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Research Paper

Comparative Research of the Amount of Cooling and Heating Loads in Three Residential, Institutional, and Educational Occupancies

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Abstract
The energy demand has increased worldwide, and the construction industry makes up a high percentage of energy consumption. Different design components, construction, and exploitation regarding construction energy consumption and the drive towards sustainability have been considered; however, energy conservation with an emphasis on the user's behaviours has been ignored. This research aims to provide a quantitative definition of the impact of behaviour on energy Loads in three residential, institutional, and educational occupancies in one apartment through survey and simulation. In this research, by allocating three different occupancies to one building in Qom, each occupant's cooling and heating loads have been compared in a one-year interval. First, the building modelling was carried out in Ecotet software and put in Energyplus software. Then, the outcomes were compared by assuming a single building and describing three different patterns of using the space in Energyplus. The results show that the reduction or increase in energy loads in each occupancy was influenced by the number of users and the patterns of their activities or clothing. Reducing the duration of the presence or changing the work hours in warm seasons of the year can significantly help reduce energy consumption in educational and institutional occupancies in hot and dry climates. The residential users' economic motives can be one of the reasons for reduced energy consumption in residential occupancies compared to institutional occupancies.

Keywords: *Building occupancy, Energy consumption, Hot and dry climate, Energyplus software, Residential and educational areas, Occupant behaviour, Energy policy.*

1. INTRODUCTION

In addition to aggravating the concern of an immediate shortage of fossil resources, the growth in energy consumption in today's societies is also confronting the world with threatening changes. The energy demand has increased across the world (Talaei et al., 2021). And almost half of the annual energy supply worldwide is used in buildings' exploitation and maintenance (Yan et al., 2018). Since most of this energy comes from fossil resources, it makes up a huge portion of annual carbon emissions (Dixit, 2017). Therefore, encouraging productivity in a building is necessary, since it causes environmental efficiency (i.e. increased efficiency can lower greenhouse gas (GHG) emissions and other pollutants, as well as decrease water use), and economic efficiency (i.e. improving energy efficiency can lower individual utility bills, create jobs, and help stabilize electricity prices and volatility) (Chenari et al., 2016). As a result of OECD countries' collaboration from 1990 to 2005, energy conservation in all aspects of energy consumption has reduced carbon dioxide emissions from 15% to 14%. In the European Union, it is assumed that although energy productivity has improved, in terms of technology and economics, in recent years, utilizing different strategies to improve productivity is still possible. The potential rate of energy conservation in residential and services sectors is respectively 27% and 30% (Lopes et al., 2012). Preserving energy resources, particularly non-renewable resources, has an unwavering relation with

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construction because the services and residential buildings make up the majority of energy consumption.

In designing buildings, energy conservation occurs through buildings' orientation, the layout of the spaces in the plan based on adjusting the space occupancy pattern with the solar cycle, choosing an envelope suitable for the climate and environmental conditions, the measurements of the openings according to the received radiation and its relevant energy waste, and also different types of openings and windows (one-layer (single-pane, double-pane, etc.), and finally, using proper methods for substituting non-renewable energies with renewable energies. Also, some strategies like shading, aerodynamic properties, and geometrical properties are considered for energy consumption [A3]. Each of the mentioned solutions can partially affect buildings' energy consumption (Rabie et al., 2021).

Building occupancy is one of the strong and influential components in energy consumption, which can significantly affect the energy consumption rate by controlling and changing some of the behavioural patterns. Building occupancy, one of the determining factors in buildings' energy consumption, has been ignored (Hoseinzadeh et al., 2021; Lopes et al., 2012). One of the main aspects of the difference in buildings' energy consumption rates is their corresponding behavioural patterns. The behaviours in an institutional or commercial building differ from those in a residential building. Taking this difference in energy consumption into account and achieving the most important factors of reducing or increasing consumption in each occupancy, and generalizing its reducing factors to other occupancies can reduce energy consumption in buildings.

1.1. Building Behavior and Energy Productivity

Studies have shown that the execution of energy instructions in the construction field, and even updating the home appliances (Üçtuğ & Yükseltan, 2012) if followed by changes in the behavioral patterns of the occupants, will have more impact on reducing energy consumption (Chenari et al., 2016).

In a study by Lopes et al., the most important factors in environmental behaviors are motivational factors, contextual factors, and habitual behaviors (as cited in Salahuddin & Alam, 2016). Different strategies are recommended by various researchers to improve energy behaviors.

This part of the study identifies behavioural patterns to be used in energy calculations and presents user profiles with different behaviours. Three underlying groups of behavioural variables were found, which were used to define the behavioural patterns and user profiles. The groups showed statistically significant differences in the scores for most of the behavioural factors. This study established clear relationships between occupant behaviour and residental characteristics. However, it seems difficult to establish relationships between energy consumption and Behavioural Patterns and household groups. In this regard, materials, thickness, and heat conductivity coefficient are considered

Consequence strategy:

1. Feedback strategy (Giving information on energy consumption and recording its impact)

2. Premium

1- Antecedent strategy:

1. Commitment

2. Determining the quantitative aim

3. Providing information

2- Structural strategies:

All mentioned factors would affect in energy consumption. Electricity use in Qom houses increases with the number of occupants. But, it also varies widely between houses with the same number of occupants due to behavior. Behavior can have dramatic influences on household energy use, understanding and pursuing initiatives that affect behavior are of great importance. The bills in one year of institutes also showed that behavior has an effective role in energy.

Finally, it is stated that, in general, to increase the impact, combined strategies should be used. In these studies, a huge part is considered for energy productivity strategies, especially feedback mechanisms (Lopes et al., 2012).

The quantitative study of behaviors and their effectiveness in the energy field is essential in moving towards energy-saving aims. Researchers and designers must be aware of space occupancy conditions, which are used as source lifestyle in parametric studies (Salahuddin & Alam, 2016). As long as there are no numeric and quantitative equivalents for the behaviors and behavioral patterns in different occupancies, there will be habitual behaviors (behaviors with disregard towards benefit or loss), and they will unconsciously continue. In this case, even technological solutions may not yield good results in reducing energy consumption and productivity.

Theoretical Foundations

Occupant behavior, therefore, represents an important research area for generating the information needed for the development of energy efficiency interventions and evidence-based energy policy in the residential sector. However, energy consumption is complex. Employing standard and simplistic behavioural profiles in energy modelling leads to a significant discrepancy between actual usage and prediction (Asadi et al., 2014).

For energy demand reduction, an approach of incorporating the complexity of behaviour is needed that captures the key determinants of energy performance to allow better evaluation of energy-saving policy programmes and retrofit options. Collecting and employing an exhaustive dataset on occupant behaviour for each household in-home energy audits is likely to be unrealistic (Azari et al., 2016).

Energy behaviors have a crucial role in promoting energy efficiency, but energy behaviors characteristics and complexity create several research challenges that must be overcome so energy behaviors may be properly valorized and integrated into the energy policy context.

Research Hypotheses

1. Energy consumption depends on the type of activities, the number of users and their clothing, and the equipment used in the building, which occurs in three different occupancies in one building.
2. Residential occupancies have the highest annual cooling and heating loads in the hot and cold seasons of the year. Also, in these occupancies, the clothing patterns and the number of users in the building can be effective in cooling and heating loads.
3. It seems that shortening the duration of people's presence and work hours during hot seasons of the year in the educational building can significantly contribute to lowering the cooling load of the space and energy conservation in hot and dry climates.

1.2. Research Aims

One of the main purposes of this research is to evaluate the difference in energy consumption, emphasizing the type of activities, the number of users and their clothing, and the equipment used in the building, which occurs in three different occupancies in one building. Determining which occupancy has the highest annual cooling and heating loads, the impact of the number of users and their clothing on the cooling and heating loads, and the quantitative consideration in residential, institutional, and educational occupancies are also the aims of this research. Therefore, measuring energy consumption in one building [1] in three different residential, institutional, and educational occupancies can introduce the quantitative impact of occupancy on energy consumption rate.

The obtained information can be considered in major energy planning in cities through network management for evaluating the peak energy demand and changing official work hours in organizations and educational environments in Qom. Also, through quantitatively determining the impact of behaviour on the building's energy consumption and notifying users through feedback strategies, the background for changing some patterns to energy-saving patterns formed in another behavioural paradigm can be prepared.

2. QUESTIONS

1. How effective can changes of occupancy be in changing energy consumption?
2. Which occupancies have the highest annual cooling and heating loads in the hot and cold seasons of the year?
3. How effective are the clothing patterns and the number of users in the building on cooling and heating loads?
4. How effective can changes of work hours in institutional and educational occupancies be on cooling and heating loads?

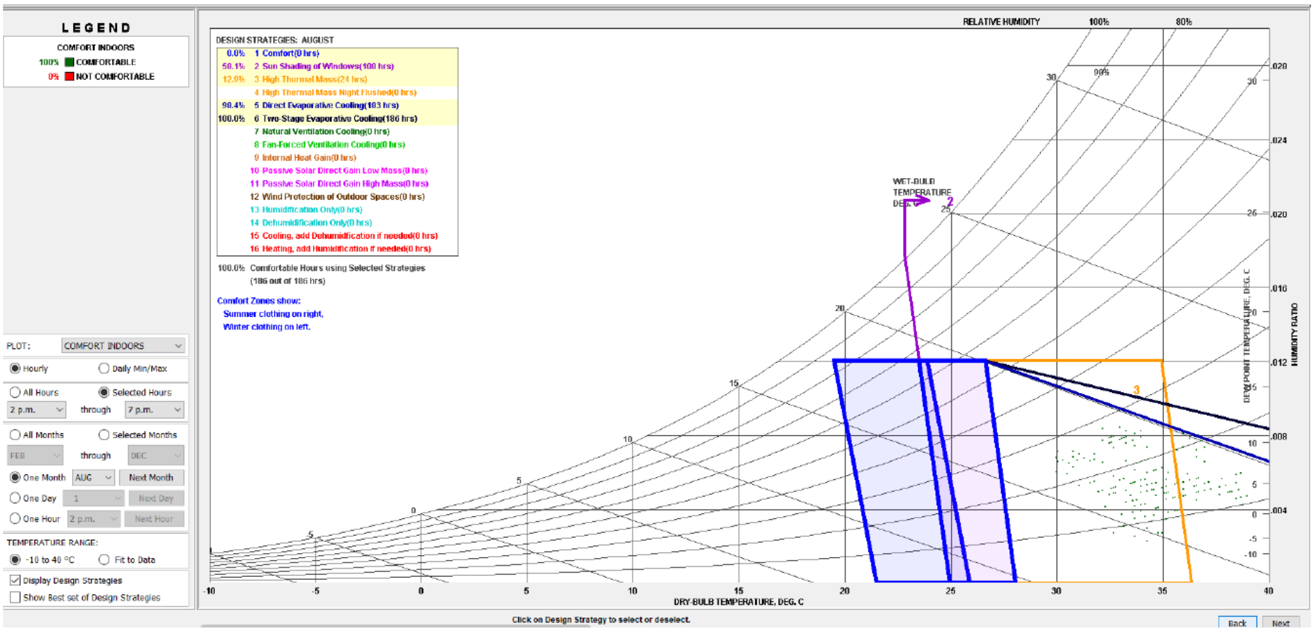
3. RESEARCH BACKGROUND:

Qom is one of the provinces with the lowest amount of rainfall in Iran and with hot and dry climate. This study was conducted in the city of Qom located in the south of Tehran province. This is the climatic data related to Shokohieh station in Qom. This station is located at 28'46°34" latitude and 17'51°50" longitude geographically, it is located at a height of 877.8 meters above sea level. Other meteorological stations in Qom province have records that the statistics were far less, so they were not highly reliable. For this part of the study, calculating the data of Shokohieh station in Qom is limited. In order to check the rate and trend of climate changes, the annual statistics of rainfall, temperature, wind, and relative humidity from Qom Meteorological Department related to the synoptic station of Shokohieh Qom from 2012 to 2022 were prepared in a controlled manner (Yousefi et al., 2017). Also, the graph of Qom climate is attached to the paper as follows:

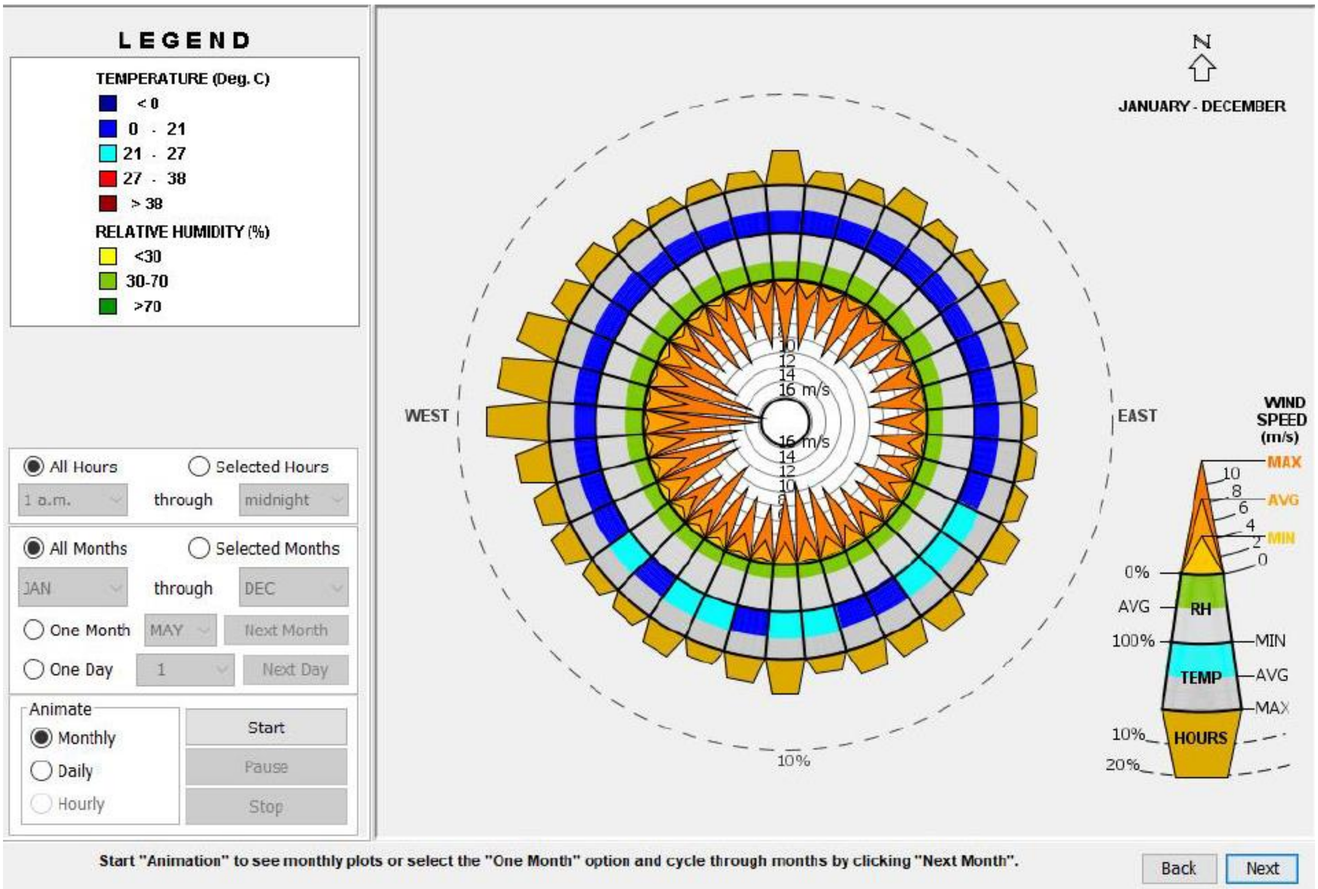
In order to investigate the wind in an area, the frequency of wind blowing, its temperature, and humidity are important and it is effective in

[1] The building is considered the mediator control variable.

architectural design and providing comfort. In other words, it should be checked in which direction the wind blows in the region and with what humidity and temperature. Therefore, with the help of Climate Consultant software, the Golbad graph should be extracted in the months of the year and the factors of humidity, temperature, direction and prevailing wind speed should be investigated. Finally, conclusions should be made seasonally.



Graph 1. Using Architectural Solutions to Achieve Comfortable Conditions



Graph 2. Checking the Direction, Humidity, Speed, and Frequency of the Wind throughout the Year

Based on the graph, adverse effects of a growing population, developing industrial and agricultural activities along with rainfall reduction, temperature and wind increase. Therefore, it is necessary to analyze the climatic variable factors trend to be considered in managing, planning, and proper development of the province. Climate change is the main challenge in this area. To that end, the Mann-Kendall test has been used to process a few climatic variables from 1989-2014 in the area. This average minimum and average annual temperature have experienced dramatic change and have positive significant variability at 99% reliability, but average annual rainfall shows no significant trend. Average annual relative humidity fluctuates wildly and in 2010, after a sudden change, follows a noticeably upward trend at 95% reliability. Average wind speed has had a rising trend since 2001, but no sudden change occurred until 2013.

The energy performance of a building depends on the building's features and active interaction of building elements, external weather conditions, internal weather settings, mechanical and electrical systems, and occupants' behaviors (Treichel & Cruickshank, 2021).

Various studies in the field of energy, with the approach to reduce energy consumption, have shown that the execution of energy instructions in the construction sector, and even updating the home appliances (Üçtuğ & Yükseltan, 2012), if followed by changes in the behavioral patterns of the occupants, will have more impact on reducing the energy consumption.

In a study by Lopes et al., it is stated that most of the research in this field has been in the residential sector. It has been carried out mostly through laboratory tests, and the efforts focused on specifying important factors in determining energy behaviors. The most important factors in environmental behaviors are motivational factors, contextual factors, and habitual behaviors (Lopes et al., 2012).

Gunay divides the studies of occupants' adaptive behaviors within the space into three parts:

1. Observational studies
2. Modeling studies
3. Simulation studies

Finally, he concludes that by choosing the proper geometry, suitable materials, and control strategies and predicting users' behaviours, the impact of users' behaviours on the buildings' performance will be reduced (Gunay et al., 2013).

A study by Gul and Patidar was conducted to analyze the relationship between the electric energy consumption rate and the users' activities in an educational building. This study used online questionnaires and interviews with employees and students to determine the users' behavioural patterns. This study has shown that as long as buildings use Building Management System (BMS), the users will have the least impact on controlling the energy consumption rate. Notwithstanding, detailed and precise information about users' behavioural patterns can effectively redesign the building's control system to optimize energy consumption (Gul & Patidar, 2015).

In a study titled 'the contextual factors contributing to Occupants' adaptive comfort' conducted in Canada, it was determined that users play a significant role in office buildings' energy use, and usually, one of the main reasons for buildings' poor energy performance is how users use energy (O'Brien & Gunay, 2014).

In a study titled 'estimating the energy consumption and power demand of small power equipment in office buildings', it is stated that the equipment with low power usage in office buildings, in addition to playing an important role in energy use, also contributes to internal heat gains. This study provides two models for estimating small power equipment's energy consumption in office buildings (Menezes et al., 2014).

A study titled 'advances in research and applications of energy-related occupant behaviour in buildings' has introduced the occupants' behaviours as the most important factor in buildings' energy consumption and considers them causing uncertainty in predicting the simulation of energy consumption. Currently, the knowledge about users' behaviours, both in building design and exploitation and reconstruction, is insufficient and has led to incorrect conclusions in modelling and analysis. There have been advancements in information gathering, modelling methods, and information analysis and simulation software in the simulation of occupants' behaviours and their quantitative impacts on buildings' energy consumption. However, despite these advancements, there remain significant challenges (Hong et al., 2016).

A study that evaluated the relationship between energy consumption and quality of life in 198 countries from 1990 to 2009 showed that despite different incomes, there is a significant relationship between energy consumption and quality of life in 70% of the countries in the study. The results from the study, contrary to previous studies, also showed that indices of quality of life, too, increase energy consumption; this phenomenon occurs in 65% of the countries in the study (Al-Mulali, 2016).

A study states that electric energy consumption in Guinea, a developing country, has increased due to increased electricity production. The most important effective problems in energy consumption growth are behavioural and psychological economy, motivational factors, cognitive biases, and cognitive psychological phenomena. It is noted in this research that the increase in production, with disregard toward motivational and society's behavioural and cognitive psychological problems in Guinea, has led to failure (Xu & Binyet, 2017).

In the study conducted by Chenery et al. about energy consumption and proper ventilation in buildings, in addition to effective methods such as natural and hybrid ventilation, users' behaviour toward ventilation is also assessed, which can influence the energy demand in buildings. This evaluation shows that ventilation is related to numerous factors, such as internal and external conditions, the building's properties, the construction's function, and users' behaviours (Chenari et al., 2016).

The study titled ‘a Study of the impact of occupant behaviors on energy performance of building envelopes using occupants' data’ evaluates the impact of occupants' life patterns on the energy exploitation of residential buildings with different buildings envelopes in different climates. For this, a multi-dwelling unit building in Iran was chosen as the research subject building, and the credibility of the simulation was assessed based on the real data of the building's energy consumption. The building's energy demand is simulated in different climates both after and before reconstruction by Energy plus. In this research, the building's energy consumption data were extracted from gas and electricity accounts, and the occupants' real-life patterns were provided through interviews and field studies. The analyses have proven that occupants' behaviours significantly affect the building's thermal energy consumption, especially in hot climates, and can change heating and cooling loads by approximately 90%. The results show that the interaction between occupants' behaviours and the building envelope is important, so much so that occupants' behaviours can change the strategy for choosing the materials for the envelope. They also showed that reducing the space occupancy load can increase the building envelope's impact on the thermal energy consumption rate. This study emphasizes the importance of utilizing real data on user behaviours in energy simulation analysis, building sustainability studies, and life-cycle assessment (Yousefi et al., 2017).

A study by Blight and Coley analyzed the impact of occupants' behaviours on Passivhaus energy consumption. This study shows the possible range of occupants' behaviours and their impact on the internal thermal energy consumption of Passivhaus buildings. Multivariate regression methods were used to identify the relation between space heating load and behavioural variables. The results showed that passive houses were less sensitive to behaviours than anticipated, and many concerns surrounding the impact of Passivhaus house users' behaviours are baseless and cannot be applied to many parts of the society (Blight & Coley, 2013).

In a study conducted in 2015 analyzing comfort in Passivhaus, it was stated that there is a strong relation between social aspects and participants' assessment of comfort in Passivhaus. Social factors (such as privacy, leisure time, and convenience), which are relatively less important in the design of these houses, lead to obvious differences in expectations of the building's function and the assessment after occupancy. This study focuses on energy performance in Passivhaus, and the experience of Passivhaus occupancy is often ignored. This study considers social factors of comfort among ‘Passivhaus’ participants. This finding practically provides new views for studying the problems concerning changes in behaviours in Passivhaus (Zhao & Carter, 2015).

In the research by Huang about the optimal design of building envelopes using simulation, it is stated that occupants' behaviours have not been amply taken into consideration in the simulations so far. The impact of occupants' behaviours on the building's energy performance and the internal environment has often been ignored. In the future, a better and more precise model of occupants' behaviours must be added to the simulation of the building's function. Behaviour is considered a human factor affecting the process of simulation (Huang & Niu, 2016).

A study in Japan investigates the social and cultural impacts of the projects constructed based on sustainable energy models on users, employers, and designers’ behaviours (Hong et al., 2016). Another study in Japan showed how improper taxes might significantly affect users' motivation toward energy productivity and the use of motivation of using less energy. To expand the use systems, users must be motivated, and electricity taxes and legal obligations can motivate families (Oliva, 2017).

Most of the energy behaviours research has been focused on the residential sector. Residential energy behavior studies are primarily field experiments to determine behavioural determinants for energy use and promote more efficient energy behavior.

The majority of energy behavior studies conducted in the past decade have been based on psychology. It is based on user psychology that one of the most relevant publications on residential energy behaviours is for Iranian dry and hot climates, such as Qom. This review consists of a systematic analysis of the factors influencing pro-environmental behavior in residential settings, as well as the types of interventions that can be used to encourage it. Environmental behavior is influenced by motivational, contextual, and habitual factors. Environmental behavior is motivated by perceived costs and benefits, moral and normative concerns, and affection from an individual perspective.

4. RESEARCH METHOD:

This is a research of the basic-exploratory variety with a case study. The research method includes surveys and simulations by Ecotect and Energyplus, the sampling in this study was nonrandom, and the case study was an educational building in Qom.

There have been various studies on occupants' adaptive behavior to space, which have considered three areas: 1) observational studies, 2) modeling studies, and 3) simulation studies (Gunay et al., 2013). In many studies about energy where experimental research has not been possible, the combination of these three studies has been used (Minaeian et al., 2020).

Energyplus software is developed by experts at Illinois and California universities and in collaboration with the American energy circle, the United States army corps of engineers, etc., for simulating the thermal performance of building walls. Energyplus is one of the most well-known simulation and building energy analysis software that, based on the physical properties of a building, occupants, equipment, and hourly annual climate data of a building's location, can calculate, or more precisely ‘predict’ the numeric variables concerning the building's energy consumption at any given time of the year. Examples of these variables are the temperatures of spaces, surfaces, heat transfer from opaque and translucent surfaces, and cooling and heating loads of a building (Duraković, 2020).

By accounting for the technical properties of the experimental building, including materials, technical details, orientation, architectural design, facilities, and lighting system, as constant mediator control variables in this study, the behavioral patterns, users' clothing, and building active hours (occupancy) are considered as independent variables and energy consumption rate as the dependent variable.

Research criteria of simulation user behavior are gathered in Table 1, also the previous studies showed energy factors that affect energy consumption.

Table 1. Information on the Research Variable

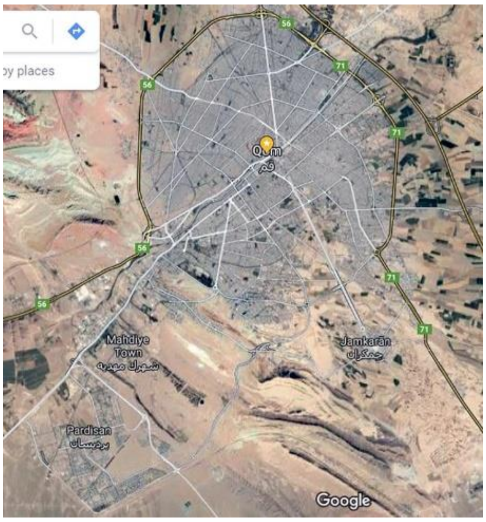
References	Basis of data		Behavior types: specific or overall evaluation		Optimized systems/parameters	Whether include actual occupant behavior model
	Assumption	Measured data	Overall	Specific		
(Masoso & Grobler, 2010)		✓	✓		HVAC, plug loads and lighting	No
(Kavulya & Becerik-Gerber, 2012)		✓	✓		Plug loads	N/A
(Hong & Lin, 2013)	✓		✓		HVAC (schedule, set point), lighting	No
(Peng et al., 2012)	✓		✓		HVAC (set point)	No
(Yu et al., 2011)		✓	✓		HVAC, water, kitchen equipment	N/A
(Duan & Dong, 2014)	✓		✓		Ten parameters identified to represent occupant model	No
(Daniel et al., 2015)		✓		Occupancy	HVAC (schedule, set point), rooms	Survey data
(Duan & Dong, 2014)		✓		Occupancy	HVAC	Survey data
(Wang & Greenberg, 2015)	✓			Thermostat and window	Ambient data and Heating set point	Yes
(Santin et al., 2009)	✓			Window and shading	Temperature set point	Yes
(Hong & Lin, 2013)	✓			Window operation	Seven parameters related to window operation	No

First, there were three educational, institutional, and residential buildings in Qom, each with approximately 6000 m^2 built-up area, and all three buildings had six floors in a similar rectangular shape. The behavioral information of the users was collected through a survey (Figure 1). It must be noted that only the educational building was modeled in the software, and as previously mentioned, it was considered as the mediator control variable. And with each outcome from the software, the extracted information about the use of educational, institutional, and residential buildings was put in Energyplus as independent variables.

According to the study conducted by Thomas, the amount of energy required to preserve the internal temperature can be measured by calculating the thermal equilibrium, where heat, from the building envelope, windows, user, equipment, and air movement from in and out of the building were considered (Thomas, 1997).

In the present research, the simulation input information was gathered through surveys. The equipment used in the space was recorded in all three occupancies and independently defined for each intended building. So, the university building was described in the software three times, each time with different occupancies: educational, residential, and institutional. Therefore, the building's technical properties, form, orientation, and location were considered constant control variables in the software.

The behaviors during one year (from the March of 2017 to April of the same year) were recorded through field studies from all three occupancies based on 365 days of the year and according to the hourly schedule of each activity and people's presence timetable and clothing. One of the samples, the Shahab Danesh University building, was modeled in Ecotect software and was put in Energyplus software as the test sample. The technical properties of the building were described based on the present and recorded conditions. Then, the use of equipment in the space, hourly activity schedule, and people's presence timetable and clothing were described in Energyplus for each occupancy for the modeled building.



The office building, agriculture jihad organization, Qom province

The educational building, Shahab danesh university

The residential building

Fig 1. The office, residential, and educational buildings of the study

The following steps were taken to model the building in terms of behavioral patterns:

1. Creating a volumetric model of the building in the mediator software (Ecotect),
2. Defining the intended building's properties and conditions, including determining the opaque, translucent, etc. walls materials,
3. Defining people's presence timetable in three occupancies: educational, institutional, and residential, based on built-up area and according to the interviews with the users[1],
4. Describing people's clothing and types of activities in three occupancies: educational, institutional, and residential[2],
5. Describing the use of electric equipment and its application rate in three occupancies: educational, institutional, and residential[3],
6. Describing the lighting schedule and its application rate in three occupancies: educational, institutional, and residential[4],
7. Analyzing the analysis obtained by the software to simulate the thermal performance of the prepared model in Qom's climate. To do this, the Qom climate data file, in epw format, was used, where climate data were recorded hourly. This file is one of the climate data files in Iran, which is approved by the developers of Energyplus and uploaded on the developers' website (Oliva, 2017). Finally, the building's energy consumption rate outcomes for cooling and heating in 12 months were separately recorded and compared with each other.

5. MODELING AND INFORMATION INPUT

5.1. The intended building's modeling by Ecotect software

The first stage of the intended building's analysis is building modeling. In order to model the building, it must be divided into separate thermal zones. In energy simulation, dividing a building into measurable thermal zones is a difficult task that requires experience in simulation. Because despite having general principles, it is different for each case. For example, in the building mentioned above, the architectural plan must be properly divided into thermal zones; people usually zone each room as a thermal zone, and their modeling corresponds to the architectural plan, which is wrong.

The definition of a zone in simulation includes "one bulk of air" that has an even temperature, and all "heat transfer plates" or "heat preservation plates" are located in the mentioned bulk of air. Modeling is carried out in Ecotect software based on all the mentioned points. To do this, first, all micro-spaces are measured in Ecotect software, and spaces with similar thermal conditions are considered as a single zone (Figures 2, 3, and 4). As shown in the plans, this building has a central corridor on all floors, and the void is in the form of a floor. The main parts of the plan, too, use a central system for cooling and heating despite spatial diversity. Therefore, the corridors and void are considered a single zone. And the other spaces in the building were considered and drawn as a single zone on each floor. Then, the floors were placed on each other in a file. The same procedure was repeated for residential and institutional occupancies. Corridor and void spaces were grouped as one zone, and the remaining spaces, which are controlled under a cooling and heating system, were defined as one zone, and only the number of users, behavioral patterns, users' clothing, and electric equipment used in the spaces were separately, and based on the conducted survey, defined as independent variables. As mentioned, to draw the windows in each zone, a window, equal in area to the sum of the areas of all windows in that zone, is drawn.

5.2. Wall Properties

The wall's materials significantly affect the building's energy consumption (Tahmasebi, 2009), which can be taken into consideration by determining the materials of the wall and their thickness in Energyplus software. Table 2 demonstrates the properties of the building's opaque and translucent walls (Figure 6).

[1] All three occupancies where behaviors were surveyed, were 6000 m^2 and similar in shape

[2] The clothing and types of activities were recorded through interviews and observation

[3] The electric equipment and application rates in all three occupancies are recorded

[4] The schedule of equipment application in each occupancy is recorded

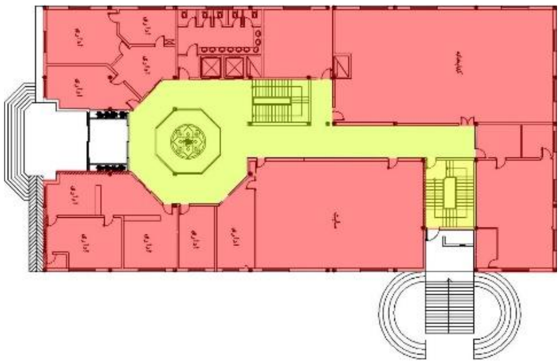


Fig 2. The ground floor plan of the experimental building

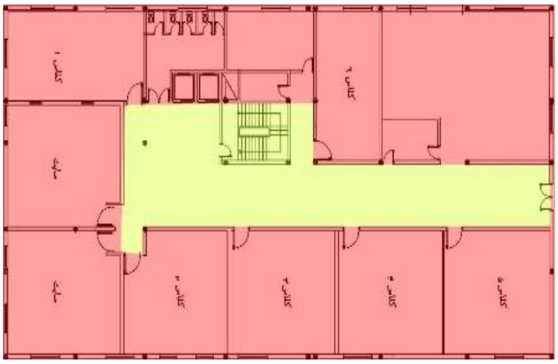


Fig 3. The experimental building's basement plan

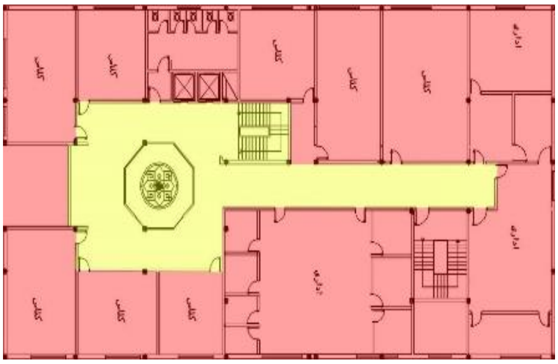


Fig 4. Floor plan of the experimental building

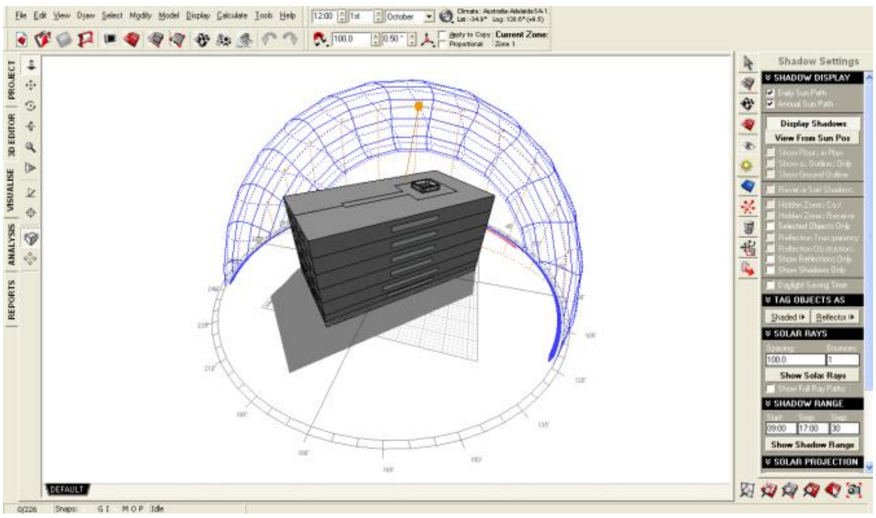


Fig 5. Volumetric modeling of the building in Ecotect software

Table 2. The structure of the building's walls (The numbers are derived from article 19 of National Building Codes guidelines)

Type of wall	Materials (From outer layer to inner layer)	Thickness (m)	Heat conductivity coefficient (w/m-k)	Density (Kg/m³)	Specific heat (J/kg-k)
Outer wall	Stone	0.01	2.3	2240	790
	Cement mortar	0.006	0.58	1900	1000
	Brick	0.1	1.185	2240	790
	Cement mortar	0.006	0.58	1900	1000
	Gypsum	0.05	0.58	800	1090
Inner wall	Gypsum	0.05	0.58	800	1090
	Brick	0.1	1.185	2240	790
	Gypsum	0.05	0.58	800	1090
Ceiling	Stone	0.01	2.3	2240	790
	Cement mortar	0.006	0.58	1900	1000
	Lightweight concrete	0.1	0.36	1120	900
	Heavyweight concrete	0.3	1.95	2240	900
	Gypsum	0.05	0.58	800	1090
Floor	Gypsum	0.05	0.58	800	1090
	Heavyweight concrete	0.3	1.95	2240	900
	Lightweight concrete	0.1	0.36	1120	900
	Cement mortar	0.006	0.58	1900	1000
	Stone	0.01	2.3	2240	790
Final ceiling	Mosaic	0.02	1.8	2560	790
	Cement mortar	0.006	0.58	1900	1000
	Lightweight concrete	0.1	0.36	1120	900
	Heavyweight concrete	0.3	1.95	2240	900
	Gypsum	0.05	0.58	800	1090
	Insulator	0.07	0.03	43	1210

Table 3. The properties of the building's double-pane windows (The structure of translucent walls)

Type of wall	Layers (From outer layer to inner layer)	Thickness (m)
Double-pane window	Annealed glass	0.006
	Air	0.003
	Annealed glass	0.003

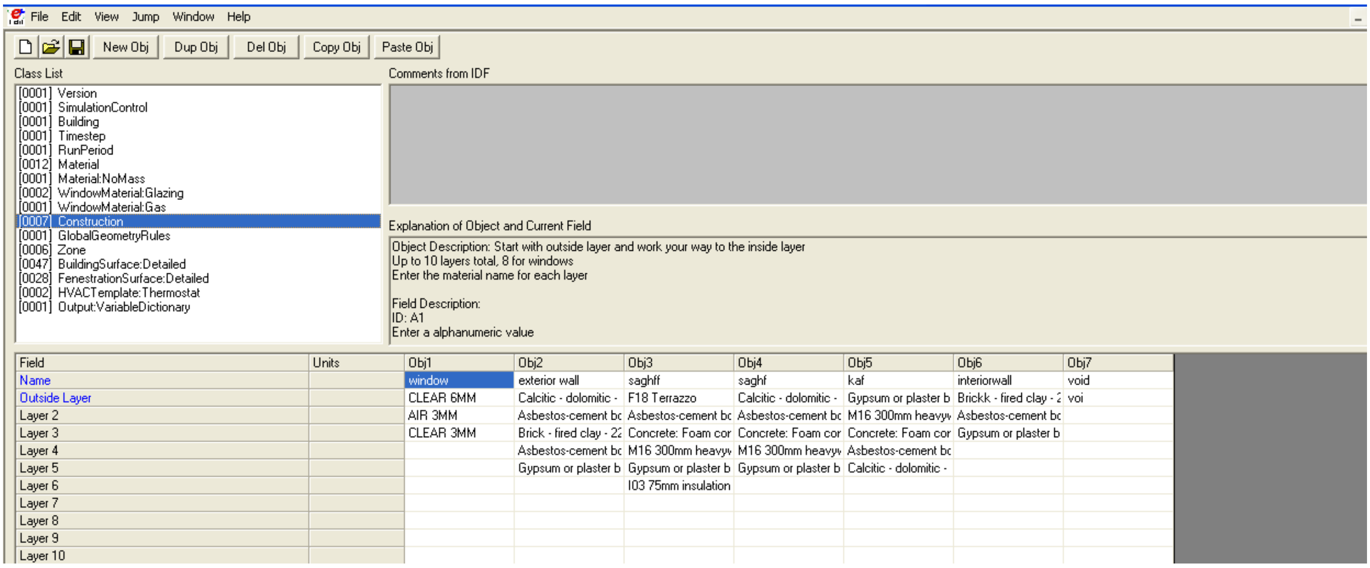


Fig 6. Defining the building's opaque and translucent walls in Energyplus software

5.3. The process of modeling the building concerning behavioral patterns in Energyplus software

In order to achieve the desired results in this research, after modeling the previously mentioned building and describing the building's volumetric properties, such as the material of the opaque walls and their thickness and the material of the translucent walls and their thickness in the software, the scenario for all of the factors involved in the building's thermal behavior, such as the number of users and the duration of their presence (Table 4), people's clothing (Table 5), the type of equipment within the building and their usage patterns, the amount of lighting equipment within the building (heat sources), were described in the software for educational, institutional, and residential occupancies. It must be noted that ASHRAE standards were used to input the data regarding people's activity rate and clothing. ASHRAE standards were used in simulation and all input data was based on that data. ASHRAE data are used as basic data (the rate of heating, cooling, etc.) for simulation. The interview is used for activity and the type of cloth in the occupancy.

5.4. Defining people's presence timetable

In this section, the scenario for people's presence in this building for all three mentioned occupancies is defined according to the survey. It must be noted that the information regarding the number of users of the building and the duration of their presence is gathered based on the field study results of the building with educational occupancy. Concerning the other occupancies, the scenario for people's presence is described based on the evaluation of a hundred questionnaires. The sample of this questionnaire is enclosed at the end of the study. As shown in Figure 6, first, people's presence timetable in the building is described in the software, and in the next step, assigned to each zone (Figures 7).

5.5. Defining people's clothing and type of activity

Based on the field study results mentioned above and the following table regarding people's type of activity and clothing, the information can be collated and described in the software. It must be noted that the information regarding people's rate of activities (Table 4) and clothing (Table 5) is gathered through ASHRAE standards. Tables 4 and 5 demonstrate the rate of some of the main activities and clothing.

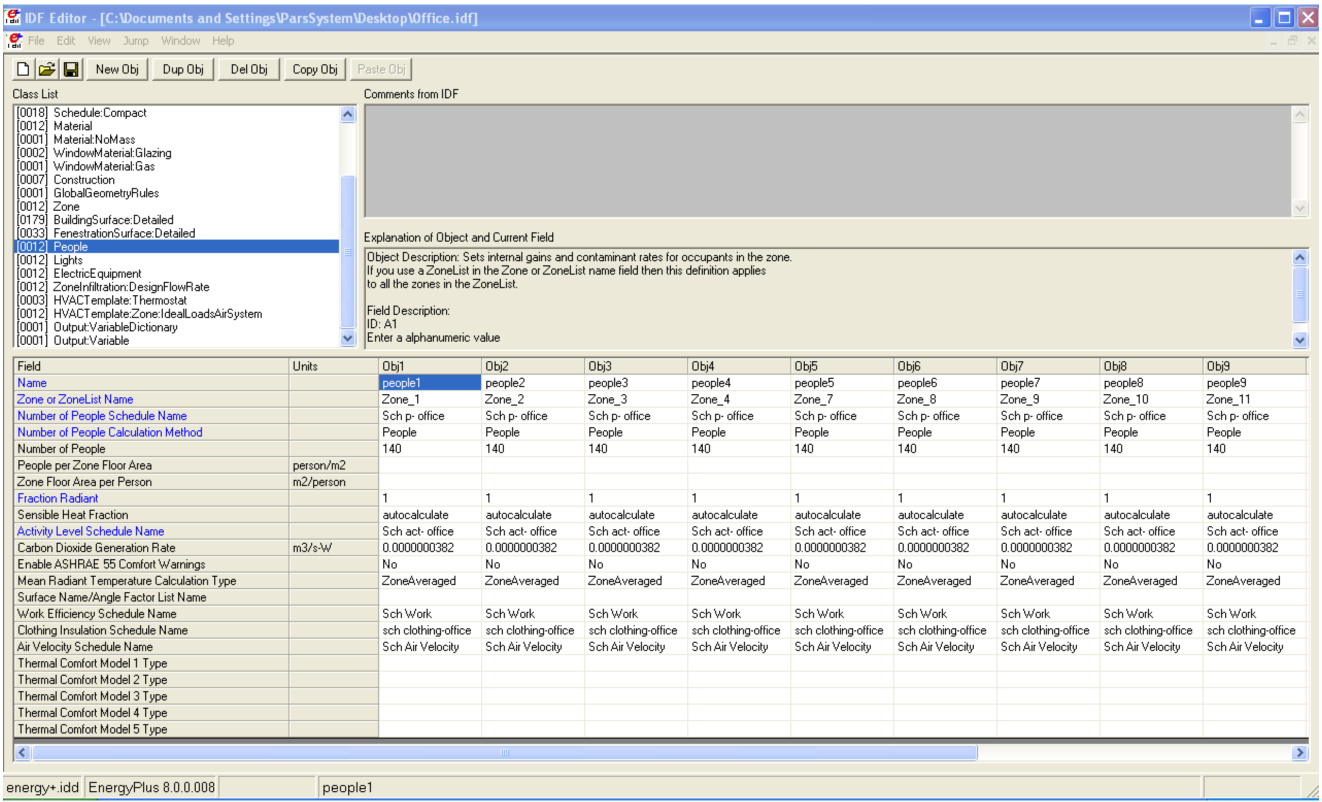


Fig 7. People's presence timetable in the three mentioned occupancies in Energyplus software

5.6. Defining the schedule of electric equipment usage and the rate of their applications

The information about the type and number of electric equipment in the mentioned occupancies is collected based on the field study results on the experimental building, and then the schedule of use of this equipment and their energy consumption rate are defined in the software (Figure 8).

Table 4. Rate of people's activities

Rate of activity (based on KW)	Type of activity
72	Sleeping
81	Napping
108	Sitting
126	Standing
207	Walking 3.2 km/h
270	Walking 4.3 km/h
99	Reading
108	Writing
117	Typing
126	Developing profiles
216	Packaging and lifting
171	Cooking
250	Cleaning
207	Shredding

(Source: ASHRAE standards)

Table 5. People's rate of clothing

Rate of clothing per clo	People's clothing
0	Naked
0.02	Stockings
0.03	Underwear
0.1	Pants
0.06	Sleeveless shirt
0.09	T-shirt
0.012	Long-sleeve shirt
0.015	Long-sleeve shirt
0.2	Pants
0.12	Vest
0.2	Jumper
0.35	Suit coat
0.55	Jacket
0.1	Shorts
0.31	Nightwear
0.4	Thick winter clothing
0.05	Short socks
0.1	Long socks

(Source: ASHRAE standards)

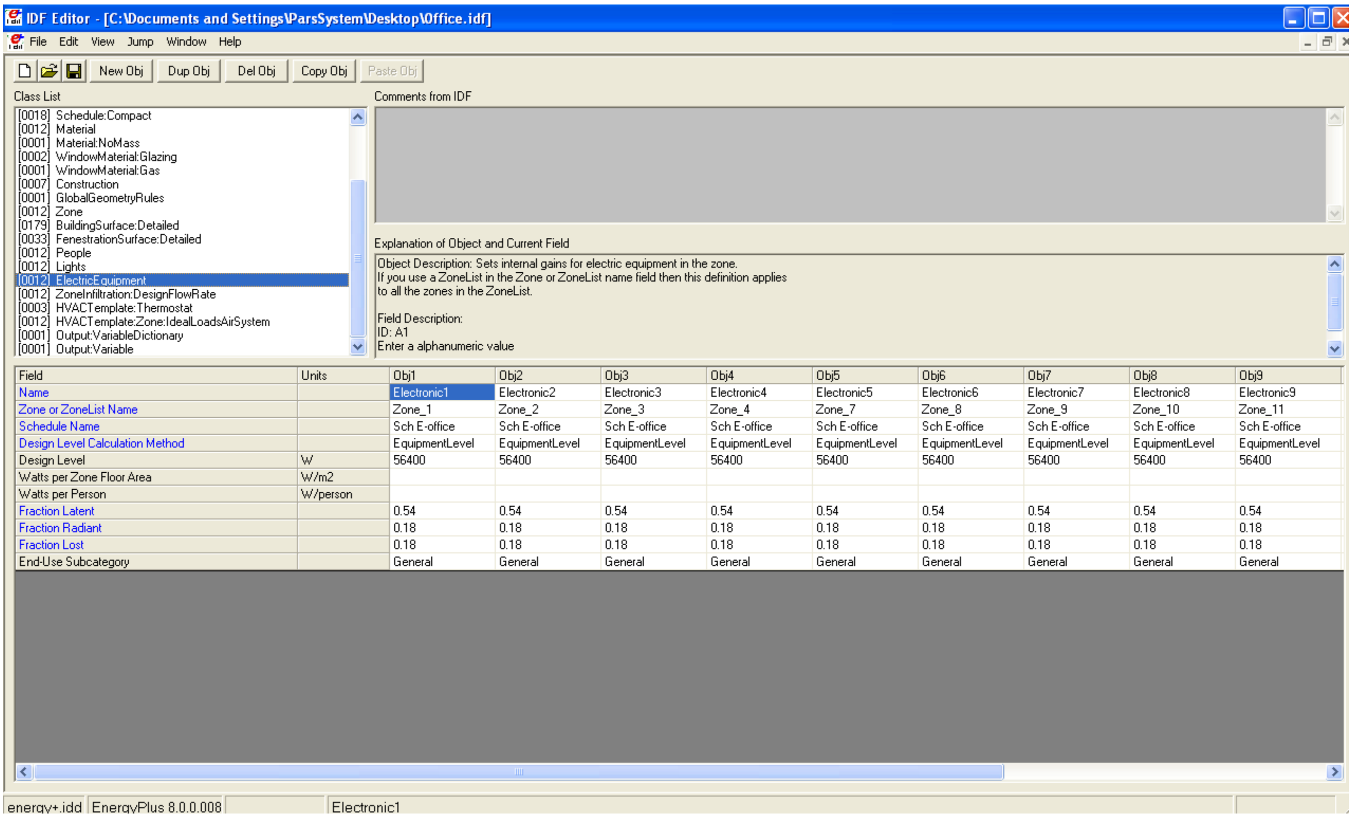


Fig 8. The table of buildings' electric equipment and its energy consumption rate in Energyplus

5.7. Defining the schedule of use of lighting and its energy consumption rate

The information about the type and number of lighting equipment in the mentioned occupancies is collected based on the findings from the field study on the experimental building, and then the schedule of using lighting equipment is determined and defined in the software. There are 520 lamps in the intended building, each drawing 20 watts (10400 watts in total).

6. ANALYSIS OF THE SOFTWARE RESULTS

The experimental building has 6 floors, including the basement, ground floor, and floors 1-4. In order to better compare the results, three floors, basement, second, and fourth floors, i.e. the lowest floor, the floor in the middle, and the highest floor in all three occupancies, were chosen. Afterward, the heating and cooling loads per kilowatts per hour, respectively, in the cold and hot seasons of the year, and the internal temperature of each floor in all three occupancies were separately analyzed and compared with each other.

6.1. Evaluation of monthly heating load in institutional, educational, and residential occupancies

The chart below illustrates the heating load in all three intended occupancies per kilowatts per hour in Qom.

As shown, the highest heating load belongs to the coldest month of the year, i.e. December, and then in November. Also, the heating load in December in the residential occupancy, 37000 kWh/m^2, was the highest, and in educational occupancy, 20000 kWh/m^2, was the lowest. This amount reduces in November and January.

6.2. Evaluation of monthly cooling load in institutional, educational, and residential occupancies kWh/m^2

Chart 2 demonstrates the monthly cooling load in all three occupancies in the hot seasons of the year in Qom. It shows significant fluctuations.

As shown, the educational occupancy has the highest cooling heat in most of the hot seasons, with a relatively large difference from the other occupancies. In June, this difference reduces, and eventually, in July, when according to the people's presence timetable, the educational building is empty, it has the lowest cooling load, showing the huge impact of people's presence on the building's energy consumption rate. Also, in August, when employees are present in the educational building, but there are no students, the cooling loads of the educational and institutional buildings are similar.

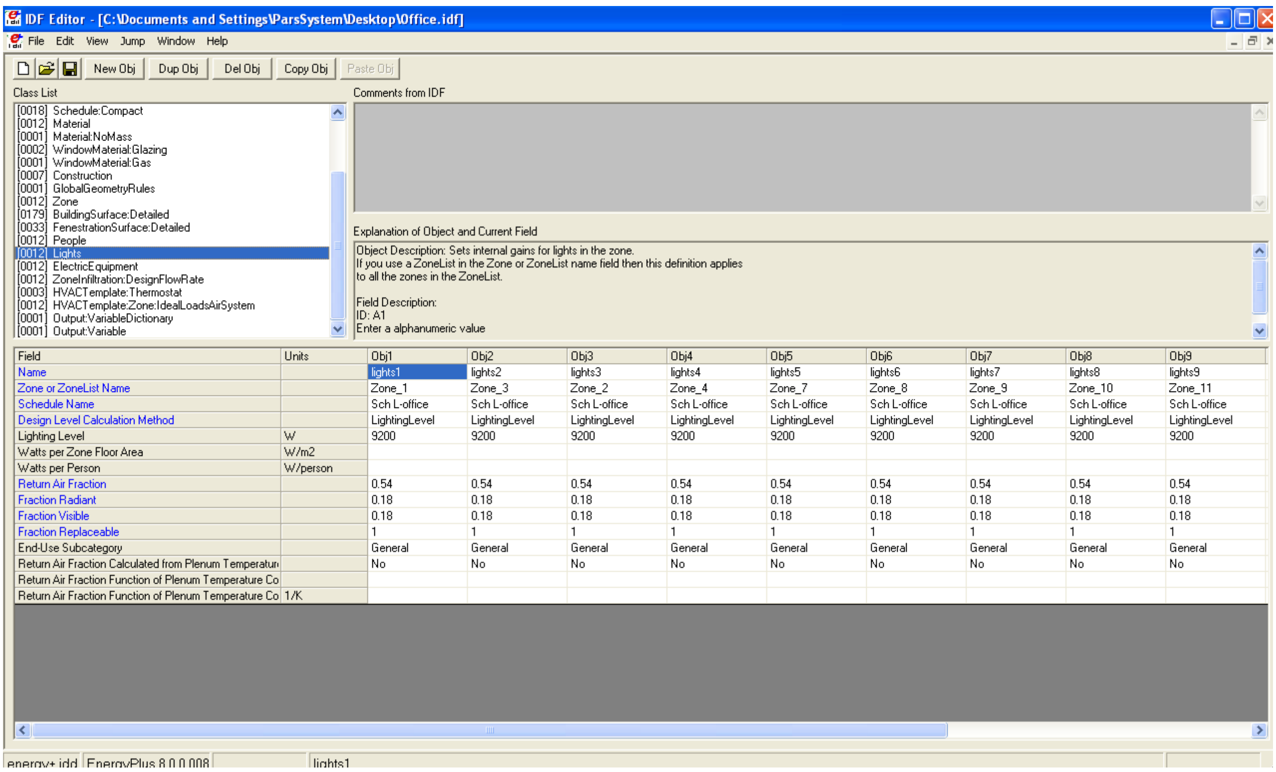


Fig 9. Defining the schedule of use of lighting equipment and its energy consumption rate in Energyplus

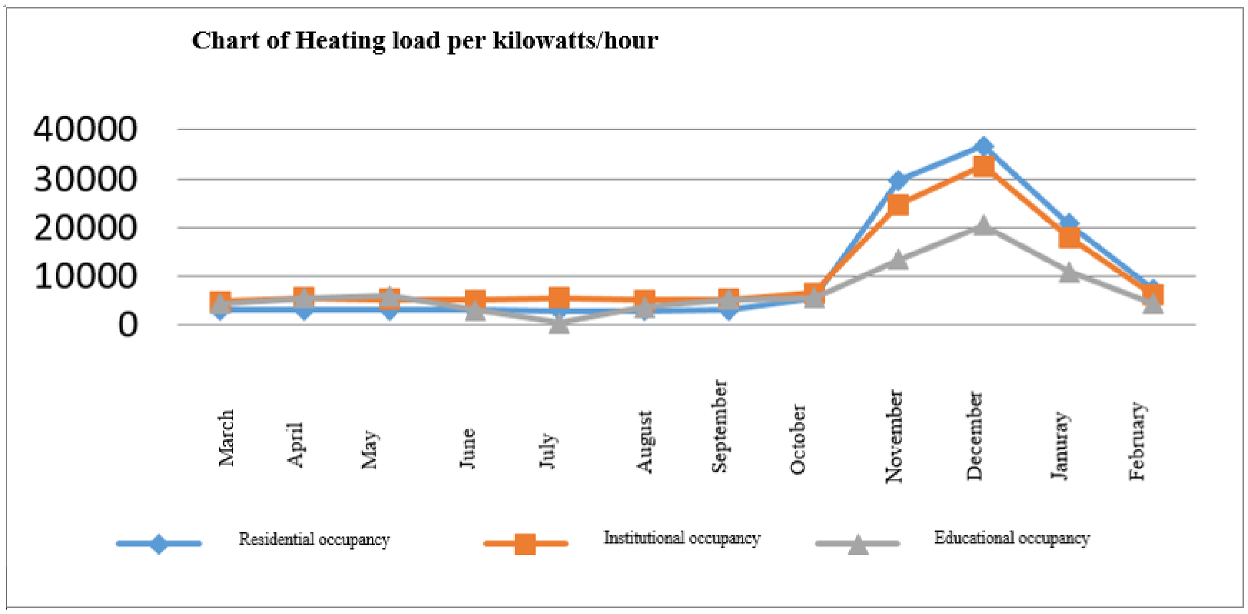


Chart 1. Comparison of heating loads in three occupancies, institutional, educational, and residential

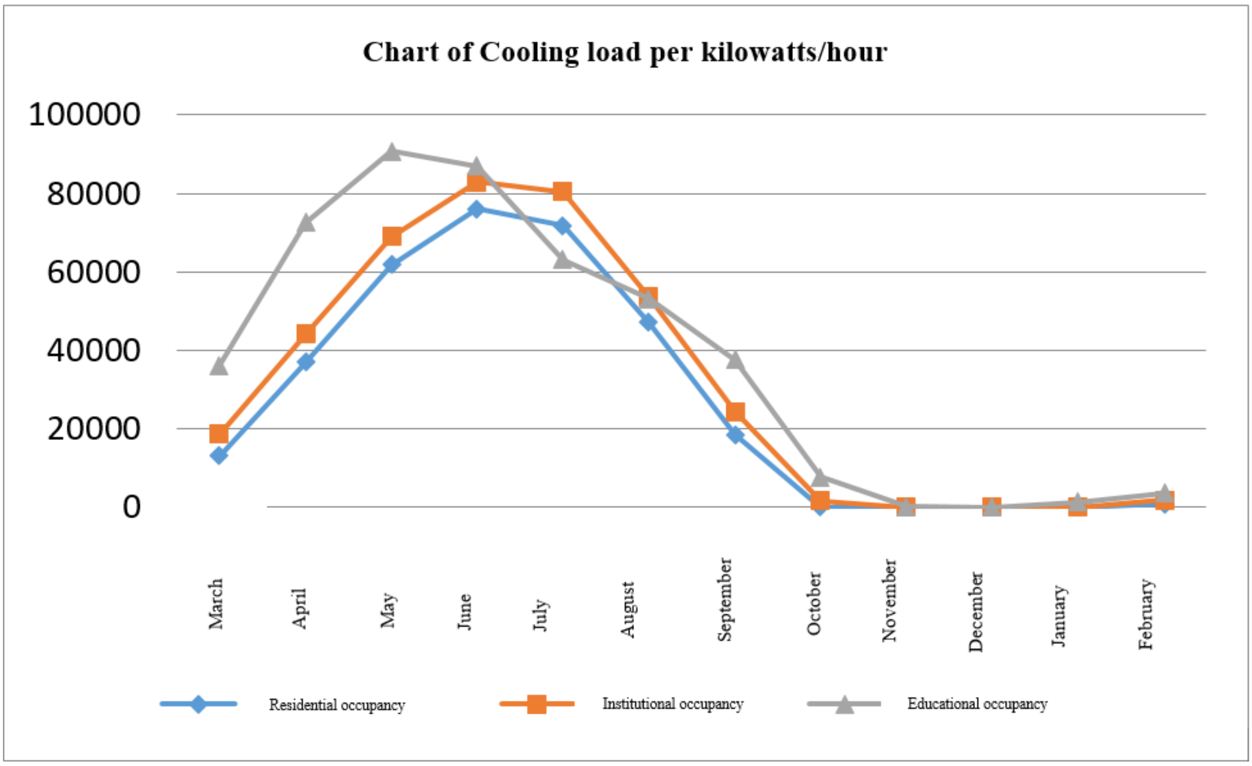


Chart 2. Comparison of cooling loads in three occupancies, institutional, educational, and residential

6.3. Evaluation of monthly mean temperature of the floors in institutional, educational, and residential occupancies

Chart 3 illustrates the monthly temperature in the three intended occupancies in Qom.

As shown, the temperature fluctuations in the educational building are less frequent than in the other two occupancies. In other words, the mean monthly temperature of this occupancy is closer to the comfort temperature; therefore, it has better conditions. Whereas the institutional occupancy has more critical conditions in terms of temperature fluctuations because, as shown in the chart, it has a lower mean monthly temperature in the cold seasons of the year and the floors are colder, and the opposite conditions occur during hot seasons of the year. And finally, the residential occupancy, compared to the other two occupancies, has in-between conditions in terms of temperature fluctuations.

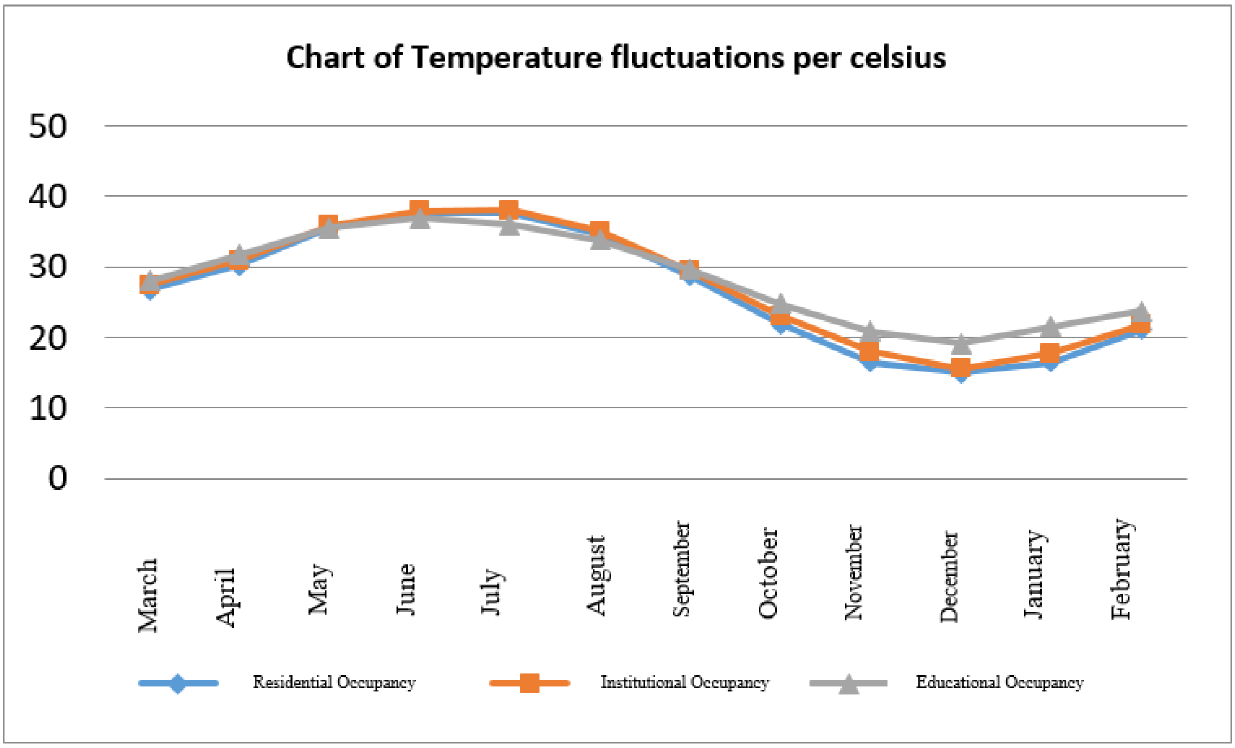


Chart 3. Comparison of the temperature in three occupancies, institutional, educational, and residential

7. CONCLUSION

To evaluate the impact of building occupancy on the energy consumption rate, three buildings with equal floor area and floor area ratio and with three different occupancies (i.e. institutional, educational, and residential) were chosen in this study. These three buildings were similar in location, buildings' forms, and built-up area, and in terms of occupancy, duration of people's presence and the number of people, their clothing, type and duration of electric equipment usage, and the number and duration of using lighting equipment. However, they had significant differences. Therefore, by considering the body of the building constant, different occupancies were defined in the software, and the outcomes were compared with each other.

In the simulation of the sample model with Energyplus software, it was shown that the highest heating load belonged to the coldest month of the year, i.e. December, and the residential occupancy. And the lowest heating load belonged to the educational occupancy. Contrarily, the educational building, compared to the other two occupancies, had the highest cooling load, with a relatively large difference, in most hot months of the year. It can be concluded that the reduction in educational occupancy's heating load is influenced by the presence of more people in the building and their clothing. The presence of more people in the space contributes to the internal temperature, and on the other hand, the clothing (winter clothing) reduces the need for thermal energy. On the other hand, the pattern of presence in residential spaces, given the constant use of space during nights, and also the recorded clothing pattern (summer clothing) in residential spaces can contribute to the increase of heating load in cold months of the year.

Occupants affect building energy use in both active and passive ways, which is the driver of energy consumption. Occupant behavior needs to be fully understood for better building performance prediction and energy optimization. The objective of this study was to review the research conducted so far to investigate occupant behavior modeling and its impact on building energy simulation and provide recommendations for future research. The application areas of occupant behavior models are discussed in the paper for enhancing energy simulation accuracy and optimized control of building systems. The state-of-the-art modeling technologies and methodologies of building occupant behavior have been studied and compared based on the characteristics, advantages, and disadvantages. It is concluded that agent-based modeling has better potential to combine occupant behavior models with energy simulation tools, whereas data mining and stochastic modeling methods have the ability to track the long-term pattern of occupant presence/absence status for demand response control. Also, the quantification of occupant impact on building energy use in simulation tools was discussed in this paper.

Assigning the highest cooling load during the hot months of the year to the educational occupancy proves the impact of people's presence on increasing the temperature of the space, so much so that the increase in the number of people in cold months of the year leads to reduced heating energy consumption.

The high cooling load in educational occupancy is lowered when people's presence in the space is reduced during June. And eventually, in July, when, according to the timetable of people's presence, the educational building is vacant, its cooling load is less than the other two occupancies, which demonstrates the great impact of people's presence on the building's energy consumption rate. During August, when there are only employees and no students in the educational building, the cooling loads of the educational and institutional buildings are similar.

Shortening the duration of people's presence and work hours during hot seasons of the year in the educational building can significantly contribute to lowering the cooling load of the space and energy conservation in hot and dry climates.

The cooling load on all three floors of the institutional building is clearly higher than in the residential building. However, the number of people present in are is equal in both occupancies. People's presence in the residential building is also continuous and longer than people's partial presence in institutional buildings. This can be due to the pattern of use of the space and the user's effort toward preserving the environment's thermal conditions, which occurs in residential occupancy with higher precision. As previously mentioned, spaces with similar thermal conditions are considered one zone, not only based on the architectural plan but even more based on users' behaviors toward controlling the thermal conditions of the space and the rate of air ventilation in each space. Given the vaster interrelationship between the spaces, the zones were considered larger in the institutional occupancy and more restricted in the residential occupancy, which is influenced by the behavioral patterns in each occupancy.

According to the results, the temperature fluctuations in the educational occupancy are less frequent than in the other two occupancies. In other words, the monthly mean temperature in this occupancy is closer to the comfort temperature; therefore, it has better conditions. In contrast, institutional occupancy faces more critical conditions in terms of temperature fluctuations. And the residential occupancy has in-between conditions in terms of temperature fluctuations.

Given the vast use of fossil resources to provide energy, proper network management and attention to peak energy demand can help manage the power supply network and reduce energy consumption. These findings can be taken into consideration in major energy planning in cities through network management for evaluating the peak energy demand and changing official work hours in offices and educational environments in Qom.

Finally, it must be noted that this article solely compares the impact of behavioral patterns on buildings' energy consumption rate, and no solution for critical conditions is recommended. It is expected that using the findings in this article, future studies can achieve proper solutions for balancing the fluctuations.

Three lessons can be learned from the statistical simulation:

1. statistical data analysis provides adequate user models for application in building simulation.
2. The Energyplus simulation is an appropriate tool to calculate the thermal building performance with a true mean value and its statistically relevant deviation.
3. Statistical simulations can be advantageously applied to the design process and enhance the significance and clarity of simulation results.

8. LIMITATIONS

This research was a case study that cannot be generalized but can make the conditions for future studies. But it can be said that the findings in this study can be used to reduce energy consumption in this case, and if expanded along with more studies, in similar cases.

One of the other limitations of this research was using the simulation method alongside the survey method. Despite taking all factors into consideration and efforts toward creating similarity and closeness with reality, some cases may have been ignored, but they might be significantly influential in the field of energy consumption. However, according to the studies, the occupants' behaviors are not always predictable and simulable, and sometimes these behaviors occur in unpredictable frameworks and with high effectiveness, which is beyond the behaviors considered by the software. Therefore, real-time evaluation of the building and evaluating the building with real changes of occupancy from institutional to residential and educational would be better, but it is impossible. The credibility of energy simulation has been once assessed in this research based on real-time data on energy consumption by comparing gas and electricity bills regarding the educational building. The real use of the building is extracted from the gas and electricity bills during a one-year period and compared with the outcomes of the software, and the simulation is thus calibrated; the occupants' real-life patterns are extracted through questionnaires and field studies.

9. ATTACHMENTS

People's presence scenario questionnaire

Dear citizen:

The following questions are designed to prepare a questionnaire for an article titled "Evaluating the change in cooling and heating loads of a building in three residential, institutional, and educational occupancies" and are a part of the first phase of comprehensive research in the mentioned field. It must be noted that due to the requirements of stage-by-stage information gathering and primary evaluation of the mentioned field, this questionnaire may seem rather simple and general at first sight, but we have tried so that it takes the least possible time for you, dear citizen, to fill out; therefore, we ask you to answer the questions with patience and precision.

1-Gender:

- Male
- Female

2-Age:

3-Education:

- Lower than a high-school diploma
- High-school diploma
- Undergraduate
- Graduate
- Ph.D

4-Family members:

- Less than three
- 3 to 5 members
- More than 5 members

5-Career:

6-Please, fill out the following form according to the hours of your presence and activities at home on different days of the week:

7-Please, fill out the following form according to the hours of your presence and activities at the office on different days of the week:

The university building bills, through which the software outcomes were assessed to compare the building's energy consumption rate in 2017 with the software outcome, are presented below.

	24-2	2-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24
Saturday											
Sunday											
Monday											
Tuesday											
Wednesday											
Thursday											
Friday											

	6-8	8-10	10-12	12-14	14-16	16-18	18-20
Saturday							
Sunday							
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Wednesday							
Thursday							

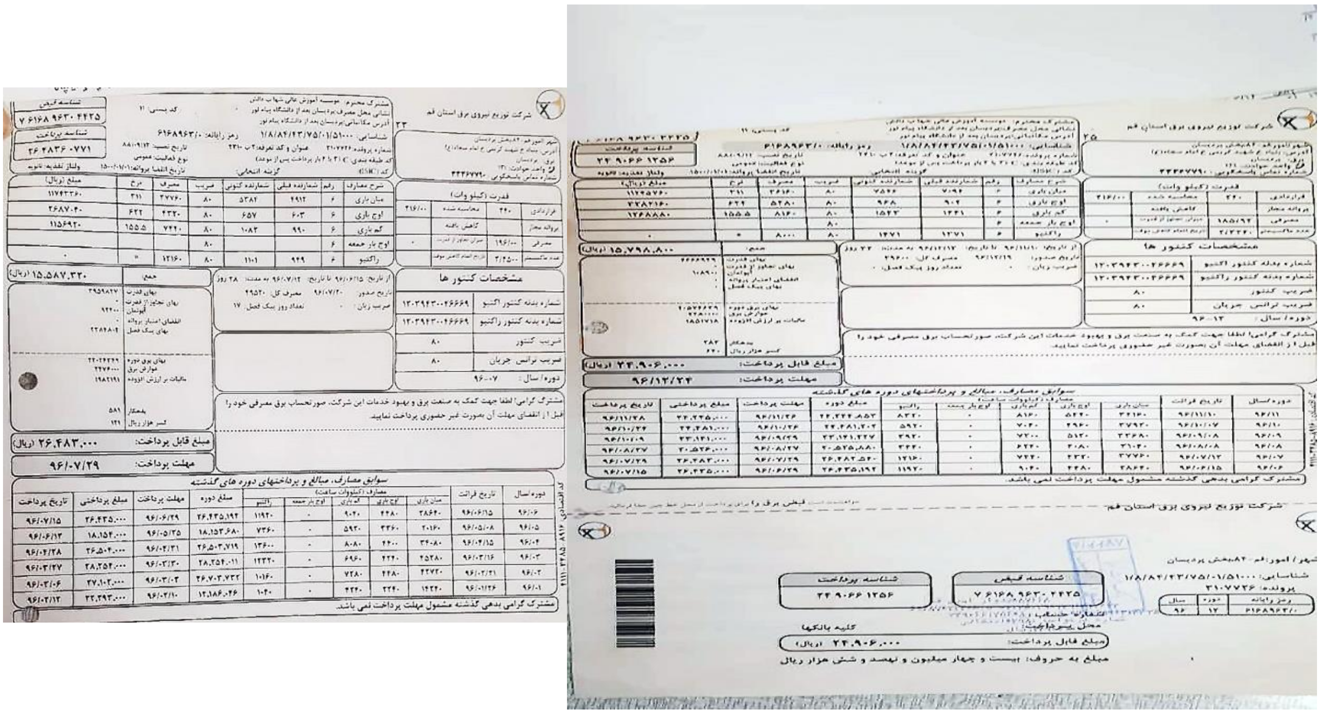

Fig 10. Electricity bills of Shahab Danesh University in 2017

Fig 11. Gas bills of Shahab Danesh University in 2017

Fig 12. Shahab Danesh University

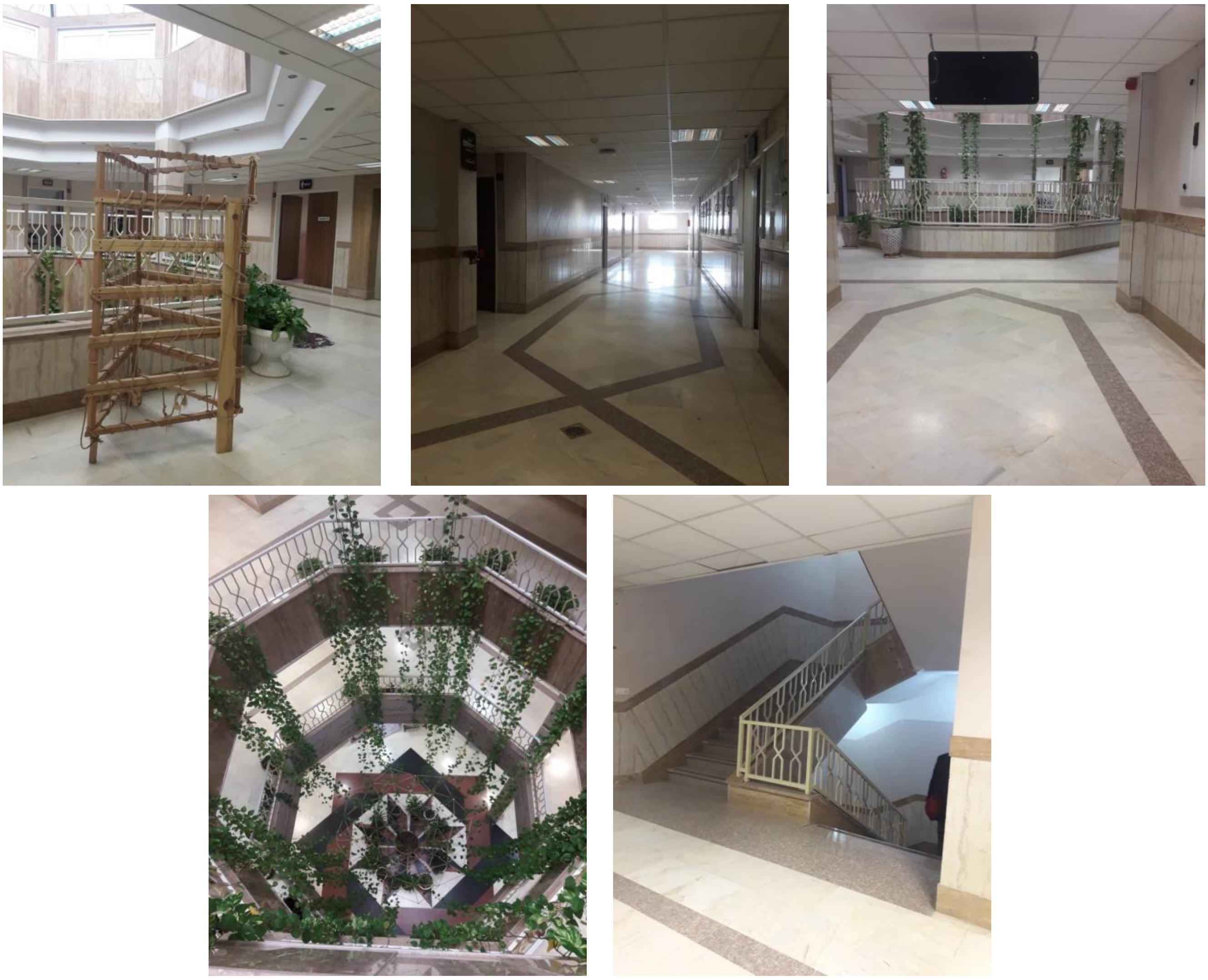

Fig 13. Shahab Danesh University

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