

# Placement of semi-enclosed spaces and energy demand

## In contemporary buildings in Iran

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*ABSTRACT: Semi-enclosed spaces are very common in the architecture all over the world. In Iran, these spaces such as court yard, patio, and etc. have several functions. One of the main function of these places is to reach to solar access and day lighting, but they can effect on energy demand in the building (heating, cooling, lighting) too. This article explains how the placement of semi-enclosed spaces in the buildings of the Iran impact on energy uses of building. For this reason several buildings with several types of placement of patio and courtyard are compared according the energy uses in buildings. The annual heating, cooling and lighting energy demand are compared. The analysis employs the Energy Plus and Design Builders simulation package to simulate configurations consisting of combinations of values of parameters in order to assess the effects of placement of semi-Enclosed spaces on the energy demand as well as heating, cooling and lighting demand of building. The reference shape is a rectangle and as the contemporary buildings in Iran.*

*Keywords: city blocks, energy, building location, sunlight.*

### INTRODUCTION

World growing concern about the environmental degradation and incremental loss of fossil fuels has made urban planners to pay more attention to the effects of urban texture on energy consumption. For this purpose, architects have also studied the thermal behavior of indoor spaces [1].

There are many factors which should be considered during the architectural and urban designs to be able to reduce the energy needs and increase the usage of renewable energy. Neighborhoods can be designed based on the maximum efficiency and productivity of passive energy through proper orientation and layout of the site, suitable urban density and an appropriate building shape [2].

Position of neighborhood units and geometry of a building influence directly on accessibility to solar radiation in each unit [3, 4]. Solar energy can be exploited passively for heating and day lighting, or actively to generate electricity and provide domestic hot water by means of solar collectors [5].

Orientation and patterns of neighborhoods can affect not only sunlight but also the airflow patterns. Placement of buildings within the site and pattern of land play important roles on temperature of micro-climate created by city blocks [1, 2, 6, 7, 8, 9].

According to Municipal laws in Tehran, architects are allowed to build 60 percent of the land and 40 percent will be considered as open space.

Several factors can effect on make decision about location of the mass in a site, including urban pattern, vision and perspective, confidentiality, Urban Landscape and Site Layout. One of the most important factors is the thermal performance and energy consumption inside the building.

This article aims to identity effect of building location in the sit on the energy demand for cooling, heating and lighting inside the building. For this purpose, one of the old textures of Tehran was chosen as the study area and their energy demands compared base on morphology of urban arrays.

### LOCATION OF MASSES IN OPEN SPACES

“What building forms make the best use of land? This question for planners and architects was addressed in the late 1960s at the Centre for Land Use and Built Form Studies in Cambridge (now The Martin Centre for Architectural and Urban Studies) by Leslie Martin, Lionel March, Michael Trace and others” [10]. Answers to this question have a lot of influence on urban planning and architecture.

In relation to form, researchers have investigated a number of simple shapes and compared the impact of morphology of urban unit on access to solar ray.



Fig. 1. Generic urban forms, based on Martin and March [10]

The forms of urban blocks studied by Martin & March were considered by the researchers who are interested in Thermal behavior of urban form. The environmental and thermal behaviors of these forms were added later to these studies. The main question was that the thermal behavior of these forms can also have determining role in the use of them? For example, Gupta compared the access of solar energy and thermal behavior of these forms according to some parameters such as building height, street width and orientation in hot and dry climate.

Gupta completed his studies by investigated the relationship between sunlight per square meter facade and energy consumption for heating and cooling inside the buildings.

Kampf et al (2010) [11] have developed a methodology to minimize energy demand of buildings in an urban area using a multi objective evolutionary algorithm and to maximize incident solar irradiation whilst accounting for thermal losses.

Steemer interested in relationship between urban micro-climate and the form of the building. He used the martin & March forms and the investigated the relationship between building density and energy consumption. He concluded that the courtyard houses have the best response to climatic conditions in London.

Ratti, Raydan, Steemers (2003) studied these form in hot and dry climates [12].

They examined three forms .The first form is the three-story traditional building located in the old context with central courtyard which its Proportions is taken from Arab cities such as Marrakech. The second form is the pavilions that are located in the same context with narrow streets. The last one is the combination of four houses with central courtyards in the first case with extroverted form which are close to contemporary architecture.

### CLIMATE OF TEHRAN

The site location has a significant impact on the heating and cooling demands of a building as well as potential for on-site energy generation. Local weather

conditions such as temperature, solar irradiance, wind speed and direction and relative humidity all determine what design strategies are most suitable for a particular site. Additionally, external factors such as vegetation, neighboring buildings, terrain are local factors that can helpfully or adversely affect site energy requirements.

Buildings and plot lines often follow roadway alignment; therefore orientation and street pattern are critical characteristics to maximize solar access. Ideally streets should be oriented in the east-west direction so that buildings can be oriented due south; however, orientation within 22.5of due south can assure proper winter gain and effectiveness of awnings and shading features without significant loss of performance.

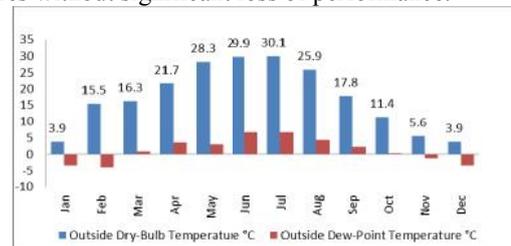


Fig. 2. Outside temperature in Tehran (Design Builder)

The latitude and the longitude of Tehran the capital of Iran are 35° 40' S and 51° 26'E. The city is situated 1191 meters (3907 feet) above sea level. Due to the expansion of Tehran, there are several weather stations. Weather data used in this paper is from Mehrabad Station. The station is located in the cold and semi hot and dry climate.

The picture below shows the amount sun's radiant energy reaches the earth's surface directly and indirectly, like what is used in the simulation.

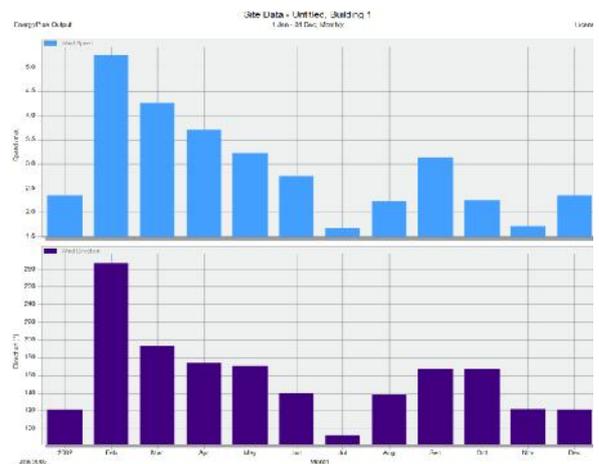


Fig. 3. Wind speed and direction (Design Builder)

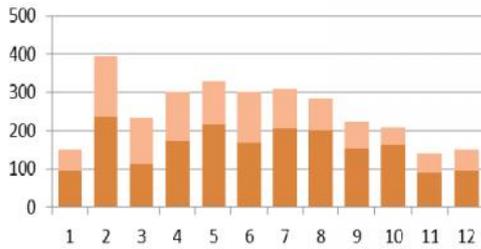


Fig. 4. the amount sun's radiant (Design Builder)

### CASE STUDY CONTEXT

In the case of studies that have been researched on this term yet, the forms of case studies, as usual, have been hypothetical and far away from real. For avoiding from this situation and obtaining to the useful results, one of the city block of TEHRAN city has been selected as the case study area and dimensions, proportions of site, number of floors and percent of opening areas on the façade, in order to attend of wide common range of case study's pattern have been researched. In the cases of different regions of Tehran, region 7 for below reasons has been chosen as the appropriate area:

- Long residential background and consolidation of urban structure.
- Allocating in the downtown(center) of Tehran
- Existing worn out urban texture and tendency of resident to rehabilitation.

According to passing SAYAD SHIRAZI highway and SHARIATI St., This part of Tehran, has been divided to three parts:

1. Eastern area, allocated at the east part of SAYAD SHIRAZI highway
2. Middle area, allocated between SAYAD SHIRAZI highway and SHARIATI St.
3. Western area, allocated at the west part of SHARIATI St.

Due to comparing of those three parts, below results have been concluded:

- Texture of region in the east part of SAYAD SHIRAZI highway is included of small and compressed parcels. (domination of mass to space)
- Texture of North West areas of region is equivalent in the connection of mass and space.
- Most of the buildings of the east area of region are less qualified than the SAYAD SHIRAZI highway's part.
- Buildings of the western part have more eligible quality and portion of new buildings or whit less constructed time (archaism) in this part is more than east part of region.

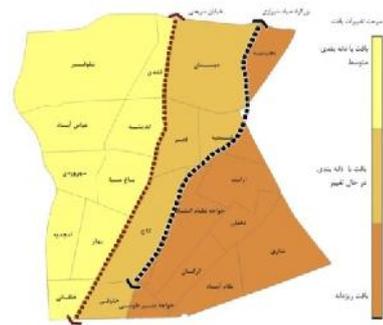


Fig. 5. Division of region to the three part according to crossing SAYAD SHIRAZI highway and SHARIATI St. (paykadeh consulting engineers, 1390)

As the below picture is specified, in the signed parts, buildings has lower qualify in comprising whit other part of region. So, both parts of these selections could be an adequate case. Bigger part is located at the east part and smaller one is in the western part of the region.

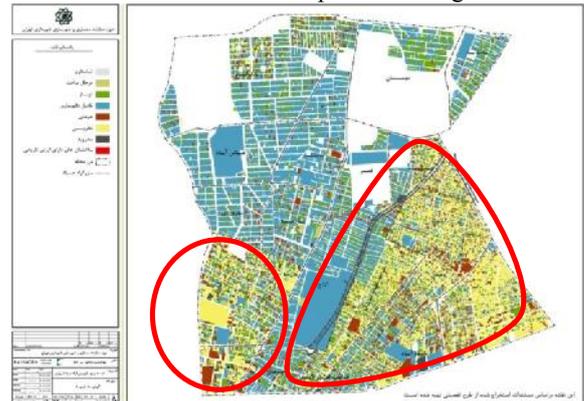


Fig. 6. Quality of buildings in the SHAREGH, DABESTAN, ARAMANE and KHAJE NEZAM sectors in the eastern part and AMJADIE, BAHAR and KHAGHANI in the western part is less than the other sectors. (paykadeh consulting engineers, 1390)

In the case of studies that have been researched on this term yet, the forms of case studies, as usual, have been hypothetical and far away from real. For avoiding from this situation and obtaining to the useful (efficient) results, one of the city block of TEHRAN city has been selected as the case study area and dimensions, proportions of site, number of floors and percent of opening areas on the façade, in order to attend of wide common range of case study's pattern have been researched.

Dominant elongation of the parcels is north-south with a 30 degree of rotation, portion of length to width is 1/3, average area of 400 square meter and 4 floor height.

As is shown in the below picture (figure), dimensions of parcels is about 13\*16, which considering the allowable construction area (60% of parcel) it has been reduced to 13\*21.6. To select constructible forms in the parcel, two adjacent parcels have been unified.

According to the laws of municipality, not any complexes is allowed to create window in the neighbor's wall. So, in the terms of creating the window, builder is allowed to construct 60% of parcel's length in addition of 2 meters more of that but a patio in the building should be considered opposite of the additional area. This point has been heeded in imagery modeling.

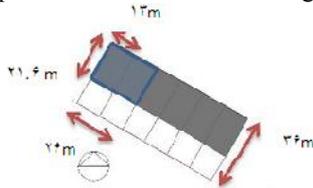


Fig. 7. division of parcels in the BAHAR St.

### SIMULATION of YARD

Location of building mass in a site generally could be studied in a six forms. All of the forms has an equal occupancy level, height, proportion, material and the same orientation. In every row of blocks it has been considered six building blocks. First form, which is named typical in this article, is the common and regular one in Tehran. In this form, the blocks are located in the northern part of site. In western blocks, openings are exposed in adjacent wall to illuminate entire parts of blocks. LINE status is mentioned to those which their building mass is located in the northern and/or western part of plot. In this case there is no need of patio. Courtyards of buildings are totally introverted which every blocks in them has been formed as L shape. According to deviation of L shape blocks, U and/or L shape urban models have been created (obtained) which both of them need a patio to exposure. Last status is named Pavilion which is boded to completely extroverted buildings.

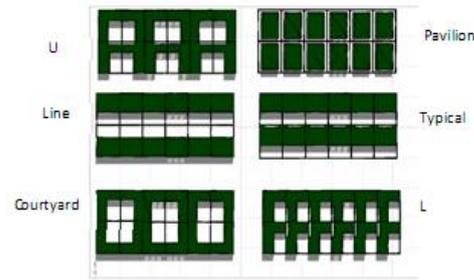
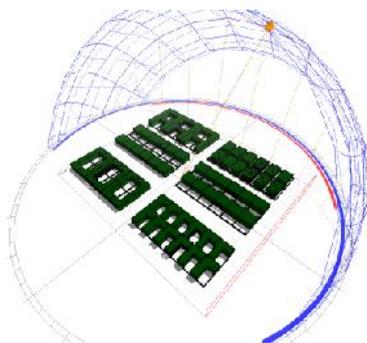


Fig. 8. status of building form in order to energy consumption

U-Value: in order of simulation procedure, selected materials for exterior walls is 0.64 and its quantity for roof is 0.310 which is in accordance with no, 19 national provisions of building. 30% of façade surface is covered by glass which this amount is more normal in the case study region.

Table 1: U-Value

Building parts	Thermal resistance (M.K/W)Rt	Element heat transfer coefficient (W/M.K)U=1/R
Exterior building walls	1.56	/
Details of UN controllable adjacent walls	1.537	.
Details of roof, adjacent of open area (the last roof)	3.17	.31

### Results of simulation

Figure 13, 14 are shown diagrams of energy consumption for cooling the buildings in summer (first of Tir till the end of Shahrivar) and for heating in winter (first of Dey till the end of Esfand). As it is shown in those diagrams, in both seasons, typical form has the least energy consumption. After that, with a very low difference, LINE form is being considered as the best. Extroverted form has the most energy consumption in both of two seasons.

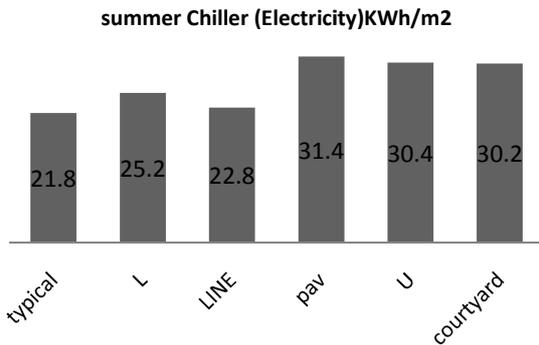


Fig. 9. cooling energy consumption

It seems that most of energy consumption in summer, which is applied to cooling the building, exists in U, Pavilion and Courtyard forms. In order of those three forms, creating window in to the eastern and western sides of buildings is caused to improve solar energy access and consequently rise the building temperature.

In L form as well as those three ones, there is not any eastern window but western windows (in order of municipality low) have been located in the patio. So, it would cause reduction of solar energy download that is received by western windows.

Two remained forms (Typical & LINE) because of their northern and southern windows have more various levels in gas energy consumption in winter rather than other forms. U, L and courtyard forms that are derived from combination of L form buildings need to an equal heating energy in winter. In such cases it could be concluded that form of building is more effective on energy consumption rather than open spaces between buildings. Typical and LINE form which has the same constructed parts are the witnesses of this claim. The greatest difference of energy consumption over a year between two forms of Typical and pavilion is 122.2 kwh/m2 which is a considerable range and indicate the significance of building allocation in a plot.

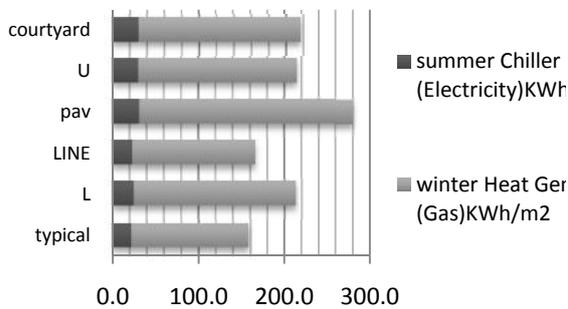


Fig. 10. Total energy consumption for heating and cooling

### Comparison of lighting energy consumption

In terms of energy consumption to exposure, central courtyard has the least and L form has the most energy consumption in this regard (figure. 10) according to consider that electrical energy consumption for cooling is more than energy requirement for lighting and total electrical energy consideration of buildings, typical form is the best choice again. (figure. 11)

### Comparison of daylight access in different forms

According to achieve daylight, extroverted and central courtyard forms have the most access and the scale of dark points (spots) are minimized in them. L and typical forms have the least access of daylight. As it is shown in the below figures (pictures) the most dark points (spots) are in these two forms.

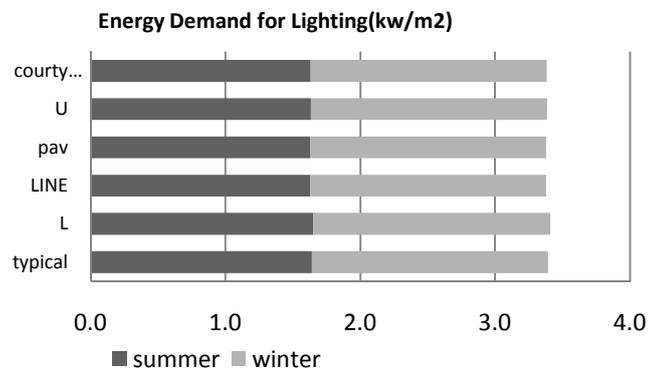


Fig. 11. annual consumption electrical energy for lighting

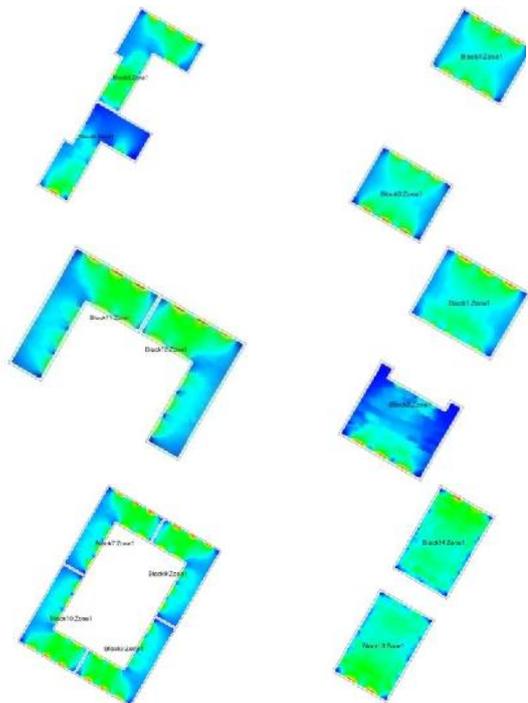


Fig. 12. Quality of day lighting in urban blocks

The typical forms, because of the close distance between buildings and using patio, have big dark space inside.

**SIMULATION OF PATIO**

According to the laws of municipality, not any complexes is allowed to create window in the neighbor's wall. Because of this, the southern blocks should have patio to access to the day lighting.

The placement of patio is based on the plan design. This article aims to study the affect of location of patio to Thermal behavior and energy demands in the building.

Six forms of patio investigated.

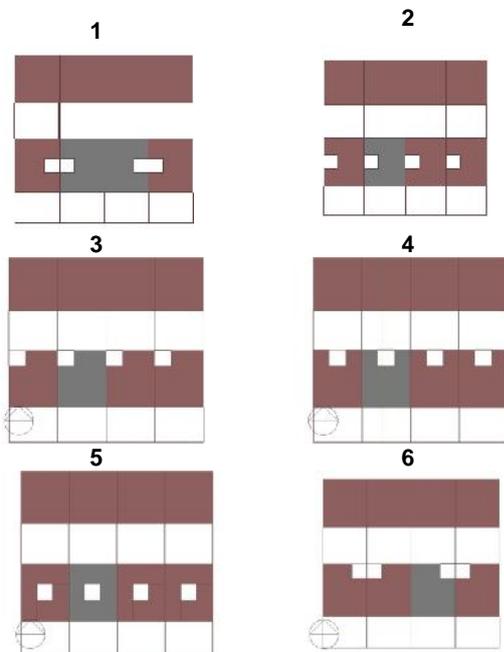


Fig. 13. The different location of patio in the buildings

Approximately, the energy demands for cooling in summer, in all forms, are same. It is because wind direction in summer. The wind direction in summer is 140 degree. As it can see in CFD analysis, the air flow through south windows is greater than the patio's window, So that the placement of patio in the building do not have affect on cooling ventilation in the building.

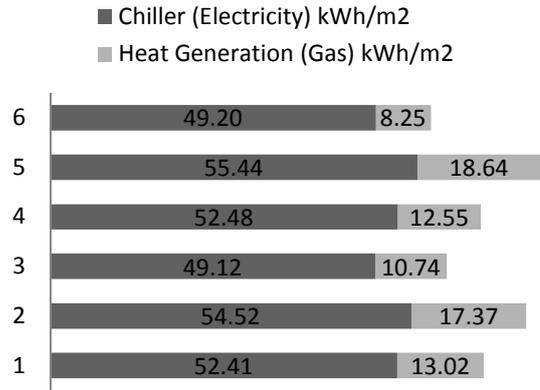


Fig. 14. Comparison of energy demands in buildings with different patio location

According to simulation, Form 3 has the lowest energy consumption and Form 5 has the highest energy demand.

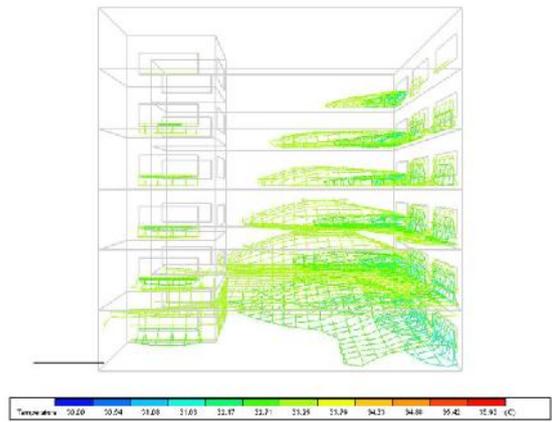


Fig. 15. The air flow through south windows in summer

**CONCLUSION**

Location of building in the site has a most important role in energy consumption and access to daylight.

The purpose of this paper is to compare the energy demands and day lighting in various forms of mass location within the site.

This result of investigation and comparison between the different forms is that the typical form is the best answer to energy consumption in summer and winter but has no good manner in day lighting.

However the linear form is not very different from conventional forms in energy demands whereas the dark spots are less than typical form and the quality and access to daylight is better.

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