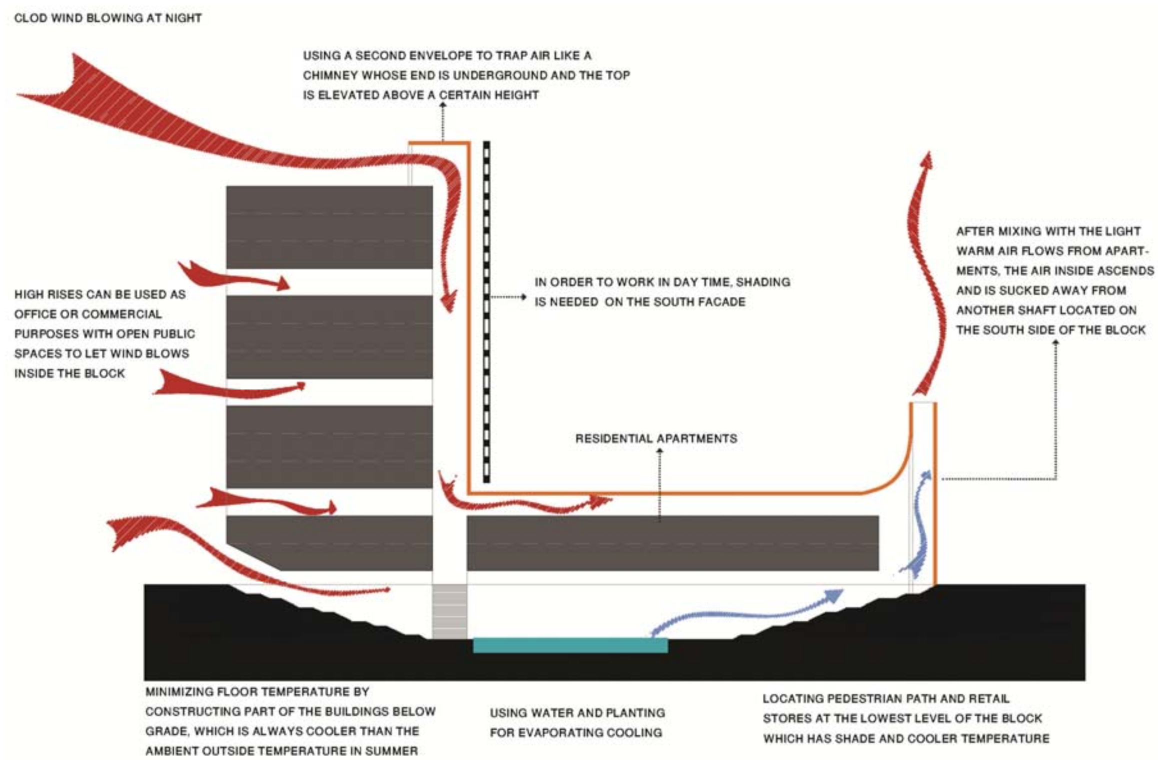


Figure 27: Applicability of the principles of a wind catcher in modern apartment building typology Source: Author

The second layer spanning building masses in the block derives its inspiration from both traditional window lattices (figure 28) and the aerodynamic concept of a wind-catcher (figure 29). It blocks sun on the building facades and pedestrian routes and also facilitates natural ventilation and filters dust. The floating roof hovering above all the buildings could channel local breezes and use air as an insulation; it can also be covered in an array of solar-photovoltaic panels (figure 27).

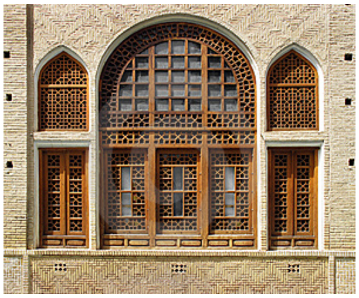


Figure 28: Traditional window lattice Source: http://www.stockphotos.it/image.php?img_id=14431900&img_type=1

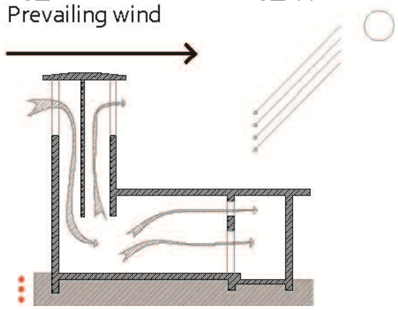


Figure 29: Traditional wind catcher, Source: Redrawn from Tolou Behbood et al. 2010.

Traditional Iranian market was another inspiration for this concept. Shaded and passively-cooled circulation thoroughfares are created at one/two level below the ground floor and are characterized by dramatic light (figure 30).

Figure 30: Traditional Iranian Bazaar Source: http://www.gooya.us/photos/2007/10/the-true-iran-a-picture-tour-of-the.php

According to the mentioned criteria, a typical city block (figure 31) is redesigned to cluster the buildings in a passively manner to create natural ventilation.

While the space between the taller buildings of the block, locating on the north side, and the second envelope skin could capture air from higher levels, water bodies and shaded streets at the basement level will decrease the air's temperature through evaporative cooling. For completing the air circulation another shaft is created between the buildings on the south side of the block to suck out the trapped warm air.

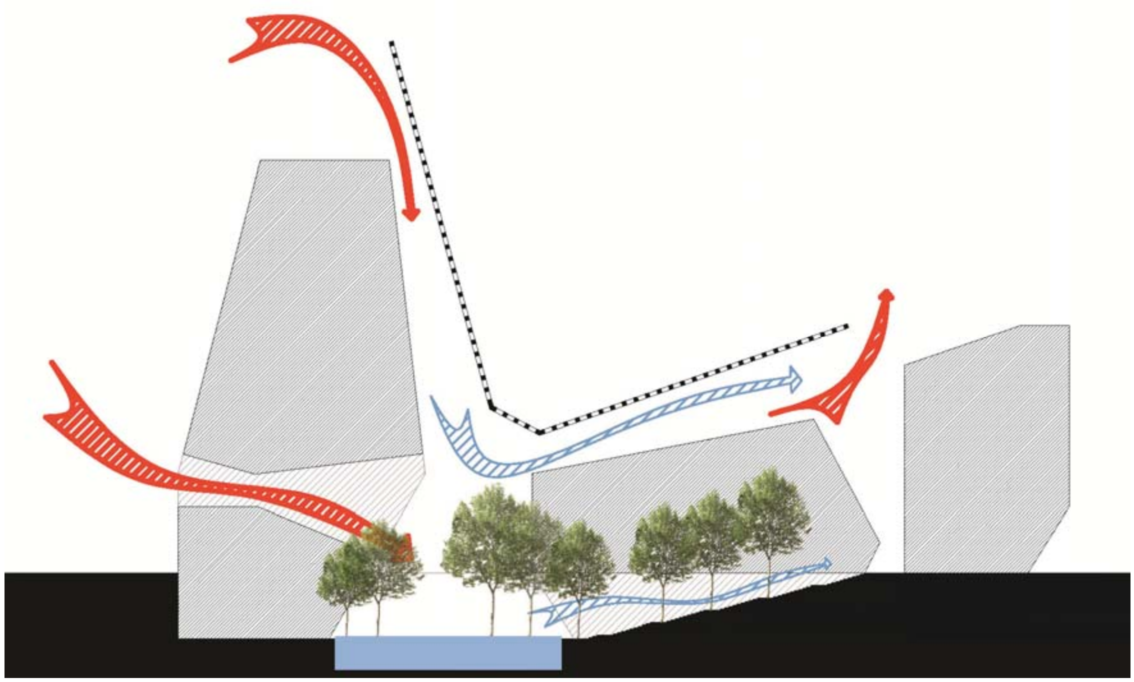


Figure 31: Section of the proposed design. Source: Author

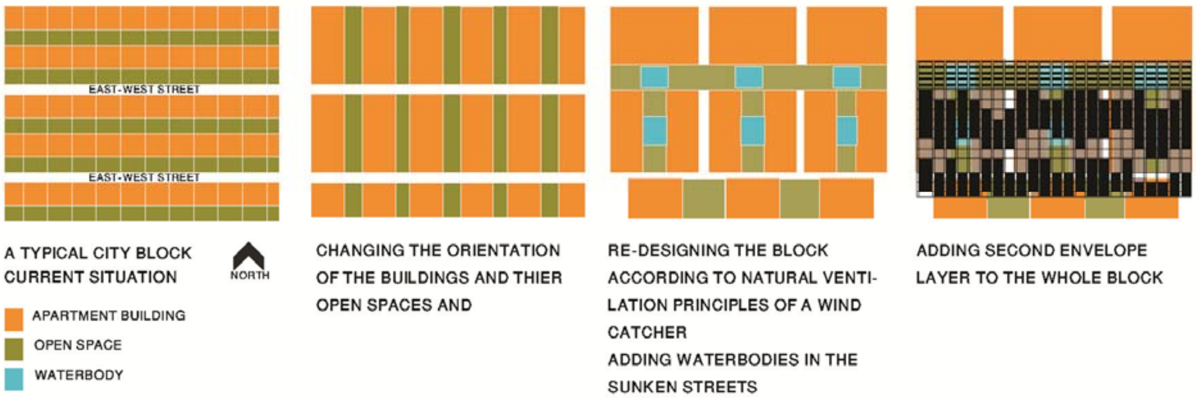


Figure 32: Plan of the proposed design. Source: Author

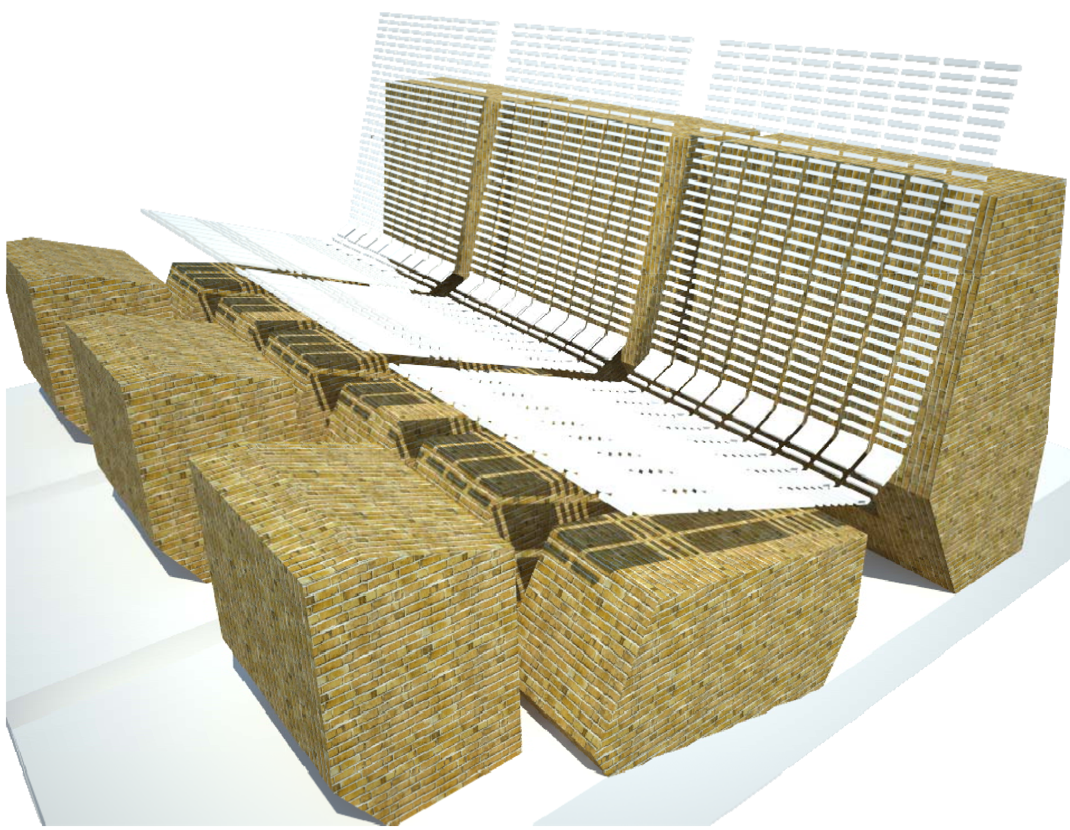


Figure 33: Volumetric explanation of implementing principles of a wind catcher into a contemporary urban block. Source: Author

3.2.2 Conceptual Design 2: Developing of a Typical City Block Using Aerodynamics of a Dome

Wind speed over a central dome- shaped roof is accelerated due to the low pressure of air at its peak. Therefore, the air beneath the dome would escape outside and be continuously replenished by inside air. Therefore, a complete circulation would be in effect (figure 34).

In order to create the same system of air movement, buildings of an urban-block were formed dome-shape. Internal open space between the buildings also takes a dome shape, with a public courtyard and a pool at the centre. Natural ventilation could occur as air drawn inside the city block by multiple wind-catchers located on high levels of buildings located on the north and north-east sides of the city block (figure 35).

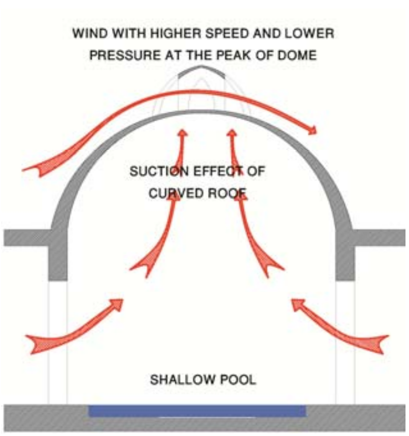


Figure 34: Dome Aerodynamics. Source: redrawn from: Tolou Behbood et al., 2010.

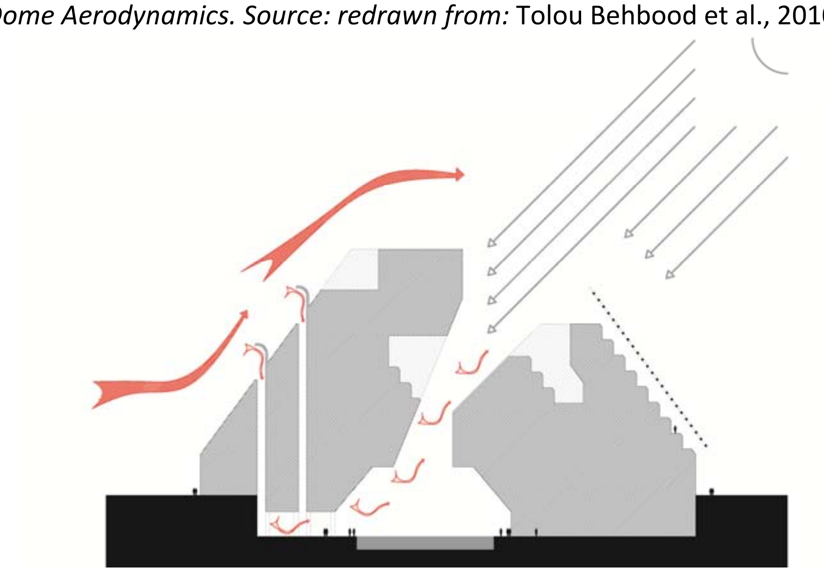


Figure 35: Site Section, Applicability of a dome shape structure into a modern apartment building typology. Source: Author

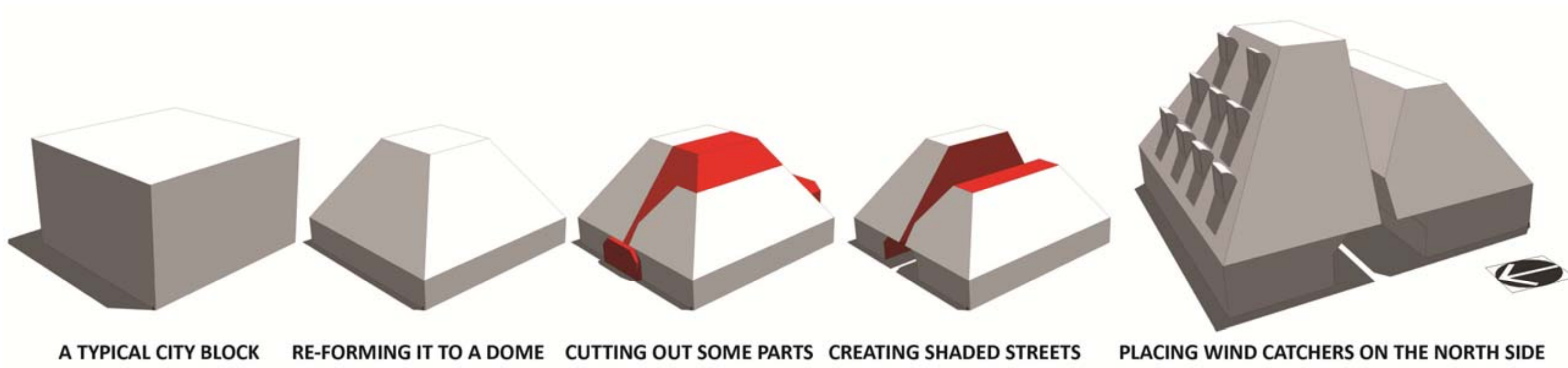
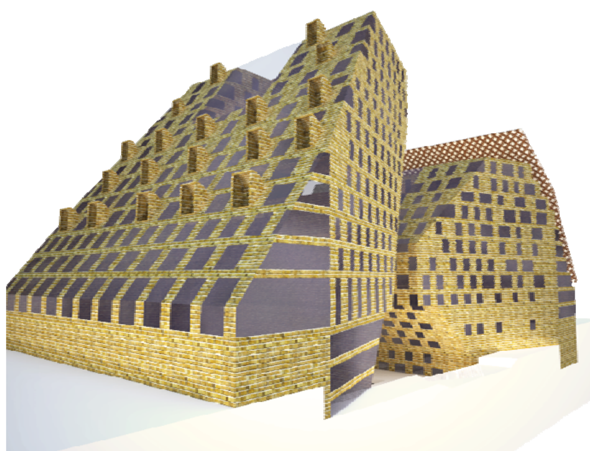


Figure 36: Transition of a block from its typical cubic form to a dome-shape, Source: Author



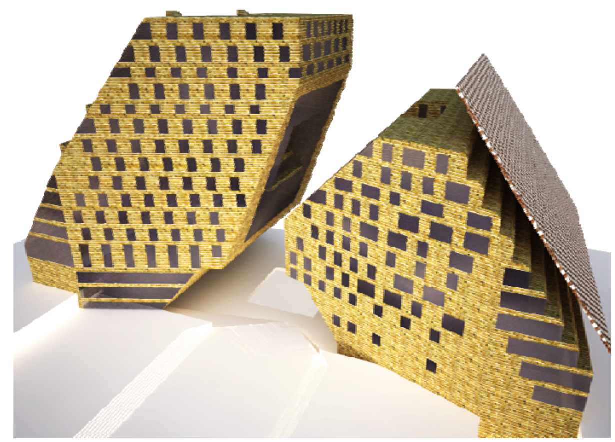


Figure 37: Volumetric explanations of applying the strategies of a dome to a city block. Source: Author

3.2.3 Conceptual Design 3: Developing of a Typical City Block using Principles of a Shaded Canopy and Irregular Streets

The third design concept deals with traditional irregular street networks and shade canopies. In this design, traditional urban circulation combines with contemporary street arrangements to create a developed street network with principles of both (figure 40). The narrow irregular street network can be applied to the compact housing to provide more climatic comfort for the neighbourhood.

An external shading is also applied to cover the roofs in a block and to shade internal streets (figure 41). The external layer works like a traditional shaded canopy shown in figure 38, which could trap air and make it work as an insulation for the roofs.

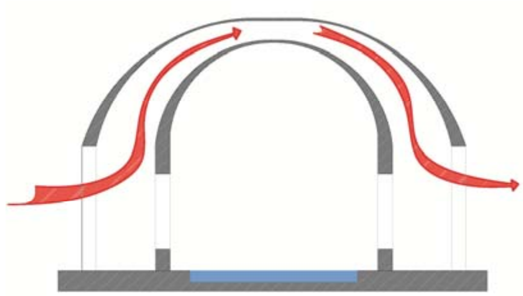


Figure 38: Shaded Canopy
Source: Redrawn from Tolou Behbood et al., 2010.

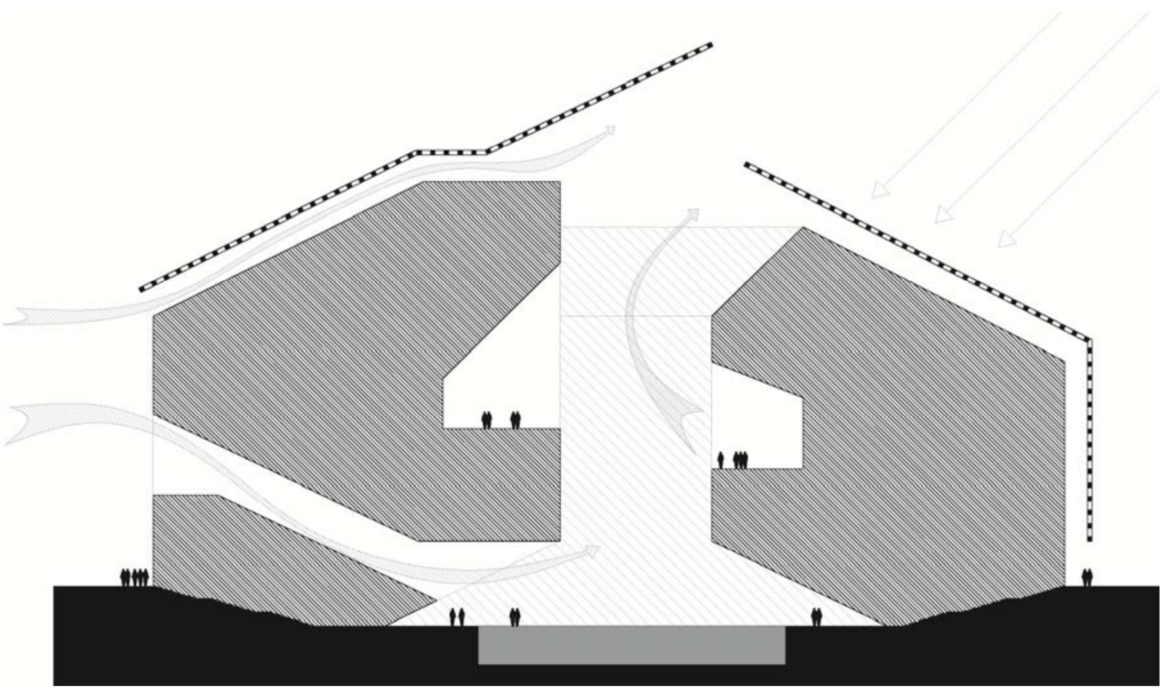


Figure 39: Principles of Shaded canopy applied to a city block-Section. Source: Author

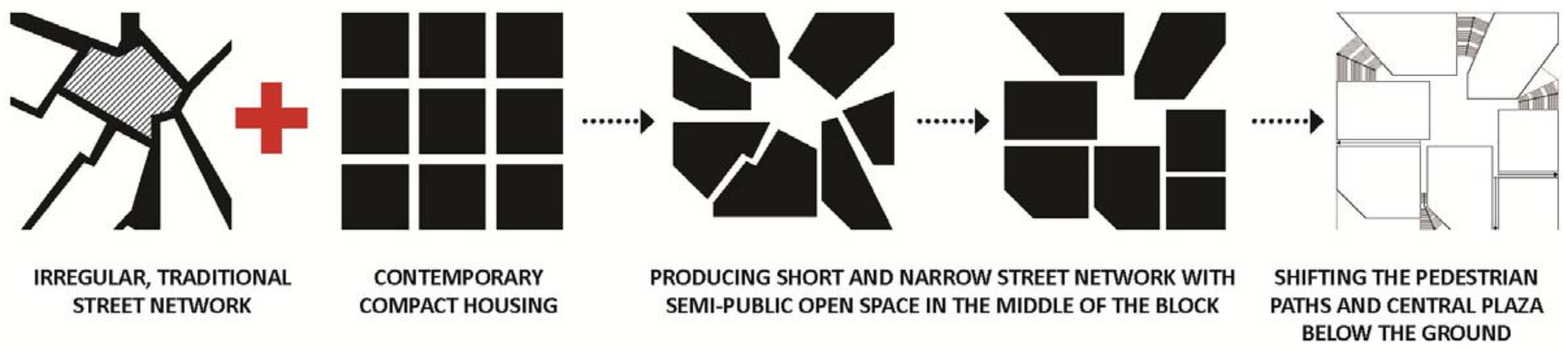


Figure 40: Combination of traditional and modern street networks. Source: Author

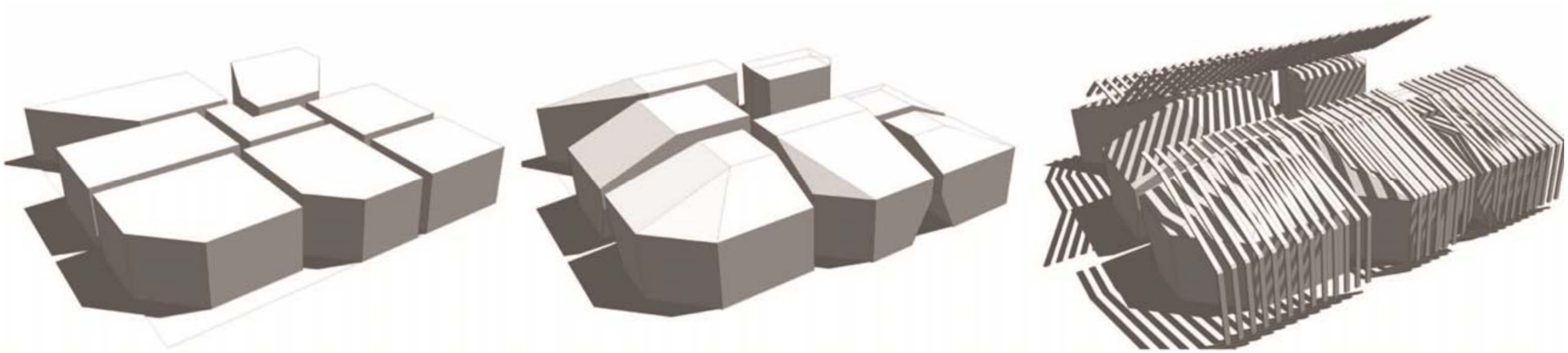


Figure 41: Transition of buildings from a flat roof shape to a dome shape.
Source: Author

The study of physical specialities and aerodynamics of traditional architectural elements of houses in desert region of Iran not only gave us the opportunity to being more familiar with the importance of energy efficiency in the past but also provided us with technical knowledge in order to create modern, low-energy architecture in this region.

The presented concepts and schematic designs were an attempt in coupling successful vernacular cooling techniques with recent building developments as alternative designs to reduce the energy consumption of in-efficient buildings.

In order to evaluate these architectural concepts from practical point of view, wind simulation programs such as CFD is needed to study the actual behaviour of wind in the proposed structures. Due to a lack of expertise and extremely high complexity of computational fluid dynamics (CFD) software, the wind simulation remains outside the scope of this thesis.

3.3 Analysis Technique and Simulation Studies

The second part of the methodology focuses on simulation tools used for advanced analysis. Solar simulation tools can be applied during the massing design phase in order to edit the orientation, volume and geometry.

"One of the greatest challenges for architects is to design buildings not only to receive more from the kind face of the sun; but also to protect themselves from the sun's unkindness. If a building could walk and change its form or skin, the solar problems of architectural design might be solved a little bit easier on the paper; but most of the buildings are standing and static creatures, so the design should be very intelligent to work on both cold and hot times through the year. As the properties of each location like temperature pattern and surroundings geometry affect the design solution, a proper approach for solar analysis of buildings is needed to answer important questions in architecture like the effect of the from and orientation of buildings, the proper amount of openness in each direction and the effect of shading or reflecting surroundings" (Samimi, Parvizsedghy & Adib ,2008).

Figure 42: Kind and Unkind Faces of the sun in passive strategy-1948 Le Corbusier Sketch
Source: http://iaakuza.blogspot.com/2009_01_01_archive.html

Proper approach of solar analysis for urban outdoors and buildings is to consider the kind and unkind faces of the sun in each location in order to choose the proper form, orientation, and amount of openness for building surfaces in each direction. Proper shape of shading devices and building masses can also be derived from this approach (Samimi, 2007). In order to define the kind and unkind parameters of the sun at every time of day-- that is, the total amount of radiation given off and the corresponding need for shade-- a model is required. Each face of the building has its own orientation, slope and surroundings; data that accurately reflects all these parameters as well as the amount of positive and negative sun radiation for each moment is necessary.

For progressive design and to analyze the situation of every point of open spaces and building faces in according to shading or reflecting effects on each other in the whole cycle of the year, a simulation program is projected as a tactical tool with required input parameters. For the purpose of this study SOLARCHVISION is proposed which is a developed programme with colourful output that can be presented in one or more parallel/perspective views and its results are easy to assess.

The SOLARCHVISION simulation program produces diagrams which show the level of comfort of the surfaces in relation to the sun radiations. Properties of building location are defined by entering such location data as latitude, elevation, turbidity, and monthly average and minimum and maximum temperatures. A third model of the site can be imported through any suitable CAD software.

Wind factors cannot be entered in SOLARCHVISION, while CFD (Computational Fluid Dynamics) analysis is beyond the scope of this thesis work as it requires skills with advanced software packages Gambit and Fluent.

3.3.1 SOLARCHVISION Simulation Case study: Najaf, Iraq

The Solar analysis of Imam Ali Holy Shrine Extension Project and the Old Town of Najaf in Iraq is conducted by SOLARCHVISION simulation program and is illustrated in following images.

In order to analyse both desirable and undesirable solar radiation available during the day and through the year, in the SOLARCHVISION model, dark blue represents the maximum comfort level for the open spaces, while dark red stands for the worst condition of comfort based on passive principles.

However, according to active strategies, the optimized areas are those in dark red which collect maximum solar radiation through the year and are resulted from high values of summer radiation. These moments could be considered as the best locations for solar panels.

As shown in the analysis model of the cropped part of the fabric, almost all the court yards and paths represented from light blue to dark blue are in their desirable situation. Wider paths represented in yellow and red show the undesirability of their situation through year.

According to solar analysis for the summer months it is found that the negative effect of the sun maximized between horizontal plane (roof) and west direction. In these warm months the east direction, in comparison to west direction, receives a slightly lower negative solar effect.

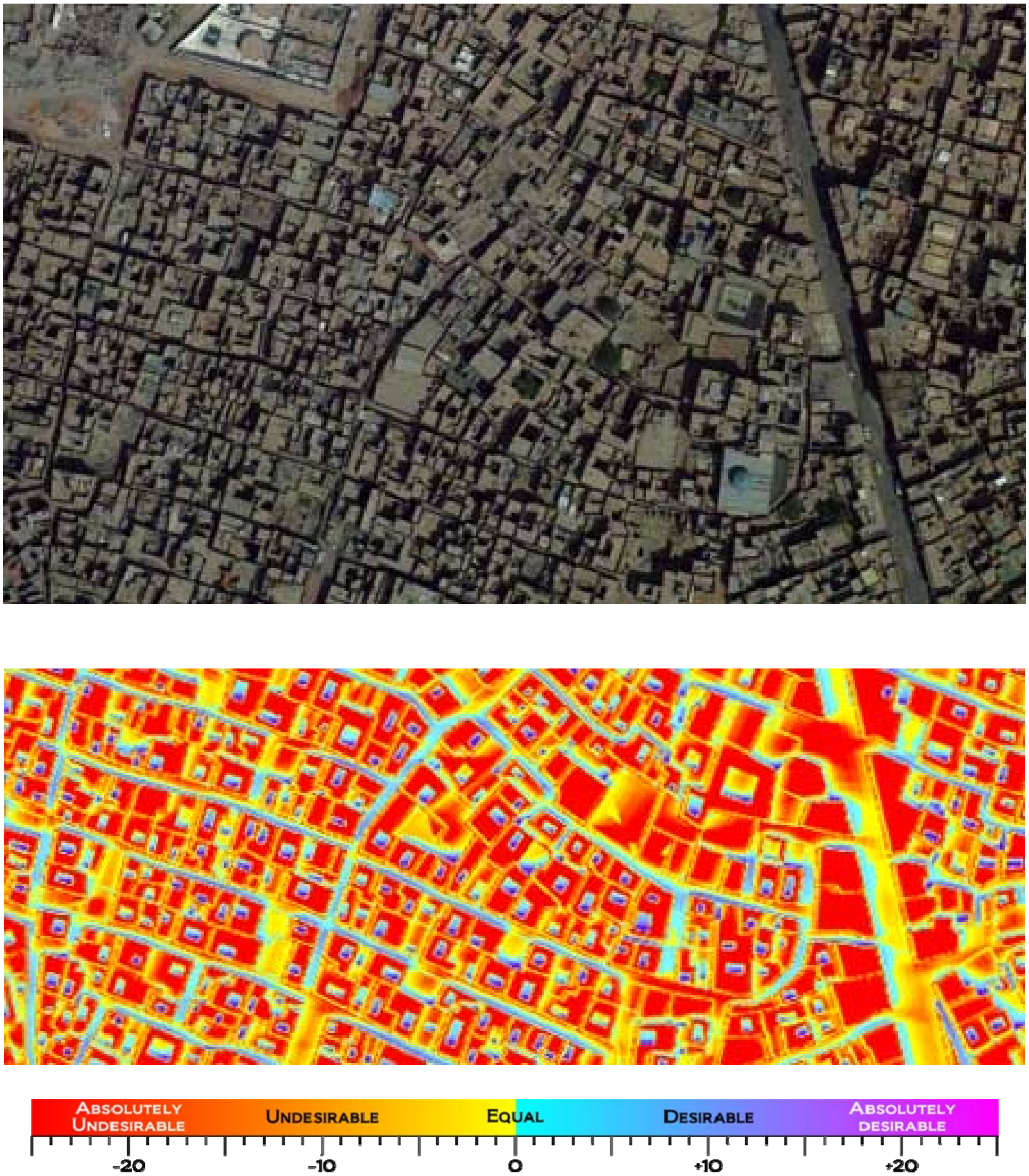


Figure 43: Top: Najaf Traditional urban fabric, Iraq. Middle: Year-Cycle SOLARCHVISION Analysis of cropped part of the fabric. Bottom: Color template. Source: Samimi, (2007)

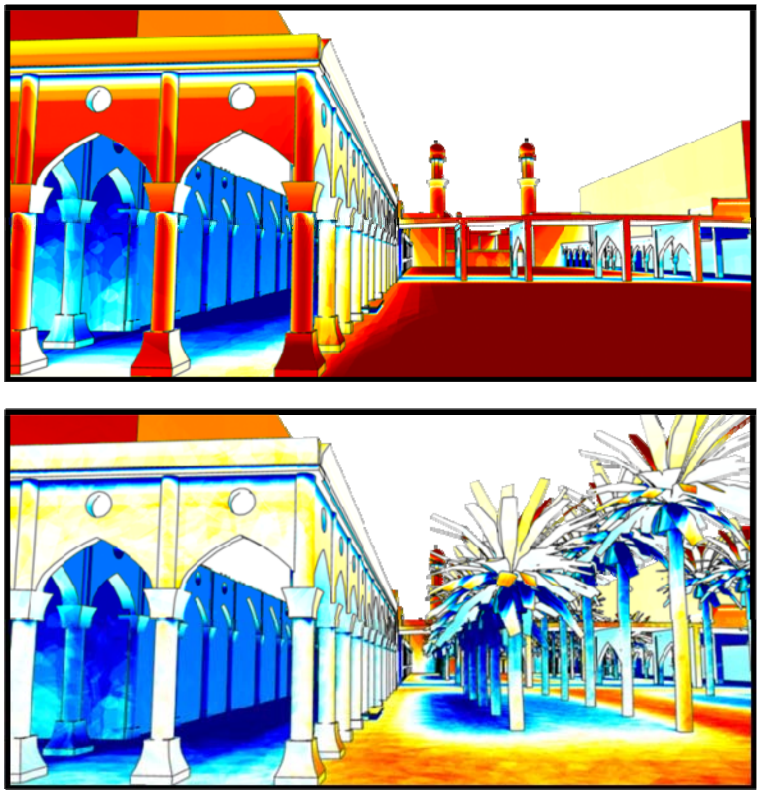


Figure 44: Year-Cycle SOLARCHVISION Analysis of Imam Ali Holy Shrine Extension Project before and after Revisions of landscape in the courtyard. Source: Samimi, (2007)

While in figure 44 the courtyard is in dark red and represents its undesirable situation, this condition could be alleviated through planting tall trees that create shadow on floor and façade surfaces. Another benefit of considering tall elements inside the courtyard is to minimize the effect of courtyard's width to its surrounding mass height.

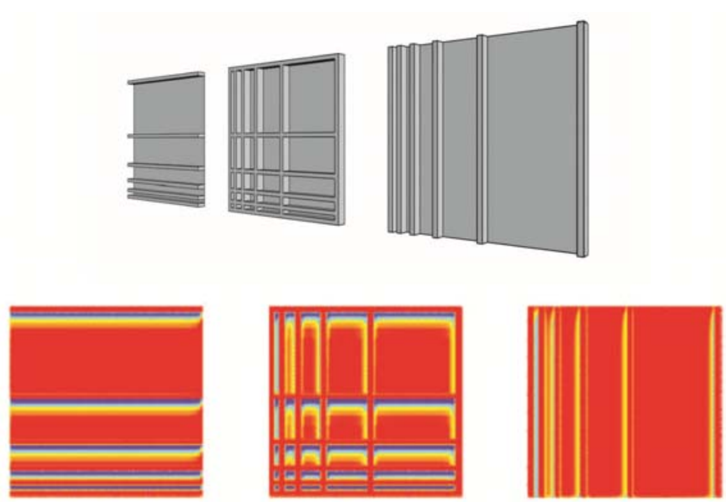


*Figure 45: SOLARCHVISION front view analysis for west facade in Najaf which shows the suitable type (horizontal) and proportion (depth = 2 * height) of louvers. Source: Samimi, (2007)*

3.3.2 Analysis Technique

The geometry of the sun’s path in each global location plays a critical role in solar analysis, and other factors such as local weather also have effects. Local faces of the sun at any given moment depend on two parameters: first, the intensity of direct and diffused solar radiation, and second, the amount needed to shade or shine to accord with a comfortable temperature.

Therefore, the position of the sun in the sky becomes crucial for each location. It should be mentioned that the parameter needed to “shade or shine” refers to the thermal face of the sun and not to its illuminative face. During the two cycles of the year the changes in temperature are not consistent, and therefore two separate diagrams are needed for the yearly local model of the sun for each location on earth.

In figure 46, the diagrams show the positive and negative faces of the sun in summer and winter for the city of Kerman which positioned on 30: 17´ 38´´ N / 57: 5´ 3´´ E.

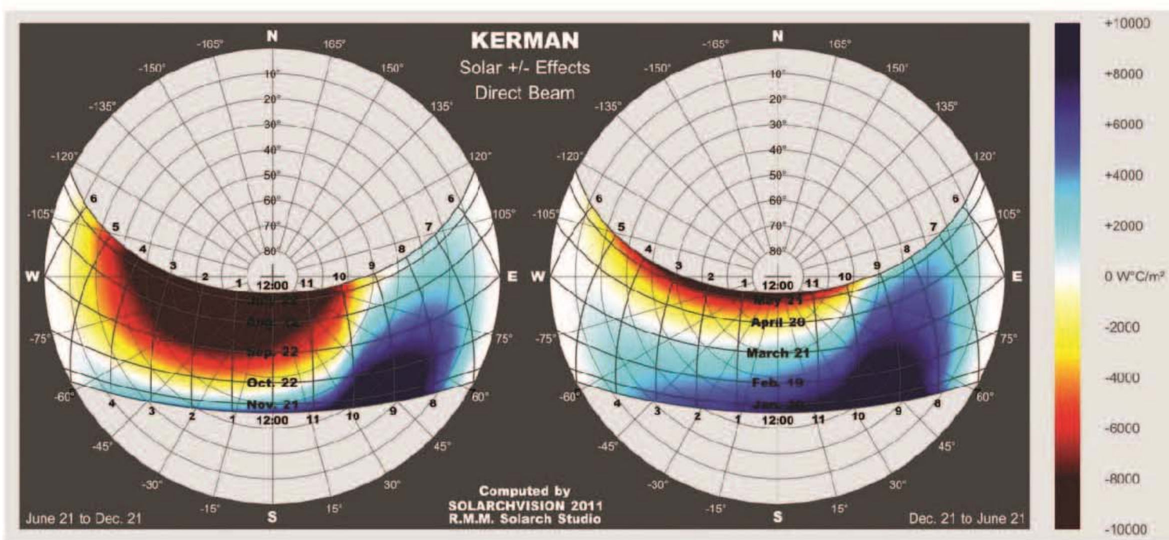


Figure 46: Left: From June 22nd to December 22nd. Right: from December 22nd to June 22nd. Kind (positive) and unkind (negative) faces of the sun for the city of Kerman (SOLARCHVISION, 2010).

The Solar +/- effects diagram shows the most valuable positions of the sun in cold periods as blue and dark blue points. These areas are the times of the day with low temperatures and high solar radiation. Although in the mornings the temperatures are at their lowest, due to low solar radiation the positive effect of the sun is not high. Furthermore, the most advantageous direct solar radiation is estimated to occur from 8 AM to 3 PM in January in Kerman.

The Solar +/- Effects diagram also identifies with red and dark red spots the times when the sun's position is such that its rays will be most harmful. These areas show times when both temperatures and solar radiation are high; this happens around noon and before sunset.

The effect of all possible directions and slopes of external building faces could be shown in a full spherical diagram by representing the comparable passive scores (figure 47).

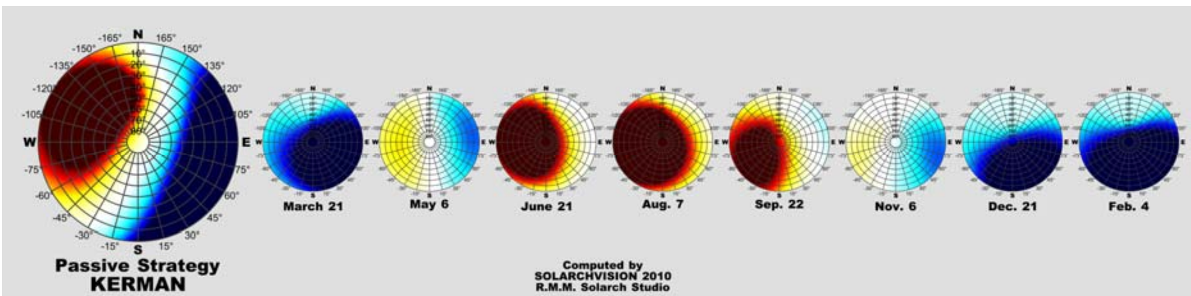


Figure 47: Full-spherical passive diagram of Kerman (SOLARCHVISION, 2010).

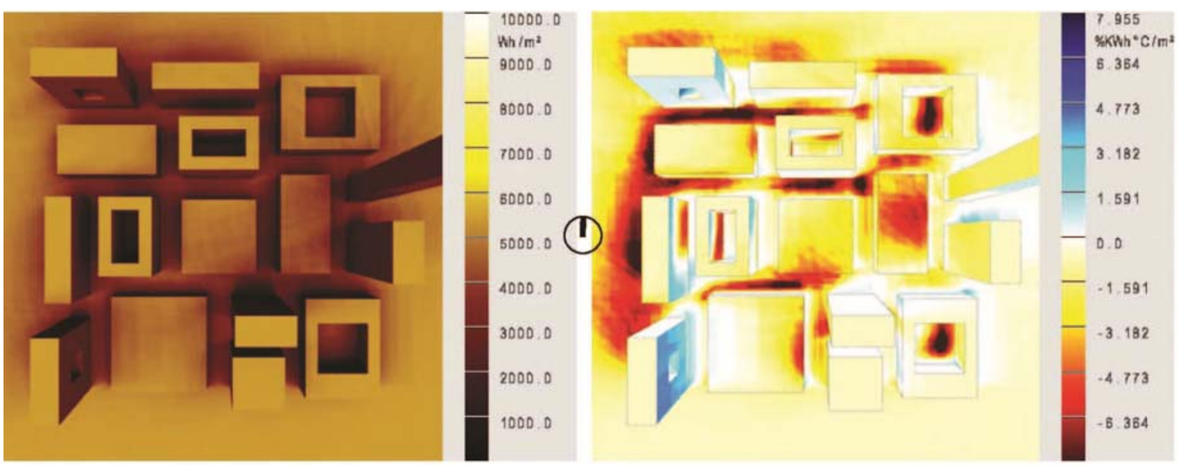


Figure 48: Year Cycle Analysis of sample building masses and paths in Kerman using SOLARCHVISION. Left: Radiation Model, Right: Analysis Model (Percentage Layer)

Based on the explained analysis technique, a year cycle solar analysis is conducted for a sample of building masses in the city of Kerman. In the analysis model (figure 48, right) two different areas are discovered; areas displayed from yellow to red which represent the uncomfortable/undesirable parts and areas displayed from cyan to blue which represent the comfortable/desirable parts.

As it is shown, the blue points are the best position for locating the openings on the facades, whereas improvements to the facades with red points should be applied to protect them in summer or/and to improve reception in winter such as shading by plants or using more reflective surfaces in the right positions.

The most optimized proportion for the shadings in different sides of a building are shown in diagrams below. According to SOLARCHVISION analysis, the best proportion to be implied to the shadings in order to block the undesirable sun radiations is highlighted in each image with a black rectangular. The darker blue represents the higher level of comfort for each window.

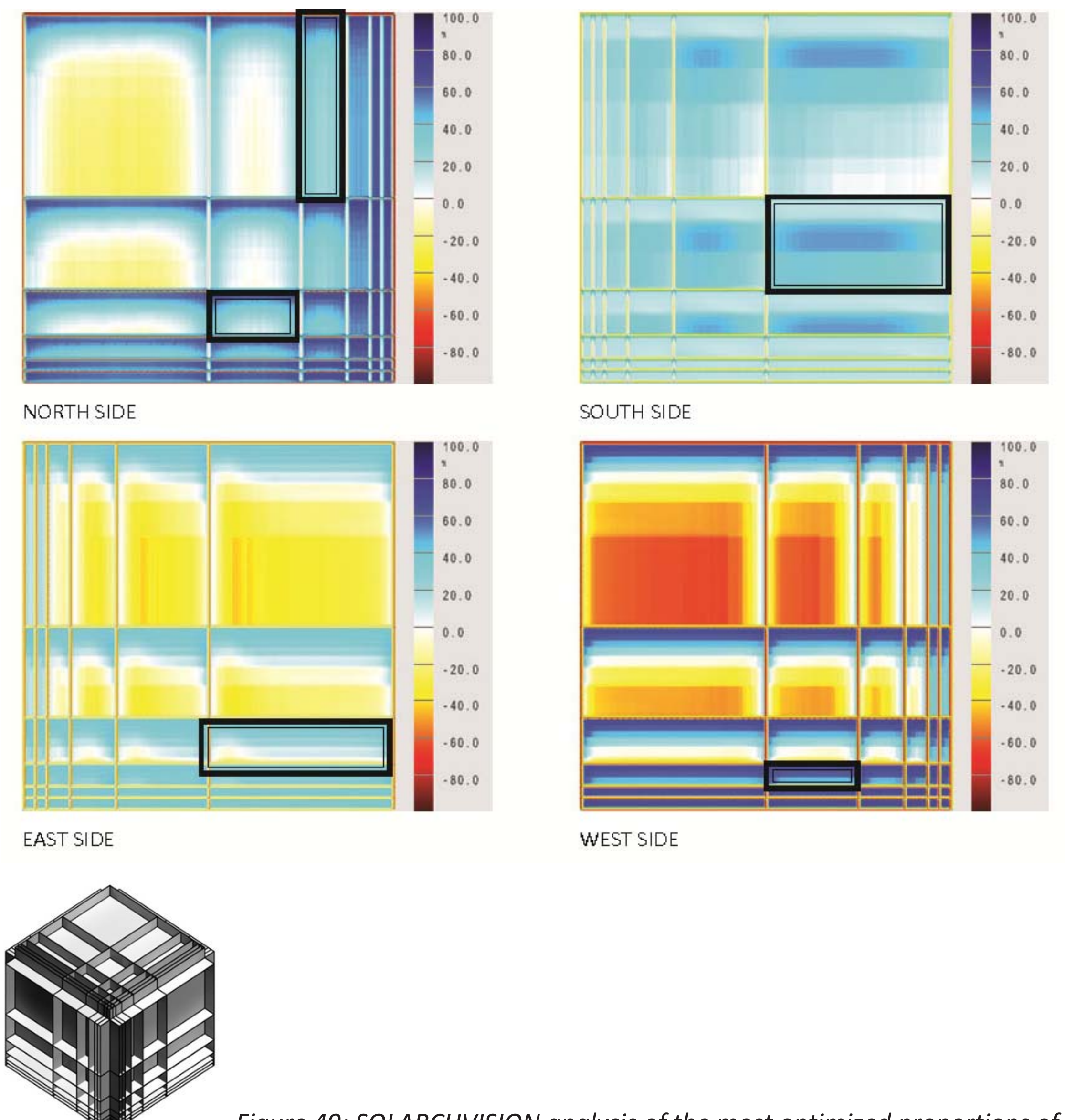


Figure 49: SOLARCHVISION analysis of the most optimized proportions of shading. Source: Samimi, 2007.

Chapter Four: Proposed Design Project

The next stage will address further design of a typical city block for which climate-sensitive strategies could be proposed. Progressive design process is also presented. Simulation by the SOLARCHVISION program would allow for evaluating the achievement of the proposed city block design from the comfort level point of view. Differences between the proposed city block to the traditional and contemporary built urban fabrics will be investigated based on solar analysis. At the end, based on the findings resulted from the solar analysis, a developed design recommendation for residential city blocks in such area is introduced.

In this thesis the focus is strongly on public spaces and the social aspects of architecture. Knowing what makes a city makes what happens between the buildings more important. Urban public spaces are important because they have an impact on human behaviour and on the quality of urban life.

4.1 Site Analysis

Kerman, a province and its capital is located in south-central Iran (Norwich, 1988). Northern part of the city is located in an arid desert area, while the highland of the southern part of the city enjoys a more moderate climate conditions. Formed before the onset of urban planning, Kerman is one of the oldest cities of Iran that was developed and re-designed in the 20th and 21st centuries. New master plan of the city has had a deleterious impact on the network of the paths through the city and had caused the spatial coherence of the ancient fabric to fracture.

<u>Site Factors</u>

Site location	Kerman, Iran	
Geographical position:	30° 17´ 38´´ N	Latitude
	57° 5´ 3´´ E	Longitude

Figure 50: *Map of Kerman, Iran*

Source: redrawn from http://jonobeiran.blogfa.com/

According to the wind diagram of Kerman (shown in appendix), there are various wind directions in Kerman through the whole year (reference):

- North and north-east wind: a hot wind that flows in summer.
- West wind: a stormy wind that contains sand and rain and blows in fall and winter.
- South-West wind: a hot wind flows in spring and contains sand and dust.

4.2 Design Criteria

4.2.1 Commons

The idea of “commons” was introduced by William Forster Llod in 1833; it involves understanding human population dynamics in parts of the environment that lay beyond a person’s own possession (Illich, 1982). Such spaces include the sidewalks and semi-public areas of streets where one can relate to the other human beings. The importance of commons from the climate-sensitive point of view is that it is only at the urban scale (between buildings and neighbourhoods) that energy-saving strategies can effectively tackle problems.

The design fulfillment of the commons in a climatically sensitive manner is what the following research design seeks to achieve. The emphasis would be on shading the commons not only for its energy-conscious advantages but also to change the perception of people at the street level so that they perceive the streets as more than just corridors for passing.

Urban design goals would be first in importance, then radiation reduction during the day and ventilation cooling at night. The nature of the climate problems is such that neither of these goals can be considered in isolation.

Direction of the Commons

Diagrams below, conducted by SOLARCHVISION 2010, show that north-south commons/streets with a slight inclination (figure 51, 1) have the maximum sun protection all day long while wider east-west oriented streets receive the most negative sun radiation (figure 51, 5).

The color template next to each diagram shows each location’s comfort rating. The darker red points represent the least shadow and the least comfort (Samimi, 2007).

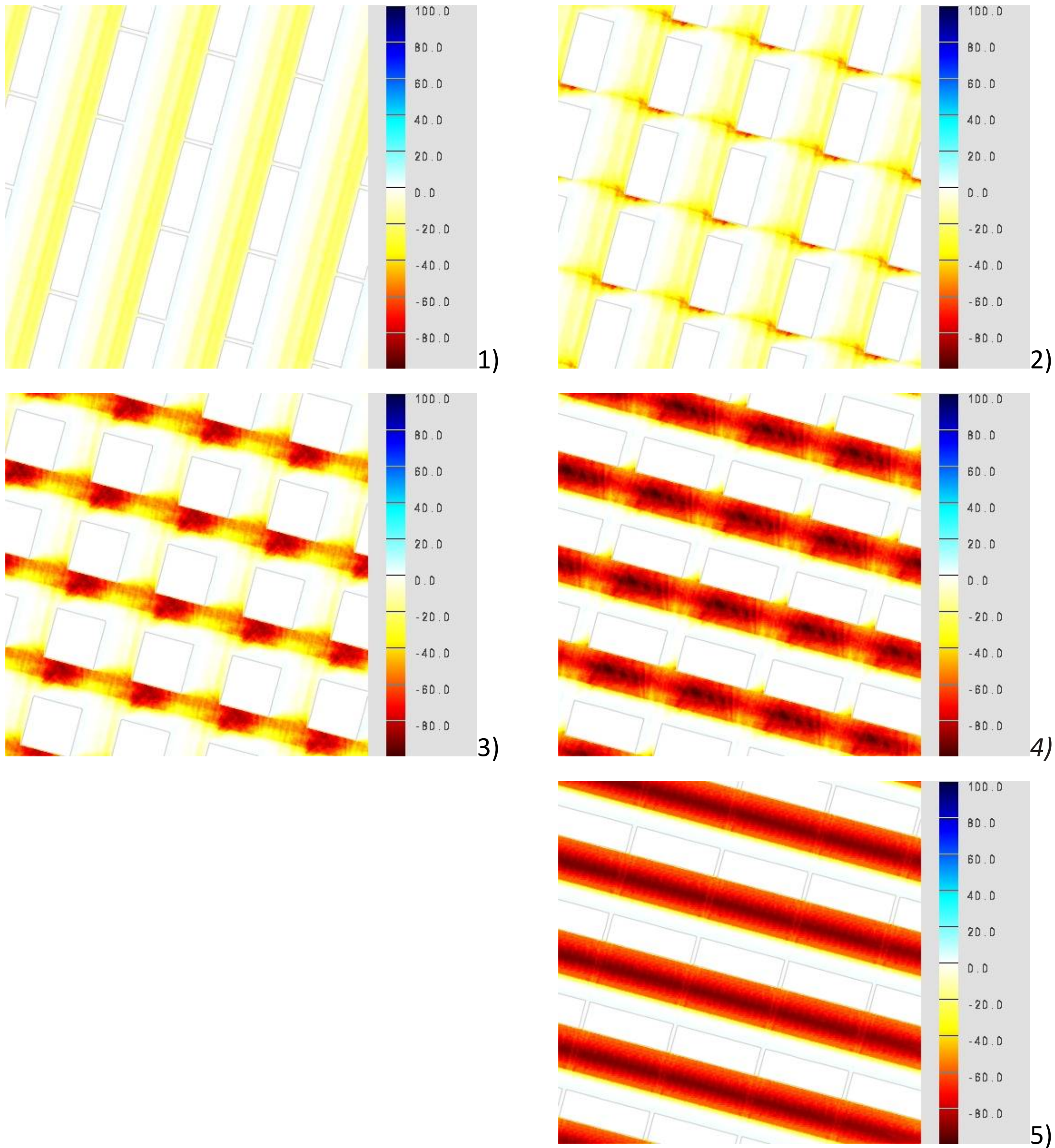


Figure 51: Direction of Commons, SOLARCHVISION Model.

4.2.2 Shadow Umbrella

The hypothetical concept of “shadow umbrella” was introduced and developed by M. Rohinton Emmanuel (1993). It refers to an urban massing that can shade itself and its immediate surroundings and can also be effective for urban sun prevention. It addresses two design issues: first, the creation of shaded urban public spaces that have direct bearing on outdoor thermal comfort and second, the use of water in achieving/enhancing ventilation and cooling and in its location (in the form of lakes, pools and fountains) relative to the built form.

The primary step in creating such a "shadow umbrella" is to determine the shadow angles. Since the idea is to shade a specific surface all day long, the lowest angles must be established first. These angles vary by location (latitudes), time of day and orientation (Emmanuel, 1993). In the northern hemisphere the northern-most solar exposure happens during summer solstice (some time between June 21 or thereabouts) and the southern- most exposure occurs on the winter solstice (December 21 or thereabouts).

In order to provide shading, a time frame limit must be established based on the general weather pattern of hot-arid regions. The general air temperature pattern shows that the maximum air temperature occurs between 10 AM and 6 PM in summer and 11 AM to 5 PM in winters. After sunset, temperature declines suddenly; therefore, cold mornings and hot afternoons can be considered as the general weather pattern in this area. Accordingly, areas where much activity occurs in the morning need no shading while areas occupied in the afternoons and until after sunset should be kept cool.

The four positions of the sun (11.00 on June 21, 18.00 on June 21, 11.00 on December 21, and 18.00 on December 21) is shown in the figure 52. The sloping plane through these sun locations represents the four critical corners.

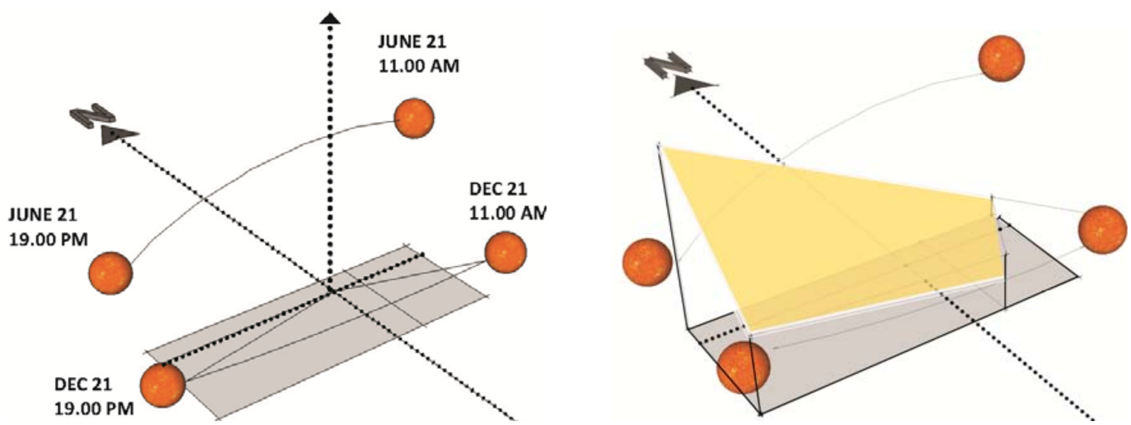


Figure 52: Left: Shadow cut-off times for regions in the northern hemisphere
Right: An ideal shadeable urban block. Source: Author.

When the negative effects of sun radiation in the afternoon are more than the positive effects of east radiation, then according to the four critical positions of the sun the sky, the "shadow umbrella" should be a sloping plane which faces the critical east and south position of sun and block to the west radiations (figure 52, left). The result of such an approach would be a north-west to south-east sloping plane that is high on the north-west to west and shorter on the south and east sides of a block, so that necessary shade could be created for the commons.

Inner facades of the volumes created through this concept and the internal streets are shaded completely through the built mass, whereas the outer sides of the volumes are shaded by shading devices.

Referring back to the determined critical positions of the sun, it turns out the block will have a proportion of 1:2 (east/west: north/south). In such a block, if the volumes should be erected in order to shade the entire block then the four positions of the sun can determine the height of the buildings (Figure 53).

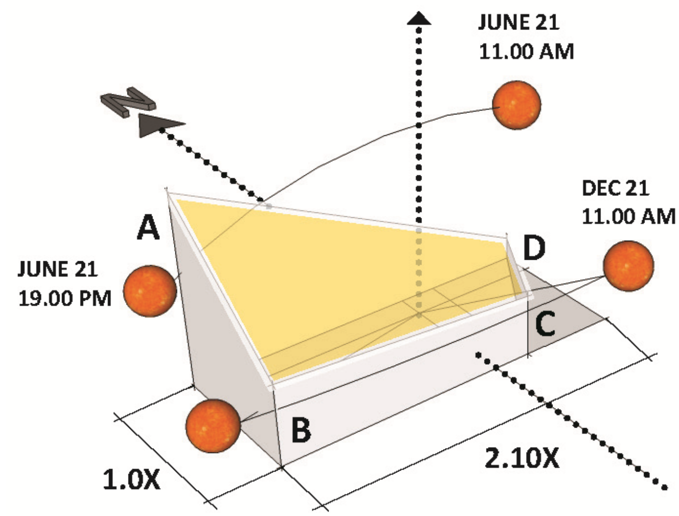


Figure 53: The sloping plane and massing heights. A: 0.80X, B: 0.40X, C: 0.25X, D: 0.15X.

Source: Redrawn from: Emmanuel, 1993.

The following design strategies are gleaned from the "shadow umbrella" developed for the hot arid regions:

- The urban density should be shaped in a way that slopes towards the north-west (i.e. smaller buildings locates in the north-east and taller ones towards north-west)
- North-eastern and south-western corners of the city block could be left open and determine the locations of natural elements such as pools that would enhance the thermal comfort of the block microclimate.
- The centre of the block can be left open.

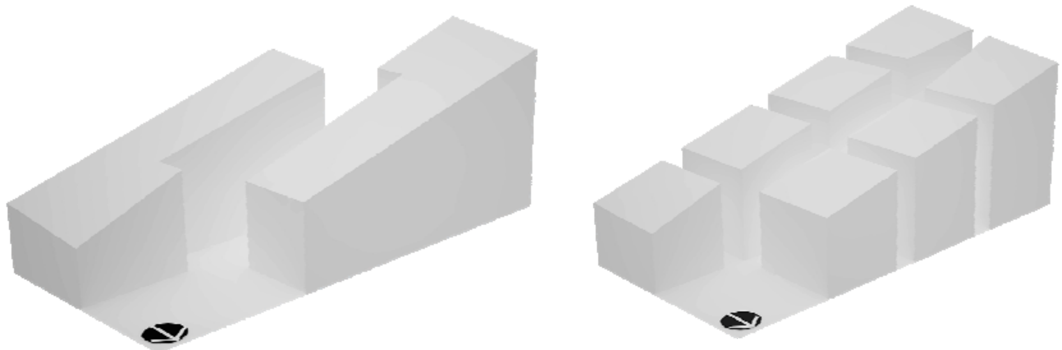


Figure 54: Proposed alternatives building arrangements,
Source: Redrawn from: Emmanuel, 1993.

According to the “shadow umbrella” concept and the determined heights and corners, a typical city block in the city of Kerman is redesigned as can be seen in figure 55.

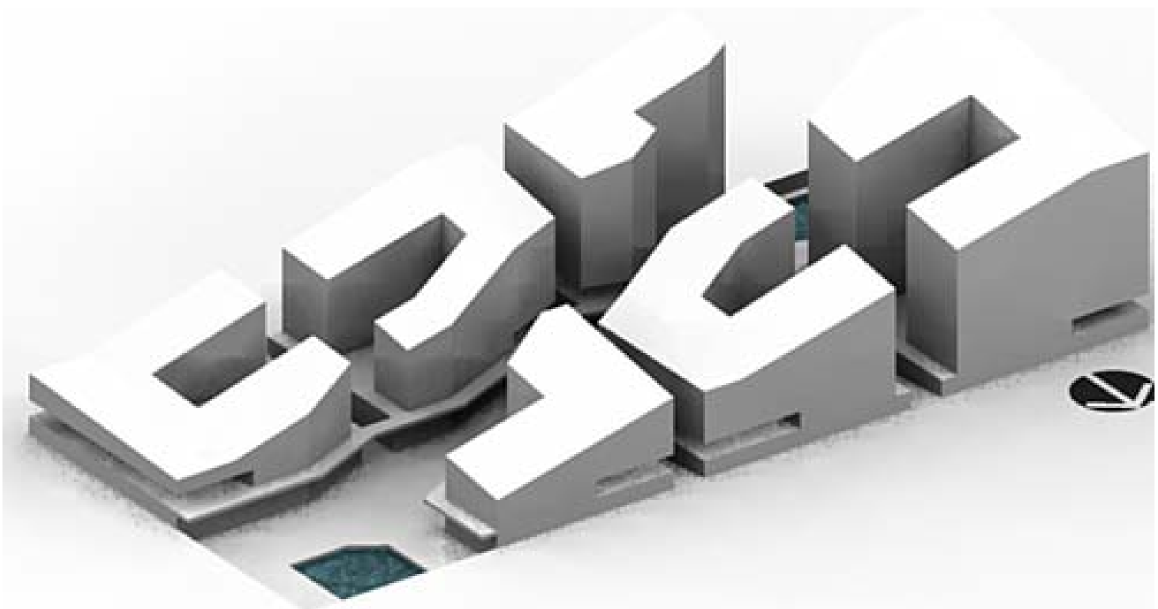


Figure 55: Volumetric explanation of the proposed shadow umbrella for a typical city block.
Source: Author

While in summer and spring with the most need of natural ventilation wind blows north-easterly to south-westerly then the main path of the block is oriented in accordance to wind direction in order to improve the air movement.

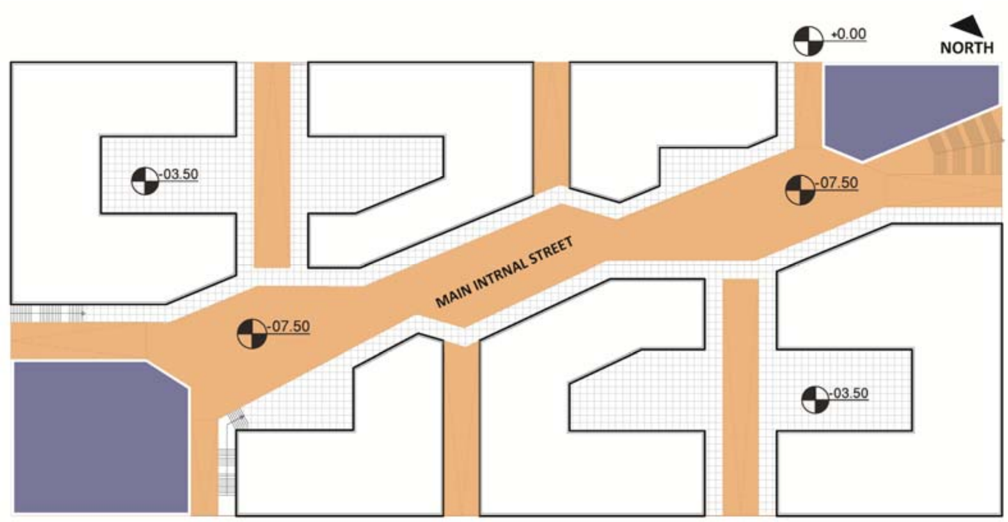


Figure 56: Floor plan of the proposed shadow umbrella - Showing the location of pools
Source: Author

4.2.3 Promotion of Urban Wind Movement

In warm regions moving around in the urban outdoors is enervating and at the same time "if you stood still you were invaded" (Ondaatje, 1979). Although shading could be the key, thermal comfort cannot be achieved through shading itself for those who move around in the urban outdoors and who don't stay long enough in one place to feel the stabilizing of the thermal equilibrium. Air movement can be the solution for places where people move around a lot.

Pedestrian Shopping Streets

Pedestrian shopping streets are inherently pleasant places as shoppers move from vendor to vendor. Bargain shopping on these pedestrian streets is something of a ritual, and creates a built form on the human scale that casts a shadow on the street itself, offers protection from motorized traffic and can encourage the movement.

The design for a roofed gathering space put forward in this thesis is a structure that functions similar to a wind catcher. The wind catcher with a pool inside a city block not only provides a shaded urban outdoor for shops and ease the movement, but also it would control natural ventilation in the neighbourhood through its specialized structure.

As explained the shadow massing and the projected open spaces on the blocks are all compatible with the general wind pattern in this region. Therefore, the location of the wind catchers can be projected as well (figure 57).

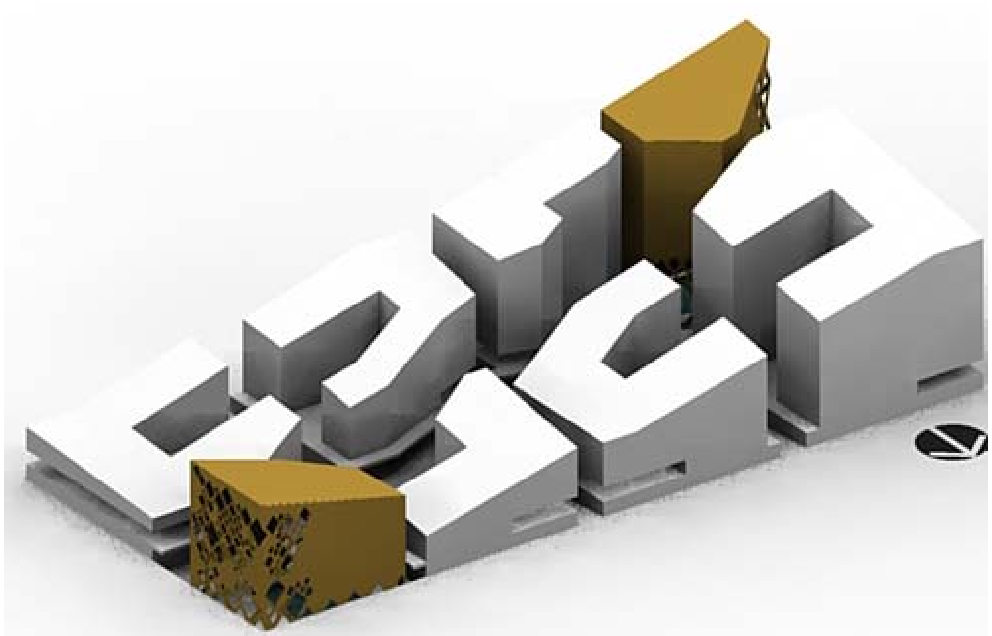


Figure 57: Volumetric explanation of the proposed shadow umbrella for a typical city block
Source: Author

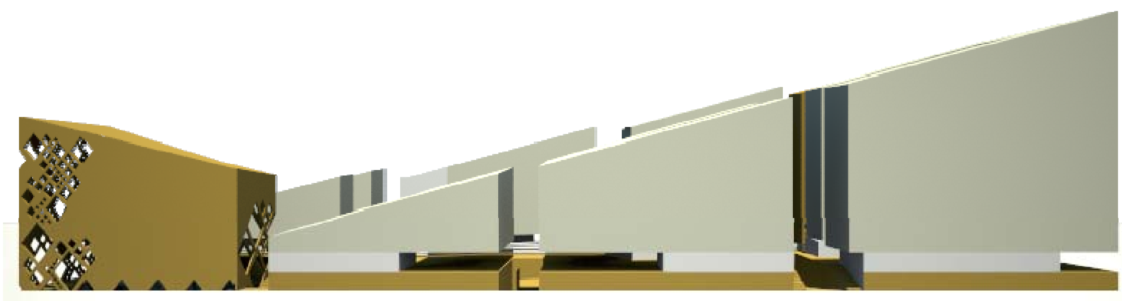


Figure 58: North elevation of the proposed shadow umbrella, Source: Author

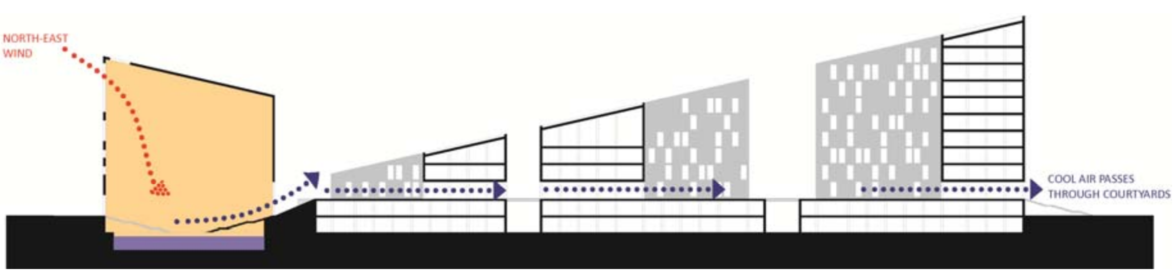


Figure 59: East-west section of the proposed shadow umbrella, Source: Author

In order to work like a wind catcher, this structure has a shaft that faces the prevailing wind to trap air. Intake air can be cooled by the effects of evaporative cooling of passing of the water provided inside. Elements suspended from the ceiling of this structure act as obstacles to trap dust and prevent its entry into the structure.

Moreover, a design of a pedestrian underground promenade on the block's main street is suggested. While it is oriented north-east to south-west to ease air movement, it is constructed two levels below the ground level for a better thermal comfort. While cool air blows from wind catchers to internal streets of the city block, pedestrian can enjoy their walk on shaded commons.

Figure 60 shows internal view to the wind-catcher structure and how it creates a shaded gathering urban space for the neighbourhood.

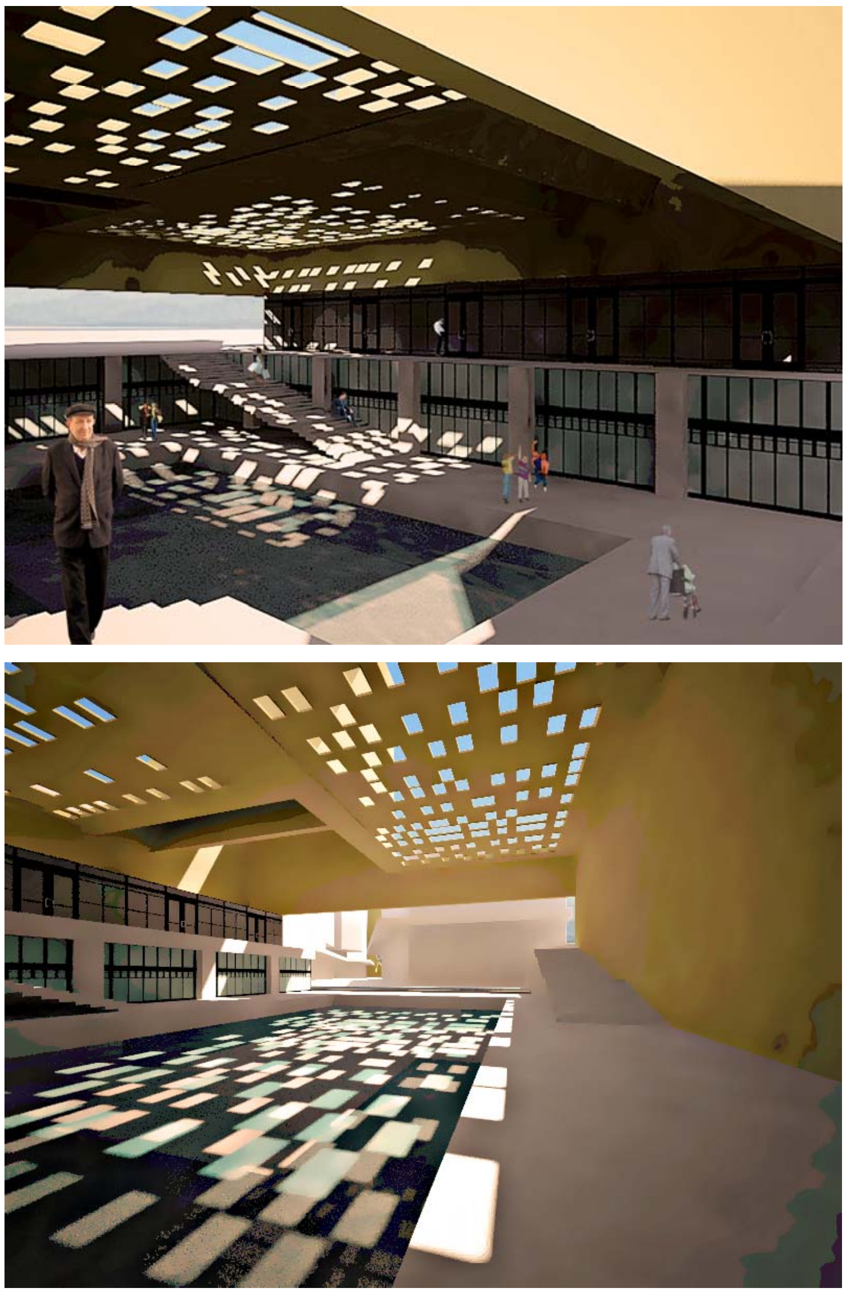


Figure 60: Internal views to the wind catcher structures, Source: Author

4.3 The Final Design Proposal

According to the mentioned design criteria and the demonstrated progressive design shown in figures 51-60, the developed proposal for redesigning a city block in the city of Kerman is explicitly illustrated in the following pages.

In the first step of redesigning a typical city block, the original shape of building masses transformed to create self-shaded volumes (figure 61).

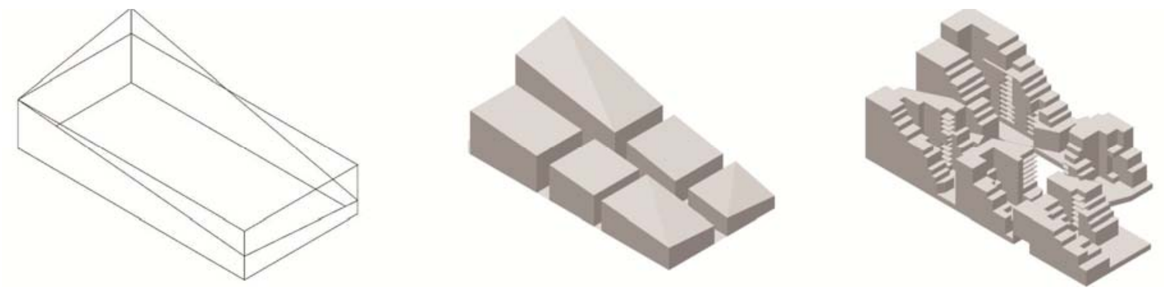


Figure 61: Transformation of the final volume (Macro scale, based on self-shaded mass concept. Source: Author

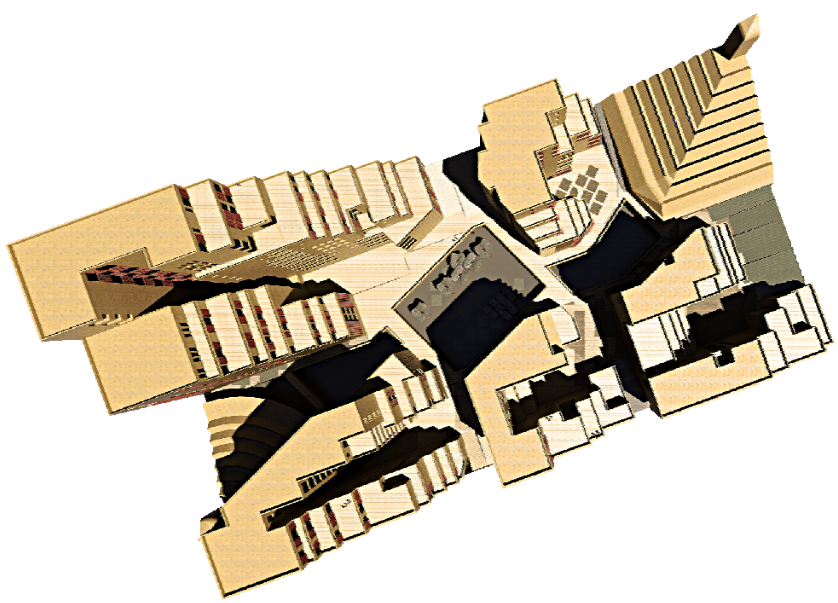


Figure 62: Top view of the proposed city block. Source: Author

While five building complexes are emerged as the result of form making process of the proposed city block, there other elements that are added to their combination to complete and satisfy the block's energy-efficiency (figure 63).

Two wind-catchers at two sides of the block on north-east and south-west corners are considered to capture spring and summer hot breezes. At levels below grade these wind-catchers provide public gathering spaces with retail stores and shallow pools for the neighbourhood. Furthermore, an open public plaza is also introduced at the centre of the block.

A continues pedestrian path is located at one level below grade to connect all the courtyards together and to prepare a semi-public path for the residents of each city block.

A shopping street at lowest level of block highlights the main internal street while create a mixed used neighbourhood with residential section on upper levels and public commercial section on the lower levels.

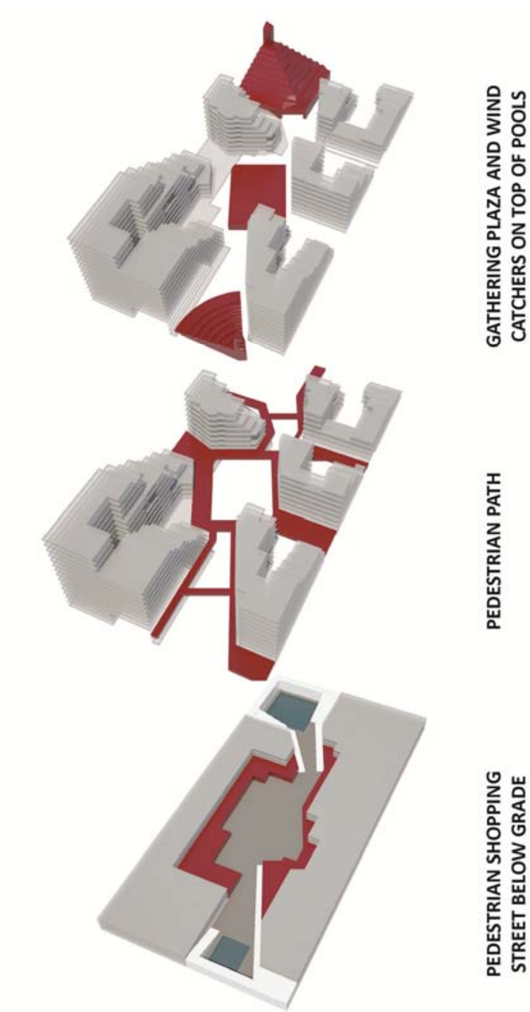


Figure 63: Exploded diagram of the city block. Source: Author

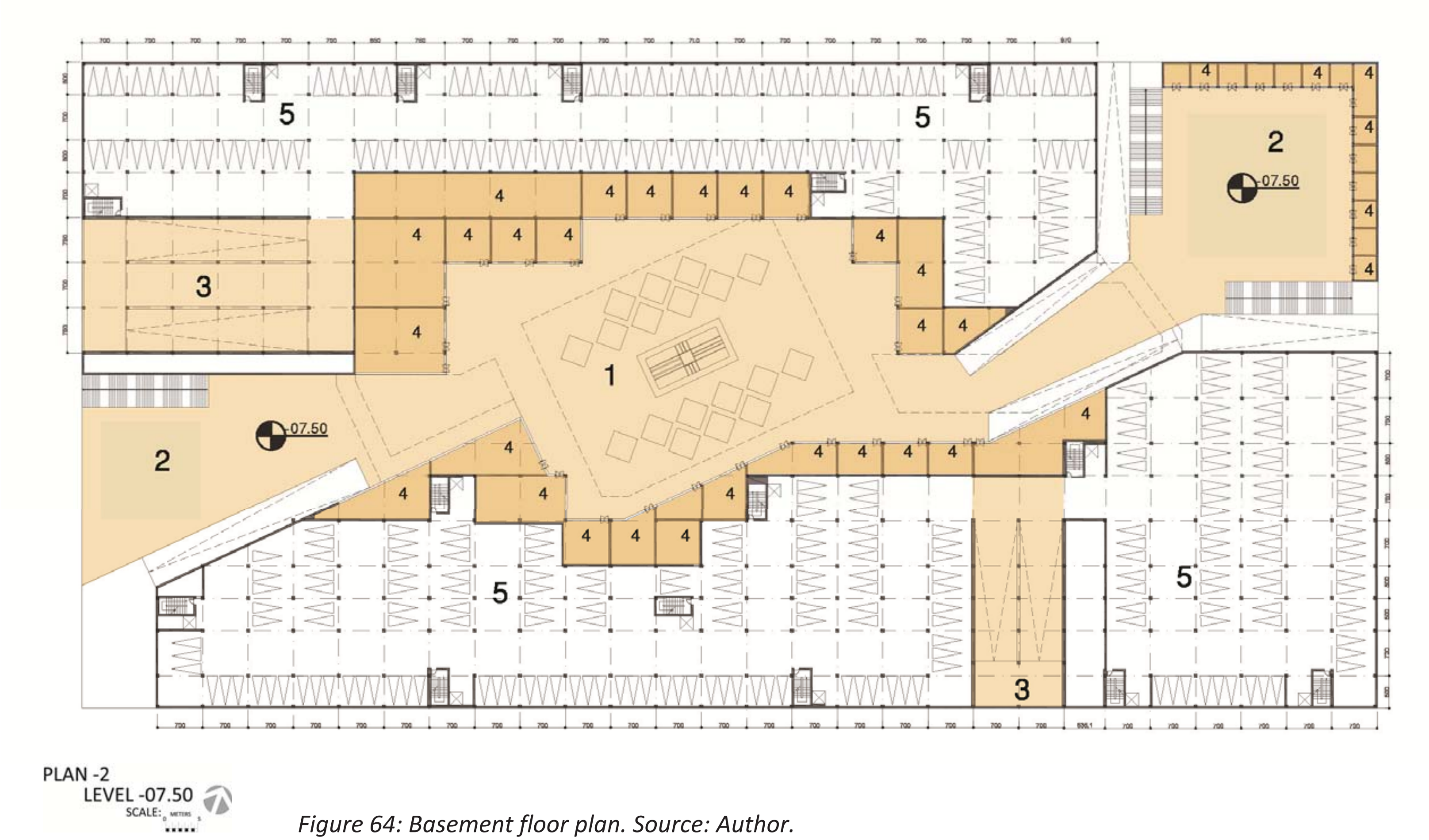


Figure 64: Basement floor plan. Source: Author.

1. *Central open plaza*
2. *Shallow pools*
3. *Parking ramp*
4. *Retail store*
5. *Parking*

Figure 65: Pedestrian path floor plan. Source: Author.

1. *Pedestrian path*
2. *Courtyard*
3. *Ramp, connecting street level to pedestrian path*
4. *Ramp, connecting pedestrian path to the lowest level of the city block*
5. *location of wind-catchers*

Figure 66: North-South site Section through the neighbourhood, showing the mixed-used characteristic of the proposed city block. Source: Author

To improve interior ventilation and thermal comfort in each floor, staircases are used as wind catchers for cross-ventilation or for their chimney effect. Furthermore, all apartments are organized to have two or even three side orientation which enhance cross ventilation. In order to reduce the effect of solar radiation for apartments with multiple sides and extensive solar exposure, proper shades are considered for windows in each orientation. Efficiency of shades in blocking sun radiations will be evaluated through a solar analysis simulation program shown in figures 83-91.

The interior spaces and their locations can also help in thermal and ventilation comfort. For this reason the main living and dining rooms and bedrooms should be located on the south side while the secondary spaces such as bathroom, hallway and staircase are best located on the north side to act as a buffer space (figure 67).

Figure 67: A typical plan of building apartments with multiple-staircase/elevator concept. Source: Author

While cool nights are an advantage in this region, in summer residences use their terraces and roofs for sleeping in order to make the best use of night breezes. For this reason in the design of the apartment buildings it is tried to consider each apartment a balcony to be used for summer nights and also as an open space that each family needs. In figure 68 the terraces/ front yards are shown in the whole proposed city block while they are explicitly illustrated in combination with other interior elements of each building in the plan drawings put in the appendix.

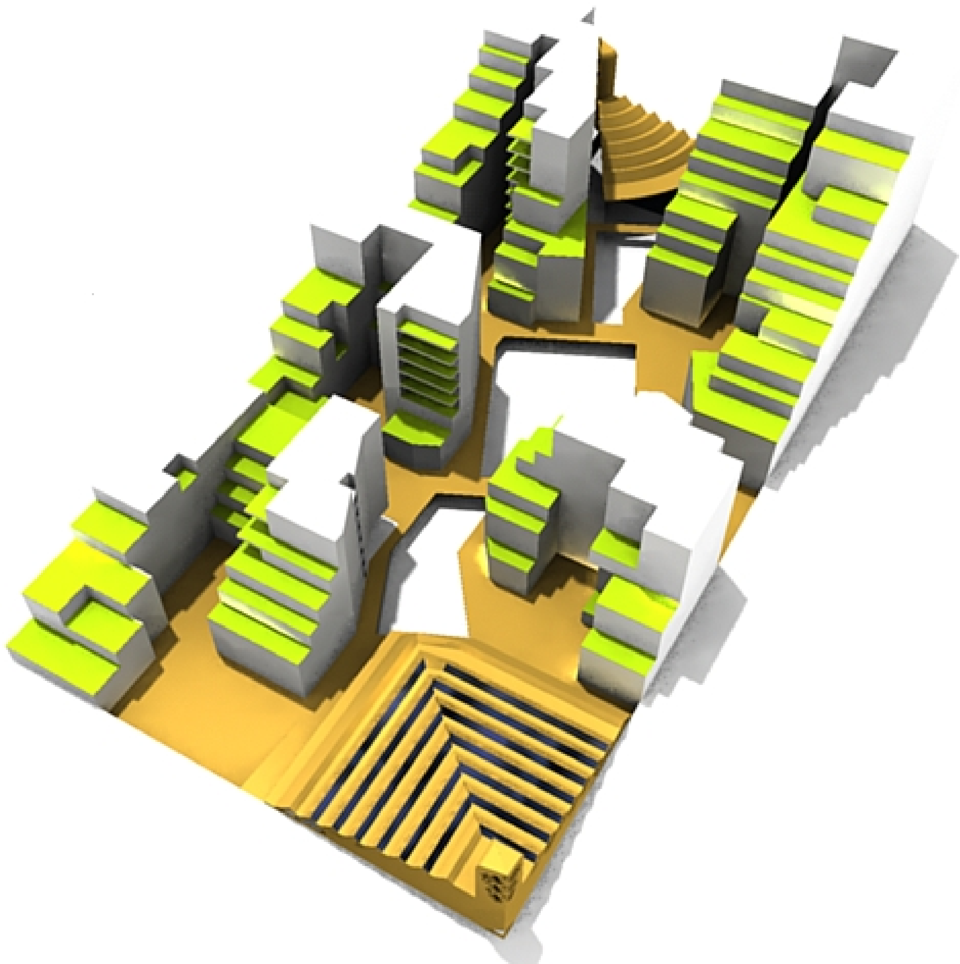


Figure 68: Front yards which are used at summer nights for sleeping. Source: Author

In the following drawing, the east-west section of the site is shown which illustrates how the wind-catchers could trap air and work in the city block (figure 69). Since their locations are based on the spring and summer breeze directions, and according to their height, cool breeze could be trapped. After evaporative cooling, humidified air would flow to the whole block and enters the buildings.

Besides improving neighbourhood's micro-climate through creating natural ventilation, wind-catchers also provide a gathering urban space for the residences at the basement level. In order to be a pleasant space to stay, openings are considered at the roof of the wind catchers oriented to east and north-east radiations in the morning. Retail stores, restaurants and places to rest are other considered to make it a lively place (figure 71, 72).

Figure 69: Behaviour of wind inside the block. Source: Author

Figure 70: South elevation of the designed city block. Source: Author

Figure 71: Internal view of the wind catcher. Source: Author

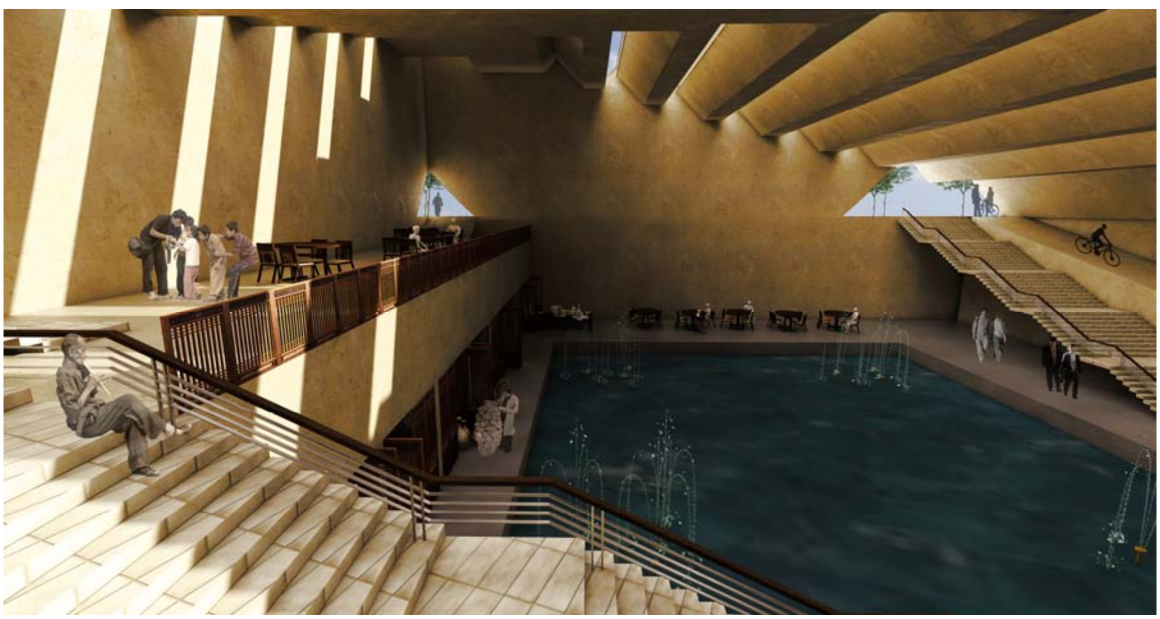


Figure 72: Internal view of the wind catcher. Source: Author

In figure 73, the designed city block is shown next to other city blocks to give an idea about the formed proposed context.

Figure 73: City block in the context. Source: Author

In the shadow studies represented in figure 74, critical hours of day can be noticed. Based on the basic study of the proposed self-shaded mass, it is clear that the streets and internal paths are in complete shade in the afternoon, while they receive sun radiation in the most hours of the cold mornings in this region.

Since the created situation is desirable, it is attempted to provide the same shadow condition in each building complex. For this reason each building is re-formed to create the same slope in order to provide the same shadow condition.

For detail shadow analysis of each moment of the proposed city block an advanced solar simulation is needed.

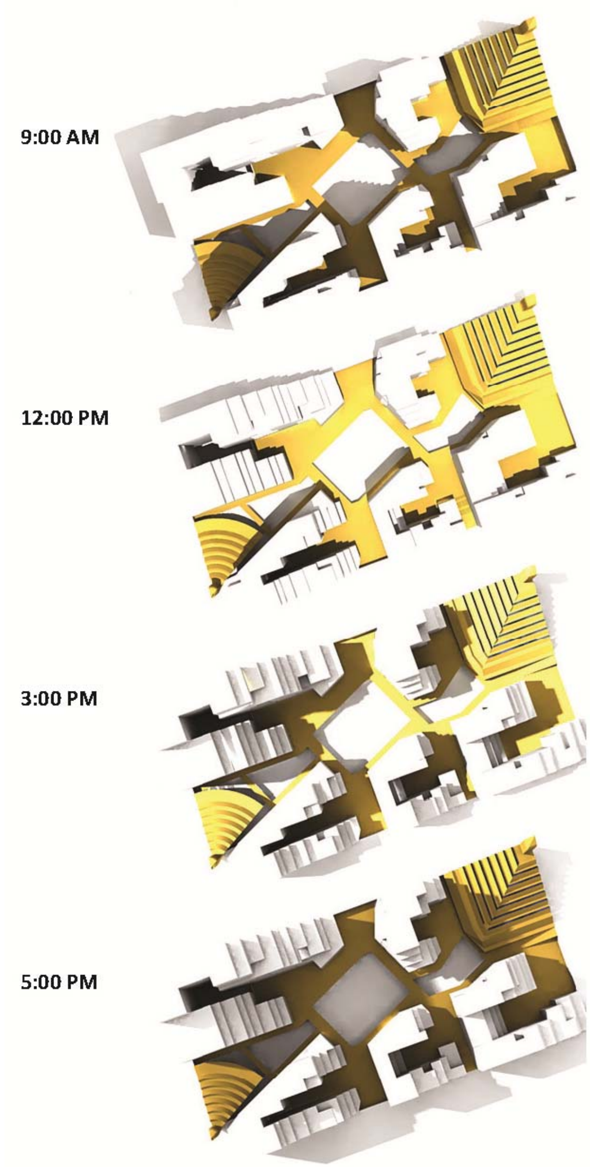


Figure 74: Shadow studies-Summer Solstice, June 21. Source: Author

4.4 Advanced Solar Analysis

Solar simulation in this section explains and predicts the level of comfort for outdoor spaces and is conducted for three different sites in the city of Kerman. As a comparison, traditional and contemporary residential neighbourhoods are simulated in order to investigate the level of comfort according to climate factors in both recent and early methods of urban design. Moreover, the proposed design development of this thesis is simulated to assess design decisions about the optimum orientation and from of the buildings in the region of Kerman.

For more accurate decision making through the design process the simulation is performed in two stages. At the first stage, the estimation of solar radiation of the site is calculated for summer, winter and the whole year cycle. In the second stage the analysis of the positive and negative effects of solar radiation on different building faces and also on open urban spaces is conducted. The outcomes resulted from the second stage of simulations are significant in developing the physical urban form in order to enhance the comfort level of urban spaces.

4.4.1 Solar Analysis of the Traditional and Contemporary Urban Fabric of Kerman

The typical model of urban fabric shown in figure 75 is a traditional layout remains in several parts of Kerman; the orientations of the streets are all according to the south-west to north-east axis that can be considered as a desirable inclination for the streets to take advantage of the morning radiation while be protected from afternoon undesirable sun.

Although it is attempted to provide the same orientation fort the new constructed part of the city, wider regular streets worsen the comfort situation in compare to the traditional areas (figure 77, 78).

In the proposed design of this thesis it is attempted to separate the pedestrian paths with traffic lanes in each block in order to create streets with minimum width and correct orientation.

Figure 75: Traditional pattern of Kerman
Source: Google earth pictures

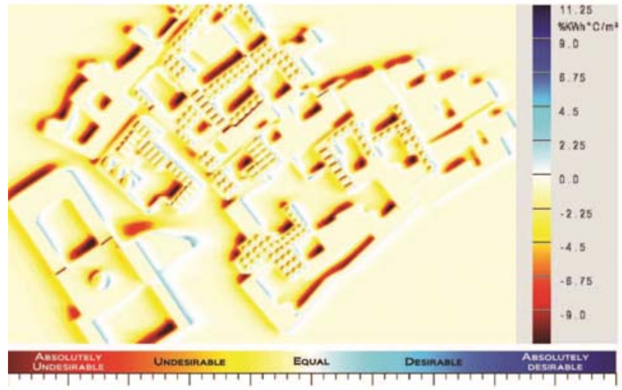


Figure 76: SOLARCHVISION Model of Year Cycle

Figure 77: Current pattern of Kerman
Source: Google earth pictures

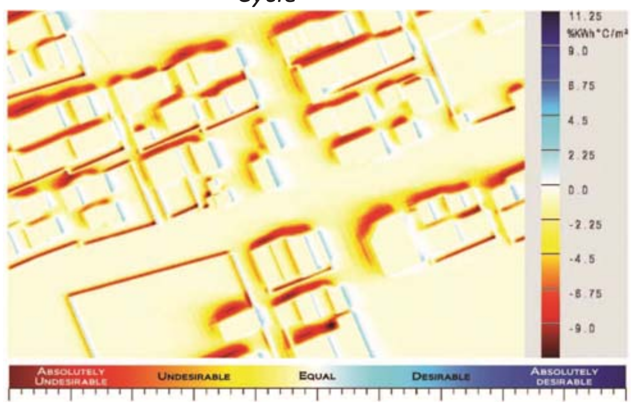


Figure 78: SOLARCHVISION Model of Year Cycle Site Radiation

4.4.2 Solar Analysis for the Proposed Design and the Findings

Solar Analysis at Macro and Medium Scale:

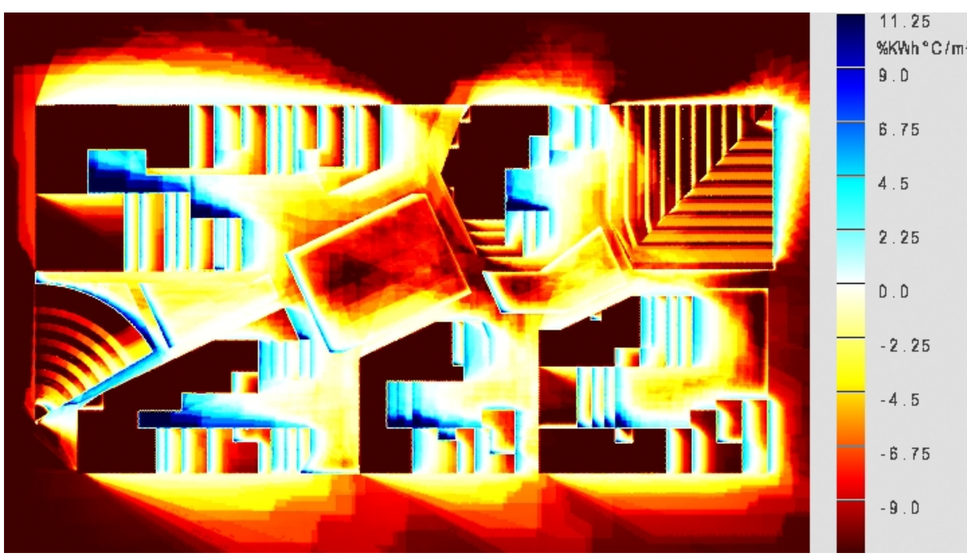


Figure 79: SOLARCHVISION Model_ Plan view_ from April 20 to Oct. 22_from Sunrise to Sunset

According to solar analysis conducted by SOLARCHVISION for the proposed designed city block in summer (figure 79), in general open spaces shown in yellow color and therefore are in a desirable situation except for the central plaza of the block which is going to be modified through planting trees and using shading devices. With the correct orientation of the block, to the north-east, south-west axis, internal streets could be considered as acceptable urban spaces from temperature point of view to be used in summer in this region.

As shown in the SOLARCHVISION model of winter (figure 80), inside the central yard of each building there is an undesirable situation due to unwanted shadings created from the height of the surrounded buildings. In addition, the sunken streets at the basement level and the central plaza can not take advantage of sun radiation in winter; however, pedestrians can be kept safe from winter winds and rains through the continuous path above street.

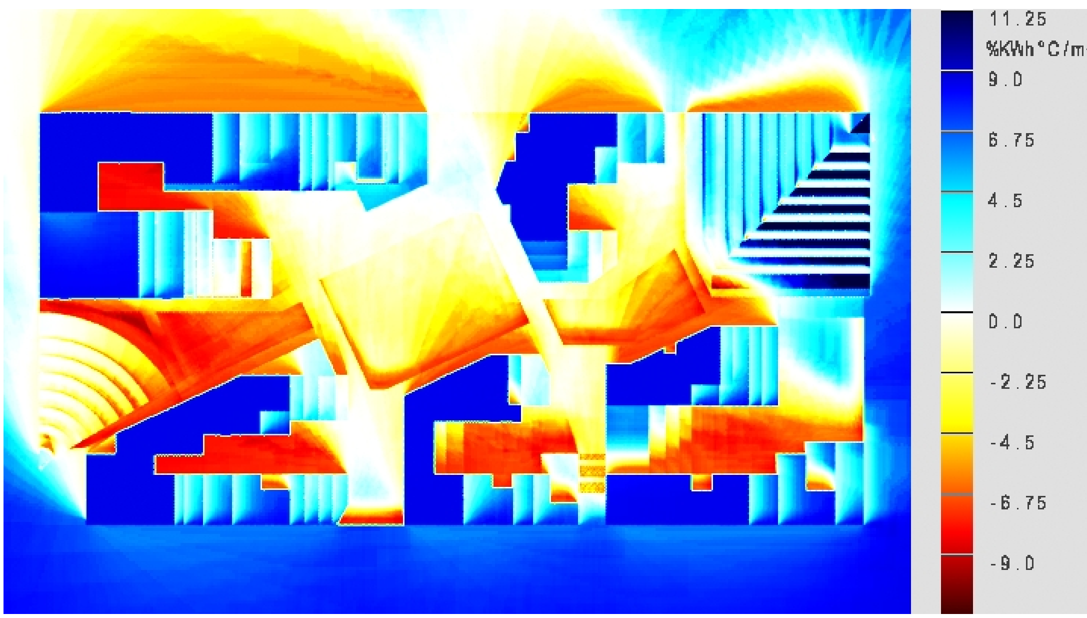


Figure 80: SOLARCHVISION Model_ Plan view_ from Oct. 22 to April 20_from Sunrise to Sunset

The following images show the central plaza in summer after considerations to improve thermal condition in the outdoors. Planting trees, providing water bodies with protections from sun radiations and implementing umbrellas/shades for pedestrians could be the possible enhancements for the urban open spaces.

Figure 81: View from pedestrian path to the central plaza of the city block. Source: Author

Figure 82: View to the central plaza of the city block. Source: Author

Solar Analysis at Micro Scale:

From the analysis conducted for the surfaces of the buildings, it can be seen that vertical louvers proposed for the south and south-east façade had not improved the comfort level in summer (figure 84), however they block the desirable sun radiation in winter (figure 85). That is why they are shown in white for summer and winter SOLARCHVISION models.

According to this fact that Kerman has cold mornings for the whole year round, it is advantageous not to block the south and south-east windows by vertical shading. Horizontal shading would be more acceptable for both summer and winter.

Figure 83: Proposed shadings for south side of the buildings. Source: Author

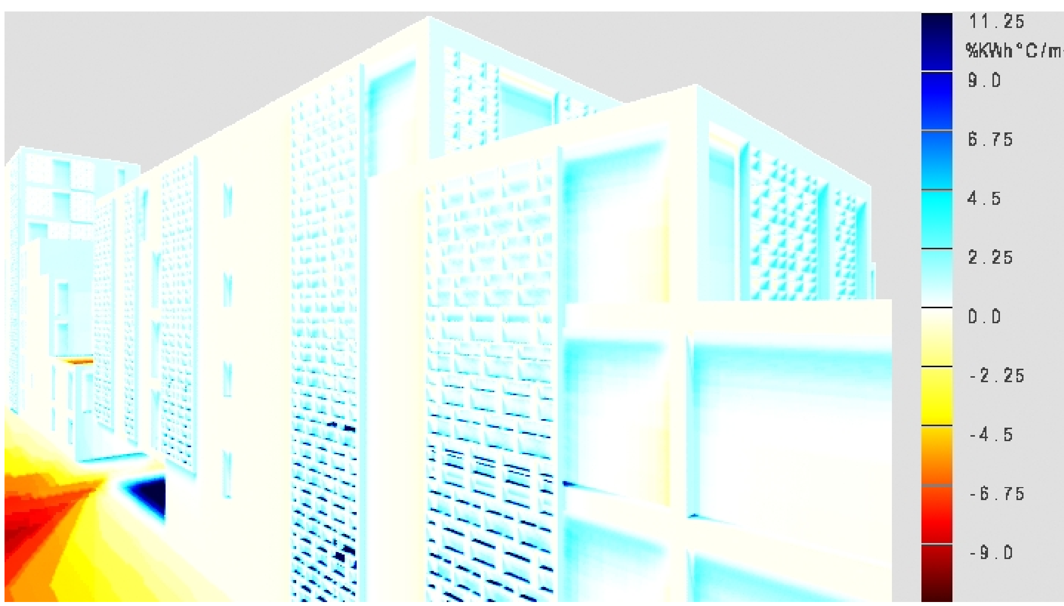


Figure 84: SOLARCHVISION Model_ South side _ from April 20 to Oct. 22_from Sunrise to Sunset

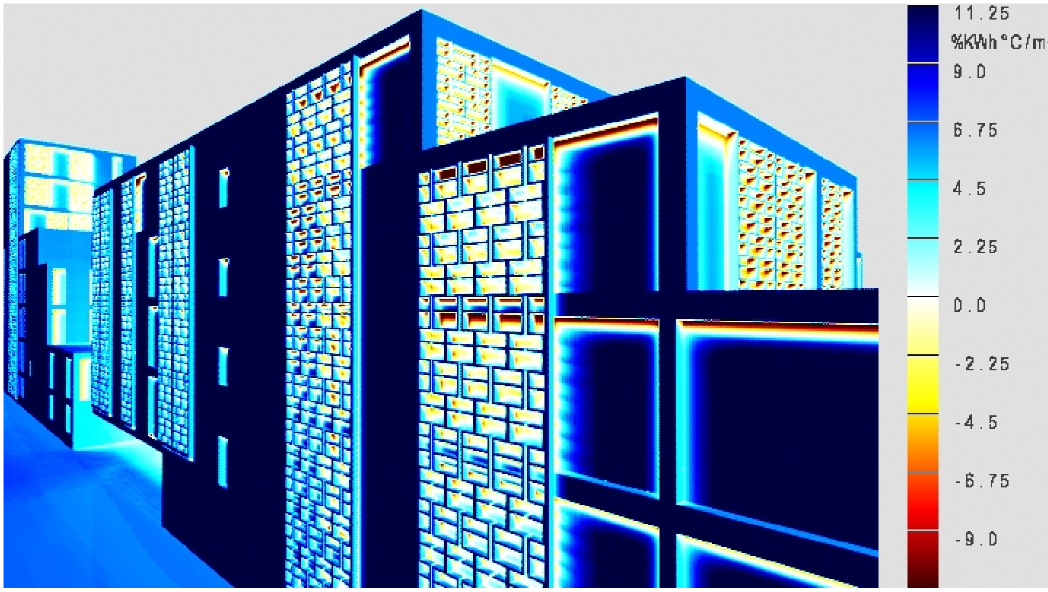


Figure 85: SOLARCHVISION Model_ South side _ from Oct. 22 to April 20_from Sunrise to Sunset

Below diagrams represent south-west and west façade of the buildings in summer (figure 86) and winter (figure 87). It is clear that the depth of the windows and balconies is considerable in evaluating the level of comfort for the building surfaces.

While windows with minimum depth and no shading shown in red stands for the absolutely undesirable condition in summer, balconies with at least two meters depths shown in dark blue represents the best level of comfort in west side of the building.

As it is obvious from white color of shadings in figure 87, they are not necessary to be considered for the south-west and west side windows in winter.

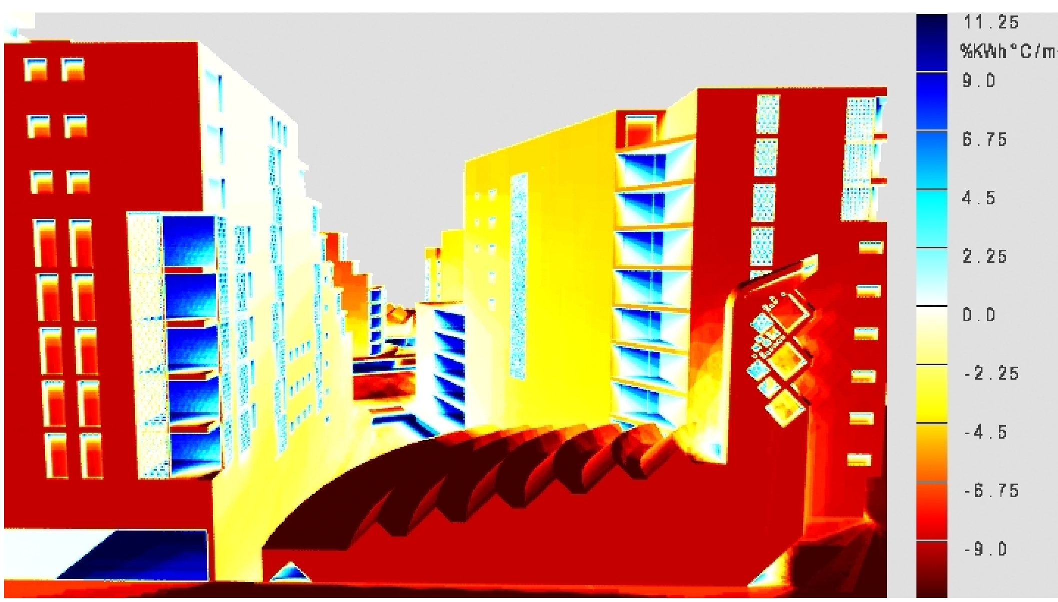


Figure 86: SOLARCHVISION Model_ West side _from April 20 to Oct. 22_from Sunrise to Sunset

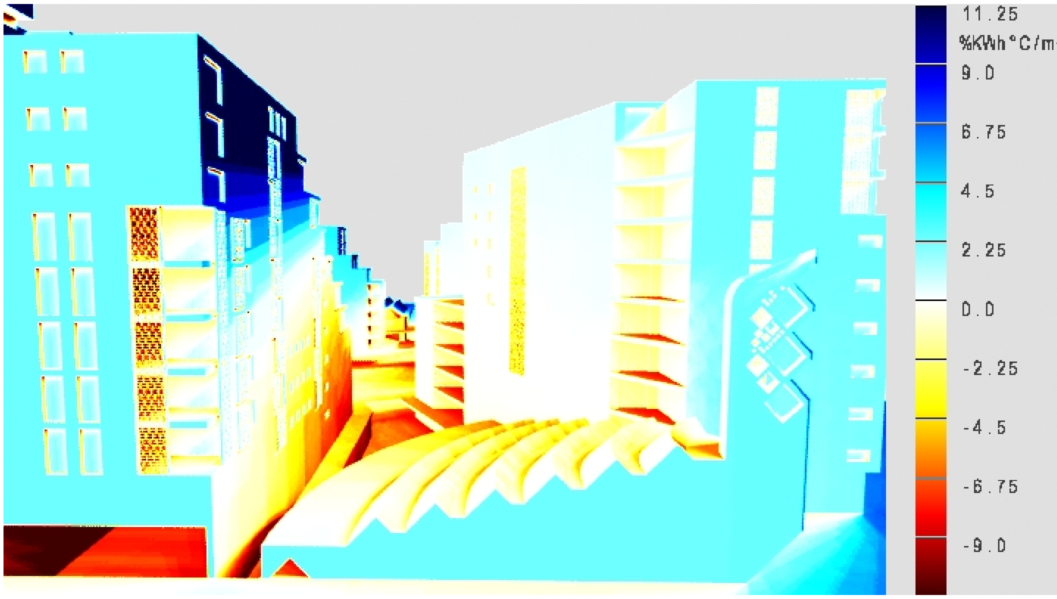


Figure 87: SOLARCHVISION Model_ West side _ from Oct. 22 to April 20_from Sunrise to Sunset

In image 89, the proposed north-west façade with horizontal shading for the windows are represented. According to the north-west side simulations of the proposed design (figure 90, 91), projected windows are not deep enough and the fixed shadings can not enhance the comfort level significantly. In order to improve the situation, fabric solar shading is suggested which could provide enough depth for the windows and at the same time it won't block the view to the outside. Another advantage of the fabric shading is that it could be rolled or removed in winter.


Figure 88: Fabric shading
Source: http://www.sunscreen-mermet.com/blind-fabric/solar-shade-fabric.htm

Figure 89: View to the north-west facade with horizontal fabric shading.
Source: Author

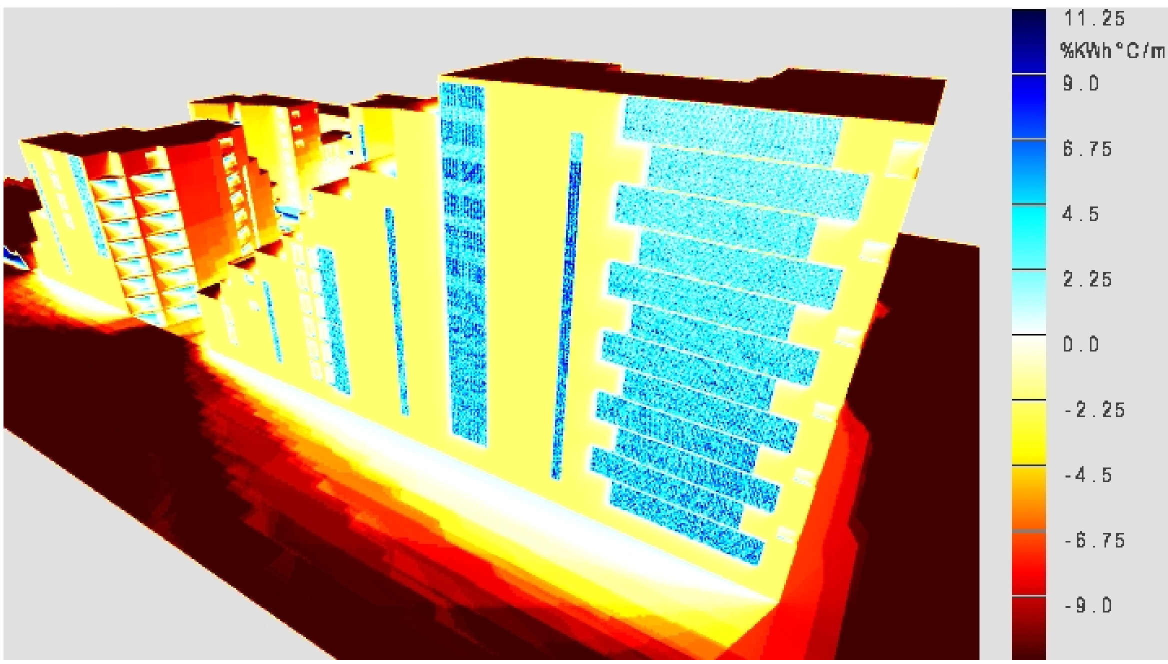


Figure 90: SOLARCHVISION Model_ North west side _ from April 20 to Oct. 22_from Sunrise to Sunset

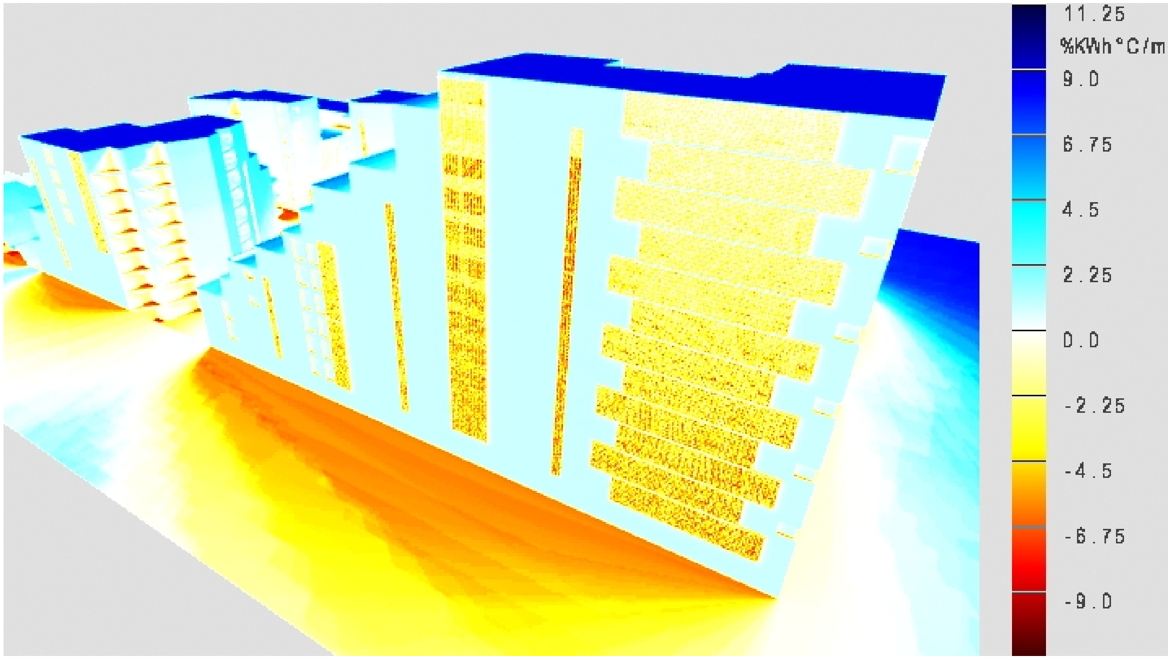


Figure 91: SOLARCHVISION Model_ North west side _ from Oct. 22 to April 20_from Sunrise to Sunset

Solar analysis simulations showed the in-efficiencies of the proposed design at both macro and micro scales. Following images illustrate the final design with possible improvements.

Figure 92: View to the central yard of a building. Source: Author

*Figure 93: View to the west facade with side of the city block.
Source: Author*

Figure 94: Volumetric explanation of the proposed design. Source: Author

Chapter Four: Conclusion

This research tried to bond the fracture that occurs between physical urban environment in Iran and energy consumption of the inhabitants in the modern life. In a practical way, adapting buildings to user's needs, traditions, social habits, and climate features while reducing the energy demand, requires architectural tools to create energy-efficient urban forms that could enhance comfort rate.

According to the research questions mentioned in chapter one, the proposed re-design project clearly illustrated the possible improvements in developing the current energy-inefficient city blocks through applying passive climate –sensitive strategies. The results would be as follows:

1. Applying "shadow umbrella" model not only provide guidance in establishing volumes with proper heights and forms in accordance with the solar and temperature characteristics in each area, but help to verify the proper arrangement for the volumes in order to enhance natural ventilation and cast the best shadow for the commons for the most part of the day. Assuming the growing popularity of applying solar-sensitive form production theories for the city blocks in cities, reduction of energy waste for the ventilation systems will occur.

   The designed self-shaded building masses proposed for hot-arid climates are considered as mid-rise apartments that could effectively make up within a high density development and into a larger scale.

2. In the transformation of the urban spaces in Iran, plazas and streets in Iranian cities had lost their identity as gathering spaces for people. The disjunction between urban public spaces and the inhabitant descended through creating places with a better thermal comfort. The proposed urban spaces were considered as pedestrian streets and plazas in combination with the location of pools and wind catcher structures in each neighbourhood to be considered as future potentials in order to revitalize the gathering spaces at the urban scale.

   Mixed used urban areas resulted from the pedestrian shopping street and the residential areas could revitalize the self sufficient districts of the past.

3. The possibility of developing an optimized form for the buildings and street network arrangements were shown through the design process and its success in improving the

level of comfort had investigated through a selected solar analysis computer program, “SOLARCHVISION”. This program by showing the desirable or undesirable cast of shadow in each moment clearly illustrated the need to “shade or shine” and the rate of comfort in each location to help improving the climatic and energy conditions.

4. In order to take advantage of traditional, climate-sensitive urban design strategies, some parts of the buildings in the proposed design were recommended to construct one (or more than one) level below the ground to create sunken. This concept not only assisted in achieving thermal comfort for the urban open spaces, but also prepared protection for the pedestrians from precipitation in winter.
5. In terms of natural ventilation improvements, sunken pathways were combined with the system of air movement provided by the wind catchers in each city block. In order to evaluate the achievement of this combination at a neighbourhood scale and in a contemporary urban fabric, wind simulation is needed.

   For the purpose of this study wind behaviour effects and its simulation are excluded due to time limitations. However, CFD (computational fluid dynamics) can be effectively conducted and applied in future in order to study the advantages of air movement as a cooling strategy in a passive design approach.

6. The use of proper materials was verified through simulations conducted by solar analysis. The rate of open to closed surfaces in each façade, the quantity and quality of shadings, and the need to employ reflective or refractive materials can also be decided through determining the effects of kind and unkind faces sun on each side of the building. Furthermore, the best location to be used for placing PV panels in an active design approach can be concluded through the mentioned studies.
7. For the surrounding buildings surfaces not fitted in the created shadow umbrella, a proper depth for windows and suitable proportions for the shadings was considered in the design model in order to protect the facades from undesirable sun radiations.

Post-Thesis Reflections

Introduction to Problem

As an architecture student and also as a residence of an energy-inefficient building for several years, I have always been curious about the ways to improve the conditions of contemporary buildings. This chance arrived while working on my master's thesis.

While the concern of this research is on the buildings in desert regions, through the research process around this issue, I realized that there was an abrupt change from methods implemented a century ago known as traditional architecture and modern methods used afterward with no transitional process or compatibility. This has become a motivation for me to look into the history of urban and building transformation and emergence of Modernism and international style in Iran.

By this time I had become familiar with the importance of passive, low- energy strategies in architectural design implemented in the past in keeping the buildings from harsh local climate. These successful traditional strategies became the main concept in the design phase of this thesis for designing modern, energy-conscious buildings in regions with hot-arid climate.

While my research and design progressed, I realized that creating low-energy passive architecture and challenging the climatic issues are not possible without considering the problems at the macro scale. As a result the focus of the design phase of this thesis had shifted away from studying and giving design alternatives for a single building and working on its technical details into proposing a design alternative at the neighbourhood scale.

Thesis Statement

The hot, arid climate in combination with non-responsive urban planning and building designs has resulted in excessive energy consumption, especially of electricity in order to keep occupants comfortable. Although it is possible to overcome many of the negative effects of an inefficient design which neglects climate by use of mechanical systems, there should be cases where these systems can be avoided. Through an architectural response on the macro, medium and micro scale, this thesis explores the role of climate sensitive strategies, practiced in the traditional architecture, in recognizing the importance of energy conservation and human's comfort while utilize them in the future constructions.

Methodology

Among these strategies, the need to control air movement and solar access in the outdoors are the main factors in taking the climate-sensitive approach in hot-arid regions.

By three schematic designs I could illustrate more explicitly the initial idea of coupling vernacular passive cooling strategies with modern technologies such as secondary envelopes of the buildings. By doing conceptual design, I understood that the behaviour of wind is so complex and unpredictable that not all the principles implemented in a single building to control wind flow could be transformed and used at a bigger scale in creating natural ventilation and reduce energy consumption in the neighbourhood.

In the next step, in order to apply design ideas and verify them on the realistic site in a desert city, a typical city block was selected and was re-designed. In this typical city block not only the streets, building locations and their volumes were designed according to climate and passive principles (i.e. macro scale), but also the interior plans (medium scale) and the windows shading details (micro scale).

At this stage, I took a moment to reassess and somehow evaluate my design proposal. Using simulation software packages to simulate solar and wind impact on buildings are valuable tools to do so. SOLARCHVISION, a solar analysis simulation tool, with the ability to show the rate of comfort became the tool to finalize the decisions. All the design decisions from urban scale to building details were simulated by SOLARCHVISION and then edited to improve the level of comfort at the urban spaces and on the building faces.

Concluding Thoughts

This thesis is an exercise in the environmental-based design and energy conscious architecture. While some would argue about the success of the suggested design proposals, I believe that future work is needed to evaluate the practicality of the design proposals in the real world. This work can present a starting point for the future investigation, namely for simulation and verification of wind behaviour around through this city block, using more sophisticated Computational Fluid Dynamic (CFD).

Appendix

Developed Plans of the Proposed City Block

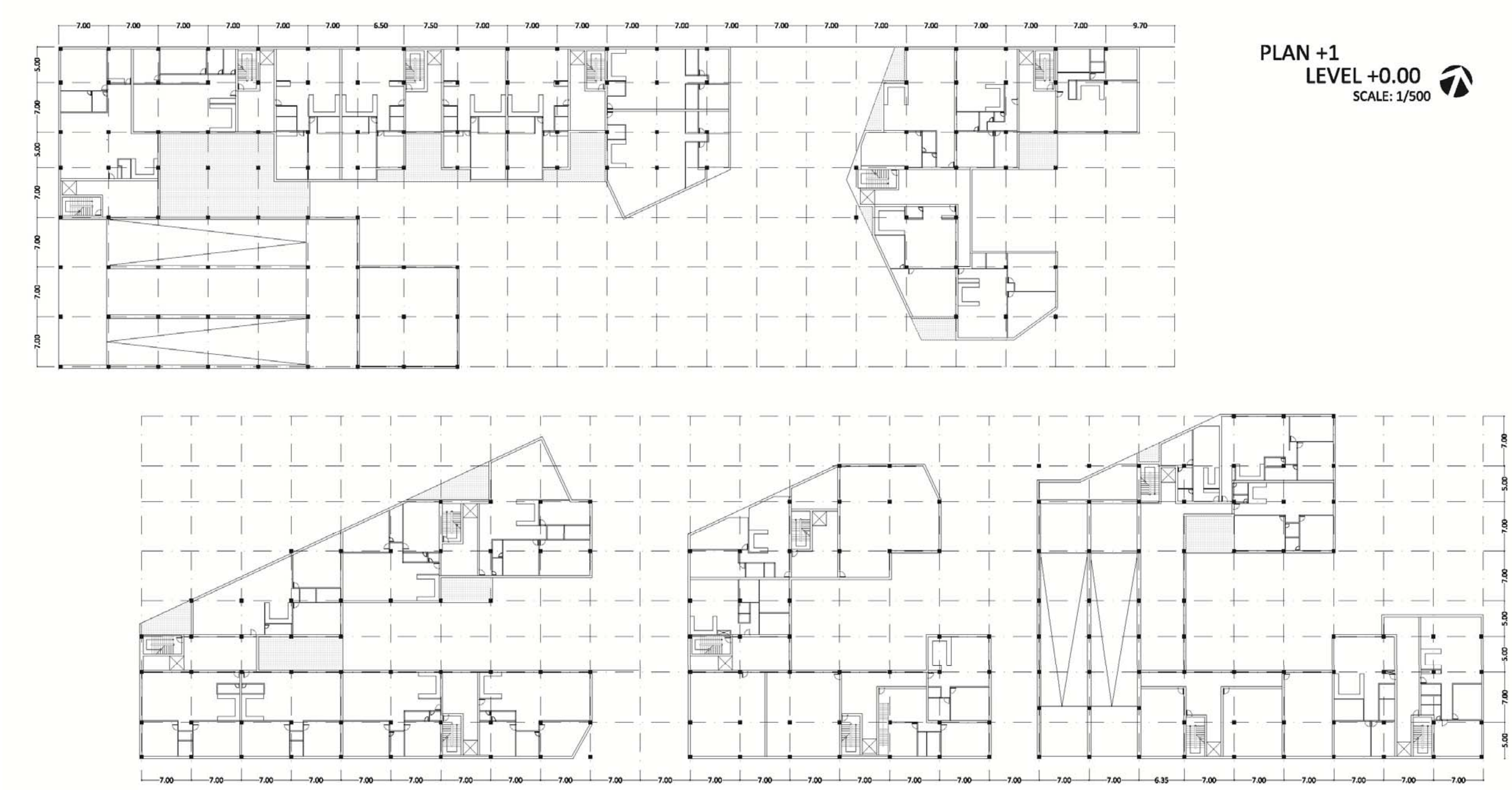


Figure A.1: Plan Level +1. Source: Author

Figure A.2: Plan Level +2. Source: Author

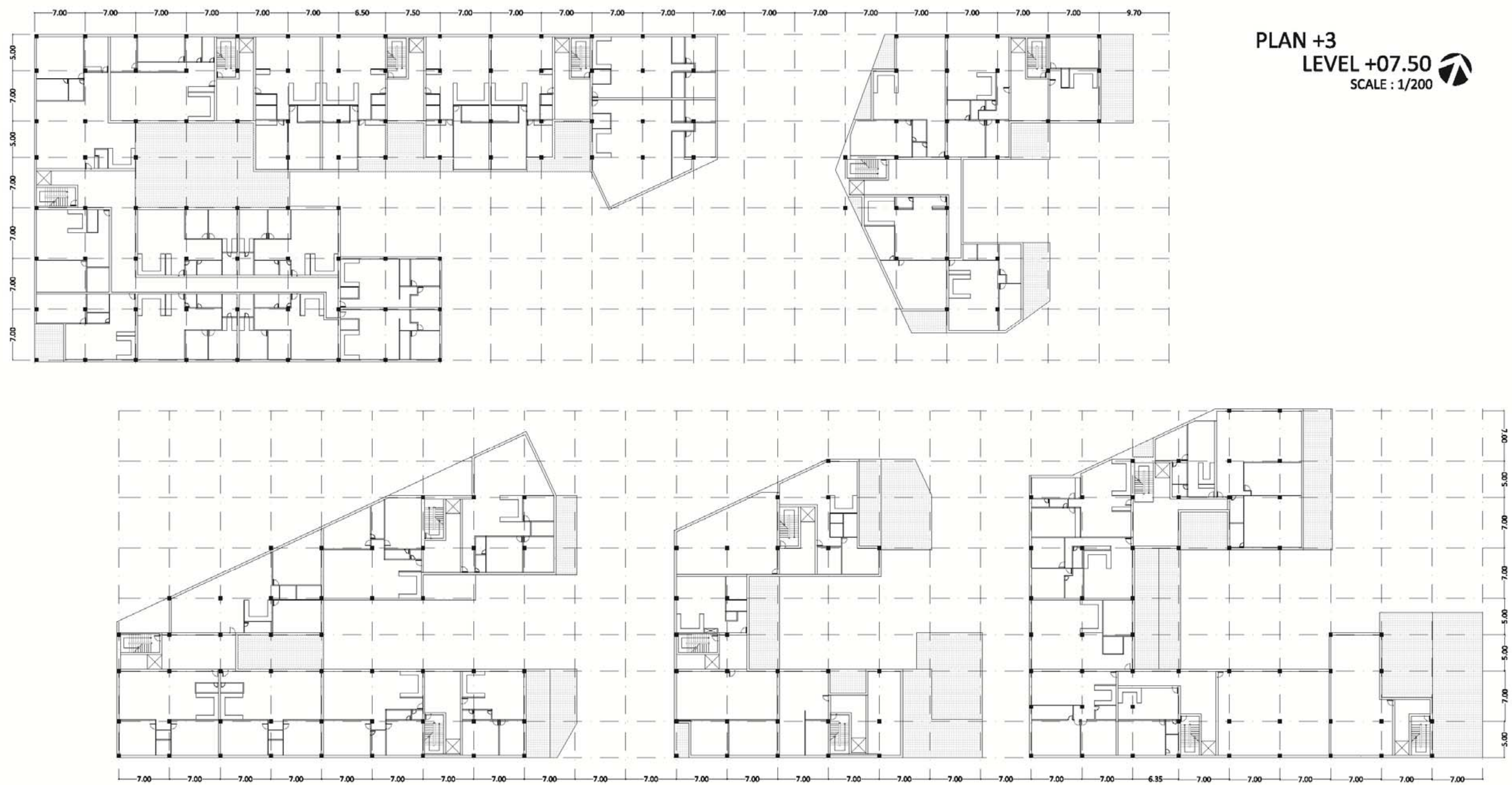


Figure A.3: Plan Level +3. Source: Author

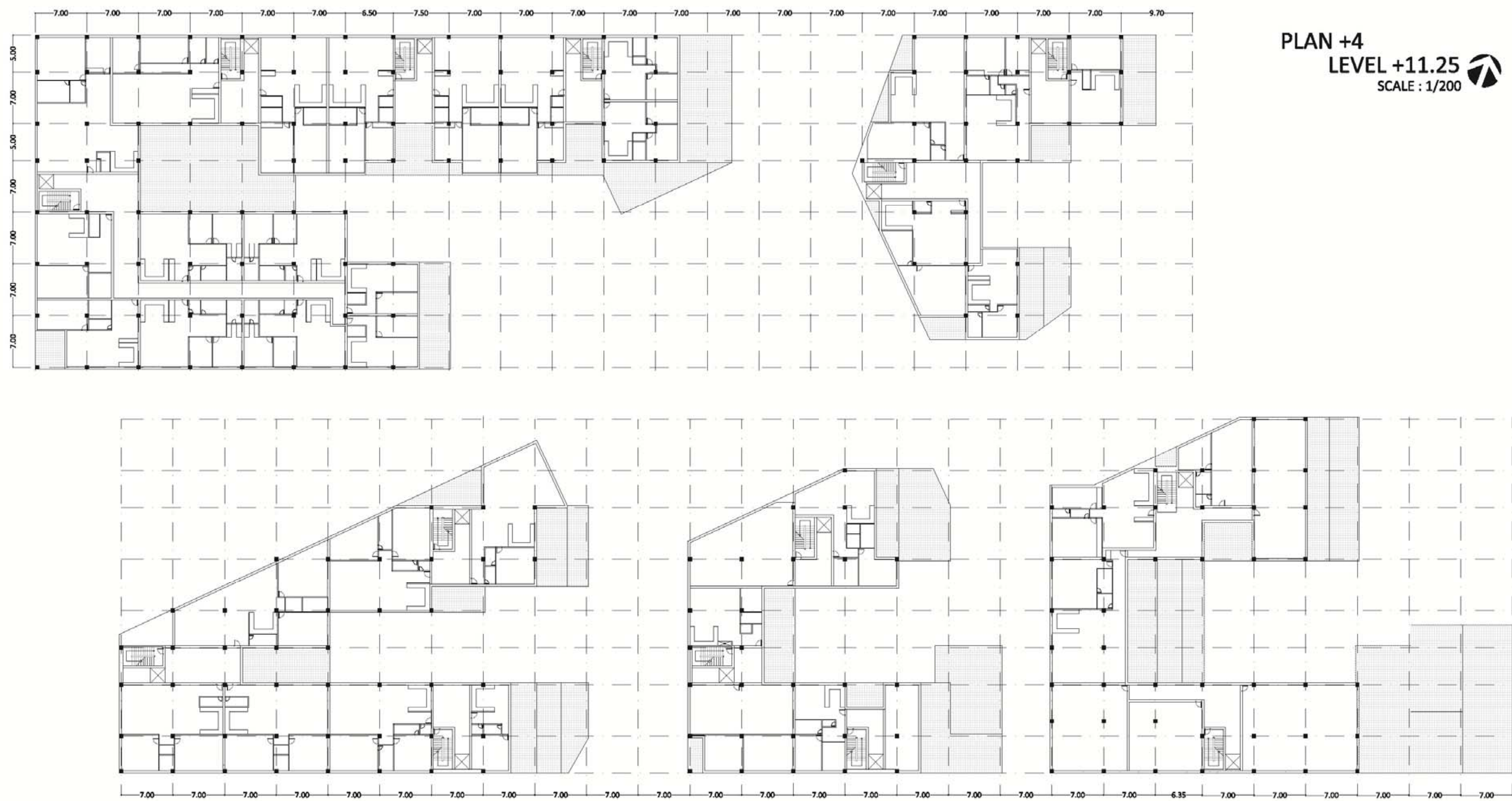


Figure A.4: Plan Level +4. Source: Author

Figure A.5: Plan Level +5. Source: Author

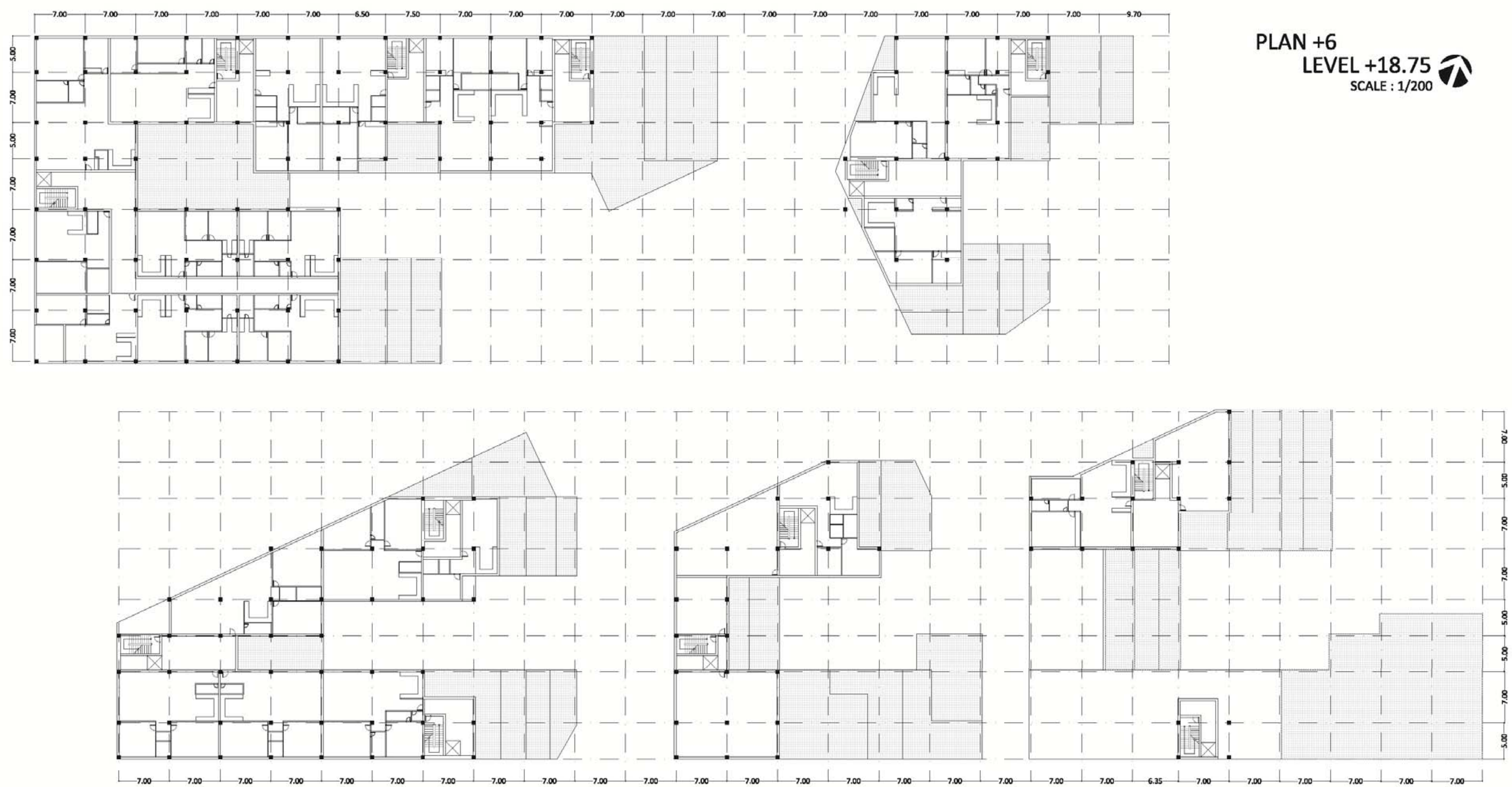


Figure A.6: Plan Level +6. Source: Author

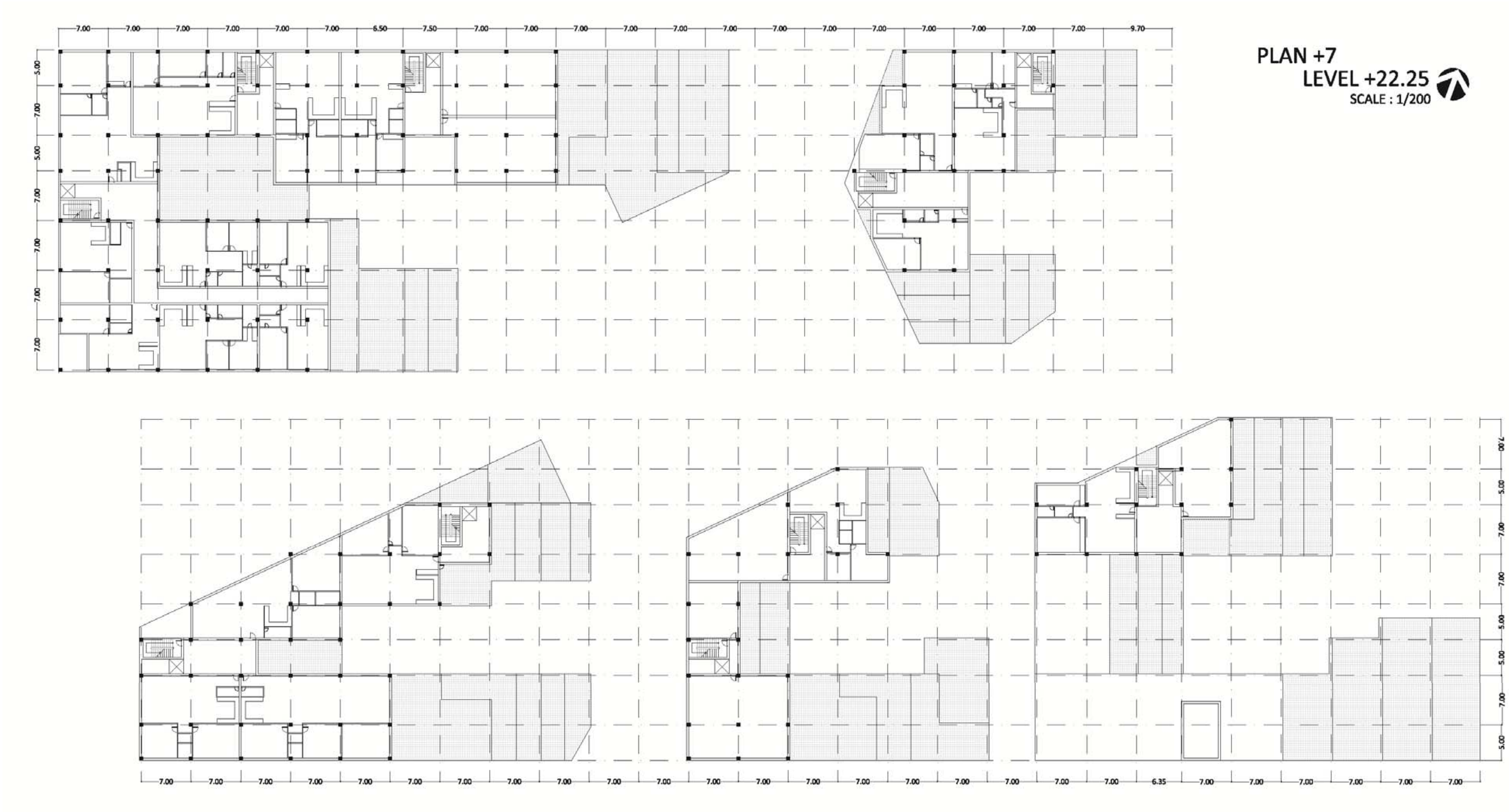


Figure A.7: Plan Level +7. Source: Author

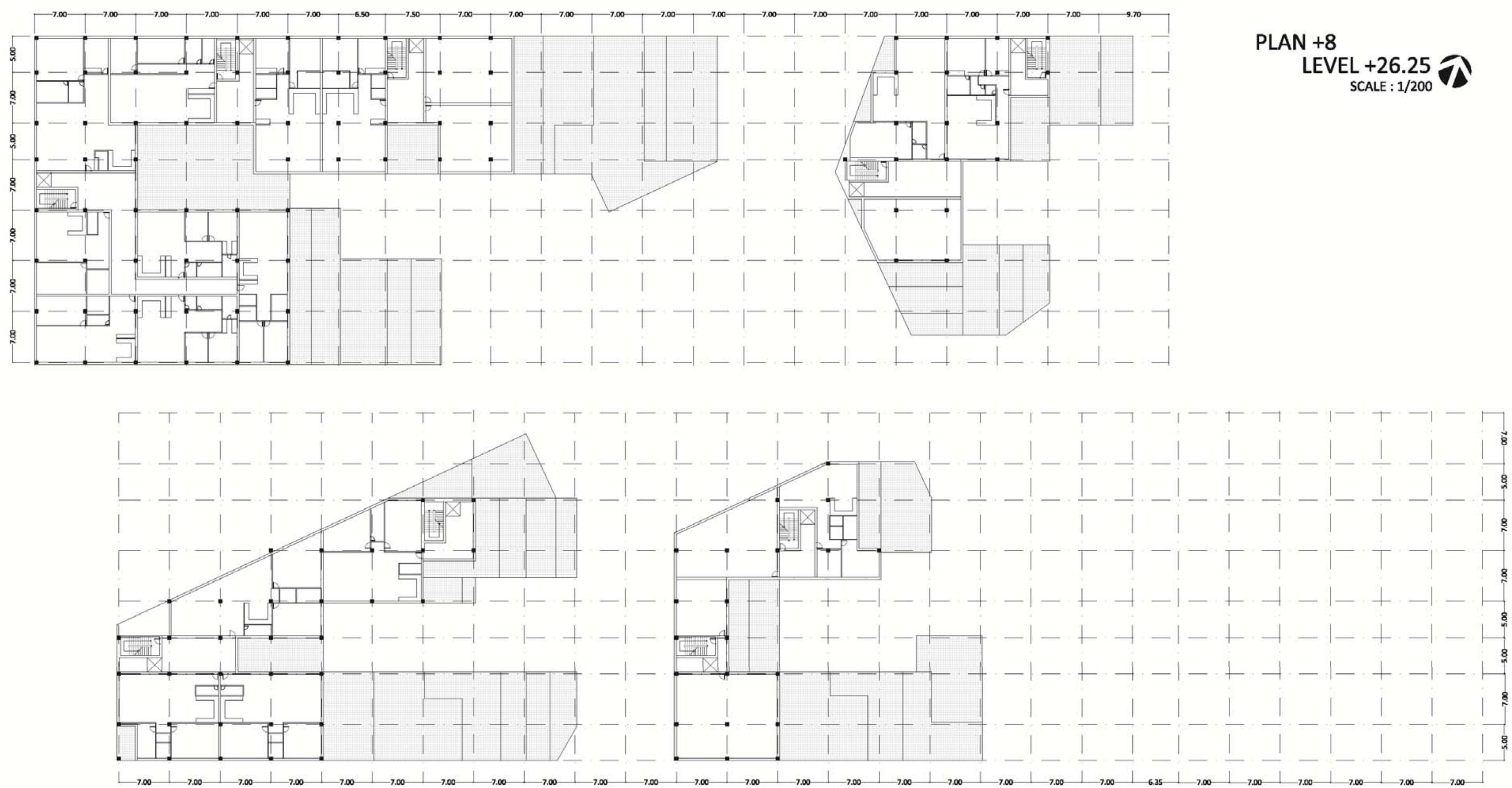


Figure A.8: Plan Level +8. Source: Author

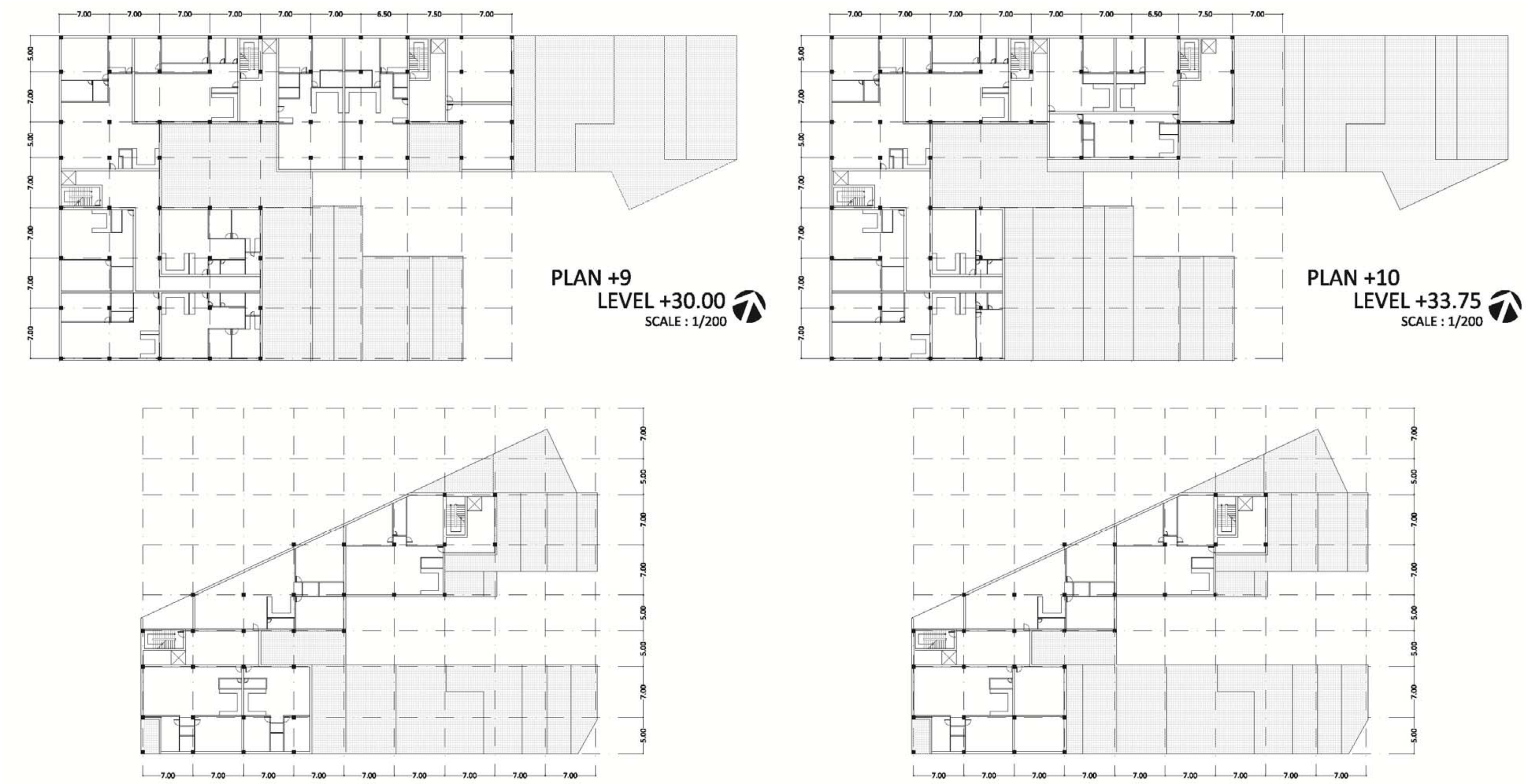
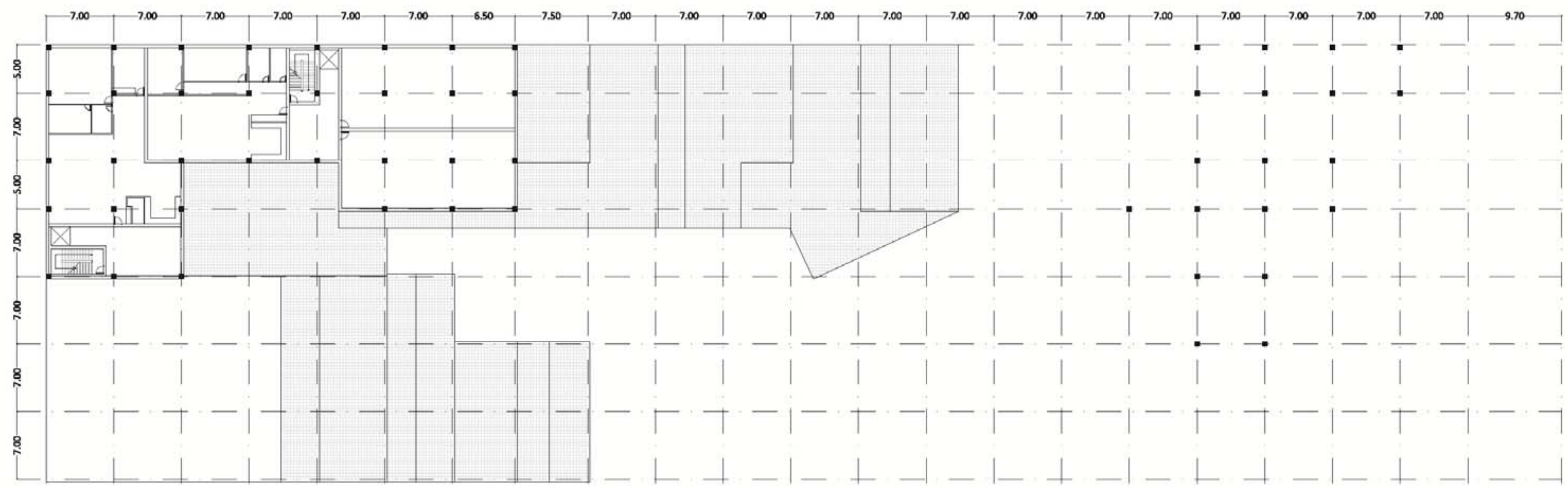
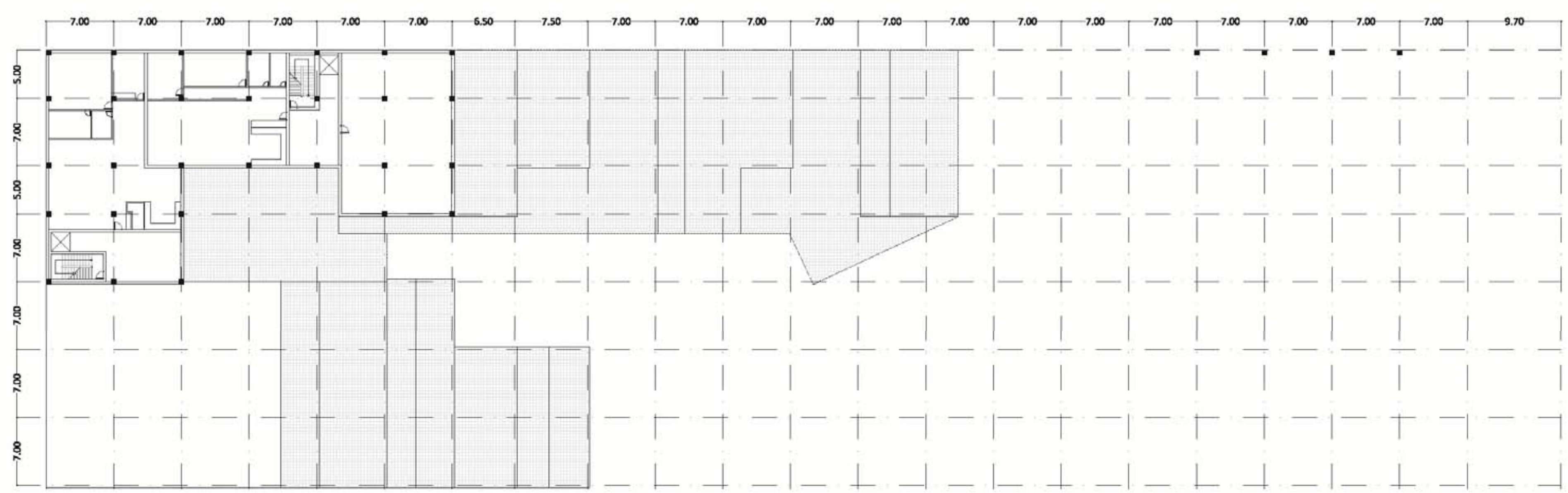


Figure A.9: Plan Level +9, +10. Source: Author



PLAN +11, +12
LEVEL +37.50
LEVEL +41.25
SCALE : 1/200



PLAN +13
LEVEL +45.00
SCALE : 1/200

Figure A.10: Plan Level +11, +12, +13. Source: Author

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