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Investigation of the Height Distribution Effect of Residential Complex Blocks on Optimization of Cooling and Heating Loads (Tehran, District 9)

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ABSTRACT

The height of buildings is one of the main features of urban configuration that affects energy consumption. However, to our knowledge, the complexity of relationships between the height parameters and energy use in urban blocks is poorly understood. In this context, the present study investigates the effect of the height distribution of buildings located in a residential complex on the energy consumption required for cooling and heating. This research simulates different possible layouts through computational software. For this purpose, first, the density of a residential complex was determined based on the rules and regulations of Tehran city and according to the site dimensions and certain site coverage. Then, the required building density was distributed in different layouts based on their diversity at different heights. The product of this stage involved 7 different layouts in which the height varied from 1 floor to the maximum number calculated in each part of the simulation. In the next step, the annual energy consumption for cooling and heating the complex was calculated for each of these layouts and compared with each other. The parametric generative model was created in the Grasshopper plugin from Rhino software, and the energy consumption was evaluated with the Honeybee plugin over one year. Also, the research findings were validated through DesignBuilder software using the EnergyPlus engine. The results of the energy simulation indicate that the height distribution of the blocks can have a significant effect on energy consumption. In the optimal case, proper layout reduces the annual cooling and heating energy consumption by 28 % and 13 %, respectively. Therefore, achieving an optimal value for each of the cooling and heating loads depends on the specific priorities and conditions of the design project. If the design project's priority is to reduce heating energy consumption, increasing the height and distributing the floors evenly between the blocks is a better answer. However, if the priority is to mitigate cooling energy consumption, the optimal layout can include low-rise blocks and a single very high-rise block.

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1. INTRODUCTION

Today, more than half of the world's population live in cities, accounting for nearly two-thirds of global energy demand and 70 % of energy-related CO_2 emissions (Poponi et al., 2016). Therefore, cities are at the forefront of the need to reduce energy consumption and carbon dioxide emissions. Thus, the development of various aspects of urban layout and configuration will lock the energy use pattern for decades to come. In other words, the combination of increasing urbanization and infrastructure that is still subject to variability provides a rare time window to realize energy efficiency (Resch et al., 2016). Therefore, with the increasing development of cities worldwide, understanding the interrelationship between the characteristics of urban environments and the physical features of buildings is essential to achieving local and global sustainability goals. Since residential buildings form a major part of the urban artificial environment, investigating the interactions of residential buildings in an urban layout is very important. It can be a good way for future decisions in urban planning, urban design, and architecture, especially in the early stages of design. In this context, according to numerous studies, the early design stage is very effective in achieving the optimal performance of sustainable buildings (Konis et al., 2016; Li et al., 2018).

Therefore, although it is difficult to achieve an accurate analysis of the energy performance of the building without considering the environment and the interaction of the buildings with each other, most studies in the field of energy consumption of residential buildings have examined each building separately. Research findings on single-building design contain valuable information on energy-efficient design. However, generalization of these findings to layout is impossible and, sometimes, creates conflicting situations. In a single building, the cooling and heating load is directly related to the receivable solar radiation, the surface-to-volume ratio,

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the size of the windows, and many other things. In cold regions, due to the need for more heating energy, it is better to increase the radiation received on the bodies, especially the south sides and, at the same time, prevent the heat exchange between inside and outside the building. This indicates a decrease in the surface-to-volume ratio on the one hand and an increase in the south surfaces and roof area, on the other hand. This relatively clear logic in the vicinity of several buildings becomes doubly complex. Increasing the south surfaces requires more buildings; this, in turn, increases the surface-to-volume ratio and the likelihood of double shading. This complexity of this situation is intensified in complex climatic situations. Therefore, despite the relatively useful information about the design of single-buildings, it is not easy to generalize energy-efficient design strategies to multi-building complexes, indicating the need for conducting independent research in this area.

Among the important and effective parameters in the layout of buildings and their interactions with each other, we can mention the issues related to the vertical layout and height of buildings in a composition consisting of several buildings, which is one of the important issues in improving building energy performance. In the present study, one of the main indicators of this issue, namely "the height distribution of the buildings in a residential complex", is examined. This study aims to fill the research gaps by exploring the relationship between the changes in the height of the blocks in a residential complex and the energy consumption required for cooling and heating. The research uses computational methods and energy simulations to explore the research questions: How to generate different strategies for different configurations and height distribution of buildings according to the specific density and cover ratio based on city zoning parameters? how does the height distribution of buildings in a residential complex affect the energy consumption required for cooling and heating? To answer these questions, first, previous studies, the final analysis of indicators, and the development of a possible correlation between independent and dependent variables were reviewed. Then, the generative model was developed to create different modes of height distribution. The obtained samples have undergone energy simulation in several stages to evaluate the cooling and heating loads, and their values are compared. Finally, after validating the findings and analyzing them, the research results have been presented. To our knowledge, no attempt has been made to optimize the height distribution of blocks in a residential complex with a comprehensive computational approach and parametric modeling in Tehran city's geographical and climatic conditions thus far. This is, thus, the first attempt to develop a mathematical model to investigate the relationship between the height parameters of blocks in a residential complex and the energy used for cooling and heating, which helps to create an optimal layout. The results obtained can pave the way for many design decisions at the early phases of the project.

2. BACKGROUND AND THEORETICAL FRAMEWORK

Research on building energy consumption is generally divided into single-building and urban scales (Rode et al., 2014; Toutou et al., 2018; Wong et al., 2011; Zhang et al., 2020), neither of which pays sufficient attention to the importance of the smaller components of the urban context. Since the 1960s, planners and architects have realized that focusing solely on individual buildings is not enough; rather, they need to extend the analysis to a group of urban buildings or blocks (Steemers, 2003). Among these, only a limited number of researches have been done on the scale of the neighborhood and urban blocks (Asfour & Alshawaf, 2015; Chen et al., 2020; Yang & Li, 2015). Regarding the larger scale of a single building, researchers have identified several physical features of the urban environment as factors affecting energy consumption in the buildings. These include horizontal building compaction (Asfour & Alshawaf, 2015; Salvati et al., 2017; Salvati et al., 2019; Trepci et al., 2020), vertical density (Li et al., 2018; Salvati et al., 2019), and differences in building height (Chen et al., 2017; Deng et al., 2016). The effect of the mentioned variables on environmental factors and building energy consumption has been studied in several types of research. Table 1 contains some of these studies.

Table 1. Several previous studies on the neighborhood and urban block scale

Study	Independent variables	Dependent variables	Year	Method	Results	Drawback
Urban block configuration and the impact on energy consumption: A case study of sinuous morphology (Shareef & Altan, 2022)	Building morphology and urban block configuration	Outdoor and indoor thermal performance	2022	Simulation	The results show the significant impact of the urban block sinuous configuration on outdoor thermal performance.	This study considers a uniform height for all buildings of sinuous configurations.
Energy efficient neighborhood design under residential zoning regulations in Shanghai (Quan, 2017)	Density, different building heights, and different layouts	Energy consumption	2017	Computational simulation experiments	The results show the great impact of the building height and the limited influence of neighborhood layout on building energy use.	This study considers the same height for all buildings in each scenario.
A parametric sensitivity analysis of the influence of urban form on domestic energy consumption for heating and cooling in a Mediterranean city (Vartholomaios, 2017)	Urban form parameters: number of floors, open space width, orientation, …	Residential energy consumption for heating and cooling	2017	Building energy simulation	There is a synergy between the strategies of high urban compactness and passive solar design, and this synergy can be achieved at different urban densities.	This research has been done in a relatively limited context.
The effect of surrounding	Arrangement of	Energy	2022	Building	The proper arrangement	This study

buildings' height and the width of the street on the building's energy consumption (Mirashk-Daghiyan et al., 2022)	adjacent buildings: number of floors and width of streets	consumption		energy simulation	of adjacent buildings can reduce energy consumption by 14.13 % compared to the initial state.	considers the same height for adjacent buildings and does not focus on the height distribution.
The study of the effects of building arrangement on microclimate and energy demand of CBD in Nanjing, China (Deng et al., 2016)	Building arrangement variations	Outdoor thermal conditions and building energy performance	2016	Numerical calculations and building energy simulation	The results indicate a quantitative correlation between building arrangement and the microclimate and building energy performance on the urban design scale.	This study only focuses on the urban scenarios with buildings in aligned arrangement, without considering the staggered arrangement.
The impacts of building height variations and building packing densities on flow adjustment and city breathability in idealized urban models (Chen et al., 2017)	Building height variation	Flow adjustment and city breathability	2017	Simulation	Taller buildings experience larger drag force and city breathability than lower buildings and those in uniform-height cases.	This study only considers six standard deviations of building height, whereas realistic cities are more complicated.
The impact of urban morphology and building's height diversity on energy consumption at the urban scale. The case study of Dubai (Shareef, 2021)	Urban morphology and building's height diversity	Cooling load	2021	Building energy simulation	The changes in the urban block morphology, particularly height diversity, have a notable impact on the cooling load.	In this research, the effect of intervening factors on the results has not been considered.
Evaluating the impact of the building density and height on the block surface temperature (Chen et al., 2020)	Building density and height	Block surface temperature	2020	Simulation model	Urban surface structures affect block surface temperatures, thermal loading of pedestrians, wind patterns, and more.	This study is only applicable to configurations with uniform height.

According to the results of studies, it can be expressed that the outdoor components, including buildings, streets, and vegetation, as well as micro-climate parameters including temperature, wind speed, relative humidity, and solar access are significantly subject to the influence of different parameters of the urban context. These factors have complex interactions with each other (Xu et al., 2020). On the other hand, microclimatic parameters also significantly affect outdoor thermal comfort and building energy demand. However, due to the lack of knowledge and tools, these issues, despite their importance, have not been well discussed in current regulations and procedures (Quan et al., 2015). In general, the urban geometry and layout of buildings, in addition to creating shadows, can greatly affect the temperature and thermal comfort; at the same time, they can trap solar radiation between surfaces, increase its wavelength, and create heat traps (Terjung & Louie, 1973). In addition, the layout of the buildings directs air flows, affecting temperature and humidity (Quan et al., 2015).

Therefore, in the layout of a complex, various factors such as granularity and proportions of blocks, orientation, compactness, and height parameters of the building are important (Leng et al., 2020), acknowledged the strong relationship of building site cover, floor area ratio, building height, road height-width ratio, green space ratio, and total wall surface area with heating energy consumption.

The parameter used in this study, namely height distribution, changes the surface-to-volume ratio and can affect the heat loss and, in general, the procedure of energy exchange with the outside environment (Figure 1).

On the other hand, by affecting the number and height of blocks in the complex, the height distribution process changes the solar radiation received by the buildings (Figure 2).

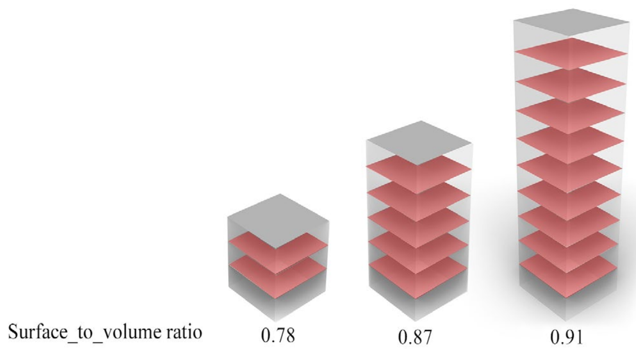


Figure 1. Variation of the surface-to-volume ratio by changing height

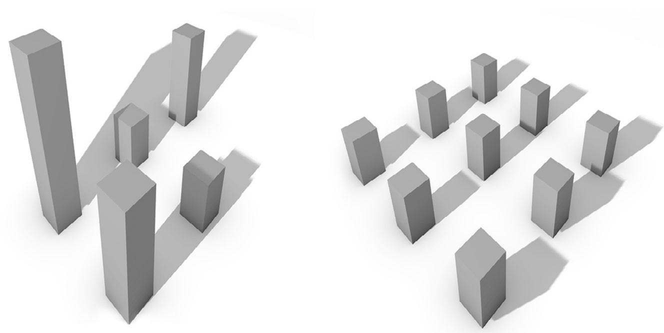


Figure 2. The effect of height distribution on the number of blocks and the quality of shading despite the constant number of floors in both cases

Due to the multiple effects of height distribution on the performance of the building and the surrounding micro-climate, predicting the energy consumption of a building under the influence of these factors is ambiguous and complex and requires research and study. For this reason, the results of previous studies are different due to the complex interaction between different patterns of space use, climatic contexts, and energy balance between different urban form factors.

3. METHOD

In general, the thermal performance of the built area can be evaluated at two levels: 1) outdoor thermal performance Chen et al., 2020; Mohajeri et al., 2016; Yang & Li, 2015) and 2) indoor thermal performance (Quan, 2017; Trepci et al., 2020; Vartholomaios, 2017). Outdoor thermal performance directly affects indoor thermal performance (Deng et al., 2016; Shareef, 2021). Thermal performance inside the building determines energy consumption. The energy inside the building is spent on various elements, such as lighting, ventilation, cooling, and heating (Shareef, 2021). The heating load is defined as the total heat energy required to maintain the temperature in an acceptable range. In contrast, the cooling load is the total heat energy that must be removed from the space to maintain the temperature in the appropriate range (Sekhar et al., 2018). A kilowatts (kW) unit or BTU[2] is used to measure the cooling or heating load.

Four tools are used to predict buildings' heating and cooling load: modeling and simulation, engineering calculations, statistical models, and machine learning-based models (Seyedzadeh et al., 2018). In general, due to the expansion of studies in this field and due to the complexity of the thermal environment of building blocks in recent years, numerical or computer simulations have become important tools for energy studies. They have successfully simulated various models from building scale to urban scale (Chen et al., 2020). Therefore, three-dimensional models representing different blocks' layout modes have been used in this study to achieve a possible relationship between the height distribution and the required energy for the heating and cooling of the building. The development of evaluated models has been carried out with a parametric modeling approach.

The research process consists of seven general steps: 1) determination of variables, 2) preparation of the modeling platform, 3) development of a generative model and different scenarios, 4) Building energy simulation, 5) review of findings and their analysis, 6) validation, and 7) conclusion (Figure 3). These cases will be discussed in more detail below.

The Grasshopper plugin in Rhino software was used to develop a parametric generator model, making algorithmic modeling and parametric simulation possible. Climate information (in this case for Tehran) has been added to the algorithm using the Ladybug plugin. The obtained information has been transferred to the EnergyPlus engine to simulate energy. This is done by the Honeybee plugin. Ladybug and Honeybee connect the Grasshopper plugin to reputable simulation engines such as EnergyPlus, Radiance, Daysim, and OpenStudio to calculate and simulate building energy, natural and artificial lighting, and more (Roudsari et al., 2013).

Finally, after completing the energy simulation process in the Grasshopper plugin, the data is re-introduced into the DesignBuilder software to test the accuracy of the findings (Figure 4).

3.1. Study area

The city of Tehran has been selected as the study area. For climate analysis, hourly data of the Tehran Climate Information File, taken from Mehrabad Airport Synoptic Meteorological Station, have been used. Table 2 summarizes the essential climate points of the study area.

[2] British Thermal Unit

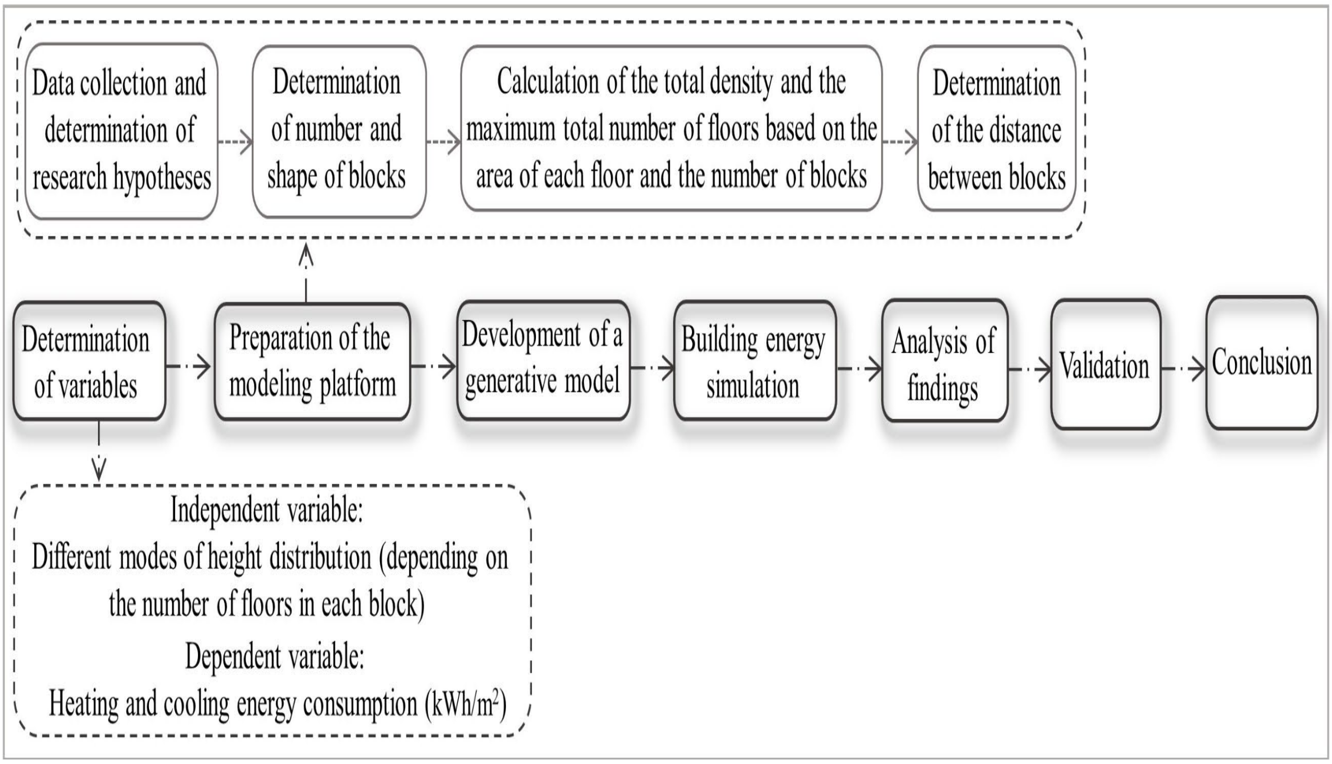


Figure 3. The research process steps

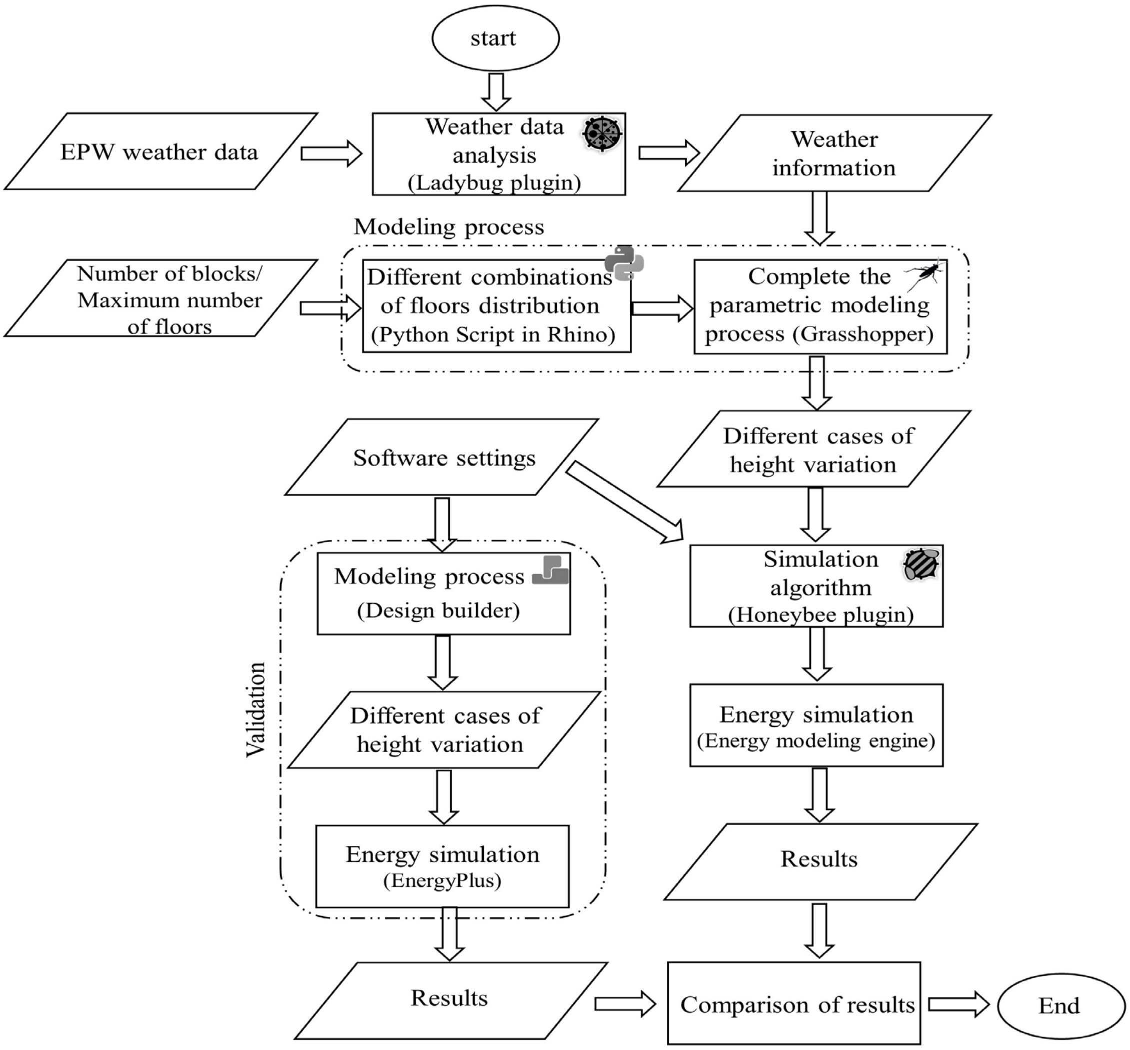


Figure 4. Method and software tools used in the building energy modeling process

Table 2. A summary of some climatic features of Tehran

Title	Description
Climate zone	Cold semi-arid climate (Köppen climate classification: BSk)
Thermal comfort condition	Summer condition: 21.5 °C to 27 °C, Winter condition: 20 °C to 23.5 °C, and relative humidity: 20 % to 65 %
Dominant requirement	Heating
Relative humidity	In summer, the relative humidity is less than in winter and dryness occurs in this season
Wind direction and wind speed	The prevailing wind blows from the west with an average speed of about 3 meters per hour

3.2. Simulation considerations

A set of assumptions is needed to start the process, including the maximum allowable density, the maximum allowable site coverage, and other basic information. In this regard, some construction rules and regulations in the city of Tehran were used. However, considering that one of the goals of this research is to employ a method to extract a proper layout from any other place, the research generative model algorithm was defined such that the rules and regulations of the same region could be utilized in the generative model for each area where the designer's intended site was located. The following initial number of blocks and their form was determined. In this regard, a residential complex consisting of 16 building blocks with a square plan, or the so-called "pavilions" form presented by Martin and March (1972), was developed. The "pavilions" form is a prevalent urban layout, and its main feature is the square shape of buildings surrounded by streets, passages, walkways, or even green paths.

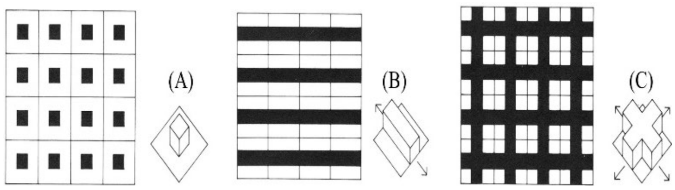


Figure 5. Buildings typology forms: (A) Pavilion, (B) Street, and (C) Court (Martin & March, 1972)

Therefore, the 4 × 4 square matrix (layout (A) in Figure 5) was selected from three different arrays presented by Martin and Mars due to the absence of the elongation interfering factor in building form and block layout. The number of blocks was selected in such a way that they would have the potential to create different modes of height distribution and prevent the creation of duplicate and innumerable modes of the layout, at the same time. According to the initial number set for the blocks, the area intended for the site, the maximum permitted building density (315 %), the maximum site coverage (35 %), and the maximum total number of floors in the complex (144 floors) were considered. Given that the obtained number indicates the "maximum" total number of floors on the site, in some stages of research, according to the requirements of that section, a smaller number of floors were used as default.

The distance between the blocks was also considered so that by removing the shading factor, the effect of height distribution on energy consumption could be investigated without the intervention of the interfering factor. In this approach, the distance between buildings is determined to as large as possible such that it is practically impossible for a building to cast shadow on another. Since the height of each floor was set at 3.5 meters, the distance between the building blocks was determined by calculating the maximum possible height of each block and then using the building shadow display tools in the Grasshopper plugin (Figure 6).

3.3. Steps and process of research

This research was conducted in three main stages:

A. Generative model

At this stage, a code or algorithm is needed that can automatically access all possible methods of distributing floors between blocks. This can be achieved through mathematical concepts such as permutations and combinations and their derivatives. With the help of the mentioned mathematical functions and by determining the number of blocks and the total number of floors required, all possibilities of height distribution between blocks can be achieved. It is important to note that the total built-up area must be considered the same in all scenarios. Figure 7 shows a part of the process that creates different scenarios of height distribution.

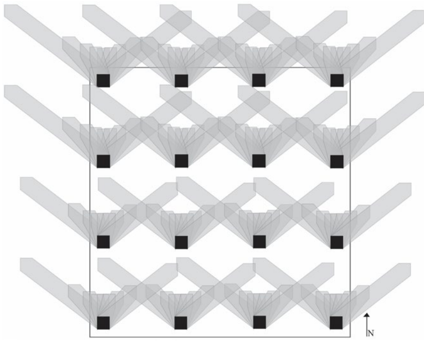


Figure 6. Achieving the right distance without shading at different times

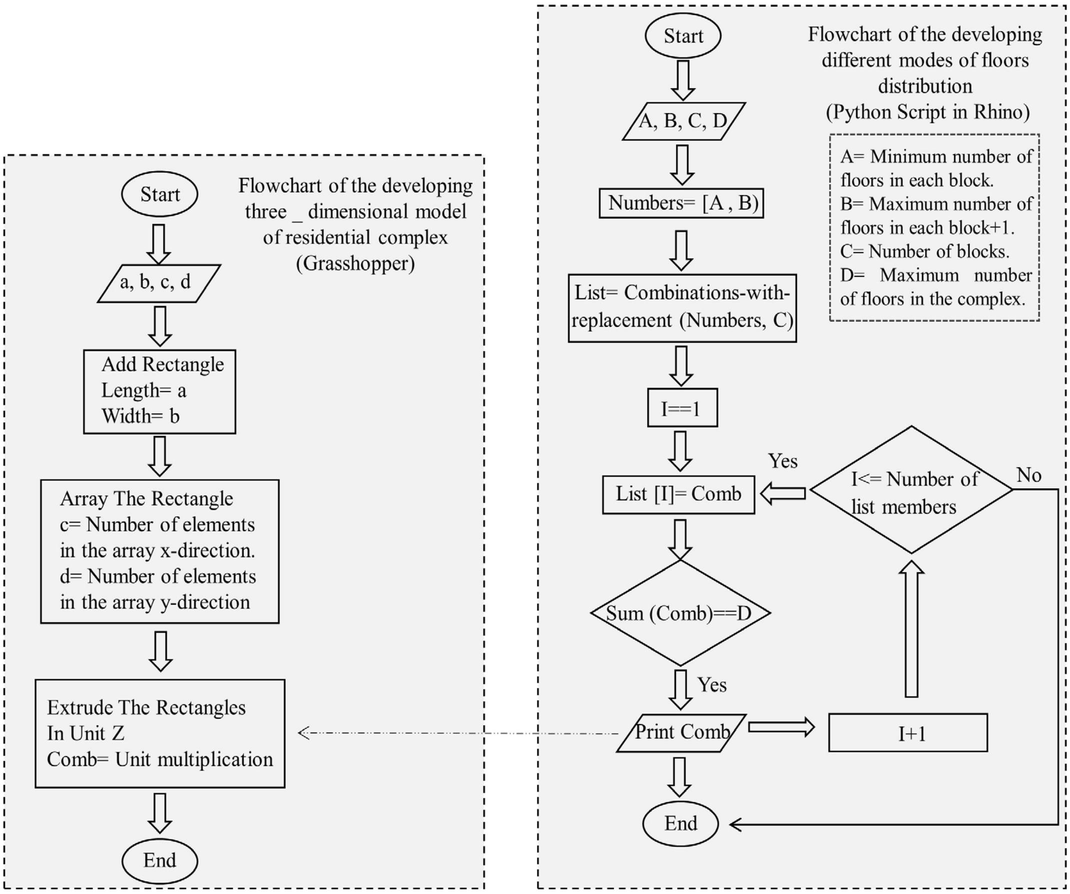


Figure 7. Flowchart of the modeling process

B. Applying settings to the software

Since energy simulations are performed in this research to compare different scenarios, the initial settings were considered in a simplified form to facilitate comparison and improve the speed of the simulation process (Table 3).

Table 3. Settings for the building energy simulation

Setpoint	Heating setpoint	20 °C
	Cooling setpoint	26 °C
Setback	Heating setback	13 °C
	Cooling setback	32 °C
Thermal resistance [m²·K/W]	External walls	1.77
	Internal floor	1.42
	Ground floor	0.6
	Roof	1.55
Others	Number of people per area	0.028
	Building program	Midrise apartment

- The HVAC schedule was determined in proportion to the average monthly temperature values throughout the year and based on the occupancy schedules.
- The lighting system was switched off to remove the resulting heat in a controlled way from the simulation equations.
- The internal floors were set to "Surface" to ensure heat flows through the interfaces between the two zones.

C. Energy simulation

In this section, the energy exchange in the selected cases is simulated using the Honeybee plugin. The effect of height distribution on energy consumption was initially investigated when the shading factor was removed and the restricted number of floors was applied for each block. According to the number of blocks determined for energy simulation (16 blocks) and the maximum number of total floors (144 floors), each block can occupy a maximum of 9 floors. If all 16 blocks have 9 floors, the total number of floors in the complex will reach 144, which is maximum. Since this study aims to investigate different modes of height distribution, in this stage, a total of 88 floors were considered as a basis. In this situation, all blocks could occupy values between 1 and 9 floors in different layouts. Considering these items, several cases of unequal distribution of floors were generated by the created algorithm. In the initial study, 4 different layouts with significant differences in height distribution were selected from the produced cases to simulate energy and compare their values with each other (Figure 8). Then, if there are significant differences in the energy consumption of the samples, the vast majority of them should be examined.

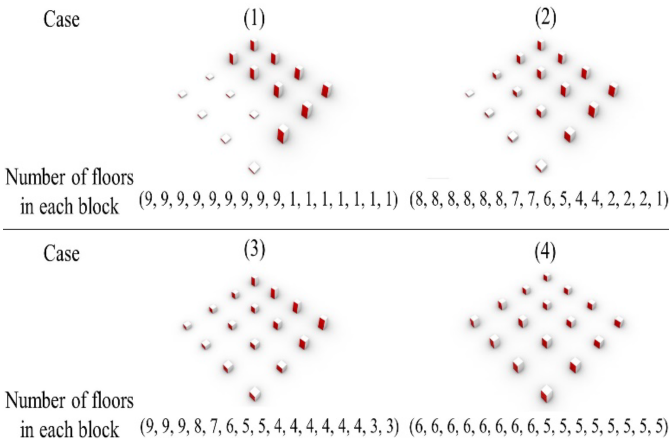


Figure 8. Selected cases of the first part of energy simulation

According to Figure 9, there is no significant difference among the 4 cases in the study of the annual heating load. However, the highest amount of cooling load (Case 3) differs 0.638 kWh/m² (about 0.5 %) from the lowest one (Case 1).

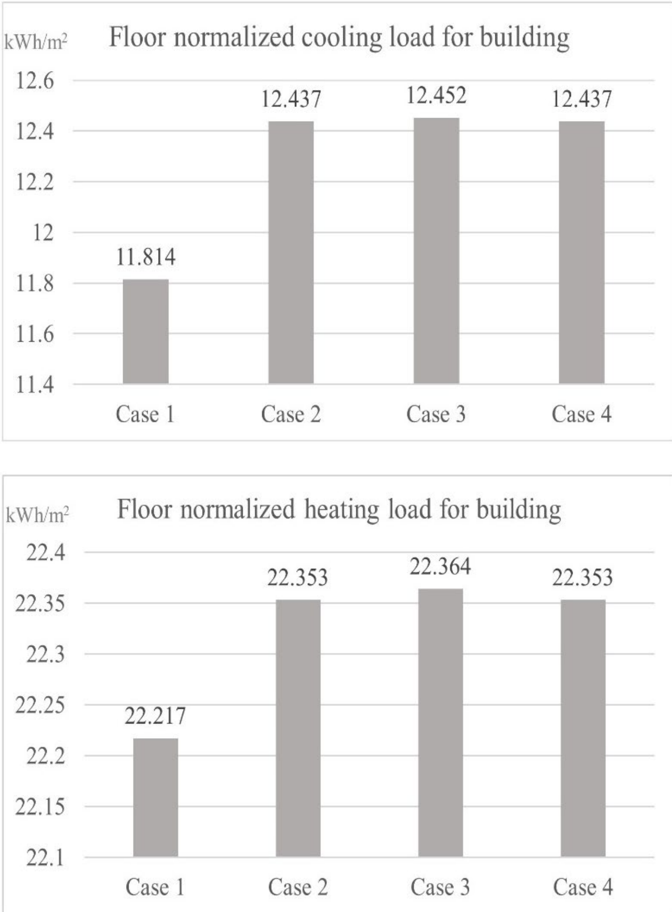
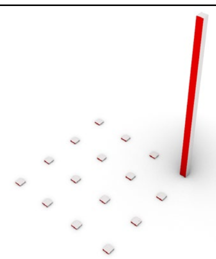


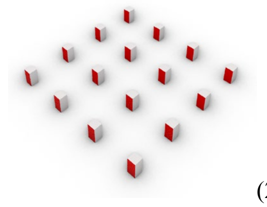
Figure 9. Comparison diagrams of annual cooling and heating energy consumption in selected cases of the first part simulation

In the following, the limit on the number of floors in each block is removed to ensure the accuracy of the results. Despite the large number of blocks (16 blocks) and in conditions where each block can have a maximum of 9 floors, the distribution of floors may be relatively homogeneous and this homogeneity affects the results of this simulation. Therefore, in this step, new cases are generated and the effect of height distribution considering the total number of 144 floors in the complex is studied.

Among the produced cases, three different scenarios were selected with significant differences in height distribution to simulate energy (Table 4).

Table 4. Selected scenarios of the second part of energy simulation

Height distribution scenario	Case
One of the blocks is a tall tower (129 floors) while the rest of the blocks are low-rise buildings.	 (1)

The height of all blocks is equal (9 floors).	 (2)
Half of the blocks are high-rise (17 floors) and the rest are low-rise (1 floor).	 (3)

4. RESULTS AND DISCUSSION

Finally, the selected scenarios were simulated (Figure 10). In the cooling energy consumption diagram, the highest value (Case 2) differs by 3.11 kWh/m^2 (about 28 %) from the lowest value (Case 1). Case 1 consists of several single-story blocks and a very high-rise block. Single-story blocks are adjacent to the ground and transfer much of their heat to the ground. Moreover, they do not receive heat from other floors. In most high-rise block floors, the cooling energy consumption rate decreases due to the higher wind speed and air temperature at altitudes is reduced. Therefore, Case 1 performs better in the summer.

On the other hand, Case 2 consists of several mid-rise blocks, all of which are located in the lower altitude range (relative to the Case 1), with higher air temperatures. Therefore, in this layout, the energy consumption for cooling increases. However, of all the reasons mentioned, the cold season is subject to different results. Thus, according to the heating energy consumption diagram, the highest energy consumption is associated with Case 1, and the lowest value is related to Case 2. Between these two cases, there is a difference of 2.34 kWh/m^2 (about 13 %) in the heating energy consumption.

In general, among the 3 cases studied, the lowest annual energy consumption (total cooling and heating load) belongs to Case 1 while the highest one belongs to Case 2 with a difference of 2.8 %.

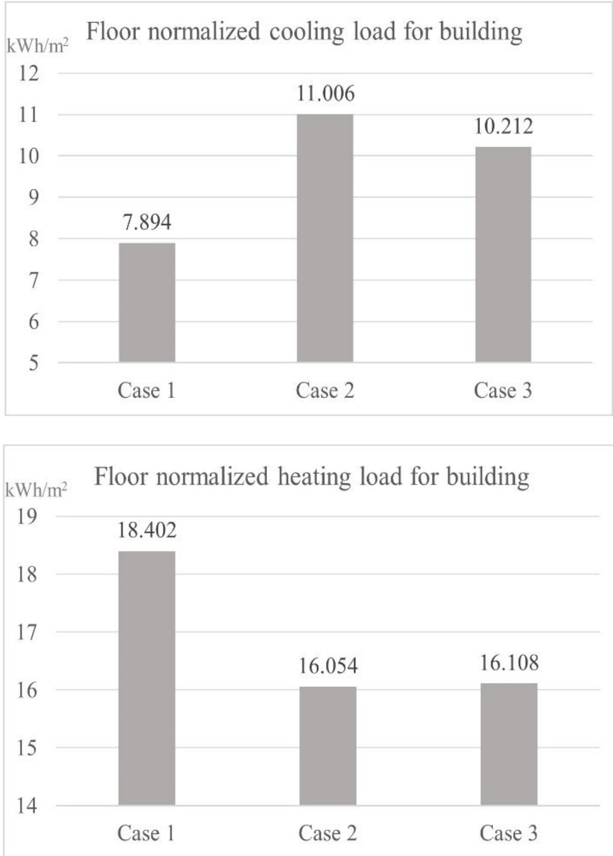
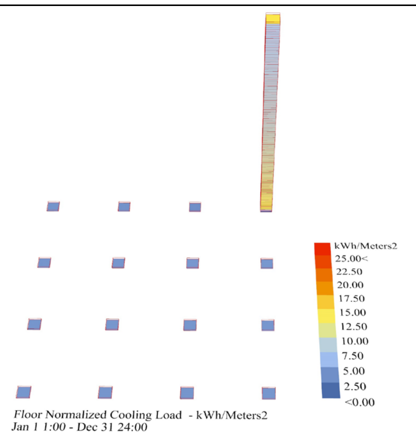
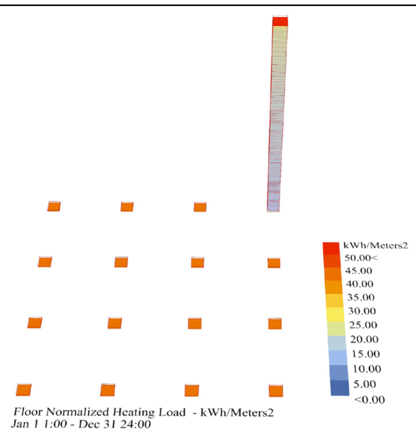
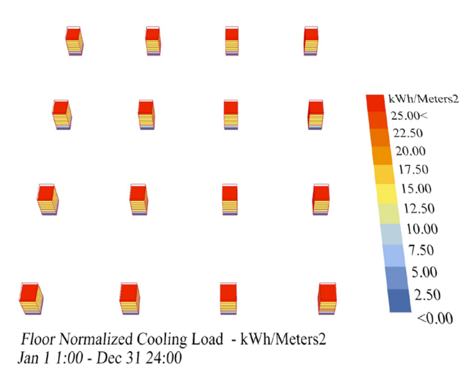
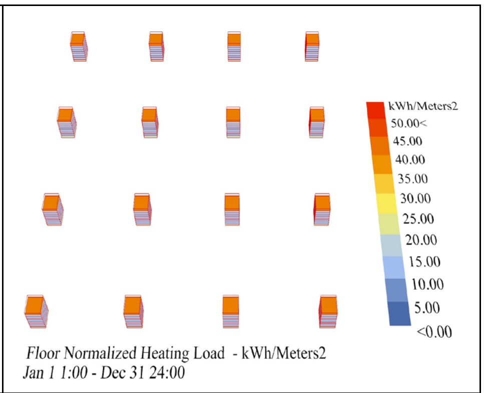
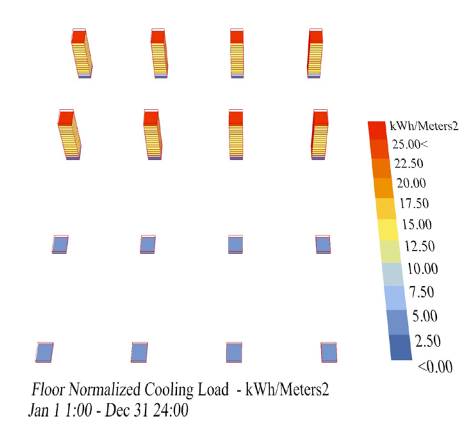
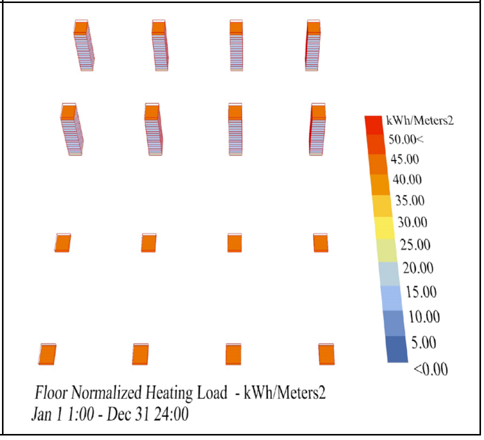


Figure 10. Annual cooling and heating energy consumption in the second part of the simulation

Comparison of the heating load on the floors shows that the heating load decreases as the number of floors in a block increases (Table 5), because significant heat loss occurs from the floor to the ground and through the ceiling to the environment. Therefore, stacking more floors on top of each other increases the ratio of floor area to envelope area, and heat loss on each floor is effectively reduced. This finding is consistent with the results of Resch et al. (2016). At higher heights, due to the increase in wind speed and decrease in air temperature, the energy required to heat the space increases to some extent (Figure 11), although it is negligible compared to the reduction of heating energy consumption made possible through increase in the number of floors.

Table 5. Distribution of cooling and heating loads among the floors

Case	Cooling load	Heating load
1		

2		
3		

A comparison of the cooling load on the floors shows that the average cooling energy consumption increases with increasing the number of floors in a block (Table 5). For example, the average cooling energy consumption in each of the high-rise blocks of Case 3 is about 3.5 times higher than the consumption of single-story blocks. Increased cooling load probably results from less surface contact with the airflow and reduction of heat loss. However, when the number of floors in a block exceeds the range of 5 floors, some cooling load is reduced due to increased wind speed and lower air temperature at altitudes (Figure 11).

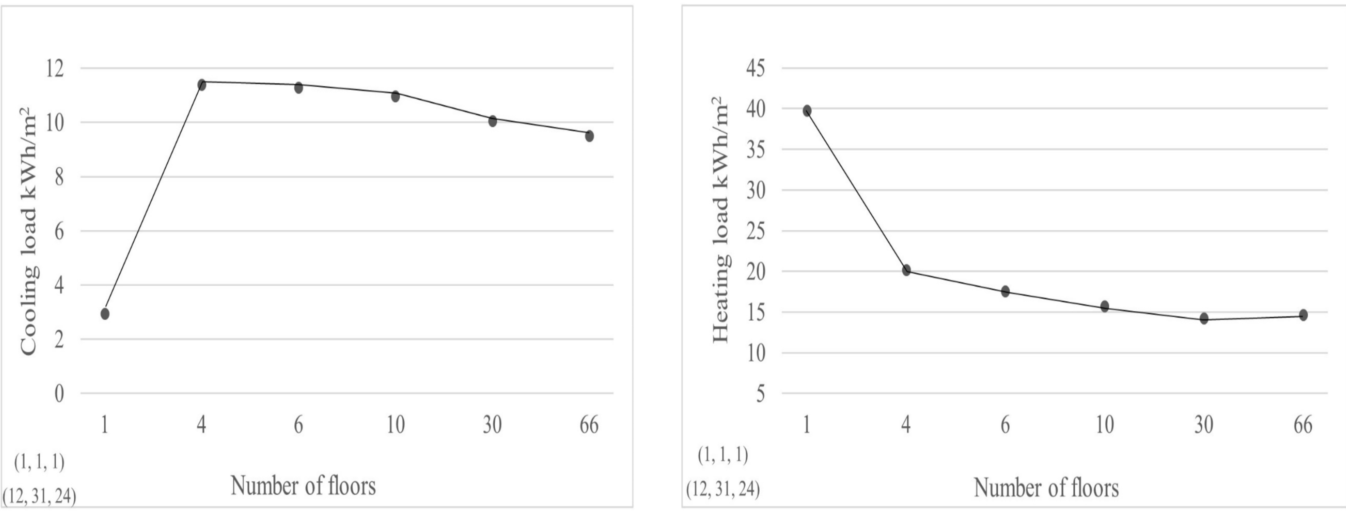


Figure 11. Comparison of average cooling and heating load in blocks with different numbers of floors

Another result is the high energy consumption on the last floor of each block (Table 5). In this regard, creating a protective surface on the roof helps reduce energy consumption.

5. VALIDATION

In the next step, to ensure the accuracy of the simulation in Grasshopper, we will validate the results with DesignBuilder software (Figure 12). DesignBuilder, the specialized software for energy simulation, is one of the most widely used and accurate software products in the energy field (Saebi Safa et al., 2020).

The specified set of the DesignBuilder software is similar to the Honeybee plugin in creating the same conditions for both emulators. The results obtained and compared with previous results are shown in Figures 13 and 14.

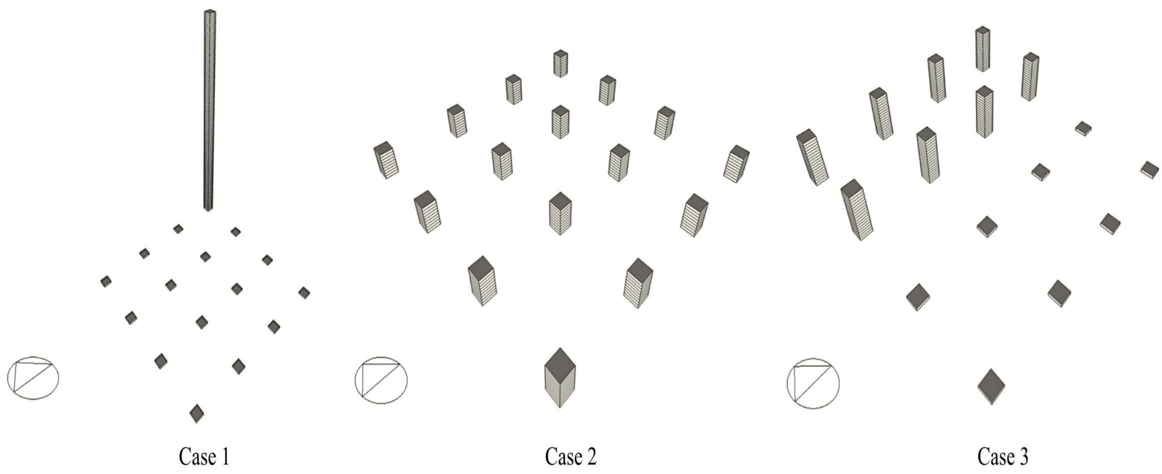


Figure 12. Modeling of the studied cases in DesignBuilder

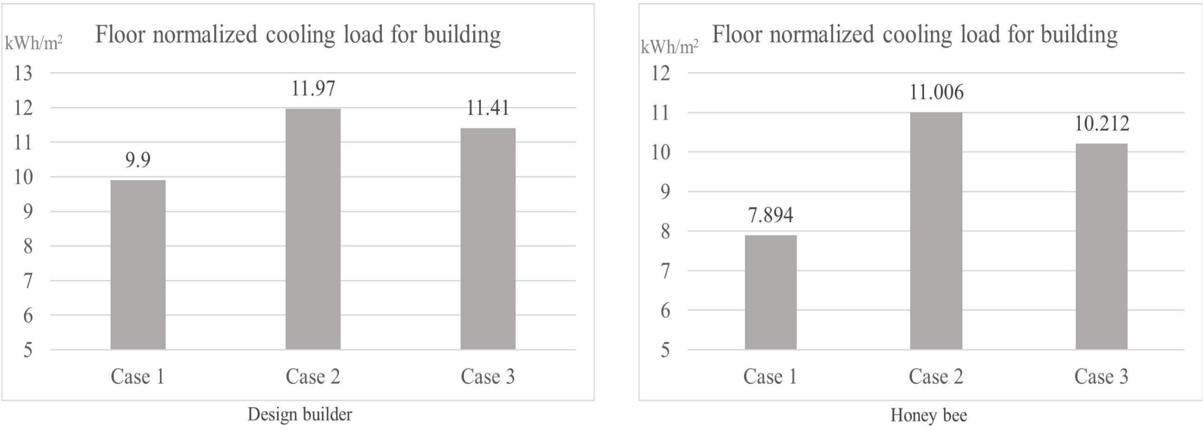


Figure 13. Comparison of cooling load consumption results obtained by Design Builder and Honeybee

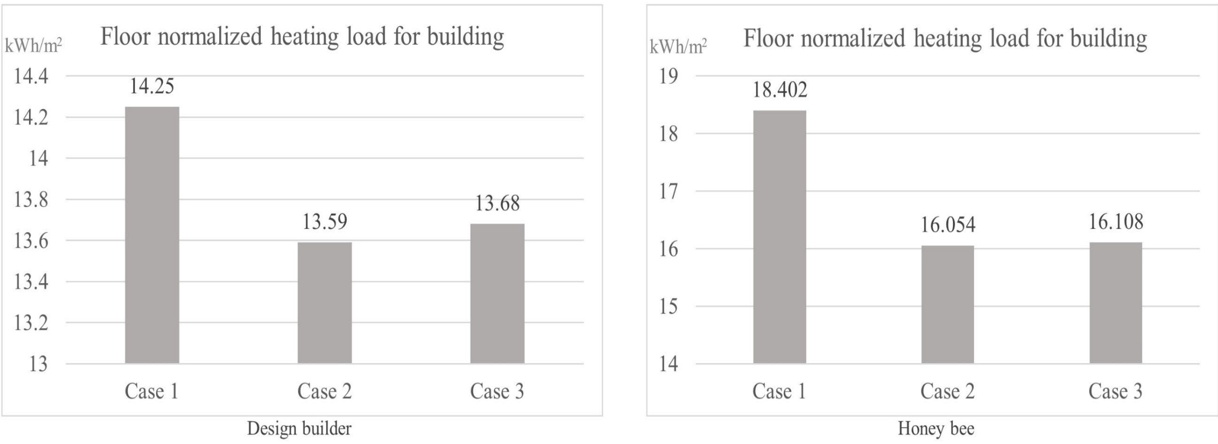


Figure 14. Comparison of heating load consumption results obtained by Design Builder and Honeybee

The general form of the diagrams in both software is similar. Also, in both software, Case 1 has the lowest annual energy consumption rate (total heating and cooling load), while Case 2 has the highest. The difference between the largest and smallest values is about 2.8 % in the Honeybee plugin and about 5.5 % in the DesignBuilder software, which can be ignored due to the minor difference.

6. CONCLUSIONS

In this research, several different layout scenarios with significant differences in the height distribution of blocks in a complex were investigated via a numerical simulation process to find a possible relationship between the height distribution and the cooling and heating load. According to the energy simulation results, the change in the height distribution of the blocks reduced the annual cooling energy consumption by 28 % and the heating energy consumption by about 13 %. Also, findings indicated that upon increasing the number of floors, the cooling energy consumption of the block increased. The average cooling energy consumption in each of the high-rise blocks of Case 3 was about 3.5 times higher than the consumption of single-story blocks. However, the decreasing trend of air temperature and increasing wind speed at high altitudes reduced the cooling load. On the other hand, the thermal energy consumption rate decreased sharply with the number of floors in a block increasing. Therefore, after determining the priorities regarding energy consumption issues in each project, a decision was made for the height distribution of the blocks to optimize the cooling or heating load, depending on the specific project conditions, costs, location, and available fuel. Then, necessary planning was made for the height layout of the complex blocks based on the leading research or other similar research. Another finding of this research was to create a protective surface on the roof of the blocks, which could reduce the heating and cooling energy consumption of the last floor by at least 50 %. The results of this research confirmed the previous research findings and complemented them. Finally, it should be noted that the present study does not consider the effect of shading in investigating different cases of height distribution. This point will be examined in future studies.

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