Journal of Urban Management and Energy Sustainability (JUMES)

Homepage: http://www.ijumes.com

ORIGINAL RESEARCH PAPER

Evaluation of the optimal form of educational building based on energy consumption (Case study: Torbat-Heydarieh city)

Pedram Hessari*, Maryam Seyf Shojaei

Faculty of Technical and Engineering, University of Torbat Heydarieh, Torbat Heydarieh, Iran

ARTICLE INFO

Article History:
Received 2021-09-01
Revised 2021-11-20
Accepted 2021-12-15

Keywords:
Energy optimization
Simulation
DesignBuilder
Ecotect

DOI: 10.22034/JUMES.2021.558191.1081

ABSTRACT

Since the building sector has a significant contribution in energy consumption, it is very important to pay attention to ways to reduce energy consumption. In this research, an attempt has been made to provide a solution for the design of the building form based on the energy consumption of educational spaces in the cold and dry climate, especially in Torbat Heydarieh city, at the building design stage. For this purpose, the climate of the region, the comfortable conditions in it, the criteria for reducing energy consumption in the building sector and the design criteria and the standards of the Faculty of Architecture have been examined and evaluated based on the available sources and documents. After conducting the studies, the location of each space has been analyzed and evaluated based on the usage and the amount of solar energy received through using Ecotect and Radiance software. The method of analyzing the form of educational building was based on the studies and the initial plan and the form were modeled in the Revit software. After considering the solutions to reduce the consumption, the energy consumption in each mode has been measured using DesignBuilder software. Then again, the lighting of each space was controlled using Ecotect and Radiance software. In the end, by entering the information into the Mabna software, the correctness of the plan has been ensured based on the criteria of the National Building Regulations of Iran.

Running Title: Optimal form of educational building

NUMBER OF REFERENCES 28

NUMBER OF FIGURES 03

NUMBER OF TABLES 08

*Corresponding Author:
Email: *p.hessari@torbath.ac.ir*
Phone: +989387783830
ORCID: https://orcid.org/0000-0002-1666-4245

1. Introduction

Energy consumption in buildings is considered as an important part of the world's energy consumption and greenhouse gas emissions. Therefore, reducing the building's energy consumption and optimizing its energy performance are two key-target areas for several researchers. Conventionally, previous studies have used different approaches based on the evaluation of several alternative design options to identify the best solution (Srhayri and et al., 2022). In recent years, in the context of vigorous development of green buildings, building energy efficiency has shifted from measure-oriented to effect-oriented, and refined design based on the improvement of green performance has been emphasized in the early stage of building design (Xinmei Deng et al., 2020). Education buildings have longer operation hours than typical nonresidential buildings (Hu, 2018). Lack of climatic studies in educational buildings and the importance of comfort in addition to a need for implementing optimal consumption patterns in these buildings have necessitated the extensive studies in this case. Energy consumption in different fields including educational spaces has promoted in different countries during the past decade with a growth of 20-40 %. (Ghanbaran and Hossein pour, 2016). In this regards, climate recognition, investigation of effective factors on building energy consumption and building simulation are very important. Simulation's effect on time design process is significant and energy performance analysis is essential to be

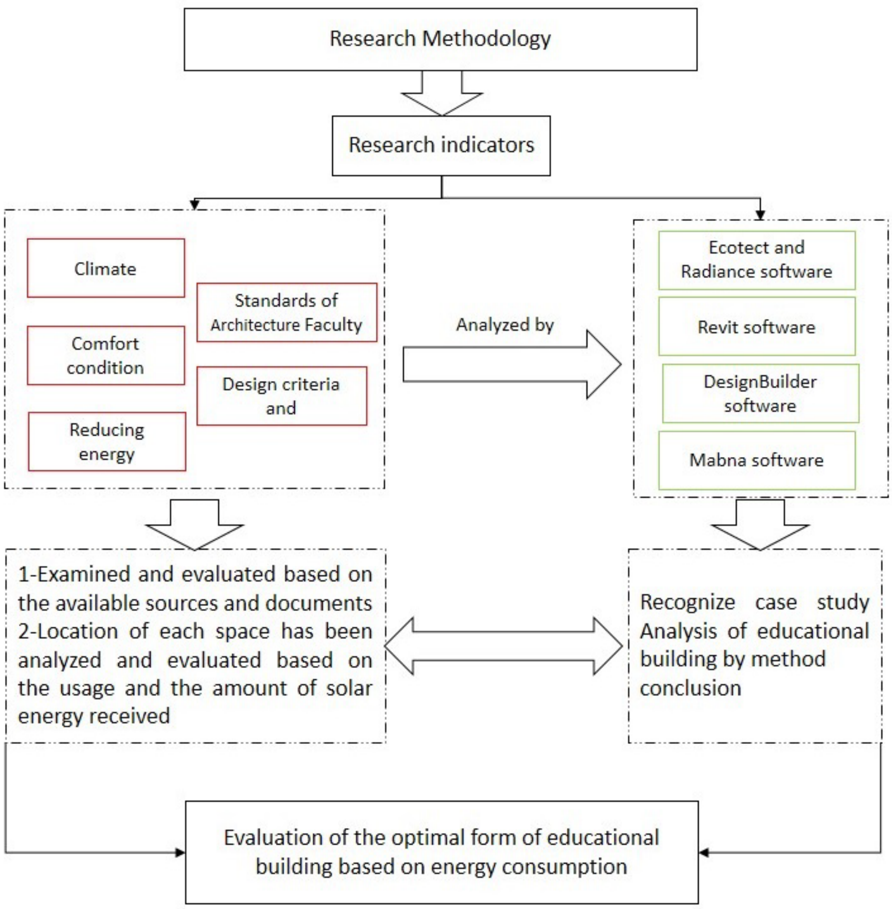


Fig. 1. Research Methodology

conducted in the first steps of design (Ghiaei et al., 2011).

Mahlab and Shafiei pour (2014) declared that the purpose of this study was to investigate the air exchange rate of 2.4 times per hour for a class of 20 students. Moreover, they indicated that air ventilation rate is satisfactory, however, by increasing the number of students to 30, carbon dioxide level rises to 800 ppm and the air needs to be ventilated with the effect of energy conservation in indoor air quality of educational buildings by simulation in Contam software Methodology. Irulegi et al. showed (2017) in a study with the results of research team proposed different renovation strategies for the winter and summer, and proved that the total energy-saving is studied through an education building in Spain. In the study done by Fonsca et al. (2018), they achieved the nearly zero-energy goal using two principals with designed a renovation plan for the Department of Electrical and Computer Engineering building in University of Coimbra, Portugal. Favrizio et al. (2018), in their research, proposed a method to detect energy performance with the aim of integrating the design of energy renovation of existing buildings by by using a method that combined heat flow measurement, infrared thermography, energy simulation and investigation. Rsouli et al. (2019), in their research, declared that moving shadings are more optimal than standing ones and horizontal louvered shading is the best choice with investigating the effect of annual performance of double-skin facades in an office room in Tehran installing standing and moving horizontal and vertical louvered shadings by space simulation in Rhino and Grasshopper and its annual energy saving by design builder. Morshed Alam and Maisum Raza Devjani (2021) in this research aim to analyze the energy consumption patterns of different spaces in a mixed-use educational building and identify possible sources of energy waste using an unsupervised data mining approach. A 5-star Green Star-Rated educational building in Melbourne, Australia, was considered for the case study. The results showed electrical and gas energy performance gaps of 2.4 and 3.1 times, respectively. Further analysis revealed that energy consumption during non-working hours was 48% of total energy consumption during the one-year studied period, which is very high and was one of the possible sources of waste. During the holidays, the mechanical system and plug loads ran as per the weekday operating schedule in an empty building, resulting in energy waste. Alshibani (2020) asserted that his study was based on the utilization of 352 real-world datasets of energy consumption of operating schools across Eastern Province in Saudi Arabia. In the developed energy prediction model, the eleven identified factors that influence the consumption of energy of constructed schools were considered. The identified factors were utilized as input variables to build the model. A systematic search among different neural network (NN) design architectures was conducted to identify the optimal network model. Validation of the developed model on eight real-world cases demonstrated that the accuracy of the developed model was about 87.5%. Moreover, the findings of this study indicate that the weakest correlation between the input variables was recorded as −0.015 between "type of school" and "AC capacity," while the strongest correlation was recorded as 0.95 between the variables of "number of classrooms" and "total air-conditioned area (sqm)," followed by "total air-conditioned area (sqm)" and "number of students," which was recorded as 0.90 (Hu M. 2018). The aim of this paper is to propose a novel building information model (BIM) –a building performance model (BPM)– a building environmental model (BEM) framework to identify the most energy-efficient and cost-effective strategies for the renovation of existing education buildings to achieve the nearly zero-energy goal while minimizing the environmental impact. A case building, the University of Maryland's Architecture Building, was used to demonstrate the validity of the framework and a set of building performance indicators—including energy performance, environmental impacts and occupant satisfaction—were used to evaluate renovation strategies. In a study by Mohelníková et al. (2020), the goal was aimed to assess the school building envelopes and their influence on energy consumption. One of the studied schools was selected for detailed evaluation. The school classroom was monitored for indoor thermal and visual environments. The monitoring was performed to compare the current state and renovation scenarios. Results of the evaluation show that the school buildings are highly inefficient even if renovated. Indoor climate in classrooms is largely influenced by windows. Solar gains affect interior thermal stability and day lighting. Thermal insulation quality of the building envelopes and efficient solar shading systems appear to be fundamental tasks of school renovation strategies. In a study by Heni Fitriani (2021), the aim was to investigate the energy consumption of existing building located in Palembang as compared to the benchmark of Indonesian Standard for educational buildings. This paper also develops an energy analysis model with BIM integration to produce accurate predictions of the educational building performance with better scenarios. The EUI calculations were carried out in two ways. First, the electrical usage used in the building was calculated and then compared with the SNI 03-6196-2000 standard. Secondly, a 3D model was developed by redrawing the building object using BIM Revit application which follows the ASHRAE 90.1 benchmark standards. It was found that HVAC dominated for about 69% of the total energy consumption for the first floor, whereas electronic appliances contributed to the highest proportion of energy consumption, which was about 66%, for the second floor.

1.1. Aim of the research

In this research, an attempt has been made to provide a solution for the design of the building form based on the energy consumption of educational spaces in the cold and dry climate, especially in Torbat-Heydarieh city, at the building design stage.

1.2. Study area

University of Torbat-Heydarieh is a public university in Torbat-Heydarieh city which is located in Razavi Khorasan province. Initial land for the construction of the campus on the current site of 5 hectares plus a sport salon of 3000 square meters was donated to the complex by the benefactors of Torbat-Heydarieh University in year 2005, and along with the intent of the university's construction officials, the educational building was established along with the laboratory and workshop complex at the university campus. Its climate is cold and semiarid (Kamyabi, 2016).

The complex was finally upgraded to Torbat-Heydarieh University with the final approval of the Higher Education Development Council of the Ministry of Science, Research and Technology on January 26, 2013. Torbat-Heydarieh University now has more than 5,000 square meters of educational, research, administrative, cultural and sporting facilities including educational, cultural and welfare complex (including library and documentation center with more than 7,000 volumes of books, informatics center with over 130 Computers, prayer's room and restaurant), equipped with two sport complexes, 2 amphitheaters, meeting rooms, equipped workshops and laboratories, greenhouse and research farms. Currently, the university has 24

Fig. 2. Geographical location of Torbat-Heydarieh city in Iran

Fig. 3. Location of faculty of architecture in University of Torbat-Heydarieh

Table 1. Comparison of bioclimatic indices and software in Torbat-Heydarieh (Source: Authors)

	Olgyay	Evans	Terjang	Climate Culnsultant software	conclusion
April	Cold	Cold	Very cool	Cold	Cold
May	comfort	Cold	cool	Cold-comfort	A bit Cold
June	warm	comfort	comfort	comfort	comfort
July	warm	Warm	comfort	Warm- comfort	Warm- comfort
August	warm	warm	comfort	Warm- comfort	warm
September	warm	Cold- comfort	comfort	Cold- comfort	Cold- comfort
October	Dry- comfort	Cold	cool	Cold	Cold
November	Cold	Cold	Very cool	Cold	Cold
December	Cold	Cold	Very cool	Cold	Cold
January	Cold	Cold	Very cool	Cold	Cold
February	Cold	Cold	Very cool	Cold	Cold
March	Cold	Cold	Very cool	Cold	Cold

majors in continuous Bachelor's Degree program, non-continuous Bachelor's Degree program, Associate Degree program and Master's Degree program in two forms: the Faculty of Engineering and the Faculty of Agriculture and Natural Resources. Longitude and latitude of Torbat-Heydarieh are respectively 59.13◦ and 35.16◦ and it is located 1333 m above mean sea level (Kasmaei, 2019).

According to Table 1 which is set based on meteorology data in a 10-year period (2007-2017), bioclimatic indices and Climate Consultant software, Torbat-Heydarieh has a cold climate.

After initial studies, Torbat-Heydarieh city was analyzed for climate and comfortable conditions implementing bioclimatic indices and software, standards and energy consumption approaches in this climate and regulations related to educational spaces design (architecture faculty). Some resources of these regulations are disciplines of national building code edited by national building code affairs office, design standards and regulations of educational spaces edited by renovation organization technical office and architecture faculty design fundamentals edited by Jafari et al., other steps are:

- Finding suitable location based on solar light consumption
- Application of energy consumption approaches to the building and comparing with initial state
- Single-space lighting re- evaluation and control in plan

2. Material and method

The method of analyzing the form of the educational building was based on the studies and the initial plan and form were modeled in the Revit software. After considering the solutions to reduce the consumption, the energy consumption in each mode has been measured using DesignBuilder software. Then again, the lighting of each space was controlled using Ecotect and Radiance software. In the end, by entering the information

Table 2. Classroom characteristics (Source: Authors)

Space	Area (m^2)	Dimensions (m)	Min height (m)	Window to floor area ratio	Window area (m^2)	Window bottom height (m)	Glass type	Required light intensity (Lux)	
								min	suggested
Classroom	60	8*7.5	3	1:5	12	1.12	electrochromic double-skin	200	500

Table 3. Illumination of theory classes from two directions by using Ecotect and radiance software (Source: Authors)

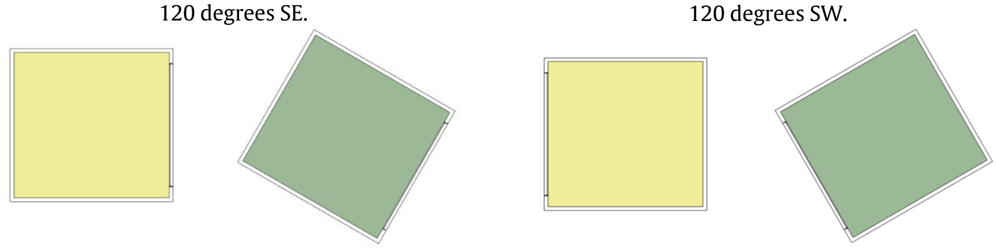
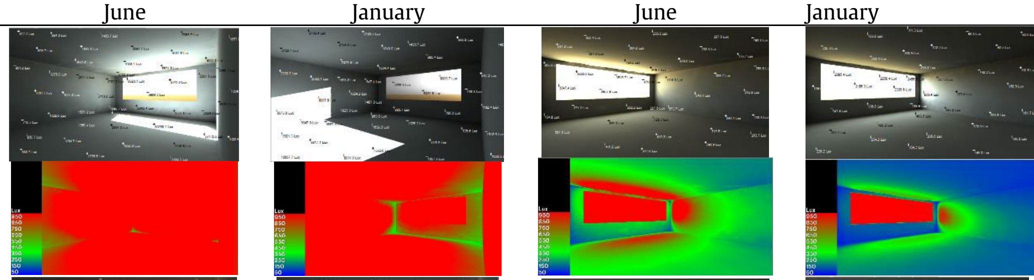
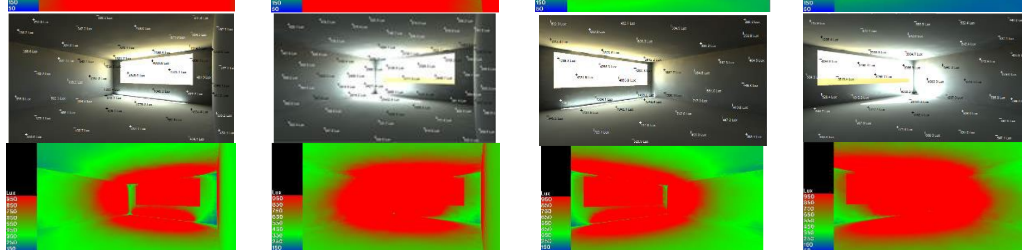
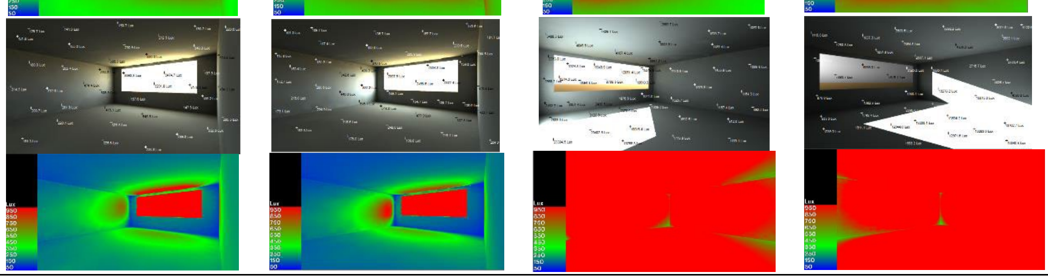
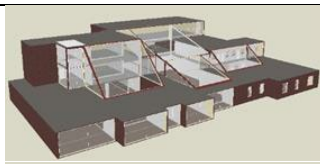
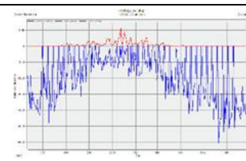
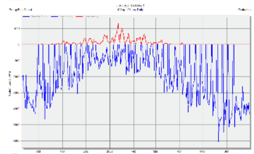
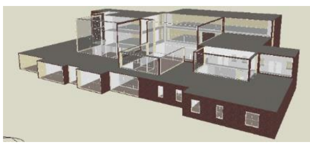
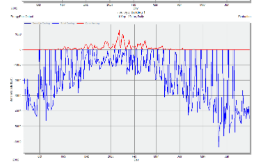
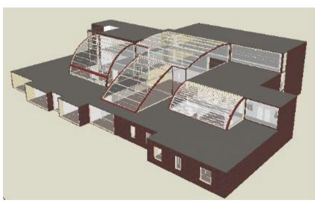
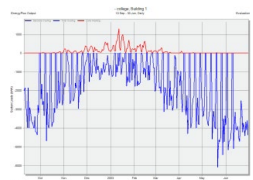
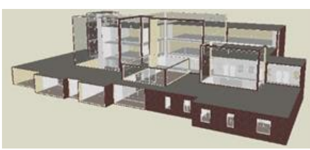
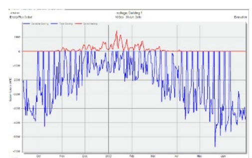
	120 degrees SE.		120 degrees SW.	
Window direction				
	June	January	June	January
8 AM.				
11:30 AM.				
16 PM. In summer and 14 P.M. for winter				

Table 4. Atrium form investigation and energy consumption (Source: Authors)

Definition	Simulation	Information			Energy consumption		Heating and cooling requirement
		Main functions	Secondary functions	Height (m)	In the whole building	Over one square meter	
Slant roof atrium		Educational building	Faculty of architecture	12	712542.08	250.54	
Spectrum roof atrium		Educational building	Faculty of architecture	12	726885.73	251.69	
Roof-level Atrium		Educational building	Faculty of architecture	12	750129.45	258.53	
Curved roof atrium		Educational building	Faculty of architecture	12	715375.42	259.60	
Atrium above the surface of the roof		Educational building	Faculty of architecture	12	789120.88	273.93	

into the Mabna software, the correctness of the plan has been ensured based on the criteria of the National Building Regulations of Iran. In following table a summary of literature is presented.

2.1. Definition of suitable location

The number of users and the dimensions of each space are determined based on per capita. To find the dimensions of opening for each space, Ecotect and radiance software were used. Therefore, each space's lighting is measureed in different times and directions for a specific window. It is recommended that window dimensions, spacing between window and floor and roof be changed to get the required light mentioned in national building code and then measured in different times and directions again. Afterwards, the results are compared in different states and techniques are presented to obtain required light based on National building regulations, regarding the space's active time.

2.2. Plan and initial investigation

After locating each space, initial spotting and

Table 5. Master classroom characteristics (Source: Authors)

Space	Area (m2)	Dimensions (m)	Min height (m)	Window to floor area ratio	Window area (m^2)	Window bottom height (m)	Middle gap width between two walls (shading depth)	Glass type	Required light intensity (Lux)	
									min	suggested
Master classroom	45	7.5*6	3	1:1	22	0	1.27	electro chromic double-skin	500	700

* Following equations are used for calculation of shadings depth:

$$D = \frac{h\ Cos\ (Z + N)}{tan\beta}$$

β

D	Shading depth (m)	(kasmaei, 2003: 53)
h	Height of the shade created by shading over the glass (m)	
Z	Radiation direction	
β	Radiation angle	
N	Angle between the line perpendicular to the window and real south direction	

Table 6. Determination of master classroom shading depth based on radiation angle and direction in a specific time (Source: Authors)

Time	N	*β*	Z	h	D
10 am. July	0	40	85	3.5	0.53
10 am. June	0	37	90	3.5	0.6
10 am. May	0	57	124	3.5	1.27

subsequently initial plan are drawn. Initial volume and the form of the building are characterized after plan drawing which are analyzed in design builder software and its energy consumption is calculated and compared in different states. For example, atrium form and its effect on energy consumption are assessed in table 4. The models are set based on energy consumption in this table.

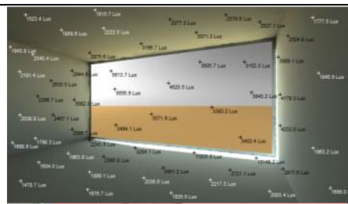
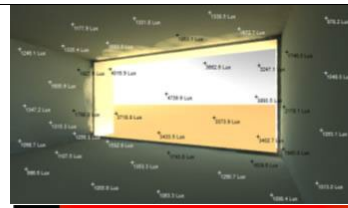
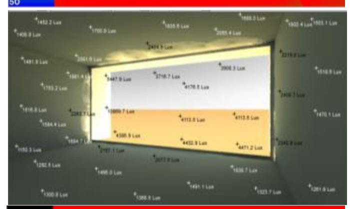
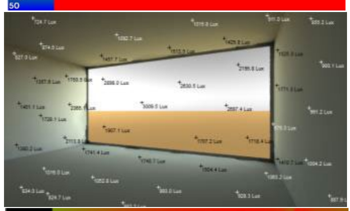
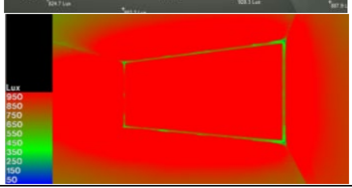
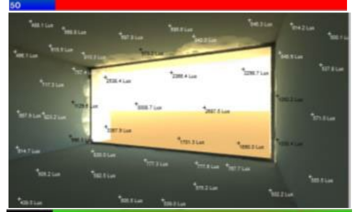
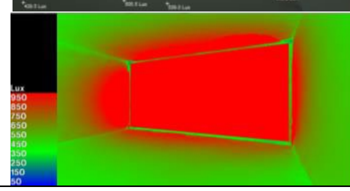
2.3. Observation

After refining design's initial volume, plan is assessed and investigated visually. After conducting the studies, the location of each space has been analyzed and evaluated based on the usage and the amount of solar energy received using Ecotect and Radiance software. The method of analyzing the form of the educational building was based on the studies, and the initial plan and form were modeled in the Revit software. After considering the solutions to reduce the consumption, the energy consumption in each mode has been measured using Design Builder software. Then again, the lighting of each space was controlled using Ecotect and Radiance software. In the end, by entering the information into the Mabna software, the correctness of the plan has been ensured based on the criteria of the National Building Regulations of Iran.

2.4. Single-space lighting

After changing the plan according to the results analysis of previous steps (controlling users comfort conditions, controlling lighting exploitation, investigating the atrium form and application of consumption reduction approaches and comparing the results with initial state) and with respect to standard and faculty design regulations, required improvements are applied and each space is investigated with the help of software to get adequate light. In this regard, plan is modeled in Ecotect and lighting in radiance. Furthermore, second wall and shading effects are studied for lighting intensity. Characteristics of master classroom and related analyses are indicated in Tables 5 and 7, respectively. The practical training of students acquires a special

Table 7. Master classroom, June (Source: Authors)

	Without second wall	With second wall
8 am.	 	 
11:30 am.	 	 
16 pm.	 	 

importance with the completion of the Master's Final Project in a studio or business in the sector. This opportunity involves the application of all the knowledge and skills acquired during the program in a real environment. The student has contact with the professional reality, acquires professional skills that facilitate their employability and foster their entrepreneurial capacity.

Regarding the above table and the analysis in Ecotect (Table 6), shading depth 1.27 in winter doesn't prevent the light from entering the space, while in summer allows the light to enter.

3. Results

After refining openings' dimensions (regarding changes in plan), energy consumption approaches are incorporated. So, Design Builder is used to investigate the effects, and finally it showed that the lowest thermal loss is presented. For instance,

Table 8. Consumed energy in final model (Source: Authors)

Energy consumption		Total area	Controlled space area	Uncontrolled space area
Per each square meter	total			
496974	170.59	2913.33	2863.38	49.95

the effect of wall insulation in thermal loss has been investigated in Design Builder. As building space is used sporadically, it is recommended that thermal inertia be minimized as much as possible and thermal insulation be located in building inner skin. According to output results in design builder, energy consumption per area is estimated 250.54 kwh/m^2 with insulation and 269.53 kwh/m^2 without.

Creating second wall in southern side of building, in addition to light intensity control, straight light can be prevented implementing proper shading angle according to 19th discipline. Considering second wall for southern side, energy consumption per square meter reduced from 25.54 kwh/m^2 to 241.54 kwh/m^2. Other works to reduce energy consumption are smart double-skin glasses and ventilation in atriums (National building code office, 2010).

4. Discussion and conclusion

As energy conservation in educational buildings besides comfort conditions are significantly important, researches seem essential in this case. To avoid energy loss in building, energy simulator software can be used. This software can be implemented before, while and after construction to calculate energy consumption costs. Investigation and analysis of energy consumption before construction are more economical and approaches and techniques are presented to reduce energy consumption. Different designs can be studied with the help of these software and the best state of energy conservation is obtained.

In this study, the location of each space has been analyzed and evaluated based on the usage and the amount of solar energy received using Ecotect and Radiance software. The method of analyzing the form of the educational building was based on the studies and the initial plan and the form were modeled in the Revit software. After considering the solutions to reduce the consumption, the energy consumption in each mode has been measured using Design Builder software. Then again, the lighting of each space was controlled using Ecotect and Radiance software. In the end, by entering the information into the Mabna software, the correctness of the plan has been ensured based on the criteria of the 19th topic of the National Building Regulations of Iran.

In addition to above items, architectural factors affect energy consumption. These include building direction, roof thermal behavior, window, natural ventilation, shading, atrium, double-skin façade and architectural design. Building material type affects energy consumption based on climate, application and architectural design. Designer must be careful of comfort conditions for users in addition to reduction in energy consumption.

According to the conducted studies and analysis, the amount of energy consumption in the proposed model of Faculty of Architecture in University of Torbat-Heydarieh is shown in Table No. 9. As it is known, the influence of energy consumption components in architectural design is very effective.

Possible next steps of the research can be mentioned below:

- Investigating changes in the height of the college building and their effect on energy consumption
- Investigating changes in green space coverage around the faculty building on energy consumption
- Examining changes in the number of users and energy consumption of the faculty building

Funding

This work has been financially supported by the University of Torbat-Heydarieh. The grant number is 109.

References

Afshar Zadeh, G.H., Zare, M.A., (2012). Comfort in Lavasan Tajrobe house, Iranshahr Andishe journal, no. 16.

Ahadi, A., Masoudi Nezhad, M., Piriaei, A. (2013). Windows accurate design to obtain adequate daylight in apartments in Tehran, Hoviat-shahr, 25:41-50. Link

Alshibani A. (2020). Prediction of the Energy Consumption of

School Buildings. Applied Sciences. 10(17):5885. https://doi.org/10.3390/app10175885

Ebrahim Pour, A., Karimi Wahed, Y. (2012). Energy conservation methods in a university building in Tabriz, Journal of Modares Mechanical Engineering, 12(4): 91-104. http://dorl.net/dor/20.1001.1.10275940.1391.12.4.8.9

Fabrizio, A., Bianco, N., de Masi, R.F., de'Rossi, F., Vanoli, G.P. (2015). Energy retrofit of an educational building in the ancient center of Benevento. Feasibility study of energy savings and respect of the historical value. Energy Build. 95, 172-183. https://doi.org/10.1016/j.enbuild.2014.10.072

Fitriani, H., Rifki, M. Indriyati, C., Rachmadi, A., Muhtarom, A. (2021). Energy Analysis of the Educational Building in Palembang Indonesia. Civil Engineering and Architecture, 9(3):778-788. https://doi.org/10.13189/cea.2021.090319

Fonseca, P., Moura, P., Jorge, H., de Almeida, A. (2018). Sustainability in university campus: Options for achieving nearly zero energy goals. Int. J. Sustain. High. Educ. 19, 790-816. https://doi.org/10.1108/IJSHE-09-2017-0145

Fuel Conservation Company (2008). Thermal insulation details in building, first edition, fall 1387, Kelid-e-Amouzesh publications.

Ghanbaran, A.H., Hossein-Pour, M.A. (2016). Investigating effective factors on energy conservation in educational spaces in Tehran climate, Naqsh-e-Jahan periodical-theoretical studies and novel technology of architecture and urban, 3-6:51-62.

Ghiasi, M.M., Mahdavi-Nia, M., Tahbaz, M., Mofidi Shemirani, S.M. (2011). Selection methodology of energy simulator applicable software in Tehran climate, Hoviat-shahr, 13:45-55.

Hshemi, F., Heydari, S. (2010). Energy conservation in residential buildings in a cold climate, Soffe Journal, 56:75-86.

Hu, M. (2018). Optimal Renovation Strategies for Education Buildings-A Novel BIM-BPM-BEM Framework Sustainability 10(9):3287. https://doi.org/10.3390/su10093287

Hu, M. (2018). Optimal Renovation Strategies for Education Buildings-A Novel BIM-BPM-BEM Framework. Sustainability. 10(9):3287. https://doi.org/10.3390/su10093287

Innovation organization technical office, Organization for Development, Renovation and Equipping Schools (2010), educational spaces design standards.

Irulegi, O., Ruiz-Pardo, A., Serra, A., Salmerón, J.M., Vega, R. (2017). Retrofit strategies towards net zero energy educational buildings: A case study at the University of the Basque Country. Energy Build. 144, 387-400. https://doi.org/10.1016/j.enbuild.2017.03.030

Kamyabi, S. (2016). Adjustment of climatic classification system on architecture of cities of Rzavi-Khorasan, geographical periodical, 13th year, 50:91-105.

Kasmaei, M. (2003). Climate and architecture, fall 92, Isfahan, Khak publications.

Mahlab, F., Shafi-pour, M. (2014), effect of energy conservation in inner space air quality (case study: educational building), Ecology, 40(4):1011-1021.

Mohelníková, J., Novotný, M., Mocová, P. (2020). Evaluation of School Building Energy Performance and Classroom Indoor Environment Energies 13(10):2489. https://doi.org/10.3390/en13102489

Morshed, A., Devjani, M.R. (2021). Analyzing energy consumption patterns of an educational building through data mining, Journal of Building Engineering, Volume 44. https://doi.org/10.1016/j.jobe.2021.103385

National Building Code Office (2010). 19th discipline of national building code (energy saving), eighteenth edition (2018), Tehran, Iran′s Tose-e publication.

National Building Code Office (2013). 4th discipline of national building code, fourth edition (1393), Tehran, Iran′s Tose-e publication.

National Building Code Office (2016). 13th discipline of national building code (design and execution of buildings electrical installations), first edition (2016), Tehran, road research center, Department of Housing and Urban.

Rasouli, M., Shabazi, Y., Matini, M.R. (2019). performance of moving horizontal and vertical louvered shadings in official buildings with double-skin façade; parametric assessment and simulation, Naqsh-E-Jahan Periodical, 9(1): 23-31. http://dorl.net/dor/20.1001.1.23224991.1398.9.1.7.6

Rezaei, N. (2016). Advanced studies center of Renewable energies emphasizing zero-energy, architecture MS.c. thesis, architecture faculty′s specialized library of Ferdowsi University, Ferdowsi university of Mashhad.

Srhayri, I., Hafs, H., Bah, A. (2022) Effect analysis of U-shape exterior walls on energy consumption of building: The case of Morocco. Int. J. Air-Cond. Ref. 30, 7. https://doi.org/10.1007/s44189-022-00007-3

Taghavi, M. (2014). Energy conservation methods in building, First National Conference of Building Management Smart Systems with Energy Conservation Methods, Qazvin, Iran.

Xinmei D., Mengyuan W., Dongxian S., Zhengyu F. (2020). IOP Conf. Ser.: Earth Environ. Sci. 531 012060. https://doi.org/10.1088/1755-1315/531/1/012060

HOW TO CITE THIS ARTICLE

Hessari, P.; Seyf Shojaei, M. (2021). Evaluation of the optimal form of educational building based on energy consumption (Case study: Torbat Heydarieh city). J Urban Manage Energy Sustainability, 2(4): 58-68.

DOI: 10.22034/JUMES.2021.558191.1081