Proceedings of 8th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2020 Month: June Volume: 8

Effect of Orientation on the Energy Consumption Pattern of the Existing Building

Samisha Budhathoki [a], Sanjaya Uprety [b]

[a, b] *Department of Architecture and Urban Planning, Pulchowk Campus, IOE, TU, Nepal*
Corresponding Email: [a] arsamisha.tundi@gmail.com, [b] suprety@ioe.edu.np

Abstract

The number of buildings is increasing abruptly and is constantly raising the issues of the energy crisis. Some several researches and guidelines have been made to reduce the energy consumption for the new construction buildings, however, there are numerous existing buildings that are consuming the huge amount of the country's energy. Therefore, it is important to study energy consumption by existing buildings and different energy retrofit methods. Energy retrofit measures are categorized into passive and active retrofit measures which include the improvement of building envelope, mechanical and electrical systems. This paper focuses on the effect of building orientation, which is one of the most important factors that affects the amount of energy consumption of the buildings. The "Ecotect analysis" software is employed to test different orientations of the existing commercial building, to obtain the importance of orientation with low energy consumption. It is found that amount of the building oriented at all directions consumes a high amount of energy for cooling purposes, while the building facing South-West consumes the maximum amount of total annual energy of 41314 Whr/sq. m/year and the building facing North-East consumes the minimum amount of total annual energy of 31361 Whr/sq. m/year. However, the load require for cooling purpose in southern direction is 11 percentage greater than that in Northern direction and the load require for heating purpose in Northern direction is 23 percentage greater than that of the Southern direction.

Keywords

Building Orientation, Passive techniques, Mixed-use Commercial Buildings, Energy Consumption

1. Introduction

Unfortunately, retrofitting of existing buildings in the third world countries focuses on structural or aesthetic measures and mainly on historical buildings for conservation [1].The energy efficiency measures are equally important for all other types of buildings as in terms of primary energy consumption, buildings represent around 40 percentage in most of the countries. Likewise, in Nepal, the energy consumption by buildings accounts for 89 percentage of the total energy consumption of national consumption [2]. There are numerous research and guidelines for the new construction for buildings of Kathmandu Valley which only serve to limit the rise in energy consumption but it does not reduce the current energy consumption. Therefore, it is utterly necessary to retrofit energy strategies in existing buildings to make sustainable development.

There is a huge number of commercial buildings being built without adopting the energy efficiency measures especially in the case of the growing city of Kathmandu Valley. According to Shakya [3], the commercial sector of the Kathmandu valley shares 10.8 percentage of the total energy consumed in 2012. The use of energy in buildings is increasing and CO2 gas emission has grown at the rate of nearly 1 percentage and electricity by 2.5 percentage [4]. The bylaws formed by the municipalities for commercial buildings only focus on ground coverage and floor area ratio and less attention is given to the energy efficiency measures and performances of the building. Hence, Retrofitting is the best option to reduce the energy consumption pattern in commercial buildings.

Existing buildings consume a huge amount of energy as they are designed poorly in terms of energy efficiency. One of the main factors for energy efficiency is the orientation but in Nepal, most of the buildings are faced according to the orientation of land and road, which doesn't receive the proper solar radiation according to their climatic condition. This research is intended to presents the methods for improving the energy efficiency of existing commercial buildings which are oriented differently. It mainly focuses on the effect of building orientation on the amount of energy consumed at the different orientations during critical months of winter and summer annually.

2. Literature review

Retrofitting can be defined as "the process of modifying something after it has been manufactured" and likewise the definition, the retrofitting in buildings is the process that involves changing its system or structure after its initial construction for the better thermal performance of the buildings and improve amenities for the building's occupants. Energy retrofit can be simply categorized into convectional and deep energy retrofit. In convectional energy retrofit, usually simple and fast methods are used and the different system is considered separately [5]. Because of the high cost of the active techniques, which rely on energy generation inside the building, this research deals with passive solar technologies that can be employed for the building design and operation.

Passive strategies for building design and processing help to avoid heat gain and to reduce cooling loads. This leads to reducing energy consumption in summer and winter periods and along the entire year and provides a range of thermal comfort for users in addition to reducing dependence on mechanical means [6]. The concept of using passive design strategies began in Europe which not only ensures thermal comfort but also energy efficiency in the buildings [7]. The first European passive house was built in Darmstadt, Germany in 1991. According to Passivhaus primer, more than 30,000 buildings have been constructed until now that work on Passive house principles [7]. Some of the important Passive solar strategies required for the energy retrofitting of the building to control the consumed energy and achieving thermal comfort are listed below:

2.1 Orientation

Orientation is an important design strategy for reducing energy consumption and improving the thermal comfort for the occupants of the building. Building orientation has been decided by the influence of views, prevailing winds, housing layouts, site topography, nearby buildings, etc [8]. Other times urban planning depends on older planning, road existing layout, which purpose is the ease of execution, road camber, etc. [8]. Also, Orientation affects the amount of sun falling on the surfaces, day lighting, and direction of the winds. It also has a significant impact on building's energy efficiency, towards net-zero energy goals, by harnessing the sun and prevailing winds to our advantages. Most of the time, the design of the buildings does not consider the energy-saving of this energy-efficient factor (orientation). Take into account prevailing winds to design building layout to make cross ventilation, or rotate the building to have solar gains in winter are restricted by the above reasons [8].

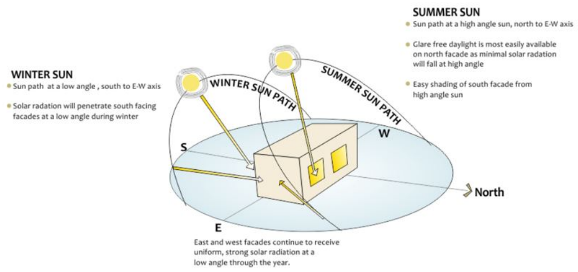


Figure 1 Solar Orientation at the Site

Figure 1: Solar Orientation at the Site

2.2 Thermal Insulation

Thermal insulation provides a region of insulation in which thermal conduction is reduced or thermal radiation is reflected rather than absorbed by the lower-temperature body. These thermal insulation products can be applied on both external and internal surfaces, but the software models developed by TRNSYS show that using external insulation has 8 percentage better energy performance, while the internal thermal insulation leads to 50 percentage less investment cost and lower payback period [9].

2.3 Window-wall Ratio

Windows and doors can account for more heat gain and loss than any other element in an isolated building envelope. While they may constitute only 8-10 percentage of the thermal envelope of a building. A well-designed glazing system can improve internal daylight levels, reduce glare, and help maintain thermal comfort by reducing heat gain and loss.

Glazing and its requirement can vastly depend upon the building orientation. Glazing on south-facing walls can be reasonably large. Where there is good solar access and exposed concrete floors to provide thermal mass, south-facing windows should be approximately 10-15 percentage of the total floor area.

2.4 Different Orientation patterns and their impact on reducing energy and achieve thermal comfort

Building orientation and openings play an important role in achieving thermal comfort and reduction of energy consumed in cooling, heating, lighting, or any other purposes [6]. It is found that many studies prefer to take the building longitudinal direction axis along the East-West Direction so that the southern façade takes the largest amount of the heat in the cold period as the north façade takes less amount in extremely hot period, depending on the azimuth and elevation angles of the sun in summer and winter [6]. Therefore, this research paper studies the different orientations and their impact on reducing energy consumption to reach the best orientation to achieve greater thermal comfort.

3. Methodology

This study is based on qualitative and quantitative methods. For the qualitative method, the energy retrofitting strategies in the commercial buildings will be studied through literature. Likewise, for the quantitative method, there will be a comparison between the existing and energy retrofitted buildings by developing an energy performance modeling concerning the best-fit climate-responsive retrofitting strategies, field base material surveys like building types, materials, and techniques. The impact of different orientations on the study model is calculated every direction in the selected study area, Old Baneshwor, Kathmandu.

4. Simulation Tool Description

The “Ecotect” simulator is an energy simulation program that is used to study the effect of orientation on energy consumption of the model at every 900. The amount of energy consumed per year is monitored to report the change during the critical methods in the summer and winter.

Simulation is carried out using the Ecotect Analysis 2011. The base simulation model is created according to current construction details, materials, and systems. The purpose of creating a base model is to estimate the annual energy consumption of conventional construction practice for the existing building. This way, it can be possible to compare the role and sensitivity of each component and system after proposed energy-efficient techniques in terms of total energy consumption. The methodology used in this paper is to establish the building model by Ecotect software based on the weather data, and the building performance (such as indoor thermal environment, indoor lighting environment, and solar radiation level) influenced by the variable design conditions are simulated.

5. The Study Area

The haphazard transformation of old houses at two fronts-replacement of 3-4 story residential houses by 6-7 commercial use or mixed-use with modern reinforced cement concrete structure – has not only to destroy the community bonds and cultural spaces in the neighborhoods but also reduced the thermal comfort inside the buildings [10]. Construction of commercial complexes in core city areas of Kathmandu has surged of late. With the Capital’s major business areas getting crowded by the day, multi-storied business complexes have indeed become a necessity.

Baneshwor, which used to be the largest residential area of Kathmandu, now are being transformed in the multi-purpose hubs. In recent years, Baneshwor has become a local financial and educational hub hosting several national banks, institutions, shopping centers, and office buildings [11]. Since it’s being one of the oldest towns, it is being used for several commercial purposes, especially around the main roads, and also residential buildings are converted into multi-use commercial buildings. The urban area in the valley increased from 3 percent in 1967 to 13 percent in 2000 [12].

For further research, a specific area in Old Baneshwor was selected as shown in Figure 5. The orientation of the main road is from east-west, the maximum of buildings located in this area are faced on North and South direction to utilize the space for commercial rental shops which can be seen from the street elevation given in figure 2.

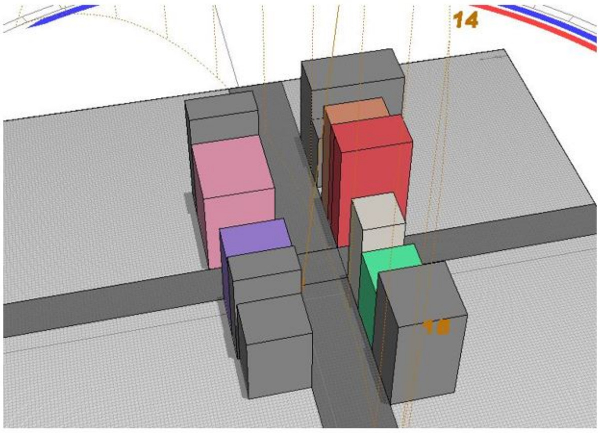


Figure 2: Energy Modelling of the study area

5.1 Data set

For the design, the area of the building modeled in Ecotect 2011. These buildings are oriented towards North and South as per the prevailing site condition. The view of the building selected for the modeling area based on the magnetic compass results in the orientation as per the figure.

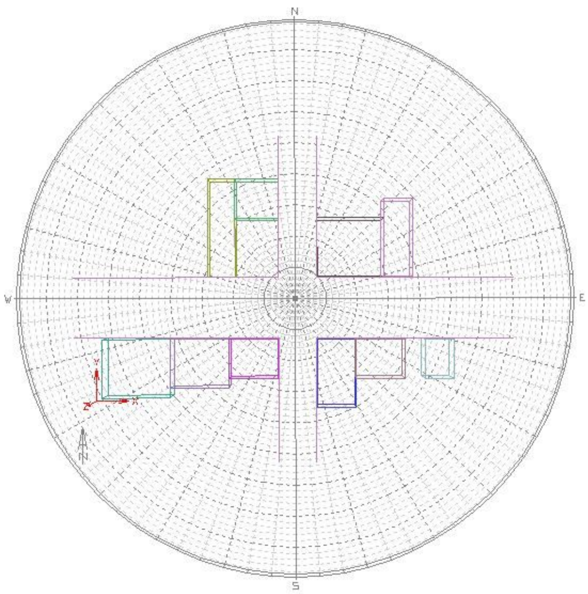


Figure 3: Orientation of the study area

This paper analyzes the different type of multi-use commercial buildings concerning their orientation, to find out the effect of orientation on the amount of energy consumption within particular the semi-attached buildings, because it is fairly generalized in the surrounding of Kathmandu. To obtain the best orientation for maximum energy saving, different orientations are tested.

The base case building has been adopted to research the thermal performance by the simulation model in Ecotect (2011).

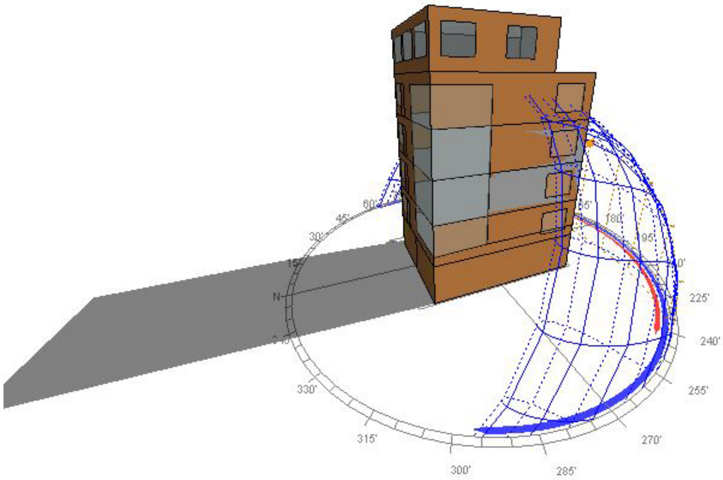


Figure 4: Sun Path of the selected building facing North-West

Table 1: Research Sample Characteristics

Parameter	Building (North-West)
Area (Sq. ft.)	740
Layers of the building (exterior)	Brick, Cement, plaster, Concrete Glazed Panel
Lighting	300 Lux LED
Heating and Cooling system	Heater
Window ratio	21.9 percentage
Glass type	Single and Double

5.2 Thermal characteristics of the study area

Table 2: Thermal Characteristics of Study area

	Longitude		$85^{0}7'$ to $85^{0}37'$	
	Latitude		$27^{0}36'$ to $27^{0}50'$	
	Elevation above sea level		1340 m	
Solar Radiation	Exposure to direct solar radiation is strong and the proportion of high surfaces in the summer			
Temperature	**Average Low**		**Average High**	
	Summer	**Winter**	**Summer**	**Winter**
	20.2^{0}C	3.17^{0}C	30.24^{0}C	21.07^{0}C
Relative Humidity	Relative Humidity is relatively high and swinging between 53% - 85%			
Rain Range	Wettest month (with the highest rainfall) is July (363.4 mm) and driest month (with the lowest rainfall) is November (8.33 mm)			
Wind Wheel	The average wind speed is about 0.95 m/s and the maximum wind speed reaches up to 13.4 m/s in May. The prevailing wind direction is westerly.			

6. Analysis and Results

The base case model facing towards the North-West has been adopted to research the thermal performance by simulation model in Ecotect (2011), representing a rectangular-shaped office building, with plan spaces, thermal zones, with 6 floors total. The base case scenario involves conventional construction technology.

The total surface exposed to the outside environment is 7416.07 sq. ft. and the window area is 1034.16 sq. ft. (21.9 percentage). The orientation of the building is North-West with a single and double (6mm-12mm-6mm) glazed facade. The following are the result of the analysis.

6.1 Building facing NE

The main facade of the building facing towards North-East at an angle of 45 degrees as shown in the figure.

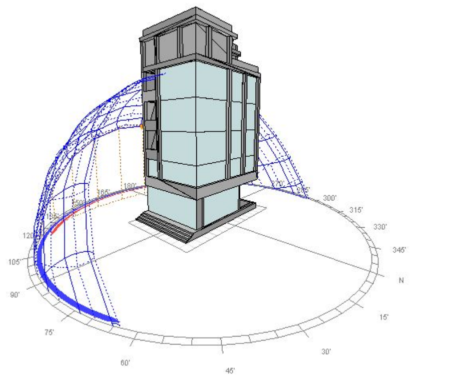


Figure 5: Building facing North-East

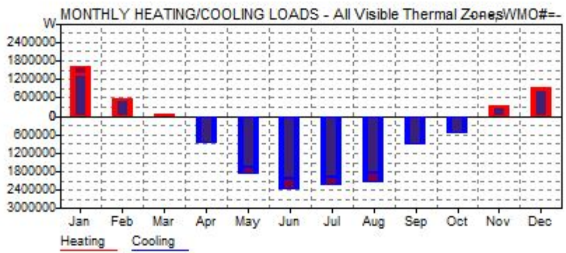


Figure 6: Monthly loads/discomfort

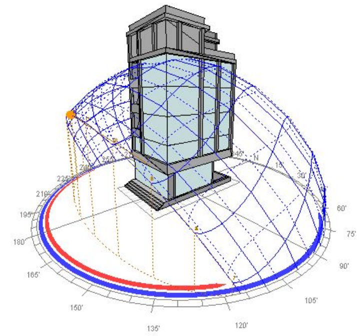
Max Heating: 21457 W at 11:00 on 5th January

Max Cooling: 24590 W at 13:00 on 27th August

6.2 Building facing SE

The main facade of the building facing towards South-East at an angle of 135 degrees as shown in the figure.

Figure 7: Building facing South-East



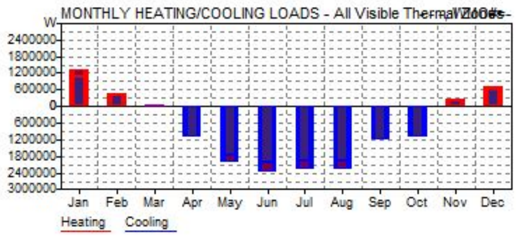


Figure 8: Monthly loads/discomfort

Max Heating: 19413 W at 21:00 on 1st January

Max Cooling: 26238 W at 13:00 on 27th August

6.3 Building facing SW

The main facade of the building facing towards South-West at an angle of 225 degrees as shown in the figure.

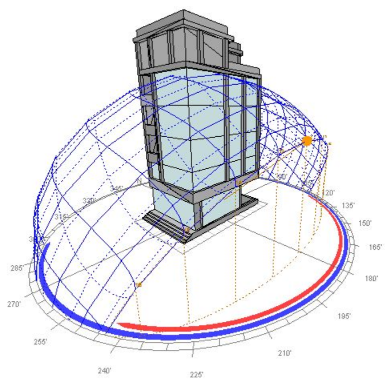


Figure 9: Building facing South-West

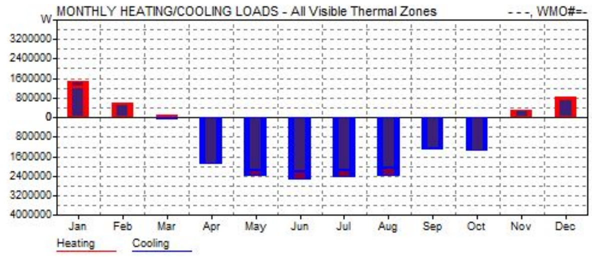


Figure 10: Monthly loads/discomfort

Max Heating: 19413 W at 21:00 on 1st January

Max Cooling: 31143 W at 15:00 on 30th May

6.4 Building facing NW

The main facade of the building facing towards North-West at an angle of 315 degrees as shown in the figure.

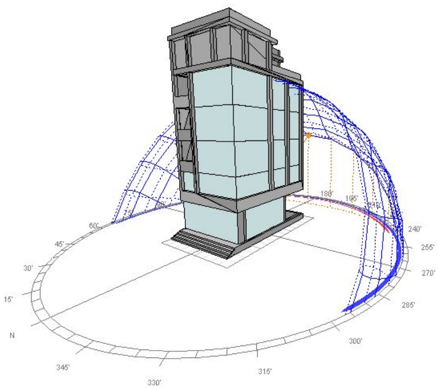


Figure 11: Building facing North-West

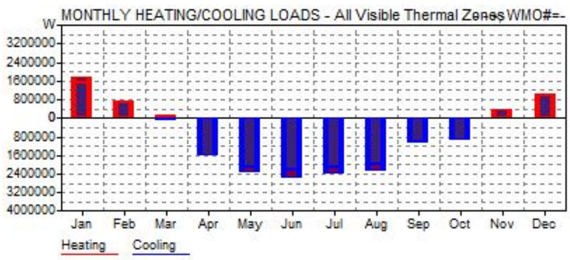


Figure 12: Monthly loads/discomfort

Max Heating: 22908 W at 11:00 on 5th January

Max Cooling: 30112 W at 17:00 on 30th May

Table 3: comparison of annual energy demand in different cases

Load (Wh/sq. m)	NE	SE	SW	NW
Heating	11044	6475	6366	9339
Cooling	20317	28169	34948	30283
Total	31361	34645	41314	39622

Table 2 shows the annual heating and cooling load calculated in Wh/sq. m/year for the simulation building orientated in a different direction by using Ecotect analysis.

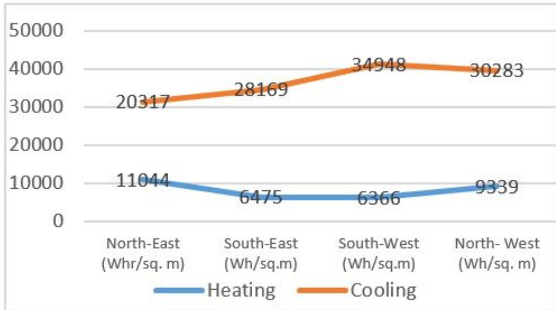


Figure 13: Total energy consumed annually in the cooling and heating in different directions

7. Findings and discussions

As can be observed for the above graphs and tables, heating and cooling loads are responsible for the energy consumed at different orientations. Moreover, most of the energy is consumed for cooling. The highest total energy load is consumed by the building facing South-West required 41314 Wh/sq. m/year, out of which lowest energy required for heating purposes among all other buildings required is 6366 Wh/sq. m/year. Followed by the building facing North-west consumed the total load of 39622 Wh/sq. m/year. The lowest total energy is consumed by the building facing North-east, as the energy required for the cooling purpose is 20317 Wh/sq. m/year, which is the lowest load required amongst the others, but the energy required for heating purposes is highest at 11044 Wh/sq. m/year. Likewise, the building facing, south-east consumed the total energy load of 34645 Wh/sq. m/year.

This represents the folds of heating loads around the southern and western directions. The above results, show that the southern façade receives warm during the winter months. Additionally, it shows that the east-south direction makes the energy consumed in summer significantly less than that in the south-west orientation.

The difference between the maximum and minimum energy demand is 9953 Wh/sq. m/year, which is very low in terms of KWh/sq. m/year. This results, that although the orientation is a factor to consider if energy saving is the objective, its influence on the total energy demand is not much important compared to other factors such as infiltrations, thermal inertia, and insulations.

8. Conclusion

With the help of computer simulation techniques, it is possible to derive the energy consumption annually at a different orientation. From the result it can be concluded that for the case of semi-attached mixed-use commercial buildings, with high sizes of windows in the main and rear facades, the optimal orientation is east to west to obtain the lower heating and cooling demands. Since, the maximum load is required for the cooling purposes, the opening should be at south façade for gaining the heat during the winter, in spite of the highest total annual energy is consumed in the southern direction, around 11 percentage of cooling load higher than that consumed in Northern Direction.

However, the optimum orientation for the least total annual energy consumption is the North-East, the total energy required for the heating purposes is 11044 Whr/sq. m/year, highest among all other buildings. The total annual energy required for heating purposes in the Northern direction is 23 percentage times greater than that in the southern direction. Therefore, for the climatic condition of Kathmandu, the best orientation is towards east and west, with large openings on southern directions to obtain maximum solar heat energy. Thus, in the designing of the buildings, the building orientation is not a determining factor because of the low energy saving, but it allow to have low energy consumption to reach thermal comfort.

References

[1] Ingy El-Darwish and Mohamed Gomaa. Retrofitting strategy for building envelopes to achieve energy efficiency. *Alexandria Engineering Journal*, 56(4):579–589, 2017.

[2] Nepal Kathmandu. Energy sector synopsis report nepal. 2010.

[3] Shree Raj Shakya. Training manual for engineers on solar pv system. Technical report, Technical report of alternative energy promotion centre (aepc) & energy . . . , 2011.

[4] IEA Energy and C Change. World energy outlook 2017, 2017.

[5] John Zhai, Nicole LeClaire, and Michael Bendewald. Deep energy retrofit of commercial buildings: a key pathway toward low-carbon cities. *Carbon Management*, 2(4):425–430, 2011.

[6] Rania Elghamry and Neveen Youssef Azmy. Buildings orientation and it's impact on the energy consumption. *ReasearchGate*, 2017.

[7] Yam Prasad Rai. *Improving Thermal Comfort of Residential Buildings in Kathmandu using Passive Design Strategies*. PhD thesis, University of Liverpool, 2014.

[8] G. Ramos Ruiz and C. Fernandez Bandera. Importance of orientation in building energy–saving. *WorldSB14*, 2014.

[9] Dionysios I Kolaitis, Emmanouil Malliotakis, Dimos A Kontogeorgos, Ioannis Mandilaras, Dimitrios I Katsourinis, and Maria A Founti. Comparative assessment of internal and external thermal insulation systems for energy efficient retrofitting of residential buildings. *Energy and Buildings*, 64:123–131, 2013.

[10] Bijaya K Shrestha and Sushmita Shrestha. Transformation of traditional building stocks in the historic core of kathmandu: Looking through the prism of culture and climate. *Protibesh: Environment, Journal of the Department of Architecture*, 13(1):5–16, 2009.

[11] Ar Sarah Jane S Pahimnayan and UAP REB. Architectural design arch 222.1 & arch 223.1. 2018.

[12] Bharat Shrestha. The land development boom in kathmandu valley. *CDS contribution to ILC Collaborative Research Project on Commercial Pressures on Land, Rome*, 2011.