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Swot Analysis of Performance Based Optimum Building Envelope Design Methods

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Swot Analysis of Performance Based Optimum Building Envelope Design Methods*

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Abstract. Nowadays, Turkey is a country largely depends on foreign country for their sources and also faced with an energy demand that continues to be above the average of world. In this content, the importance of energy efficiency in the agenda increase in terms of provide ensuring security of energy supply for Turkey. Nevertheless, the building sector, where very high levels of energy consumption continues to develop. Digital technologies provide opportunities to meet this requirement with its digital data format and operation method supporting all project stages. When remark to the importance of designing the process directly in the architecture instead of the final product, "Performance-based design" offers schematic and productive point of departure by providing maximum benefit from digital technologies and understanding that sustainability is whole factors and results. The use of digital technologies (BIM) optimizes all of the "better", "lighter", less energy, and more everything in performance-based design. The most effective role of building envelope design methods with regard to realization of energy targets is solar energy because it is easier to applicate structure than others, and at the same time the technologies that are produced in this field develop and spread rapidly. For this purpose, when the samples which the configuration depending on the angle of the sunlight for building envelopes for the maximum efficiency in energy save or gain are examined, it is determined that three methods are used. In this context, it is aimed to identify the Strong, Weaknesses, Opportunities and Threats aspects of the current building envelope design methods by SWOT analysis. Thus, how the strengths of the methods and opportunities are assessed, how the weaknesses are translated into strengths, and what can be done to remove constraints is researched. According to SWOT Analysis, the third design method has been concluded that the optimum solution in other design methods with is three potential factors and one problem. However, in all three methods, the common problem is ignoring the shadow creation situation of adjacent buildings in designs in built environment and the risk which an effective optimum solution of the probability of reaching in terms of energy. In this context, the third design method, which is determined as the most appropriate method is proposed to be used together with the Solar Envelope method, so that an optimum solution should be reached considering the potential of creating shadows on the building designed for the surrounding buildings.

* This paper is prepared by making use of Ph. D. thesis study of Meryem ALAGÖZ whose supervisor is Prof.Dr. Figen BEYHAN in Institute of Science and Technology in Department of Architecture in Gazi University.

1. Introduction

Solar-based building facade design approaches are extremely important for Turkey, which relies heavily on foreign countries for energy supply, to achieve its sustainable development goals. Depending on the incidence angle of the sun's rays, three different methods have been developed for the correct shaping of a building envelope for achieving maximum yield in energy saving or energy gain. All of these methods have been solely applied in open areas and in certain building types. It is clear that these methods need to be further developed and refined in order to benefit from sunlight at a maximum level within the context of neighbouring relations of buildings designed in structured environments within a city. In this study, SWOT analysis was performed on these methods to determine their strong and weak, sufficient and inadequate, necessary and unnecessary aspects; and how to make use of and benefit from the strengths and opportunities of the methods, how weaknesses can be transformed into strengths, and what can be done to remove the limitations and constraints of these models were investigated.

2. Performance Based Design

After the performance approach began to be used in buildings in the 1970s, the terms performance based building or performance based design began to be used in the studies and efforts on the implementation and dissemination of this approach instead of performance approach or performance concept in buildings. In fact, the focus of all these terms on buildings is the same. It is to design and construct buildings with high performance or at the desired performance level [1].

Performance based design is defined by Oxman as the synthesis of two properties of digital design: geometry formation and performance evaluation by simulation. Performance is a decisive factor in the formation of form and geometry, which is inherently integrated into the process [2]. There is a transition from "creating form" to "finding form". In this transition, building performance is the guiding factor.

The geometrical or material properties of the model are to the forefront at the end of this process and parametric design systems are at the centre of the main system. Predicting the behaviour of the system is based not only on analysis but also on performance information and the interaction with the environment together with simulation support [3]. Schewede defines the simulation element as a digital bridge between the designer and the digital representation in the performance-based design process, as seen in Figure 1.

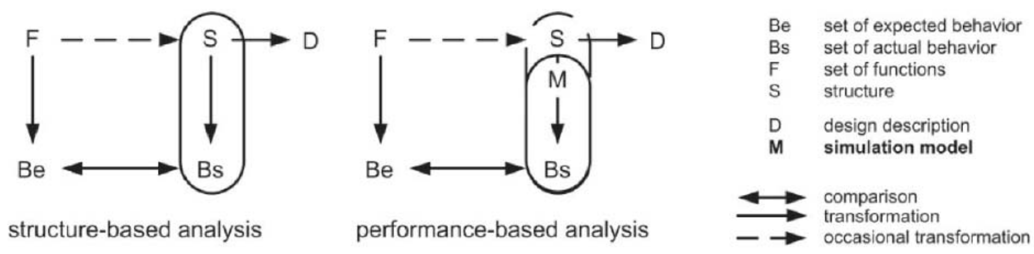

Figure 1. Structure-based and performance-based design processes [3]

3. Building Envelope Design Methods Dependent on Solar Data

3.1. Design Method 1 - Regular Modular Form

It is the shaping of building envelope surfaces by rotating the modular masses in regular forms at certain angles to expand surfaces receiving sunlight or protect from sunlight. Since the starting point of design is a regular form such as a square, rectangle, or polygon, and the variations created by rotating these shapes will be in certain patterns, achieving optimum solution takes longer with this method compared to others.

Algorithm, origami and biomimetic design techniques can be used to create this design method. Algorithm is defined as a sequence of steps necessary to solve a problem. If there is more than one way to solve the problem, the option that is most appropriate to the conditions is selected [4]. In origami, known as Japanese folding art, geometry, continuity and order is important, and it is created by intermeshing modular forms [5]. In biomimetic technique, on the other hand, it is argued that all the features that should be in an architectural design such as energy saving, aesthetics, perfect functionality, robustness are complete in their natural examples, and design process is started with a form inspired from nature [6].

- Housing Design at Patras University Campus, Greece;

At Patras University - Greece, a regular modular design study with a student housing complex function and a focus on heat-saving was carried out (Figure 4), [7].

Figure 2. Student Housing Complex plan and façade [7]

The residential masses repeat in a regular rectangular form. Each of these forms was brought together at different angles, and their position in the solar orientation diagram was determined and analyzed. Exposure to sunlight in winter and summer months was identified and shadow conditions were determined (Figure 3).

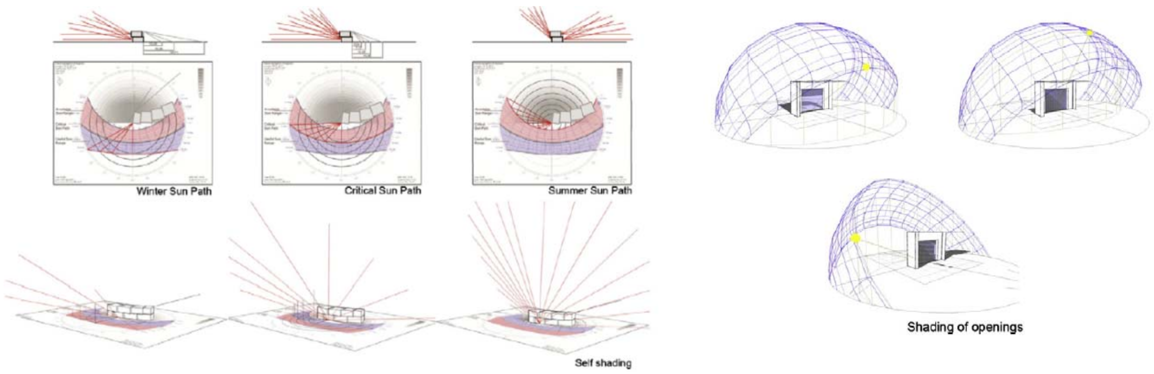

Figure 3. Student Housing Complex solar and shadow analysis [7]

A formula was developed using the level differences of sloping terrain to increase sunlight-collecting surfaces and prevent shading. Thus, optimum positions and angles of building masses were identified (Figure 4), [7].

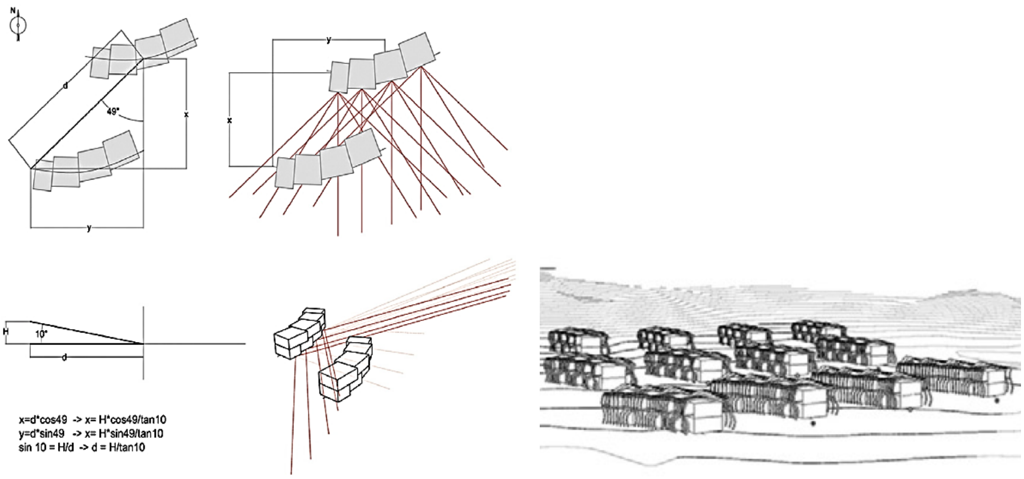

Figure 4. Use of sloping terrain in design [7]

After the design decisions of the building envelope were made, different combinations sequences were investigated to select the optimum model by performing solar climate analysis. According to the positioning studies made on sloping terrain, it was found that the masses must be positioned on 2 virtual curves. As a result of the experiments, northern and southern fringes and their inclination for buildings located on different elevations, profile lengths for shading, and how the balconies would be positioned in relation with these profiles were studied and evaluated for each façade. Finally, optimum solution models were determined and the final model was obtained (Figure 5) [7].

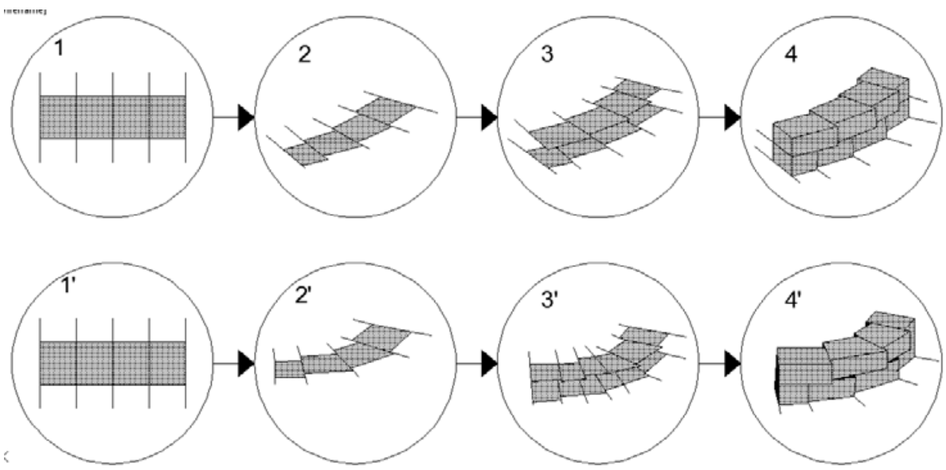

Figure 5. Regular modular composition steps shaped according to building envelope properties

3.2. *Design Method 2 - Irregular Modular Form*

Irregular Modular Form method uses the parametric model freely to describe a set of design criteria with a quantitative and geometric concept. As it is in regular modular form design method, algorithm, origami and biomimetic design techniques can be used to create this design method.

- Karle Town Centre – HUB 1 Office Building, Bangalore, India, 2012

The New York-based Merge Studio Architecture group designed a wave shaped irregular modular façade in Bangalore, India, to retain solar radiation to prevent excessive heat gain on building façades due to sunlight, as it should be in this climate, while accommodating daylight and air comfortably (Figure 6). It consists of prefabricated modules, aluminum composite panel and high performance glass. Designers are aiming to obtain a "Leed Gold" certificate for this office building [8].

Figure 6. Karle Town Centre – HUB 1 Office Building [8]

As seen in the concept drawings (Figure 7), the HUB 1 office building is located next to Karle Town Center. The width, length and height dimensions in mass are indicated three dimensionally. The position of predefined 3-D masses in the solar orientation diagram were determined according to the coordinates, and solar radiation on 21 June and 21 December, when the sun was at its steepest and most oblique angle, were detected (Fig. 7).

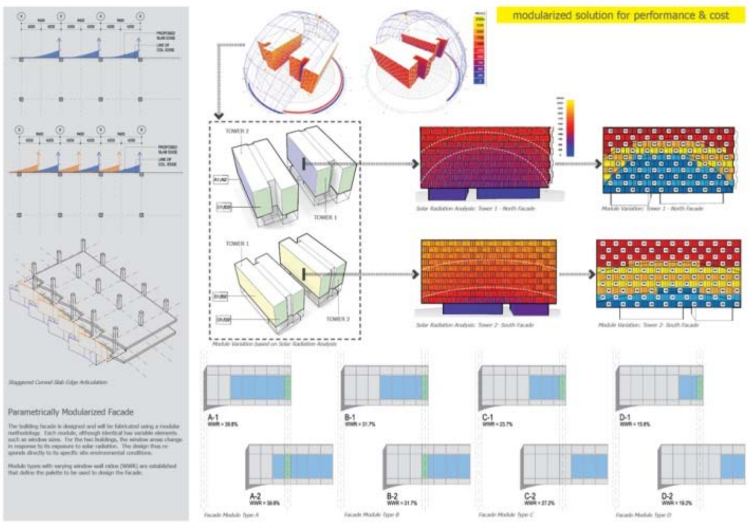

Figure 7. Solar radiation analysis and variations of modules [8]

Points with too much light, too much shading and optimum shading relative to the angle of incoming sunlight were detected. According to the solar radiation analysis, **irregular modules on the façade were positioned in various variations at different angles**. With just façade movements, 15-16% energy saving is achieved (Figure 8), [8].

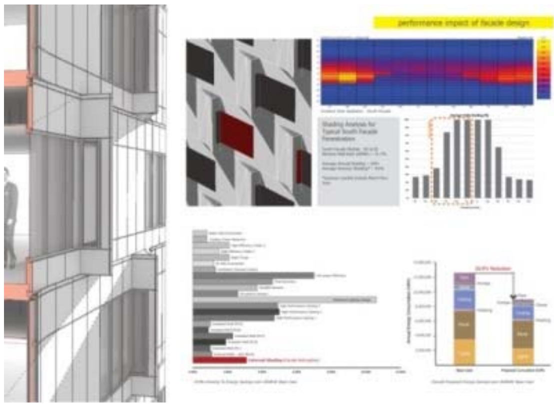

Figure 8. Determination of the angle of irregular modular façade elements according to sunlight [8]

3.3. Design Method 3 – Solar Rays

In the Solar Rays method, a rough solid of the area to be designed is initially formed on the basis of m² and height before the design process starts. Unlike other methods, a design shape is created based directly on sunlight falling on the rough solid created prior to designing a modular shape. This design method can be created by using Louvered Gird Shell technique. According to this method, the building envelope can be closed or opened for maximum shading or utilization of the sun, based on several solar data such as the azimuth angle and the earth's distance to the sun at the design location [9].

- New structure design around the castle in Amsterdam, 2011;

In addition to the castles from 1900s, additional structures reflecting today’s technology and built to be used as administrative building housing the personnel, cafés and botanical gardens were designed with solar ray method (Figure 9) [10].

Figure 9. New structure design [10]

Based on environmental analysis data, a stain study was conducted to determine where to locate each function (Fig. 10), [10]. Morning and afternoon solar light angle calculations were made for functional groups whose locations around the castle were already determined. The solar rays needed for the botanical garden were taken into consideration when making these calculations. The angles perpendicular to solar rays falling on each functional group in the design area were calculated (Figure 10), [10].

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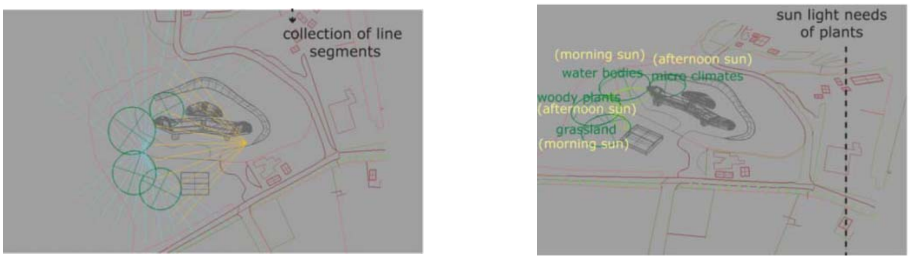

Figure 10. Sun light rays falling on the design area and angle calculations [10]

In order to guide the design, the intersection points between the line set perpendicular to solar rays and the mass (3d) were determined (Figure 11).

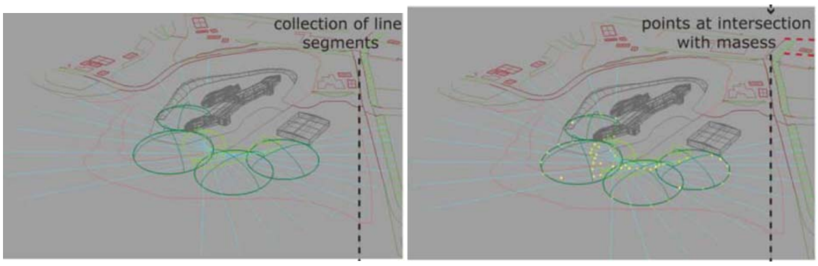

Figure 11. Intersection points between the line set perpendicular to sun light rays and the mass

Based on these points in the mass, a new design process was initiated (Figure 12).

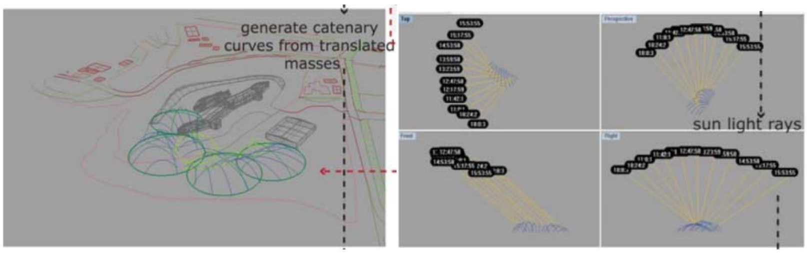

Figure 12. Intersection points between the line set perpendicular to sun light rays and the mass

Curved arches were formed in the direction of these points. However, sufficient spaces were created in certain parts of the design so that the botanical garden could utilize sunlight (Figure 13).

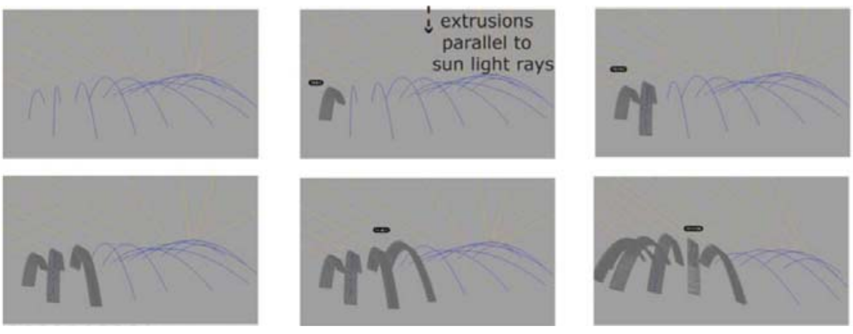

Figure 13. Design of curved arches based on lines perpendicular to sun light rays

As a result, a building envelope was obtained that prevented excessive heat gain by auxiliary lines perpendicularly intersecting sun light rays and therefore providing maximum benefit from the sun (Figure 14), [10].

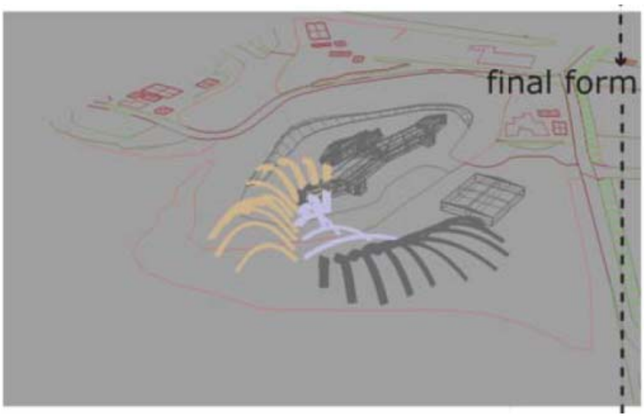

Figure 14. Optimum form obtained according to sun light rays

4. Evaluation of Design Methods - SWOT Analysis

SWOT analysis of existing building envelope design methods was performed and the situations where these design methods were inadequate during the design process were comparatively identified. Thus, the adequacy of design methods based on solar data, which is one of the increasingly important sources of renewable energy in the world, was questioned in every context and solution proposals were presented in cases when the design methods were inadequate. SWOT analyses for the design methods are given in Table 1, Table 2 and Table 3.

Table 1. SWOT analysis for Design Method 1 – Regular Modular Form

STRENGTHS (+)	*Regular variations can be created with regular modular forms*
WEAKNESSES(–)	*Since variations that are created by rotating regular forms will be in certain patterns, reaching the optimum solution takes longer with this method compared to others*
OPPORTUNITIES (+)	*This method creates a more systematic solution process compared to other methods*
THREATS (–)	*If this method is used to design monotonous buildings or in built environment, correct data cannot be reached since there may be shades in the design area*
	SWOT ANALYSIS-DESIGN METHOD 1

Table 2. SWOT analysis for Design Method 2 – Irregular Modular Form

STRENGTHS (+)	*Flexible solutions can be reached since the dimensions and angles of similar but not exact components are prepared in different variations*
WEAKNESSES(–)	*Since irregular forms are created by using parametric data of regular forms, this results in loss of time during the design process*
OPPORTUNITIES (+)	*Since prepared variations are irregular, reaching the optimum solution faster than regular modular form method*
THREATS (–)	*If this method is used to design a structure in built environments, correct data cannot be reached since there may be shades in the design area*
	SWOT ANALYSIS-DESIGN METHOD 2

Table 3. SWOT analysis for Design Method 3 – Solar Rays

STRENGTHS (+)	*Formation based on sun light rays can be done directly in Rhino-Grasshopper environment without searching for regular or irregular forms*
WEAKNESSES(–)	*Problems can be encountered in application phase since alternative shapes consist of non-modular different angles and forms*
OPPORTUNITIES (+)	*Since formation is directly done in Rhino-Grasshopper environment, optimum solution is reached faster than other methods*
THREATS (–)	*If this method is used to design a structure in built environments, correct data cannot be reached since there may be shades in the design area*
	SWOT ANALYSIS-DESIGN METHOD 3

5. Results and discussions

Once the SWOT analyses of the mentioned methods are carried out, comparatively determining the strengths and weaknesses and identifying inadequacies by determining opportunities and threats will clearly reveal the most appropriate method to eliminate process constraints. According to the results of the SWOT analysis in Table 4, it was determined that "Design method 3-Solar Rays method" is the most appropriate method for reaching optimum solutions with three potential factors and one problem it contains.

However, as in other methods, using this method to design a structure in built environments may result in shades in the design area, and therefore correct data will not be reached and an optimum shape for energy usage will not be created.

Table 4. SWOT Analysis Evaluation Table

	ANALYSES / METHODS	POTENTIALS				ISSUES			
		Regular variations	Reaching optimum solution fastest	Systematic and regular design process	Flexible Solutions	Searching for initial regular/irregular form	Loss of time during design process	Ability to design monotonous buildings	Inability to be used within built environments
1	Design Method 1 Regular Modular Form	●		●		●	●	●	●
2	Design Method 2 Irregular Modular Form				●		●		●
3	Designe Method 3 Solar Rays		●	●	●				●
CONCLUSION	Design Method 1 Regular Modular Form	● ●				● ● ● ●			
CONCLUSION	Design Method 2 Irregular Modular Form	●				● ●			
CONCLUSION	Designe Method 3 Solar Rays	● ● ●				●			

6. Conclusions

Performance evaluation from the beginning of the design process is the key to achieving a sustainable design in terms of energy efficiency. It is important to measure whether high-performance buildings achieve their intended performance targets and metrics. These targets can be measured by specific analyses. Computational and parametric tools and simulation software brought by digital design has made it possible to complete this process efficiently and correctly. Fundamentally, designs can be analyzed in terms of energy consumption, daylight intake, light and shadow relationship with itself and its surroundings, radiation gain, wind use and natural ventilation [11].

In all of the existing methods, the structures/buildings in the near vicinity of the design and that would cast a shade on the design are not taken into consideration. As a result, these methods are often used in designs with functions such as a "pavilion" in areas where construction is less common. In order to use the method, appropriate for each function and location, the shadow of surrounding buildings cast on the designed structure should also be taken into account. For this purpose, we are conducting a new method-oriented study focusing on obtaining maximum benefit or protection from sunlight by using “Solar Envelope” and “Solar Rays” methods together, taking into account the shadowing potential of surrounding structures.

These methods will act as guides in the use of design methods in new applications. Thus, by minimizing energy loss, it is thought that an important approach for optimum energy gain in buildings and structures can be created.

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