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Optimal Configuration of Spatial Planning for Energy-Efficient Buildings

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Abstract: The project phase is where the life-cycle of a building starts. The best decisions are made during the design or pre-project step. In terms of both economic resources and time, changes to specific design decisions made at this step are inexpensive compared to subsequent steps of architectural planning, not to mention the course of the construction's operation itself. The choices made during the design phase determine to a large extent whether the architectural design decisions of a building are achieved, whether the building and site can be used appropriately, and whether the project is economically viable. With BIM, building spatial planning is possible. As a result, architects can evaluate the proposed structure, its impact on the ecology, and the ecology's impact on the structure more comprehensively and at an earlier stage. This research proposes an energy modeling approach for the BIM-based spatial planning phase of a construction. The proposed method will result in an energy model for specific sites and building resolutions when utilized to create a spatial modelling for a construction. The energy model can then be used for new architectural creations. In this study, 36 different alternative scenarios were designed in terms of the rate of construction height to construction spacing, orientation factor, and form factor. With the help of BIM and GBS softwares, the energy consumption values of the alternative scenarios in cooling and heating load conditions were compared, and the alternative scenario with the minimum energy consumption was tried to be determined with spatial planning parameters.

Keywords: BIM; energy efficiency; green building; spatial planning; urbanism

1 INTRODUCTION

In the building and construction sector, sustainable development is a powerful force for financial, environmental, and social progress with less negative results for the ecology. Energy consumption in buildings has been shown to increase rapidly with industrialization and urbanization [1]. Buildings are responsible for 40 percent of total energy usage, 70 percent of electricity load, and 40 percent of CO_2 emissions [2]. It is necessary to build maintainable applications in the construction and building sectors in order to develop energy performance, especially by utilizing spatial management techniques.

The validity of the design is based on the success of its implementation, and both academic and practical circles have placed great emphasis on this issue. Therefore, the objective and scientific assessment of the results of the application of spatial design has long been a topic of debate among designers, managers, and academics. It is quite challenging to determine with accuracy whether spatial design has been successful. It is also theoretically impossible to take one final decision on the relatively static outputs of design in a constant time and space.

Investigators say that the goal of design application assessment is not to debate whether a plan is successful or not, but rather to look at the effectiveness and process of the design application and give feedback based on the data. This feedback is used to make changes to the system of policy, content, operation, and design mechanism [3-5]. Continuous review and reflex on the results of the real application are necessary as a prerequisite for improving the control effectiveness of spatial design [6].

The evaluation of the design application initially depended more on the project evaluation on simulation. Implementation, a seminal work by Pressman and Wildavsky, is important information for early planning, implementation, and evaluation [7]. However, implementation reveals the unique aspects of spatial planning in a physical or geographical form [8]. Therefore, since the mid-2000s, studies on the evaluation of spatial planning implementation have gained more attention, especially at the simulation level [9]. A lot of country rules and regulations do not provide a specification for the spatial planning concept. In norm, spatial design refers to specific methodologies utilized in the industry that impact people's distribution and efficiency in varying sizes of spaces. Spatial planning occurs in a few degrees: regional (region design), urban (city design), international, and national strategies. The most significant aim of strategic spatial design is to connect territorial development's certain aspects through integrating ecological, financial, social, and cultural strategy. In Turkey, the word "spatial design" is often associated with the Turkish term "regional planning" and is used in reference to regional or urban strategy [10].

The degree of functional and a space's physical accessibility from one given reference point is known as its depth. In this respect, special attention is given to structures that serve purposes that require a more in-depth study of the spatial arrangement and have a more complex distribution of social activities. Many authors have studied hygienic buildings in an effort to identify appropriate layouts and measures that integrate theoretical elements with realistic flowcharts and navigational aids [11]. Li et al. determine spatial design as an operation that models the required urban matrix depending on the city's current matrix (by devaluing, continuing, or preserving it) [12]. According to Olugboyega et al., the desire to lead the industry in this area is the primary motivator for adopting Building Information Modelling (BIM), even though there hasn't traditionally been an industrial demand for it [13]. Ribeiro et al. provide environmental, energy, schedule, economic, and geographical analysis using the latest BIM tools to deliver real all-life value to clients. By using BIM, the team can produce new delivery schedules for each scenario that is implemented, leading to increased efficiency in document production and distribution [14]. According to Sampaio et al., BIM models can provide walk-through representations to help clients make decisions; real-time, online designer input can speed up the design process and improve design quality [15]. BIM models allow the construction process to be visualized and can make the process inherently safer, according to Sampaio et al. [16]. The ability of 4D BIM to present dynamic construction processes on screen facilitates communication between designers and construction planners about the sequence of work, according to Sampaio et al. [17]. According to an evaluation by Green Building Studio simulation, the use of BIM can lead to cost savings and increased efficiency, as it reduced requests for information by 32% [18]. BIM can decrease the time required to prepare a cost estimate at a high ratio, according to research through Nawaz et al. In addition, 4D BIM provides comprehensive scheduling capabilities that can accurately estimate the time required for each construction activity, as well as plan future projects and the resources required for them [19]. To clarify the relationship between space and its content, Qanazi et al. and Srirangam et al. examined the research on mapping the dynamics with Space Syntax [20, 21]. The arrangement of spaces and functions within a particular social activity network is considered form according to The Space's Social Logic. The definition of depth and how it relates to activities are the main points of contention [22].

Rapid construction has emerged due to technological developments in the field of construction and the increase in people's desire for a qualified and comfortable life. In our country, as a result of unplanned urbanization, rapid construction, and ignoring energy-efficient design, the natural environment has been gradually destroyed, and energy resources have come to the point of depletion [18]. For this reason, by adopting the concept of sustainable energy in architecture, it is aimed at creating settlements that reduce the negatory effect of the building on the ecology and use energy resources effectively. The primary aim of the concept of sustainable power is to ensure the natural energy resources' effective utilize without harming the energy demand's natural cycle. A very large portion of energy resources are consumed by residential settlements in our country. For this reason, the energy consumption of residential settlements should be reduced first.

The interest in design aimed at reducing energy consumption has emerged naturally for the solution of environmental consequences. In addition, environmental problems have led to the formation of designs that are energy-efficient. Therefore, in the solution of environmental and energy-related problems, the technical information necessary for determining the design parameters that will reduce energy consumption should be created and presented to the designers. Within the framework of the technical information created, the optimum values of design parameters such as the location of buildings relative to each other, location, direction, and building spacing, which are effective in reducing energy consumption, should be examined.

This study was conducted in Ankara, the capital city of Turkey, where the density of settlements and housing is increasing day by day. While creating the study, BIM systems, which are developing day by day, were used to compare and develop settlement texture design alternatives and to make calculations related to energy efficiency.

In the study, the effectiveness of BIM systems will also be examined by using BIM models in reducing energy expenditures in the settlement texture and building. Within the scope of the study, Autodesk Green Building Studio is utilized for simulation and BIM-based Autodesk Revit 2020 programme is utilized for modelling. Depending on the results of the study, it is expected that residential settlement design proposals aiming to reduce energy consumption for the purpose of the study will be developed through BIM and these design proposals are expected to guide the new settlement textures planned to be designed [23].

2 BUILDING INFORMATION MODELLING

In the construction sector, BIM is a new technique and one of the latest trends. This technique uses three-dimensional modeling to design, communicate information, and analyze a building plan [24]. BIM facilitates the modification and sharing of design data through digitization. Contractors and design consultants can use the BIM simulation to obtain a calculated model of the building plan that closely resembles the actual design for the building area. This improves contact between team members throughout the design lifecycle, manages risk, reduces rework, and allows for more efficiency operation and sustainance of the building plant [25]. Three-dimensional modeling is related to the design database and displays the overall geometric data, spatial relationships, quantities, materials, and dimensions of the design elements [26].

BIM is a strong tool that can be utilized to display the whole life-cycle of a building, from maintenance and operation to construction and design. Through supply a common three-dimensional modelling of the design, it can aid to define potency conflicts among group members prior to operation and allow them to make any changes. It is almost a design stakeholder engagement, involving engineers, architects, owners, contractors, and tool managers, who overall have reach to the shared planning modellings. This ensures that all the stakeholders involved are aware of any changes or updates and makes it easy to make changes to the design. With BIM, even minor changes can be quickly shared and updated with overall planning stakeholders [27].

BIM is the process of managing and generating information about a group of buildings or a building. It involves a considerable amount of data that has an effect on each of the structures (their design, planning, construction, etc.) in the area or environment of the designed construction.

BIM is fast becoming the main strategy for the numerical combination of information and data in the management, implementation, and planning of facilities for building. But, in the present, BIM planning, construction practices, and integrated design have failed and are underestimating the advantages that BIM supplies to the sector at different indications [28].

Thus, the management and generation of data about the building should start with the management and generation of data about the region in which the building is to be constructed. Recently, the probabilities for the development and application of BIM have been widely analyzed all over the world [29-31]. BIM is researched from different frameworks:

- Data management in the course of building step [32, 33],
- Implementation of online building work researches [34],
- Formation of BIM of present constructions by utilizing laser scanning [35],
- Design effectiveness comparisons of four-dimensional CAD crosscheck to two-dimensional CAD [36],
- Data exchange with respect to International Finance Corporation norms [37], and
- BIM data administration modeling from the form framework [38].

Communication operations and data exchange are such significant prerequisites for the improvement of a project [39]. Some researchers propose the data for BIM and GIS information [40-42]. For this purpose, building components and geographic information system information should be transformed into a semantic virtual information format [43, 44]. Others suggest hybrid modeling for BIM and an increased digital platform [45, 46]. In the actual world, enhanced digital mechanisms can relate an object to a digital model that represents it [47]. Three-dimensional building modeling can also be utilized for analyzing fire extinguishing works [48]. The combination of information from these 2 diverse arenas outputs in an interdependent impact that can encourage the transformation and evolution of industry, institutional collaboration, and processes.

In order to obtain and utilize detailed data about a construction, BIM must be associated with spatial and geographical data, as constructions are inherently linked to their environment; hence, the distances to various engineering substructures influence the utilization of a construction. This is also significant for the maintainable improvement framework. It is significant that overall data about a province is stored together for maintainable improvement. This hybrid data should include data about individual buildings and specific areas in the province [49]. In a country, the implementation of BIM to spatial planning in building planning is extremely dependent on the legislative framework for building. This expresses the specific actions of the law (technical construction rules, laws, regulations, hygiene standards, etc.) that organize the building operation and how they arrange it in a specific region. It is well known that the building industry is organized differently in diverse countries. Therefore, it is important to improve spatial modeling for building design to meet the needs of Turkey.

Two-dimensional floor plans are usually used for planning, discussing, presenting, and evaluating the efficiency of spatial planning projects in the traditional sense. However, each person may interpret the same two-dimensional floor plan in a different way, depending on his or her expectations, thus changing his or her perception of the intended pattern. In other words, the use of two-dimensional floor designs can lead to miscommunication and a waste of valuable time as a result of conflicting participant expectations [50-52]. Building Information Modeling has a parametric feature that allows structural data to be applied to a component and used to determine whether the result complies with applicable codes [53]. BIM helps the designer accurately and quickly understand the information related to the landscape and the drawing when there is an elevation shift [54].

In another way, BIM reduces the time needed to check compliance with regulations while facilitating the design of spatial models of buildings and the rapid presentation of design results [55]. Before using a two-dimensional drawing for space planning, it is usually necessary to confirm the nature and purpose of the space. The use of conventional two-dimensional floor plans also requires a number of procedures;

-Creating several floor projects with diverse positions,

-Simulating the circumstantial relationship among diverse locations utilizing the graph theorem,

- Providing the generation of the detailed technical drawing and the elevation technical drawing after the floor plan, and

- Assessing the relationship between the floor project and the elevation drawing to ensure conformity between the two.

BIM speeds up, lowers the cost of, and improves the overall standard of community planning [56, 57].

In daily life, spatial design is thought to be one of the most significant research areas presently in existence, as it has an immediate impact. The modeling operation utilizing the known and current Building Information Modeling processes and tools has existed to develop the energy efficiency of the building body with its spatial planning.

Reducing energy consumption in housing estates, which account for a big proportion of energy usage, will contribute to the national economy and help other ındustries to reduce energy consumption. To this end, it is important that studies to reduce energy consumption are first carried out in settlements that involve more users and are of a larger scale. In order to overcome the problems due to rapid urbanisation, it is important to make optimal energy efficiency decisions at the settlement scale. Energy performance works carried out at the settlement scale will provide a reference for energy performance works to be carried out at the building, element and volume scales, which are smaller units [57-59].

In this context, the use of BIM systems will make it possible to assess the potential for reducing energy consumption in the design phase using BIM systems and to obtain the desired results as a basis for further studies. From the view point of the BIM systems' applicability and the BIM models' production, it will be possible to reduce energy consumption in housing and settlement textures and to widely use energy efficient settlement textures and housing designs. In addition, it will be possible to transfer it to the construction process and application project by using simulation cycles in the design phase of architecture. This will make it possible to create healthy, energy-efficient and comfortable environments [60].

In order to reduce the energy usage of the construction, energy performance targets should be set to include all sectors that consume energy, and priority should be given to the use of space management. The following sections provide information on the proposed changes to the building to achieve this.

Stage 1: The architectural designer specifies a numerical design of the development area from the regional design tool, with its general constraints and requirements, in their Building Information Modelling simulation window. As an element of the Regional Design Tool, this design already takes into consideration the development area's surroundings; health protection areas for agricultural buildings, factories, protection areas for roads, forests, water bodies, buildings, lines, urban development typologies, boundaries and development areas. The area design must also include data on the permitted density of development.

Stage 2: A building's spatial design is interactively carried out. The designer selects where to place the structure within the structure field in the structure zone depend on the structure boundaries or lines.

Stage 3: The designer chooses the building's spatial shape from the spatial shapes' library presented through the simulation, taking into consideration the overall 3D of the structure; width, height, and length.

Stage 4: The designer sets the required characteristics for the exterior separation structures (roof, windows, walls, etc.) from offered a library through the simulation: arrangement and number of windows, degree of acoustic insulation.

Stage 5. Then the modelling is utilized for energy-efficient architectural plan.

The lack of traditional methods and computer-aided design tools in the design phase has led to the prominence of the concept of BIM with the technology's development. In BIM management, all data belonging to the building works in connection with each other and is integrated. BIM software develops simulations by making calculations with various thermodynamic laws, some assumptions, and equations. The inputs of the building energy model are the parameters affecting energy use. These parameters are data such as building geometry, heating, cooling, lighting, ventilation systems, thermophysical properties of building materials, renewable energy systems, control strategies, and efficiency of systems. By combining the inputs of these parameters with local weather data and using physical equations, BIM programs calculate the thermal loads, the response of the systems to these loads, and the resulting energy use. The interaction of heating, cooling, and lighting systems is also taken into account. In addition, measurements such as user comfort and energy costs can be made. These programs can make simulations for a year or less [61]. The inputs required in a BIM-based energy analysis are: land and building location, building orientation, weather data, location and height of the building, type of building use, number of storeys, three dimensional geometry of adjacent buildings, three dimensional model of the building to be analyzed, curtain walls, including walls, floors, windows, roofs, foundations, shading elements, and doors, as well as building elements and detailed specifications [62].

3 RESULTS AND DISCUSSION

In this study, firstly, different settlement texture alternatives were created to reduce the amount of energy consumption in settlement textures. Different settlement texture alternatives were determined for Ankara province based on the frequently used settlement textures. Ankara province is located in the hot-dry climate zone. According to TS-825 Thermal Insulation Rules for Buildings, which are still in force in Turkey, Diyarbakır province is located in the 3rd region as the heating degree day zone [63, 64]. The climate data used in the evaluation were obtained from the weather station closest to the location of the project through the system after determining the location in the Revit program. The Revit program uses a system with a large database of climate data. There is no possibility to enter external climate data into the program yet. The determination of the most appropriate values for energy expenditures in the settlement texture alternatives was made by means of BIM software Autodesk Revit at the building scale and settlement scale. Then, annual energy consumption amounts were calculated for the reference residential structure selected with the developed options. Energy models made in the Autodesk Revit program were analyzed through the Green Building Studio system. Green Building Studio is an Autodesk Revit plugin. The cloud-based tool called Green Building Studio enables it to undertake building performance simulations at the start of the design process in order to maximize energy efficiency and strive toward carbon neutrality. All building components such as roofs, ceilings, windows, doors, and walls are used in Revit to automatically generate an energy analytical modelling. After that, Green Building Studio receives this data for energy simulation. The building, location, and certain detailed modellings and energy can be changed using the energy settings. Designing high-performance buildings in a fraction of the time and expense of traditional approaches is made possible by Green Building Studio [65].

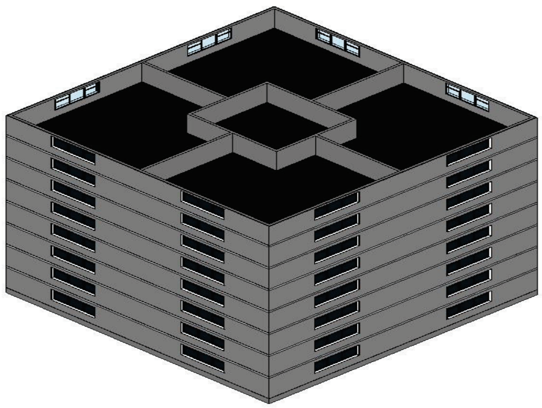
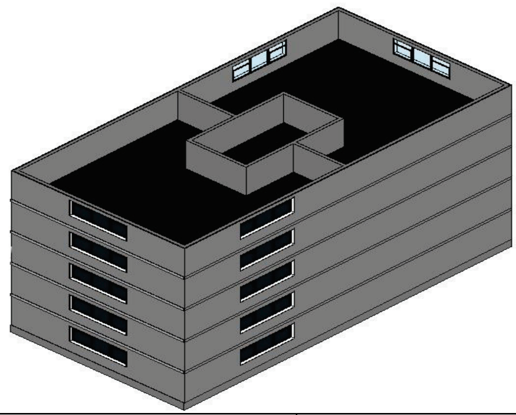
One of the most important parameters in determining the structure of a settlement is the buildings' location in relation to each of the others and the spacing between constructions. As this parameter determines the degree of utilisation and protection of buildings from sunlight, it is important in reducing energy expenditure. In the alternative settlement patterns created, the distance between buildings was determined as the rate of building height to building spacing. Two diverse building height/building spacing ratios, 0.75 and 1.50, were determined during the creation of the settlement patterns. The (building height/building spacing) ratios and road widths in the alternative settlement patterns are shown in Tab. 1.

Table 1 According to (building height/building spacing) ratios and street widths in settlement pattern alternatives

Building Height / Building Spacing	Street Width		
	10 Storeys (30 m)	15 Storeys (45 m)	20 Storeys (60 m)
0.50	60	90	120
0.75	40	60	80
1.50	20	30	40

Another parameter in this evaluation is the building form. In determining the building forms, the common plan types in Ankara province were taken into account. All buildings in the settlement texture are considered to have the same form. The reference buildings to be analysed in the settlement texture consist of modules with a floor area of 169 m^2. 19 m^2 of these modules are allocated to circulation areas and 150 m^2 to residential areas. Form factors were then determined as the ratio of building width to building depth. Two diverse form factor alternatives of 1.00 and 2.00 were created for rectangular and square based plan types. For form factor 1.00, 4 modules were combined to form a square-based plan, while for form factor 2.00, 2 modules were combined (Tab. 2).

Table 2 Identified plan types and dimensions

Form Factor 1.00		Form Factor 2.00	
			
Width	26 m	Width	26 m
Depth	26 m	Depth	13 m

In the settlement pattern alternatives, the all buildings' height is assumed to be 3.00 m. Three different building heights of 10, 15 and 20 storeys were determined. Buildings were created in a split layout. In creating the developed settlement textures, the building layout types commonly used in Ankara province were used as a reference. The settlement textures are composed of 9 equally shaped residential buildings. The building in the centre of the settlement texture was identified as the reference building (Fig. 1).

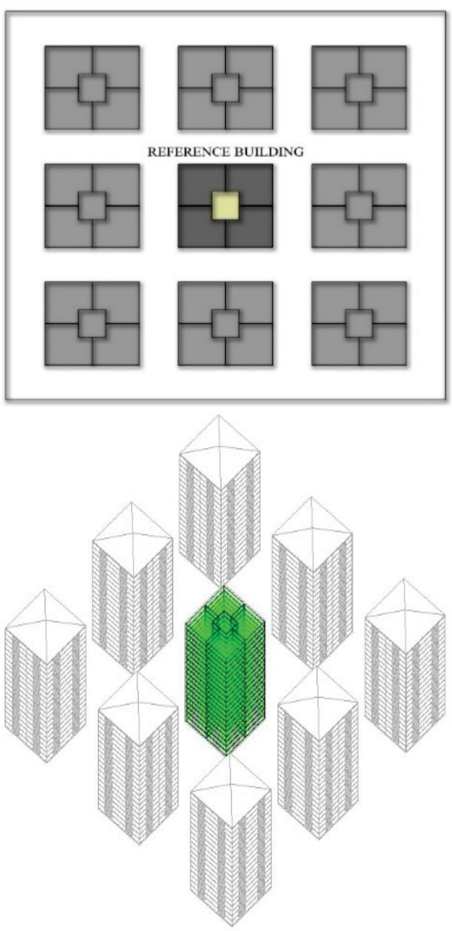


Figure 1 Settlement fabric and location of the reference building

The orientation of buildings and settlements determines the effect of the external environment on the building. For this reason, orientation is important in assessing the effect of the external environment on reducing energy expenditure. These orientations are northsouth and northeast-southwest. Fig. 2 shows the orientation of the buildings.

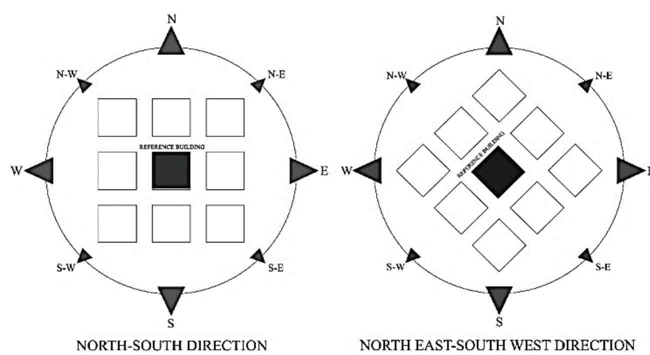


Figure 2 Orientation of buildings in settlement patterns

The thermophysical and optical features of the construction external wall, solar radiation and air temperature are important parameters as they affect the heat gain and heat loss of the construction. The thermophysical and optical features of the materials used in the outer shell of the buildings in the developed settlement textures were defined taking into account the standard TS 825 - Thermal Insulation Rules in Buildings. The determined layer and thermal values are given in Tab. 3 [17].

The alternatives were coded in order to optimise the parameters determined in the study. The codes are displayed in Tab. 4.

As a result of the research, cooling, total and heating energy consumption were calculated. The energy consumption of 36 different alternatives is shown in the Fig. 3.

Table 3 Determined layer and thermal values

	U Value (W/(m²·K))
Wall	0.4051
Suspended Slab	8.3333
Floor Slab	0.7729
Roof	0.33

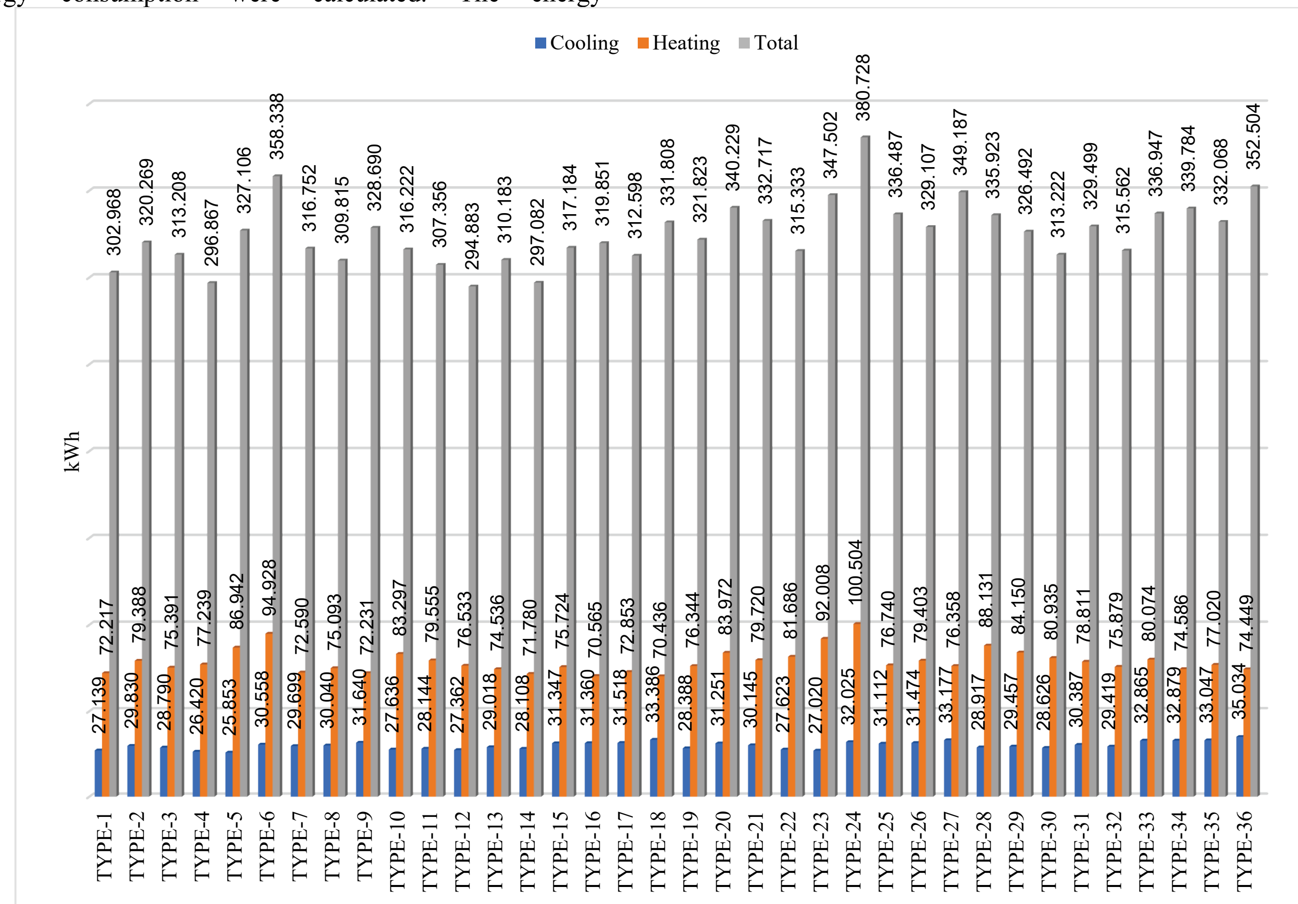


Figure 3 The energy consumption of 36 different alternatives

Table 4 Codes of the alternatives of the settlement structure

Form Factor	Number of Floors	Orientation	Building Height / Building Spacing ratio	Code
1.00	10	N-S	0,50	Type-1
1.00	10	N-S	0,75	Type-2
1.00	10	N-S	1,50	Type-3
1.00	10	NE-SW	0,50	Type-4
1.00	10	NE-SW	0,75	Type-5
1.00	10	NE-SW	1,50	Type-6
1.00	15	N-S	0,50	Type-7
1.00	15	N-S	0,75	Type-8
1.00	15	N-S	1,50	Type-9
1.00	15	NE-SW	0,50	Type-10
1.00	15	NE-SW	0,75	Type-11
1.00	15	NE-SW	1,50	Type-12
1.00	20	N-S	0,50	Type-13
1.00	20	N-S	0,75	Type-14
1.00	20	N-S	1,50	Type-15
1.00	20	NE-SW	0,50	Type-16
1.00	20	NE-SW	0,75	Type-17
1.00	20	NE-SW	1,50	Type-18
2.00	10	N-S	0,50	Type-19
2.00	10	N-S	0,75	Type-20
2.00	10	N-S	1,50	Type-21
2.00	10	NE-SW	0,50	Type-22
2.00	10	NE-SW	0,75	Type-23
2.00	10	NE-SW	1,50	Type-24
2.00	15	N-S	0,50	Type-25
2.00	15	N-S	0,75	Type-26
2.00	15	N-S	1,50	Type-27
2.00	15	NE-SW	0,50	Type-28
2.00	15	NE-SW	0,75	Type-29
2.00	15	NE-SW	1,50	Type-30
2.00	20	N-S	0,50	Type-31
2.00	20	N-S	0,75	Type-32
2.00	20	N-S	1,50	Type-33
2.00	20	NE-SW	0,50	Type-34
2.00	20	NE-SW	0,75	Type-35
2.00	20	NE-SW	1,50	Type-36

When analysing the cooling energy consumption amounts in relation to the building height to building distance ratio, which is the first parameter, it can be seen that the alternatives with a building height to building distance ratio of 0.50 generally have the lowest cooling energy consumption. The alternatives with a building height to building spacing ratio of 0.75 and the alternatives with a building height to building spacing ratio of 1.50 were found to have the lowest cooling energy consumption.

When the cooling energy consumption was analysed in terms of the orientation factor, which is a second parameter, it was found that the north-south orientation generally consumed more energy than the north-east-south-west orientation.

When analysed in terms of the form factor, a third parameter, it was found that alternatives with a form factor of 1.00 used less energy for cooling than alternatives with a form factor of 2.00.

The second step was to analyse the heating energy consumption. In terms of heating energy consumption in the analysed alternatives, it was found that the alternatives with a ratio of building height to building distance of 0.50 generally had the lowest heating energy consumption, followed by alternatives with a ratio of 1.50 and 0.75 respectively.

When analysing the orientation, which is another parameter in terms of heating energy consumption, it is found that north-south orientations generally consume less energy than northeast-southwest orientations.

When analysing the form factor parameter in heating energy consumption, it was found that alternatives with a form factor of 1.00 used less energy than alternatives with a form factor of 2.00.

The final step was to analyse the total energy consumption. When the total energy consumption amounts were first analysed in relation to the building height to building spacing ratio, it was found that the alternatives with a building height to building spacing ratio of 0.50 generally consumed less energy. It was then found that the alternatives with a ratio of 0.75 and 1.50 respectively consumed less energy.

When the orientation parameter was analysed in terms of total energy consumption, it was found that north-south orientations generally consumed less energy than northeast-southwest orientations.

Finally, the form factor parameter was analysed in terms of total energy consumption. In terms of total energy consumption, as with cooling and heating energy, alternatives with a form factor of 1.00 generally consumed less energy than alternatives with a form factor of 2.00.

4 CONCLUSIONS

It makes sense to consider solar gain, ventilation, noise and other factors using BIM. BIM benefits the entire lifecycle of a building project. For example, it enables more productive construction, better design decisions and more efficient maintenance and management of building portfolios. BIM supports architects in all aspects of sustainable design. It harnesses the idea of enhancing reality with greater effectiveness and quality. It enhances artistic vision with cutting-edge technological solutions that influence green planning. The introduction of BIM has ushered in a new age of diverse applications in the field of urban design. While there are many of these applications, the most significant are those related to infrastructure, roads, future planning, land use, engineering management, urban development, spatial analysis, waste management, archaeological area management and other implementations. BIM represents the building as a three-dimensional model and provides a complete library of object-oriented parametric information.

In this research, annual energy consumption amounts were evaluated comparatively. Subsequently, suitable settlement pattern alternatives and optimum values of design parameters were determined. The yearly energy usage amounts of the reference building considered in the settlement pattern designs were compared numerically. The alternatives showing the lowest energy consumption amount among the design parameters were selected as the optimum parameter value for the settlement texture. When comparing the alternatives, it was discovered that those with a building height to building spacing ratio of 0.50 often used less energy. The alternatives with a ratio of 0.75 and 1.50, respectively, were then discovered to use less energy. Similar to the energy utilized for cooling and heating, alternatives with a form factor of 1.00 typically consumed less energy overall than alternatives with a form factor of 2.00.

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