BUILDING ORIENTATION AND ITS EFFECT ON HOUSE PLAN CONFIGURATION FOR THE CLIMATE OF LAHORE

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Abstract: This study on Passive design considerations for the solar orientation focuses residential buildings for its application in retrofitting the developments is proposed for energy conservation by the government and private sectors. This study integrates the experimental findings on test rooms at main orientations as a PhD dissertation for implementation in the residential sector in addition to many other identified features. Different practical environmental data is calculated for climatic consideration in architectural and urban design. The standard house planning and its configuration is presented in relation to orientation for the thermal control. The results of experimental study and simulations showed the SW an optimum orientation for heating and cooling requirements.
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1. Introduction

Solar access is the key factor affecting any building and it varies seasonally at a given geographical location hence there is a need to heat or cool the building within the available variations of sun at different orientations (Brophy at el., 2000). Thermal comfort, solar exposure and daylight in any built locality is affected by the buildings' orientation, form with the glazing ratio of each facade, adjacent topography and surrounding structures. It has been concluded in the literature review that, N-S orientations were performing better than the E-W. The planning of access roads on a site influences solar access considerably because it controls the plot orientation.

For urban design of housing, it is justified to divide innumerate climates into a limited number of zones , though it is difficult to classify (Sodha et al., 1986). Temperature is an important aspect of climate and has been used to grade climatic zones in the world on a scale of climatic archetypes as given in the following Table1.

Table 1 Climates are characterized by the temperatures.

Climate type	Temperature range
Hot	over 30 ° C
Tropical	with averages above 20° C
Subtropical	4 to 11 months above 20° C
Temperate	4 to 12 months at 10° to 20° C
Cold	1 to 4 months at 10° to 20° C
Polar	12 months below 10° C

Source: www.maps of world.com, accessed on 1st November, 2009.

The rate of heating and cooling of the surface of earth is the main factor determining the temperature of the air above it and the solar radiations have an indirect effect on the air temperature (Das, 2006), (Tzonis et al., 2001). Temperature difference on the earth's surface causes significant variations locally. Climatic conditions get changed by the variation of temperatures of land and sea on earth's surface. The diurnal and seasonal temperature variations are affected by the sky conditions (Olgay, 1963). The building envelope gets hotter when they are exposed to solar radiations, and the temperature inside the buildings vary than the outside air temperature due to the thermal properties of the envelope materials (Fry and Drew, 1964). Temperature is also affected by the altitude and orientation of a location. Pakistan has a variety of climates and climatic zones like very cold, humid, arid range in addition to hot and very hot. The southern parts of the country receive heavy rains. The northern part is outside the monsoon belt. The extreme northern areas are dry and experience very cold winters with heavy snow fall but mild summers. However, July and August 2010 showed a significant climate change in the northern and western parts of the country. The city of Lahore has the changing seasons which set a difficult task for the building designers.

For a building designer and architect, all the parameters of weather are important including wind speed and its direction, sunshine hours, solar radiations and the relative humidity of the air in order to apply thermal considerations. Therefore, for

thermal comfort estimation of cooling or heating loads in buildings are important.

Pakistan has a wide diversity of habitat due to the large variation in climate and landform. The climates vary from hot, dry desert, temperate in northwest, and arctic in the north (Figure 1). Pakistan has the cold mountainous area, the high desert of Baluchistan and the hot desert of the Indus and the warm humid breezes of the coastal areas. Five different climatic regions have been recognized in Pakistan due to diverse climatic conditions and through the seasonal extremes of the climate, as shown in Figure 3.4b, classified by ENERCON, (1990).

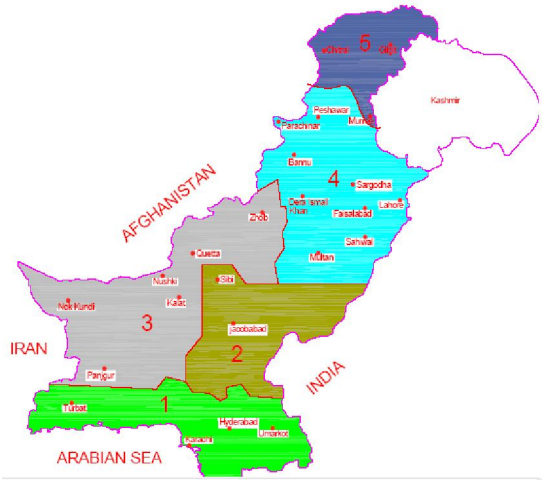

Figure: 1Climatic zones of Pakistan.

Source: ENERCON, Manual (1992), Islamabad.

Each zone also has its own architectural and cultural variations. Lahore is located in the Zone 4, which is characterized by the high summer of May and June when midday temperatures rise well past the forties. During the cold weather of December and January, the night time temperatures fall close to freezing.

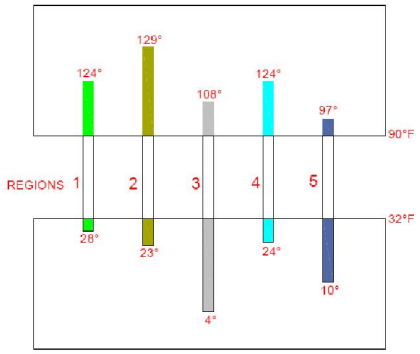

Figure 2 Maximum and minimum temperatures recorded in Lahore.

Source: Enercon, Building Energy Codes for Pakistan.

The Earth's orientation affects the amount of solar radiation received at different latitudes on earth. Figure 3.2 demonstrates the positions of the Earth in its orbit and it varies from declination angle of +23.5o on 22nd June (summer solstice position) to -23.5 o on 22nd December (winter solstice). The zero declination angle on both, 21 March and September 22 (Equinox positions), is important to understand the building design problems.

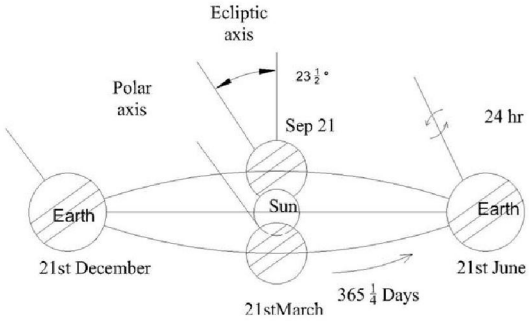

Figure 3 Relative positions of the Earth and Sun throughout the year.

Source: Solar Passive Building, book published in Oxford Pragamon Press, 1986.

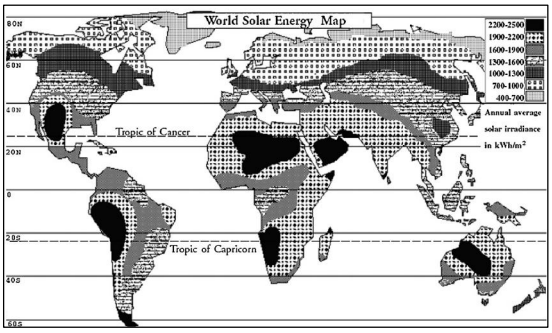

Figure 4. Global solar radiation Map of the World. Source of images: Gordon Weyn and Energy Sector

Assessment for USAID/Pakistan June, 2007 and Jan Kreider, Advanced Solar Design, College of Engineering and Applied Science, Department of Civil, Environmental and Architectural Engineering, University of Colorado at Boulder, USA.

The climate of earth is determined by the energy input from the sun. The solar geometry and the energy flows from the sun are important at a location on earth with regard to passive design technique.

It may be depicted from this map (red spot) that the annual average solar irradiance of about1900 to 2200 kWh/m2, is falling on the latitude of Lahore as shown in Figure 4.

The latitude of Lahore varies from 310 15' to 310 45'and Longitude from 7401 to 740 39. Lahore is situated at an elevation of 213 meters (712 feet) above the mean sea level.

Though the principal climatic elements of any location are solar radiation, temperature, humidity, wind, precipitation and special characteristics such as lighting, earthquakes, dust storm and so on when human comfort and building design are considered (Konya, 1980) but it may also be stated that the rate of recurrence of certain amount of climatic data for example monthly mean minimum and maximum temperatures, their diurnal range, monthly mean, maximum & minimum relative humidity and wind direction and velocity for any location must also be collected and analyzed. The average minimum and maximum temperatures in different months of the year in Lahore are shown in the Table 2.

Table 2 Average Minimum and Maximum temperatures in different months of the year in Lahore.

Months	Average max. Temp.	Average min. Temp.	Months	Average max. Temp.	Average min. Temp.
January	19.8oC	5.9oC	July	36.1oC	26.9oC
February	22.0oC	8.9 oC	August	35.0 oC	26.4oC
March	27.1oC	14 oC	September	35.0 oC	24.4oC
April	33.9oC	19.6oC	October	32.9 oC	18.2oC
May	38.0 oC	23oC	November	27.4 oC	11.6oC
June	40.4 oC	27.4 oC	December	21.6 oC	6.8oC

2. SUNSHINE HOURS IN LAHORE

It is an established fact that the duration of daylight varies over different Latitudes and various seasons on earth. The sunshine hour is the time between sunrise and sunset at any latitude on any day. Sunshine hours recorded for the year January 2008 to August 2009 by the Meteorological Department, Lahore are shown in the Table 3.0 The total sunshine hours in 2008 were 2720.80, indicating the comparative severity of the sun shine in the different months of a year in Lahore. The greater hours of sunshine in 2009 in summer season indicate that a higher cooling load requirement in the buildings as compared to heating requirements in the winter season in Lahore. The greater number of sunshine hours can be related to the low cloud cover in the respective months and availability of less cloudy hours which is associated with low humidity in the air.

Table 3.0 Total sunshine hours in the year 2008 and 2007 (metreological department)

Date	Jan.	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2008	199.9	204.3	264.2	261.9	269.9	204.5	202.5	211.3	255.6	248.9	221.4	176.4
2009	185.2	220.3	238.5	276.2	310.5	308.7	252.9	228	-	-	-	-

Source: Meteorological Department, Lahore.

It is clear from the above table 3 that the sunshine hours are the maximum in the month of May. The buildings can be oriented according to the sun path sun in the respective month for the desired amount of sunshine.

3. IDENTIFIED FEATURES OF HOUSE PLAN CONFIGURATION

For the sustainability, the form of residential plans in Lahore are studied, the essential elements of planning are identified after wide survey of the new and older developments in and around Lahore. The houses are found whether at large or small scale, contain essentially some architectural spaces to be designed or planned in different configuration. They are listed in the following Table 4.

Table 4 Essential architectural design components of a house.

Essential Features/zones	Optional features/components
Car –Porch	Terrace
T.V Lounge/Living-room	Verandah/s
Drawing- room	Powder- room
Dining- room	Study- room
Bed- room/s	Store- room
Bath room (attached)	Dressing- room
Kitchen, (dry and wet)	Pantry
Stair- case	Laundry
Servant- quarter	Guest- bed

Unlike other buildings, the residential buildings are occupied in one way or the other for whole of the 24 hours and therefore they must be considered for thermal comfort for the whole day and night. There can be a number of orientations in any locality and the components/zones in a house can face any orientation. Windows being the main recipient of solar load are more important in orientation. In general practice, windows are provided for the view and aesthetic consideration of the facades by the professionals and the users. Day lighting, ventilation and solar loads are not given priority in design.

The orientation can be related to the sustained house plan configuration in Lahore, as follows:

1- Almost all the residences are comprised of a number of zones and each zone in a house planning can have different temperature profile due to different exposure to sun resulting in a different heating or cooling load and therefore each zone can have an independent heating and cooling system.

2- The different temperature profiles result in different solar- loading conditions imposed by outside environmental conditions through the building envelope. The loads are mainly due to the sun and its orientation facing each zone. Other loads are internal loads from the artificial lighting, occupants, air leakage and ventilation. All these loads are lower in comparison to the other building types.

3- Residential buildings usually are of smaller size single or double story houses in practice in Lahore. Multi- family houses are similar to the single- family detached house which has exposed walls in all the four directions. In some cases various zones in a house plan may have certain exposure to the sun which might not be the desired orientation. As the Architectural Design is dictated by aesthetical consideration which may impede the integration of passive features when they are without quantification. It is essential that each zone in a plan configuration should have proper load calculation (ASHRAE 2002).

4- The flow diagram including essential and optional features of a typical house form are shown in Figure 5. The main entrance to the house is essentially attached with the car porch. The drawing room and the guest rooms are approached either through a lobby or passage directly linked with the TV lounge/ living room. The living room and the dining room are connected with the kitchen so that guests from the drawing room can reach the dining room with maintaining the house privacy requirements. The bed rooms including master and the children bed are designed together and have a direct social link with each other.

5- The plan configuration contains the architectural spaces exposing to different orientations. Despite the guidelines for the energy efficient house design, each zone in a house plan configuration does not seem to have the desired orientation because of the typical house form and space organization. Therefore, a quantitative knowledge regarding the positioning and laying the living spaces in a house plan can be given priority with relative effect to the solar exposure.

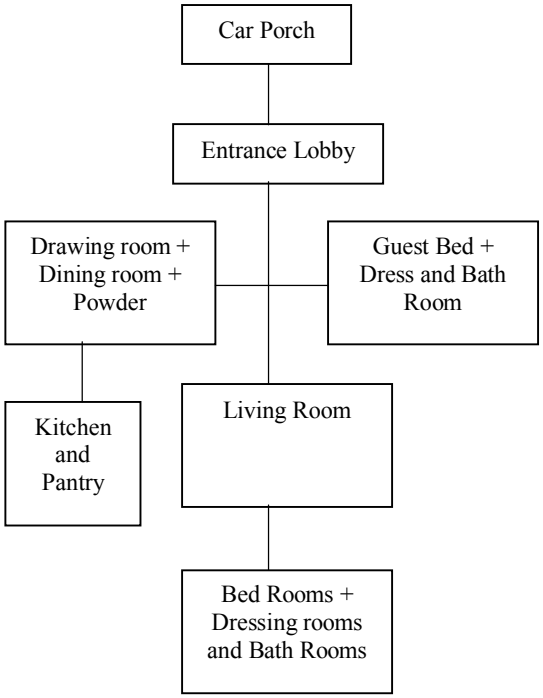

Figure5:Identified essential features of a typical house plan configuration

The flow chart of activity is shown in the above figure which attained its form due to the social, cultural and functional needs of the society. The guest room essentially has to be placed near the entrance lobby. The living room has acquired a central location as it is assumed to be the center of activities in a residence. The bath rooms are attached to the bed rooms mostly through a dressing room. Thus each component or zone in the plan configuration has a special character attached with its space and function and need a special solar exposure for the indoor thermal comfort.

3.1 SUN PATH CHART FOR LAHORE AND PLAN CONFIGURATION

The Sun Path Diagram (SPD) is the graphical projection of the arc of sun through the sky on to a horizontal plane. The horizon is represented by the outer most circle and the observation point in the center (Figure 6). The solar radiations greatly vary with the weather, latitudes and altitude. Pakistan

is located between the 25o N and 35o N latitudes where the percentage of the direct solar radiations are very high (ENERCON, 1992). The direct radiations affect the buildings greatly by entering through the windows. The SPD can be used for any latitude to determine the position of sun in terms of angles of altitude and azimuth angle at any hour of the 21 day of each month. SPD for Lahore, Pakistan is shown in the Figure 3.7a.

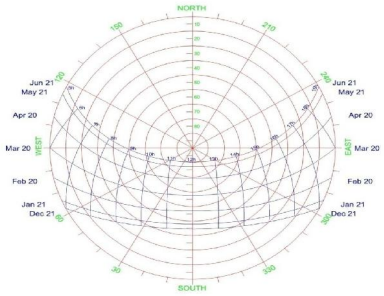

Figure6: SPD for Lahore, Pakistan.
Source: ENERCON Design Manual, 1982.

The altitude angles are represented by concentric circle spaced at 10 degrees interval. Zero degree represents the outer circle and 90 degrees is the center point. The radial lines represent the azimuth angles. Twenty first day of each month is denoted by the elliptical curved lines superimposed on the concentric circles. Each sun path line is marked with twice path of two months as it is composed of two halves. Cross lines at right angles to the circles show hours of the day listed at the upper most line of sun paths.

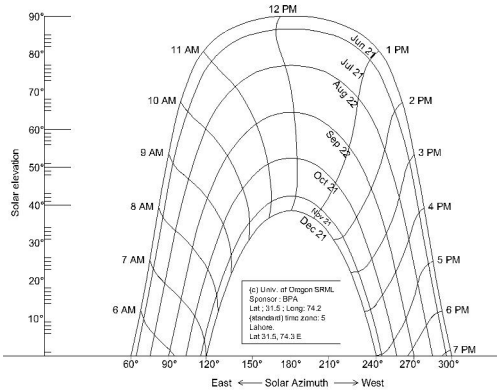

Figure 7: Sun altitude against the Azimuth Angles for 32o N, Lahore.
Source: University of Oregon, Solar Radiation Monitoring Laboratory (2008).

For finding the position of sun in Lahore, 32o N latitude, mark the sun path line of month and locate the time line perpendicular to it. On the crossing of these lines, the altitude angle can be read on the concentric circles. Following this point towards the radial lines, reading on the outermost circle gives the azimuth angle as described above for the summer and winter solstice dates. The minimum and maximum altitudes attained by the sun paths on 32 0N latitude are 34.5o and 81.5o.

The sun's rays have an altitude of 0° at 5:00 a.m., on 21st June as shown in the SPD for the latitude of Lahore. The sun's azimuth angle at 6.00 am is 62o E/W and 118o E/W on 21st June and 21 December respectively. It has an altitude of 12o according to SPD at 6.00 a.m, in Figure 3.7b on the summer solstice day; whereas, the altitude angle reaches 81.5 at 12 noon on the same day. The Altitude angles for summer and winter solstice positions in Lahore are shown in Figure 3.6. The azimuth angles for the summer and winter solstice positions are S62o E/W and S118o E/W. The azimuth angles east ward in the morning and westward in the afternoon. The SPD is the appropriate way for determining the position of sun at any hour or any day of the year. The SPD is composed of two paths of summer and winter solstice positions of sun. Therefore, each line of sun path is marked with two Roman numbers on the SPD.

As the city of Lahore lies in the northern hemisphere, theoretically, the solar radiations on south facades receive three times more radiations in winter months than other orientations of facades. Whereas, in summer period, the south facades receive the lesser amount of radiations than eastern or western facades except north facing façade of a building as the sun never goes to the north orientation (SPD, Figure 3.7a). Amount of sunlight is greater in summer due to longer sunshine hours than in winter therefore sunlight is distributed towards east, west and south orientations of a building. The impact of solar radiations on four cardinal directions and the horizontal surface of a building are shown in the Table 5.

Table 5 Impact (BTU/ sq.ft/day Radiations on different orientations of a building at 32o N Latitude

Season	East	West	North	South	Roof
Summer	1207	1207	452	563	2596
Winter	620	620	140	1606	954

Source: Crowley and Zimmerman, 1984.

It is evident from the above table that the solar radiations are greater in winter on south orientation and lesser on east and west orientation

whereas in summer, the impact is reverse. Similarly, in winter season the impact of solar radiations increases from 8.00 am to the maximum at 12 noon and then deceases at 4.00. p.m. However, the west exposure is more troublesome for buildings in summer due to higher afternoon temperatures combined with the effect of radiations.

4.IDENTIFIED SOLAR ALTITUDE ANGLES FOR LAHORE

The Solar Altitude Angles for 32oN latitude calculated by the author for the location of Lahore and the value for important dates are reproduced in Table 6.

Table 6 Solar Altitude Angles at noon for the solstice and equinox positions
at 32o N, Lahore.

Month and Date	Ka (solar altitude coefficient) (Butler 2002)	Altitude of Sun at noon due south in degrees
21st January	69.5	37.5
21st March and 21st September	90.0	58
21st April	101.5	69.5
21st June	113.5	81.5
21st September	90.0	58
21st October	78.5	46.5
21st December	66.5	34.5

As a rule of thumb, the sun's altitude on equinox at noon (21 March and 21 September), is 90 minus the latitude of the given site. This information of altitude angle on the site can be helpful in designing shading device with south orientation on these dates. The altitude of sun is the smallest on 21 December and the earth's axis is tilted away from the sun for northern hemisphere (Figure 8).

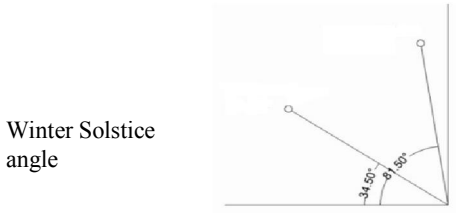

Figure 8 Calculated altitude angles for solstice positions of sun in Lahore.

5. ANALYSIS THROUGH SIMULATION

While incorporating the sun path chart and the weather data for Lahore, simulations were also conducted to verify the experimental data and results. The house plan configuration simulated was as shown in Figure 9.

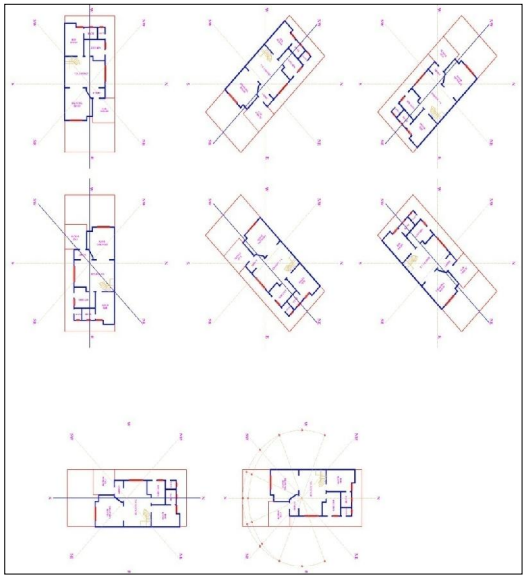

Figure 9: Simulated house plan configuration

The results of the study showed that significant part of energy can be conserved by appropriate control of heating and/or air conditioning. The results of experimental study and simulations showed the SW an optimum orientation for heating and cooling requirements.

CONCLUSIONS

As evident from the above theoretical considerations for a passively designed energy efficient house design in Pakistan, it is very important for the building design professionals and researchers to incorporate the solar data provided in this study for the buildings sustainability.

Although the passive design guidelines are available for different climatic zones in the world but the key information for controlling the sun in either summer conditions or for winter seasons are not available in the country particularly for the fast growing cities. Many studies in the literature review have demonstrated that the sun affects the temperatures inside the buildings depending upon the orientations. Thereby, these orientations affect the heating and cooling of those spaces for thermal comfort inside. Local climatic conditions are required to be known especially the ambient temperature behavior which affects the indoor temperature

profiles in various zones of a house configuration. In which windows, their respective sizes, site conditions and material of building envelop with respect to sun orientation are very important.

This study on Passive design strategy for the solar orientation focuses new or old buildings for its practical application in retrofitting the existing residences and development of new urban settlements by government and private sectors. The study for orientation in occupied houses has the limitations due to the lack of control of various environmental factors by the occupants. Therefore a complete passive design solution regarding solar data is suggested for the architects or building professionals for the adaptation of orientation in house plan configuration.

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