BIM-based optimum design and energy performance assessment of residential buildings

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Buildings are the largest energy consumer in the world, according to the United Nations Environment Program. Most of the energy will be used during the building life-cycle stage. Thus, achieving sustainable development at the national level requires minimizing the impact of buildings on the environment by reducing energy consumption. Using Building Information Modeling technology in energy performance assessment could be significantly reduced time and cost. This study aimed to optimize energy consumption in a residential building using BIM technology. The main focus of this study was to evaluate energy performance through the simultaneous evaluation of building components using BIM technology with a conceptual design approach, comparison, and reduction of energy consumption. To investigate different design ideas were created several conceptual masses in Autodesk Revit software with a top-down design approach. After reviewing the conceptual masses, the main building form was chosen for modeling. Then, building energy consumption was computed using related tools in this field, based on the type of materials, equipment, and project location. Finally, the most optimal mode was selected by examining different energy consumption forms. The results of parametric studies on alternative schemes of energy optimization showed that 58.46% of energy cost savings could be achieved compared to the initial model of the building on a 30-year time horizon.

keywords: *Energy consumption, Energy performance assessment (EPA), Energy simulation, Building energy efficiency, Building Information Modeling (BIM).*

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NOMENCLATURE

Abbreviations

ACH Air Changes per Hour
AFUE Annual Fuel Utilization Efficiency
BIM Building Information Modeling
Clr Clear
Eff Efficiency
HVAC Heating, Ventilation, and Air Conditioning
LoE Low emissivity
PV Photovoltaics
R13+R10 Construction material
SEER Seasonal Energy Efficiency Ratio
Sgl Single
Trp Triple
VAV Variable Air Volume
WWR Window-to-Wall Ratio

1. INTRODUCTION

In 2019, U.S. residential and commercial buildings used more than 39.2% of the nation's total energy and more than 71.1% of the electrical energy [1]. Emerging technologies are helping to reduce the energy use intensity by enabling cost-effective and energy-efficient technologies to be developed and introduced into the marketplace. Some of these technologies include HVAC, water heating, and appliances, windows and building envelope, solid-state lighting, grid-interactive efficient buildings, sensors and controls, and building energy modeling [2, 3]. Building energy models are usually created separately from building information models, and energy analysis is done with a separate analysis tool [4, 5]. In the traditional way of evaluating energy performance, which designers manually simulate an energy model, there are serious problems such as error-prone data duplication, data leaks, and redundant data processing and storage [6]. The building energy model can be generated more quickly by leveraging existing data from BIM, and the use of multiple analysis tools is more practical [4]. Buildings cause environmental pollution due to energy and resource consumption, emission of pollutants, and waste disposal throughout construction, maintenance, and demolition [7, 8]. Furthermore, the impact of energy consumption is significant in the building usage phases, which can last multiple decades [9]. Therefore, it's essential to analyze building energy performance when the most critical decisions are made (especially the design phase) [6]. The building energy performance analysis requires access to specific information such as properties of materials, U-value, and technical systems during the initial phase of design. This information is one of the factors determining the energy performance of the building [10]. Building Information Modeling is a technology for improving productivity and efficiency in the construction industry by taking advantage of the information generated throughout the facility life-cycle using a consistent system [6]. The best description for building information modeling is a data model, which is made by integrating 3D digital techniques with different methods of information related to a specific engineering project [9]. One of the main benefits of BIM in both the initial phase of design and subsequent stages of analysis is building energy simulation [4]. This technology makes it possible to continuously measure energy performance for the whole life cycle of a building [11]. Building energy simulation programs can be used effectively in the initial phases of design to evaluate "what-if" scenarios in the search for optimal solutions [12]. These programs can provide useful insights into changes that can improve energy performance. The parametric nature of BIM programs allows the suggested changes to the building energy model to be quickly updated [4]. In Iran, a considerable amount of energy annually is consumed in the household, public, and commercial sectors. According to the latest existing data, the share of buildings' fuel consumption in 2016 was 34% of the total energy consumption [13]. The limitation of energy resources and the significant growth of using them compared with the worldwide average have doubled the necessity of optimizing energy consumption in Iran. Due to the high share of energy consumption in the building sector, accurate analysis of thermal and cooling loads of the building and efforts to reduce energy losses is an effective way to reduce energy consumption. Building information modeling provides the capacity to generate and manage all the information about a building during its life cycle, which will be used in energy performance assessment [6]. Many types of research have been done on the main potential and value-added as a result of BIM adoption to achieve energy efficiency in the energy sector [9, 14–28]. However, in the optimum design and energy performance assessment based on BIM, there has not been much-focused research using simulation and analysis. Looking at the previous studies can be found that there are not any researches to study energy performance assessment through the simultaneous evaluation of building components using BIM technology with a conceptual design approach, comparison, and reduction of energy consumption. These components include building orientation, window-to-wall ratio (WWR), window shades, window glass, wall construction, roof construction, infiltration, lighting efficiency, daylighting and occupancy controls, plug load efficiency, HVAC, operating schedule, photovoltaic panels efficiency, payback limit of photovoltaic modules, and surface coverage of photovoltaic modules. This research achieved the lowest level of energy consumption in the studied building by examining the simultaneous combination of building components and showed that the use of building information modeling technology in evaluating energy performance could significantly reduce energy consumption in the life cycle of the building.

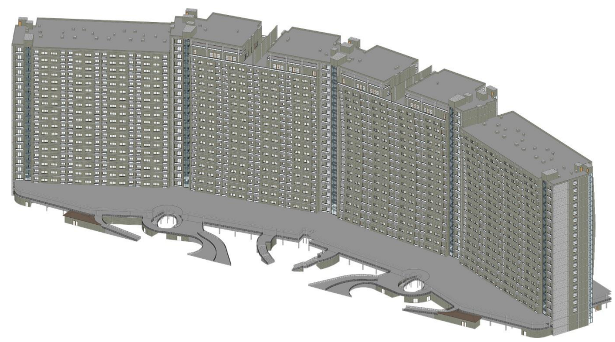


Fig. 1. The 3D view of the simulated building in Autodesk Revit software.

2. METHODOLOGY

A. Software Selection

Autodesk Revit 2020 was chosen to create a building information model for several reasons. One, Autodesk Revit provides various strategies for model creation using either a bottom-up or top-down design approach. Two, using the Autodesk Insight plugin, it's also possible to perform energy analysis in Autodesk Revit software. Three, support of building data output in standard formats such as IFC and gbXML, which makes it possible to perform energy analysis by other energy analyzer software. To perform energy analysis in this study was used related tools in the energy field. This tool was chosen because of its ability to quickly create an energy model and visualization in the initial phase of design. Moreover, Autodesk Green Building Studio (GBS) software was used to obtain the results of climate data analysis and building energy consumption index. Also, this software was used to validate the results of energy analysis. Thus, by sending the energy model to the Autodesk Insight software, a file will be sent to the Autodesk Green Building Studio software simultaneously. Using an Autodesk account provides the ability to review energy analysis. It should be noted that both Autodesk Green Building Studio software and Autodesk Insight software are flexible cloud-based services that allow for simulation of building performance to optimize energy efficiency. In addition to the reasons mentioned for choosing the software, it can use the minimum hardware resources of the system and provide a very high speed of energy analysis in cloud computing. Fig.1 shows the 3D view of the building case study in Autodesk Revit software.

B. Case Study

This case study is a residential building located in a region with a mild climate. The building area is about 191000 m2, located in Anzali trade-industrial free zone, Gilan province, Iran (37°27'14.7"N, 49°40'03.4"E). The main reasons for choosing this building were to study the form and orientation of the building and the cost changes caused by changing the effective parameters to optimize energy consumption using Building Information Modeling technology. To examine different design ideas were created several conceptual masses in Autodesk Revit software with a top-down design approach. Then, the floors and types of materials and energy settings were defined for each mass. Finally, after generating the energy model and sending the related file to the Autodesk cloud services were received the results of energy analysis. After reviewing the proposed designs in terms of energy cost as well as considering the items such as project location, site scope, building height, facilities, and project cost, the main form of the building was chosen for accurate modeling and energy analysis. Table 1 shows the comparison of different building forms.

The results of this analysis show that module-1 has the lowest energy consumption, among other modules. The cost of energy consumption based on Table 2 parameters is 13.4 USD/m2/year. Accordingly, the energy use intensity is equal to 110 kWh/m2/year, as shown in Table 1. The building orientation, in this case, is based on the geographical north. Thus, the angle of the building is automatically determined by the software, based on the building form and the project geographic coordinates. The window to wall ratio in all directions is 40% by default. All windows have shades with a depth of 45.72 cm. Also, the type of windows in the conceptual model was double-glazed windows without any external coating. The walls structure used in the conceptual model is lightweight walls with typical mild climate insulation, and the roof structure is lightweight and without insulation. As shown in Table 2, according to the BIM parameter were adjusted the values of building infiltration rate, lighting efficiency, plug load efficiency, operating schedule, and building's HVAC system. This building has no daylighting and occupancy controls system and photovoltaic solar panels. After adjusting the parameters affecting energy consumption, according to Table 2, the energy cost would be 6.56 USD/m2/year. Accordingly, the energy use intensity would be equal to 81.6 kWh/m2/year. The building orientation relative to the previous model (initial model) isn't changed and based on the geographical north. The windows ratio to the northern and southern walls is 40% by default. These windows have shades as high as 2/3 of the window height. Also, the type of these windows in the conceptual model was triple-glazed windows with low emission. Due to the lack of significant efficiency have been removed the eastern and western windows from the conceptual model. The walls structure in the conceptual model is according to Table 2, and the roof structure is lightweight and without insulation. The building infiltration rate was considered 0.17 ACH. The value of the lighting efficiency is assumed to be 3.23 W/m2. The values of the plug load efficiency and the operating schedule were adjusted according to the BIM parameter. The building's HVAC system was assumed to be a high-efficiency variable air volume system. Also, the building has a daylighting and occupancy control system. Finally, to achieve the highest level of energy efficiency were used the photovoltaic solar panels. For this purpose, the photovoltaic solar panels were used with a yield of 18.6% and surface coverage of 90%. The payback limit of these panels was assigned for 30 years. The results of this analysis show that the use of building information modeling technology for adjusting the parameters affecting energy consumption in conceptual designs can save up to 51.04% in energy cost. Based on the energy use intensity, this value would be 25.82%.

C. Baseline Energy Model Specifications

The building energy model requires a set of parameters depending on analysis tools and specific studies. Table 3 shows the basic parameters of the building energy model as the basis of design. These parameters include materials with thermal properties, building occupancy, plug loads, HVAC, building natural infiltration rate, lighting density and efficiency, internal heat gains (plug loads and occupancy), operating schedules, thermostat set-point temperatures, and natural ventilation. These parameters are specified by the BIM title in the provided data.

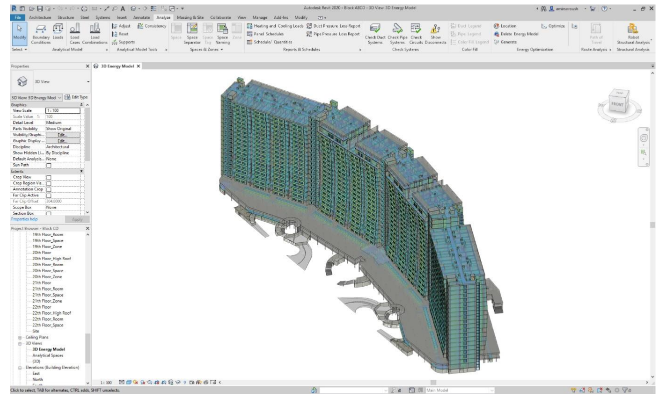


Fig. 2. Creating the energy model using building elements in Autodesk Revit software.

Table 3. Basic parameters of building energy model

Input parameter	Value
HVAC System	Residential 14 SEER/0.9 AFUE Split/Packaged Gaz <5.5 ton
Area per Person	105.82 m2
Sensible Heat Gain (per person)	73.27 W
Latent Heat Gain (per person)	58.61 W
Power Load Density	10.76 W/m2
Lighting Load Density	10.76 W/m2
Plenum Lighting Contribution	20%
Occupancy Schedule	24 Hours
Lighting Schedule	All Day
Power Schedule	All Day
Outdoor Air (per person)	2.36 L/s
Outdoor Air (per area)	0.30 L/ (s.m2)
Unoccupied Cooling Set Point	27.78 °C
Infiltration (ac/h)	None
Fabric U-values	
External walls	20cm concrete block (U-value 6.5 W/m2K)
Internal walls	10cm concrete block (U-value 13 W/m2K)
Shear walls	45cm reinforced concrete (U-value 2.3244 W/m2K)
Floor	22.5cm concrete slab (U-value 4.6489 W/m2K)
External doors	Wooden, Single-Flush (U-value 2.1944 W/m2K)
Terrace doors	Wood frame with single clear glass (U-value 5.6212 W/m2K)
Lobby doors	Metal frame with single clear glass (U-value 6.5580 W/m2K)
Elevator doors	Metal (U-value 3.7021 W/m2K)
Windows	1/8 in Pilkington single glazing (U-value 3.6886 W/m2K)

3. BUILDING ENERGY SIMULATION AND DATA ANALYSIS

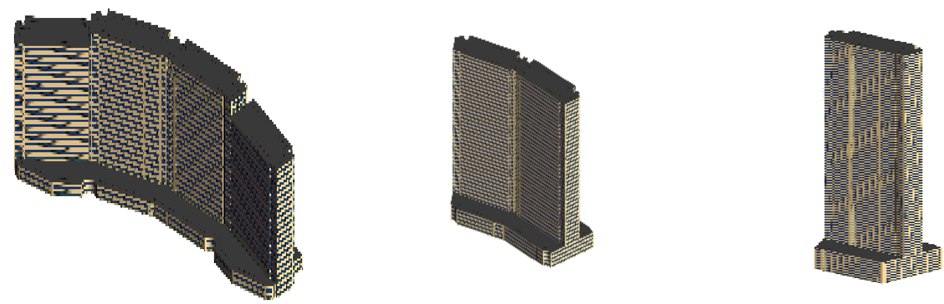
A. BIM Data Export Process

After modeling and adjusting the parameters required in Autodesk Revit software (Table 3), was created an energy model using the analyze tab (Fig.2). Then, an Autodesk account was used to send the energy model and receive the data analysis results. It should be noted that by sending the energy model through Autodesk Revit software to Autodesk Insight software, simultaneously, an energy model will be sent to Autodesk Green Building Studio software.

B. Climate Analysis

After sending the energy model, the climate data, as the first element of the environment in which the building is located, were automatically taken from the nearest weather station database.

Table 1. Comparison of different building forms based on the simulation of energy consumption in conceptual masses

		Module-1		Module-2	Module-3
					
Floors		22		43	84
Units		1070		1073	1084
Height (m)		81.7		159.4	311.1
Building Form		Energy Cost	Saving	Energy Use Intensity	Saving
		USD/m2/year	Percent	kWh/m2/year	Percent
Module-1	BIM Parameters	13.4	0	110	0
	Optimized Parameters	6.56	51.04	81.6	25.82
Module-2	BIM Parameters	13.5	0	108	0
	Optimized Parameters	7.33	45.7	89	17.59
Module-3	BIM Parameters	14	0	111	0
	Optimized Parameters	8	42.86	96.3	13.24

The data related to design conditions based on dry-bulb temperature and Mean Coincident Wet Bulb temperature (MCWB) are shown in Table 4. Fig. 3 shows the average of the minimum and maximum daily temperatures every month. Fig. 4 shows the wind speed frequency distribution based on annual data. The wind rose diagram is also shown based on annual data. This graph represents the relative frequency of direction and wind speed over a period of time at a specific location. Fig. 5 shows the relative frequency of direction and wind speed in the summer and winter seasons.

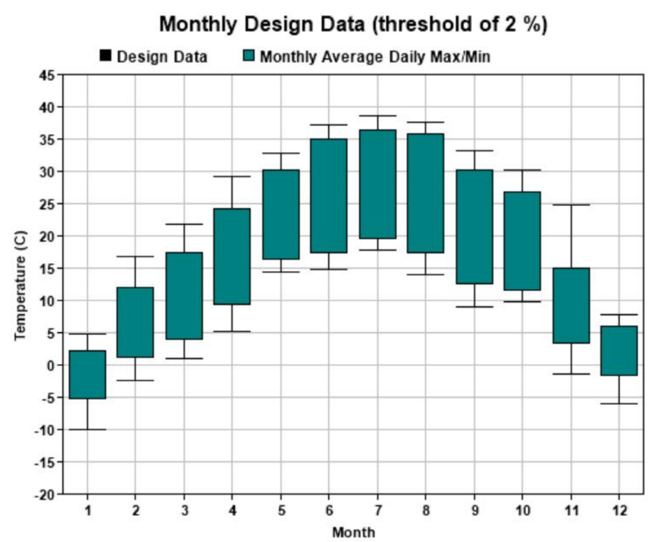


Fig. 3. Average maximum and minimum daily temperatures on a monthly basis.

Table 4. Basic parameters of building energy model

Annual Design Conditions				Unit: SI
Threshold	Cooling		Heating	
	Dry Bulb (°C)	MCWB (°C)	Dry Bulb (°C)	MCWB (°C)
0/10%	39/2	18/1	-10/4	-11/3
0/20%	38/8	17/9	-9/8	-11
0/40%	38/4	17/9	-9/2	-10/4
0/50%	38/2	18	-8/8	-9/8
1%	37/3	17/3	-7/6	-8/9
2%	36/4	16/9	-4/8	-6/5
2/50%	36	16/7	-3/9	-5/7
5%	34/1	15/8	-1/9	-3/7

C. Solar Orientation Study

This study investigates how solar radiation on building surfaces. After setting parameters such as project location, date, time, and time interval, will be obtained a graphical presentation of solar radiation (Fig. 6). The results indicated that block A (located on the western side of the site) with the most sunlight received during a day, had a better position compared to other blocks.

D. Energy Effective Parameters Analysis

Fig. 7 for block A shows the highest energy cost in July. According to this analysis, ventilation fans and space cooling have the largest share compared to other parameters affecting energy consumption. The maximum energy use intensity in block A is observed in January (Fig. 8). Obviously, space heat and ventilation fans have the highest share among other parameters. Accordingly, the highest level of energy consumption based on energy cost is seen in July and August, and based on energy use intensity is seen in January and December. The schematic diagrams of energy consumption for blocks B, C, D, and the

Table 2. Basic and optimized parameters of energy consumption in conceptual masses

Building Form	Module-1	Module-2	Module-3
Energy Cost (USD/m2/year)	13.4*, 6.56**	13.5*, 7.33**	14*, 8.00**
Effective Factor		Input parameter	
Building Orientation		BIM	
WWR (S)		BIM (40%)°	
Window Shades		BIM (0.4572 m) *	
		2/3 Win Height**	
Window Glass		BIM (Double Pane Clear – No Coating) *	
		Trp LoE**	
WWR (N)		BIM (40%)°	
Window Shades		BIM (0.4572 m) *	
		2/3 Win Height**	
Window Glass		BIM (Double Pane Clear – No Coating) *	
		Trp LoE**	
WWR (W)		BIM (40%) *	
		(0%) **	
Window Shades		BIM (0.4572 m) *	
		BIM (No Shade) **	
Window Glass		BIM (Double Pane Clear – No Coating) *	
		BIM (No Window) **	
WWR (E)		BIM (40%) *	
		(0%) **	
Window Shades		BIM (0.4572 m) *	
		BIM (No Shade) **	
Window Glass		BIM (Double Pane Clear – No Coating) *	
		BIM (No Window) **	
Wall Construction		BIM (Lightweight Construction – Typical Mild Climate Insulation) *	
		R13+R10 Metal**	
Roof Construction		BIM (Lightweight Construction – No Insulation)°	
Infiltration		BIM (None)*	
		0.17 ACH**	
Lighting Efficiency		BIM (10.76 W/m2) *	
		3.23 W/m2**	
Daylighting and Occupancy Controls		None *	
		Daylighting & Occupancy Controls**	
Plug Load Efficiency		BIM (10.76 W/m2)°	
HVAC		BIM*	
		High Eff. VAV**	
Operating Schedule		BIM (24 Hours)°	
Panel Efficiency (PV)		None*	
		18.6%**	
Payback Limit (PV)		None*	
		30 years**	
Surface Coverage (PV)		0%*	
		90%**	

*Base Model, **Optimized, °Unchanged

middle-lobby are similar.

4. BUILDING SIMULATION RESULTS

The results of this analysis show that block A has the lowest energy consumption, among other blocks. The cost of energy consumption based on Table 6 parameters is 13 USD/m2/year, as shown in Table 5. This value for blocks B, C, D, and the middle-lobby is equal to 13, 13.6, 14.1, and 14.1, respectively. Accordingly, the energy use intensity for blocks A-D and the middle-lobby would be equal to 112, 119, 126, 119, and 191 kWh/m2/year, respectively. The building orientation, in this case, is based on the geographical north. Thus, the angle of the building is automatically determined by the software, based on the building form and the project geographic coordinates. The windows ratios to the northern, southern, eastern, and western walls are 16%, 20%, 7%, and 5%, respectively. These values are 18%, 22%, 9% and 7% for block B, and 21%, 23%, 7% and 8% for block C, and 21%, 21%, 5% and 10% for block D, and 15%, 25%, 13% and 14% for the middle-lobby, respectively. The shades of all windows were considered by default. Therefore, the windows installed on the terraces would use their overhead ceiling as a shade. Other windows installed on the surfaces of the external walls lacked a shading system. As shown in Table 6, the type of windows is based on the software-defined element. The walls and roofs materials are shown in Tables 3 and 6. The values of the building infiltration rate, lighting efficiency, plug

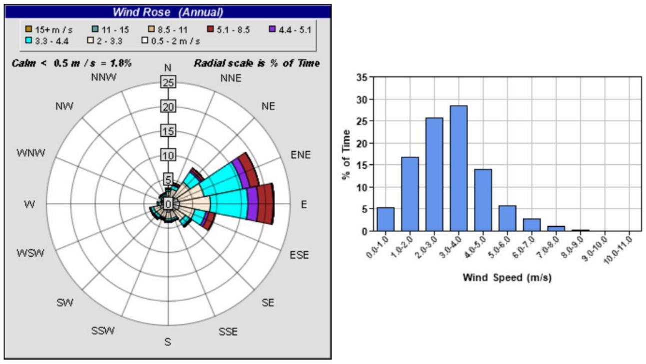


Fig. 4. Wind speed frequency distribution (Right) and Relative frequency of direction and wind speed (left).

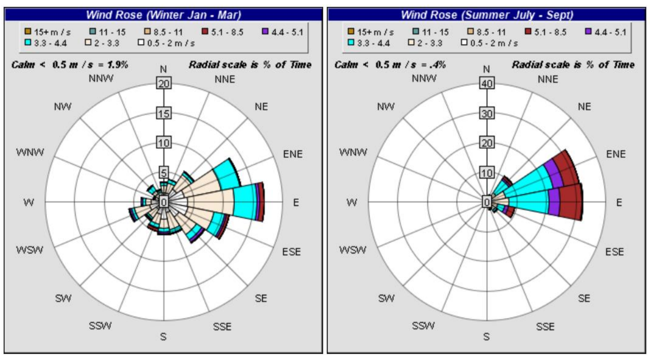


Fig. 5. Relative frequency of direction and wind speed in summer (Right), and in winter (left).

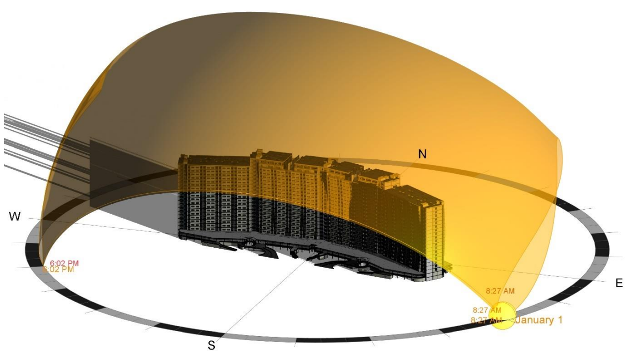


Fig. 6. Solar radiation on building surfaces.

load efficiency, operating schedule, and building's HVAC system were adjusted according to the BIM parameter (as shown in Table 6). This building has no daylighting and occupancy controls system and photovoltaic solar panels. After adjusting the parameters affecting energy consumption, according to Table 6, the energy cost of block A would be 5.4 USD/m2/year. This value for blocks B, C, D, and the middle-lobby is equal to 6.47, 6.66, 5.89, and 8.03, respectively. Accordingly, the values of energy use intensity for blocks A-D and the middle-lobby would be equal to 86.7, 99, 105, 99.6, and 170 kWh/m2/year, respectively. The building orientation relative to the previous model (initial model) isn't changed and based on the geographical north. The windows ratios to the northern and southern

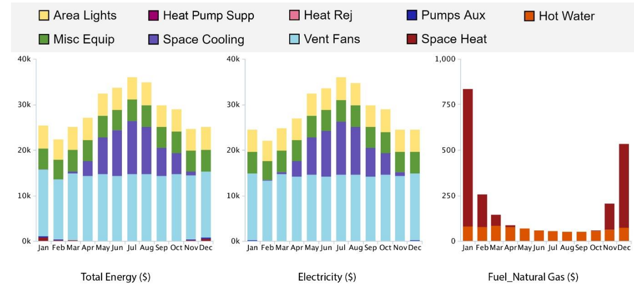


Fig. 7. Energy consumption index based on energy cost, Block A.

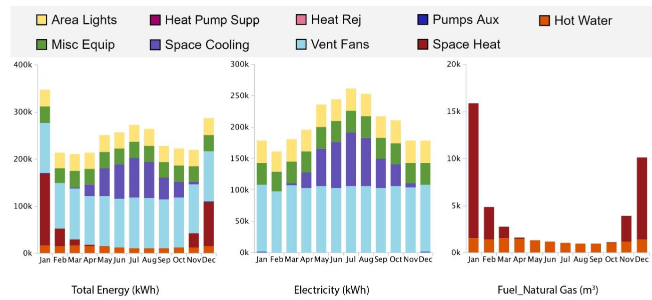


Fig. 8. Energy consumption index based on energy use intensity, Block A.

walls are unchanged and equal to 16% and 20% for block A, 18% and 22% for block B, 21% and 23% for block C, 21% for block D, 15% and 25% for the middle-lobby, respectively. For all blocks, the northern window shades are considered by default. Moreover, the southern window shades were selected as high as 2/3 of the window height. As shown in Table 6, the type of northern windows was determined based on the software-defined element for all blocks. The triple-glazed type with low emission was chosen to be used in southern windows. Due to the lack of significant efficiency, have been removed the eastern and western windows from the building model. The walls and roof structure are shown in Table 6. The building infiltration rate was considered 0.17 ACH. The value of the lighting efficiency is assumed to be 3.23 W/m2. The values of the plug load efficiency and the operating schedule were adjusted according to the BIM parameter. The building's HVAC system was assumed to be a high-efficiency variable air volume system. Also, the building has a daylighting and occupancy control system. Finally, to achieve the highest level of energy efficiency were used the photovoltaic solar panels. For this purpose, the photovoltaic solar panels were used with a yield of 20.4% and surface coverage of 90%. The payback limit of these panels was assigned for 30 years.

The results show that the use of building information modeling technology for adjusting the parameters affecting energy consumption can save up to 58.46% in energy cost for Block A. This value for block B, C, D, and the middle-lobby are 50.23%, 51.03%, 58.23%, and 43.05%, respectively. However, based on the energy use intensity, this value would be 22.59%, 16.81%, 16.67%, 16.30%, and 11% for blocks A, B, C, D, and the middle-lobby, respectively. The saving based on energy cost can be calculated by Eq. (1), and saving based on energy use intensity can be estimated using Eq. (2).

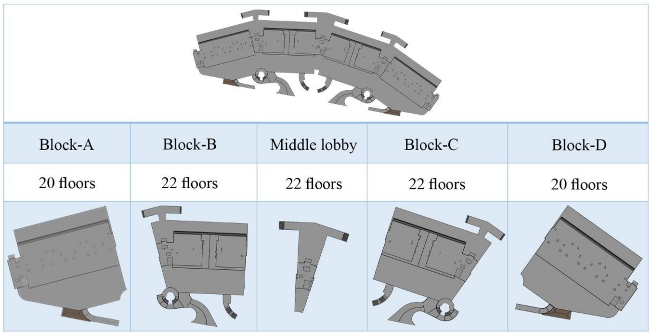


Fig. 9. Separation of building blocks for energy analysis.

$$Block\ A \rightarrow \left(\frac{5.4-13}{13}\right) * 100 = -58.46\% \quad (1)$$

$$Block\ A \rightarrow \left(\frac{86.7-112}{112}\right) * 100 = -22.59\% \quad (2)$$

Table 5. Comparison of different energy consumption scenarios in the building blocks

Building Block		Energy Cost	Saving	Energy Use Intensity	Saving
		USD/m2/year	Percent	kWh/m2/year	Percent
A	BIM Parameters	13	0	112	0
	Optimized Parameters	5.4	58.46	86.7	22.59
B	BIM Parameters	13	0	119	0
	Optimized Parameters	6.47	50.23	99	16.81
C	BIM Parameters	13.6	0	126	0
	Optimized Parameters	6.66	51.03	105	16.67
D	BIM Parameters	14.1	0	119	0
	Optimized Parameters	5.89	58.23	99.6	16.3
Middle lobby	BIM Parameters	14.1	0	191	0
	Optimized Parameters	8.03	43.05	170	11

5. RESEARCH LIMITATIONS

Due to the software limitation in sending the shade surfaces (max. 10000 surfaces) as well as the number of doors (max. 4096 doors), the whole building energy analysis was not possible in the cloud. For this reason, as shown in Fig. 9, each block of this residential building is analyzed separately. Finally, due to increased shade surfaces, the ceiling elements were removed from the building model.

6. DISCUSSION

As mentioned, due to the software limitations in sending the energy model, the building blocks were separated from each other and were removed the ceiling elements from the building model. Therefore, the thermal height was 4 m on the first floor and 3.7 m on the other floors. This building could have lower energy consumption than the obtained values, due to the implementation of ceiling elements during the construction phase and reduced computational height of the spaces as a result. However, the results show that block A has the lowest energy consumption. Considering the similar materials and equipment used, this can be due to the building orientation towards the geographical north of the region. Accordingly, by the implementation of other blocks in the direction of block A, the lowest energy consumption can be achieved as a result of the maximum solar radiation during a day. This study shows that the results from the conceptual model analysis are acceptable compared to the results from the actual building model. It can be useful in the early stages of decision-making for the project.

7. CONCLUSION

Today, most of the environmental problems in the world are related to the use of fossil fuels, especially in the construction sector. In Iran, considerable amounts of energy are consumed annually in the building and housing sectors. In this study, after reviewing the conceptual masses and choosing a building form, an exact model of building elements was created in the Autodesk Revit software. Then, the energy model was generated based on the BIM parameters. Finally, adjusting the parameters affecting energy consumption led to the reduction of energy costs in the building. Finally, the results of parametric studies on alternative schemes of cost optimization showed that 58.46% of energy cost savings would be achieved compared to the initial model of the building on a 30-year time horizon. The results showed that optimizing the energy consumption of the building using building information modeling technology could significantly save energy costs. In this regard, the optimization of energy consumption would reduce environmental pollutants emissions and contribute to the preservation and sustainability of the environment. It should be noted that the general method and findings of this study can be used in all regions of the world.

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Table 6. Basic and optimized parameters in building energy consumption

Building Block	Block A	Block B	Block C	Block D	Middle lobby
Energy Cost (USD/m2/year)	13*, 5.40**	13*,6.47**	13.6*, 6.66**	14.1*, 5.89**	14.1*, 8.03**
Effective Factor			Input parameter		
Building Orientation			BIM		
WWR (S)	BIM (20%)°	BIM (22%)°	BIM (23%)°	BIM (21%)°	BIM (25%)°
Window Shades			BIM*		
			2/3 Win Height**		
Window Glass			BIM (Sgl Clr) *		
			Trp LoE**		
WWR (N)	BIM (16%)°	BIM (18%)°	BIM (21%)°	BIM (21%)°	BIM (15%)°
Window Shades			BIM°		
Window Glass			BIM (Sgl Clr)°		
WWR (W)	BIM (5%) *	BIM (7%) *	BIM (8%) *	BIM (10%) *	BIM (14%) *
			(0%) **		
Window Shades			BIM*		
			BIM (No Shade) **		
Window Glass			BIM (Sgl Clr) *		
			BIM (No Window) **		
WWR (E)	BIM (7%) *	BIM (9%) *	BIM (7%) *	BIM (5%) *	BIM (13%) *
			(0%) **		
Window Shades			BIM*		
			BIM (No Shade) **		
Window Glass			BIM (Sgl Clr) *		
			BIM (No Window) **		
Wall Construction			BIM (Concrete Masonry Units) *		
			R13+R10 Metal**		
Roof Construction			BIM (Concrete, Cast In Situ)°		
Infiltration			BIM (None)*		
			0.17 ACH**		
Lighting Efficiency			BIM (10.76 W/m2) *		
			3.23 W/m2**		
Daylighting and Occupancy Controls			None*		
			Daylighting & Occupancy Controls**		
Plug Load Efficiency			BIM (10.76 W/m2)°		
HVAC			BIM*		
			High Eff. VAV**		
Operating Schedule			BIM (24 Hours)°		
Panel Efficiency (PV)			None*		
			20.4%**		
Payback Limit (PV)			None*		
			30 years**		
Surface Coverage (PV)			0%*		
			90%**		

*Base Model, **Optimized, °Unchanged

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