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Bioclimatic Façade Design Based on Daylight Parameter and Optimization of Alternatives Through Genetic Algorithms: An Office Building in Ankara

Gün Işığı Parametresine Dayalı Biyoklimatik Cephe Tasarımı ve Alternatiflerin Genetik Algoritmalar Aracılığı ile Optimizasyonu: Ankara'da Bir Ofis Binası

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ABSTRACT

Today it is clear that, for the mitigation of climate change, built environments should be designed according to energy efficiency criteria. For this reason, environmental conditions must be evaluated for site-specific designs based on sustainability. To design energy-efficient structures, it is essential to evaluate the parameters such as sun, wind, and material in the environment and to create alternatives for the orientation of the buildings. In this context, in this article, based on the climatic conditions of Ankara, the facade features of an office building were determined as a result of optimization simulations, and alternatives were created. The environmental condition data of the model, which was designed using the Rhino–Grasshopper program, were obtained with the Ladybug plug-in. Thanks to the Honeybee plug-in, the position of the sun was determined according to the day and time zones determined in Ankara, and in this way, alternative facades were produced to the facade design at the location of the building. By using the genetic algorithms, the best of these design alternatives was determined. This optimization method was achieved by detecting the highest peak thanks to frontal optimization based on solar radiation with Rhino–Grasshopper's Galapagos plug-in. Results show that the partitions on the facade changed according to the position of the sun. These partitioning alternatives were processed with Galapagos as different alternative inputs, and as a result, facade partitioning with the best possible alternatives emerged.

Keywords: Bioclimatic design, daylight analysis, facade optimization, genetic algorithm, ladybug–honeybee analysis

ÖZ

Günümüzde sürdürülebilirlik ilkesine dayanarak yere özgü tasarımlar üretebilmek için çevresel koşulların değerlendirilmesi gerekmektedir. Enerji performanslarına dayalı yapıların tasarlanabilmesi için çevredeki güneş, rüzgar, malzeme gibi parametrelerin değerlendirilmesi binaların tasarlanacakları konumlardaki alternatiflerinin oluşturulmasında fayda sağlamaktadır. Bu bağlamda bu makalede, Ankara'nın iklim koşullarına dayalı olarak bir ofis yapısının, cephe özelliklerinin optimizasyon simülasyonları ile alternatiflerinin tasarlanması ve bu tasarım alternatiflerinin genetik algoritmalar sayesinde değerlendirilmesi ile optimum cephe tasarımının saptanması gerçekleştirilmiştir. Rhino–Grasshopper programı kullanılarak tasarlanan modelin çevresel koşul verileri Ladybug plug-in'i sayesinde elde edilirken Honeybee plug-in'i aracılığı ile de Ankara'da belirlenen gün ve saat dilimlerine göre güneşin konumu saptanmış ve yapının bulunduğu konumdaki cephe tasarımına alternatif cepheler üretilmiştir. Genetik algoritmalar kullanılarak bu alternatif cepheler içinde optimum cephe modelinin seçilimi gerçekleştirilmiştir. En iyinin seçiminde, Rhino–Grasshopper'ın Galapagos eklentisi ile güneş ışınımına dayalı ön optimizasyonu yapılmış ve en yüksek tepe noktası tespit edilmiştir. Sonuçlar, cephedeki bölümlemelerin güneşin konumuna göre değiştiğini göstermektedir. Cephedeki bölümleme alternatifleri Galapagos ile farklı alternatif girdiler olarak işlenmiş ve sonuç olarak mümkün olan en iyi alternatiflerle optimum cephe tasarımına ulaşılmıştır.

Anahtar Kelimeler: Biyoklimatik tasarım, gün ışığı analizi, ladybug-honeybee analizleri, cephe optimizasyonu, genetik algoritma

Introduction

Considering the architectural design inputs, it is possible to talk about the environmental and physical relations of all the buildings designed specifically for the site as a context. Developing the design method of the building by evaluating it with environmental conditions provides the passive energy system in the architecture. This provides the comfort and health of the users. Givoni (1992) stated that when the climate data of the environment are analyzed, evaluating the wind speed, wind direction, daylight, and humidity analyses and adjusting them to coincide with the ASHRAE comfort range and determining the values according to the months make the design conditions of the buildings more efficient. These design models are used today as a design method that integrates with environmental data, which can be called "bioclimatic," as well as passive energy supply methods. Watson (2020) states that the "biology" and "climate" effects of the bioclimatic design method should be combined and the building and the landscape should be designed together.

Considering all these environmental conditions, in the literature review part of the study, how bioclimatic design methods have developed during the academic research process is discussed. The importance of environmental values is included in the scope of evaluation in a case study of the article (Figure 1).

In the application process of the study, the facade of an office building was designed based on the environmental data of Ankara province. The environment and context of this office building were considered alternative facade models that were developed with the computational design model as a result of bioclimatic calculations by taking the current location into the values.

In this process, first, the analysis data were modeled and then the environment of the building and its context were integrated with the close environment model. As a result of the analysis, alternatives have been created for the city of Ankara, which reaches very intense temperatures in the summer months, in which the kinetic facade model can be transformed. Then, these alternatives were associated with the genetic algorithm method, and the best alternatives were determined as a result of optimization.

Literature Background

This part provides a short literature review on the subject (Figure 2). First of all, Givoni (1992), using the Olgyay bioclimatic charts system, has implemented passive cooling systems for buildings in very hot regions. In their study, Noble and Kensek (1998) developed sun envelopes via computer and compared these models with the models they produced by hand. As a result, settlements on the land were determined by daylighting calculations in the study. Knowles (2003) argues that solar envelope values should be made as mobile systems with the landscape to provide a comfortable environment by using the energy system of the building in housing planning. Manzano-Agugliaro et al. (2015) examined the scale variation of bioclimatic architectural systems from urban planning to architecture. Passive and active construction systems were also included in the examined systems.

Based on the academic studies in this field, it has been emphasized that the studies on the need to provide maximum comfort area, especially by considering the environmental conditions of the applications in local architecture, have increased more recently.

Watson (2020) emphasized that bioclimatic structures should provide a particularly microclimatic feature at their scale. He emphasized that the climatic features between the buildings should also be considered on an urban scale. Considering the studies in which the performance-based changes of the kinetic facades in the building based on the position of the sun are taken as an example, it was decided that the methodology of the study should proceed in parallel with related studies (Hosseini et al., 2019; Özerol & Selçuk, 2021). However, in addition to these studies, the alternatives created for the facade design of the office building were optimized.

Environmental Analysis With Computational Design Technologies

Today, real-time data analysis can be obtained through computational design technologies. Thanks to the developing technologies from CAD software technologies to BIM technologies, the processes of focusing on the energy systems of the buildings have been included in the early stages of the design. In our work in which computational design technologies are used, the Rhino–Grasshopper program, which has been used by architects for a long time, was preferred as the parametric design interface. It has become an important factor for the progress of the study that the climatic data obtained from an empty land in the built environment in Ankara can be captured and integrated into the program through plug-ins.

Ladybug–Honeybee Analysis

Installed as an add-on to the Rhino–Grasshopper interface, Ladybug–Honeybee[1] provides environmental analysis data. First of all, information about the current location is determined via the Honeybee plug-in (URL-1). These data can be imported as raw data as EPW[2] data (Figure 3).

Daylight analysis data obtained from the EPW data in the city of Ankara are expressed as shown in Figure 4. Bulb temperature and point temperature here are considered for July and September. Considering the intense temperatures in the region, the month of July was chosen as the limitation of the study.

Then, as the other limitation of the study, a value of 20 <a was determined and only the hot hours due to daylight were preferred. Wind analysis was used in the second part of the study. In this, this stage, the prevailing wind direction, force, and spread

[1] https://www.ladybug.tools/

[2] "EPW weather file define basic location information such as longitude, latitude, time zone, elevation, annual design conditions, monthly average ground temperatures, typical and extreme periods, holidays/daylight saving periods, and data periods included" (URL-2).

Figure 1.
Method.

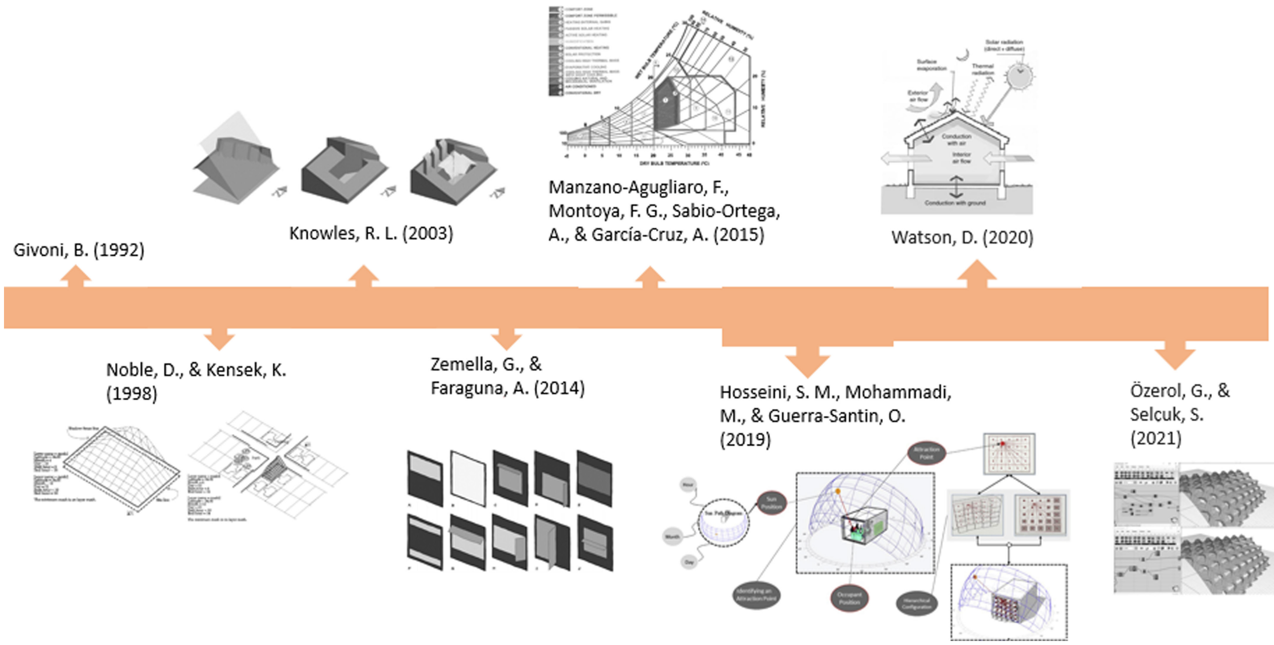

Figure 2.
Related Literature as a Timeline.

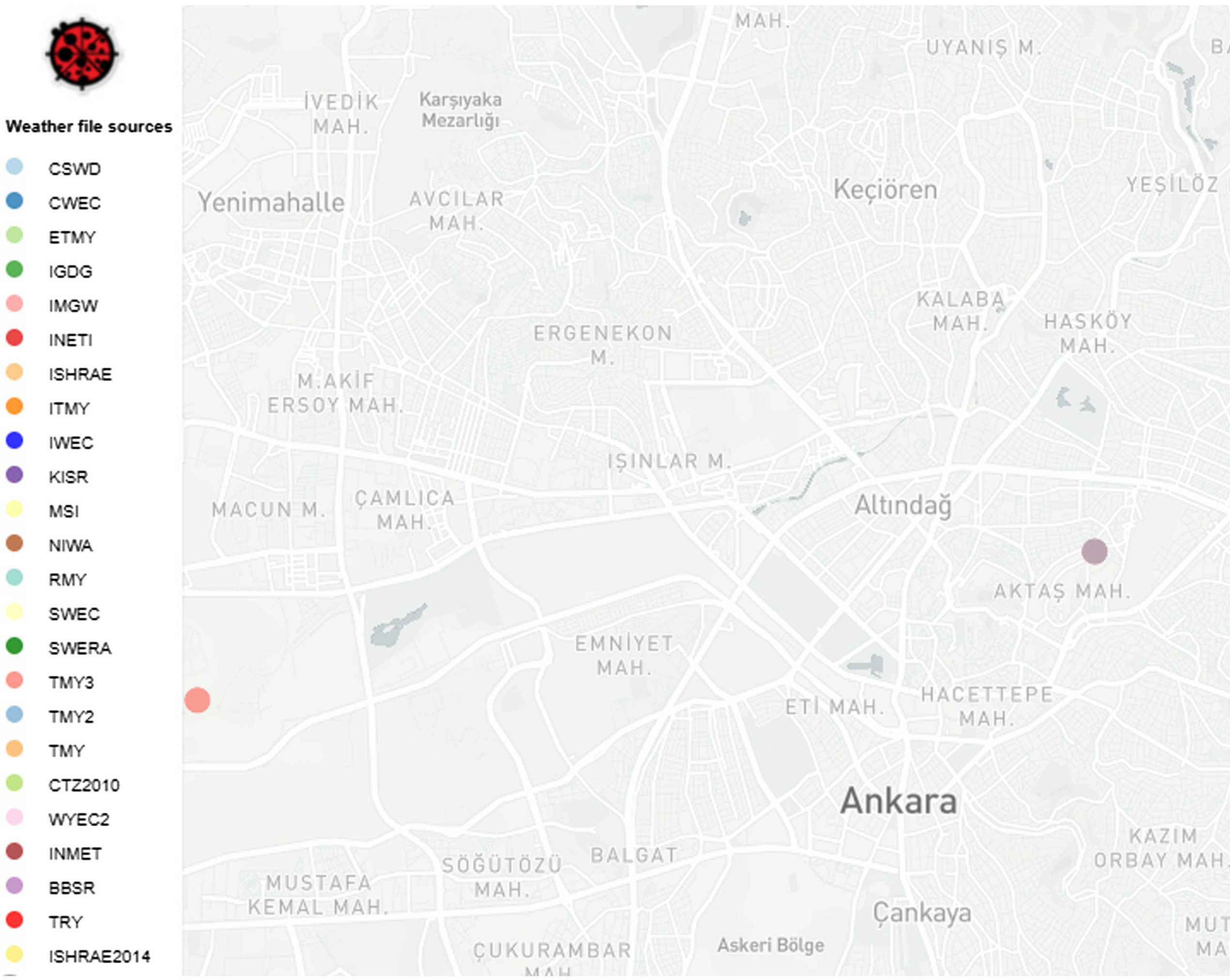

Figure 3.
EPW Data for Ankara City.

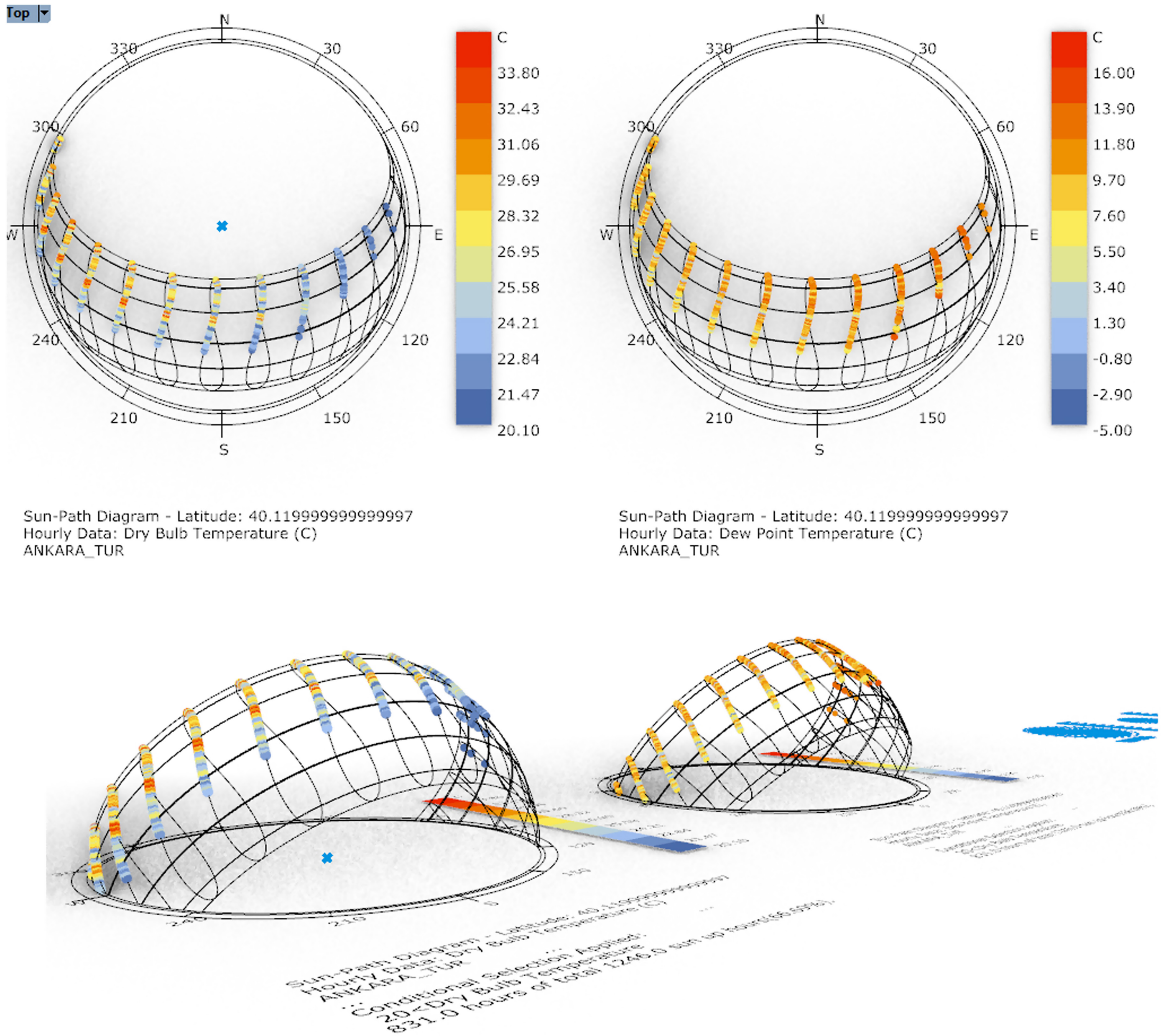

Figure 4.
Bulb Temperature and Point Temperature of Ankara.

were analyzed (Figure 5). In addition to these analyses, radiation data were also obtained numerically.

All obtained values provided data for the modeled structure with its surroundings. Analyses are shown in situ.

Mass Modeling with Environment and Overlapping by Environmental Analysis

In this process, a massive three-dimensional model of the office building was completed, including the existing buildings and their immediate surroundings. Afterward, the analysis data obtained on this mass model were overlapped. A clear day and time range are given for July and September. According to these determinations, the positions of the sun were re-evaluated. (Figures 6 and 7).

It is important to evaluate the determined values together with the office building; however, due to the high residential buildings in the surrounding area, there is a lack of sunlight on the facades of the building.

Kinetic Facade Modeling

A facade model proposal has been developed for those changes according to the direction of daylight on the facade of the environmental factor design model. This façade model is created with triangular façade modules. The center points of the surfaces of each module can be opened or closed according to their distance from the selected sun positions. In this way, it will open in a way that will receive more daylight during low peak hours, and it will move to be partially closed during peak hours (Figures 8 and 9).

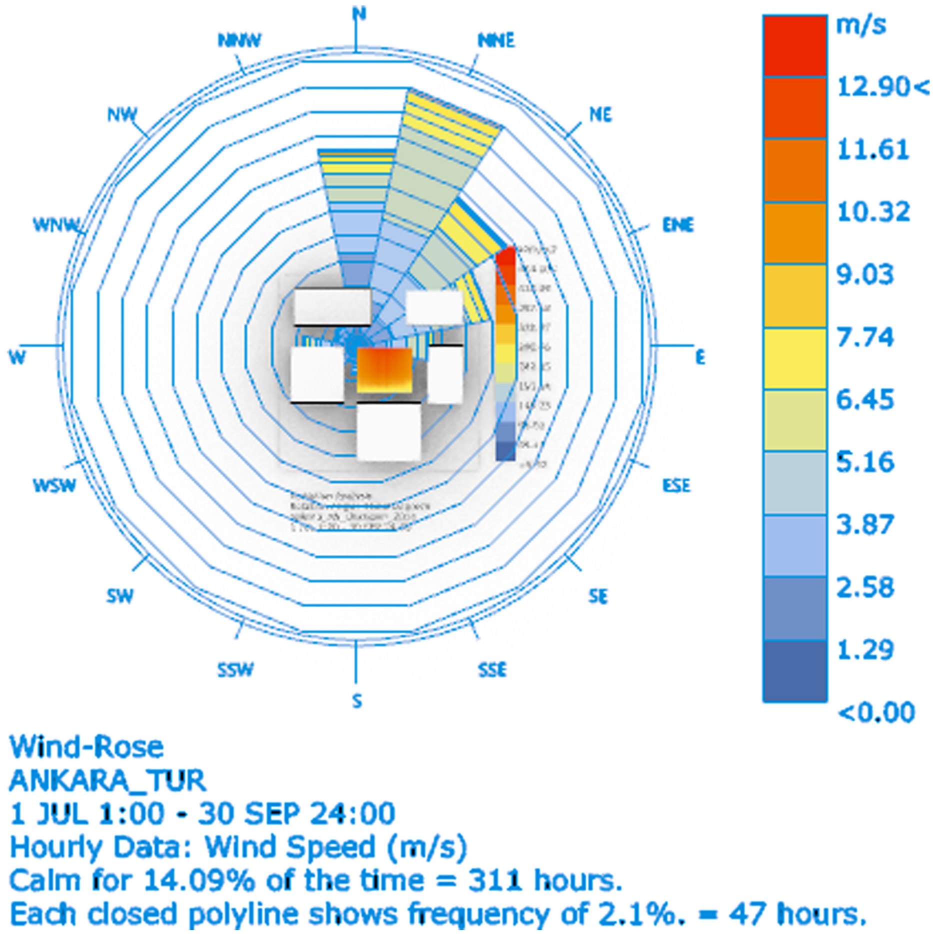

Figure 5.
Wind Rose.

While "23" parameter degree is the state of the façade when the sun is in the position where the sun is more inclined, "70" parameter degree is evaluated according to the position of the sun at the top and changes the orientation of the façade panelization.

Considering these integer parametric values, it is possible to change the magnetization according to all positions and hours of the sun. However, since the changes and transformations in the facade are very close to each other, finding the most ideal

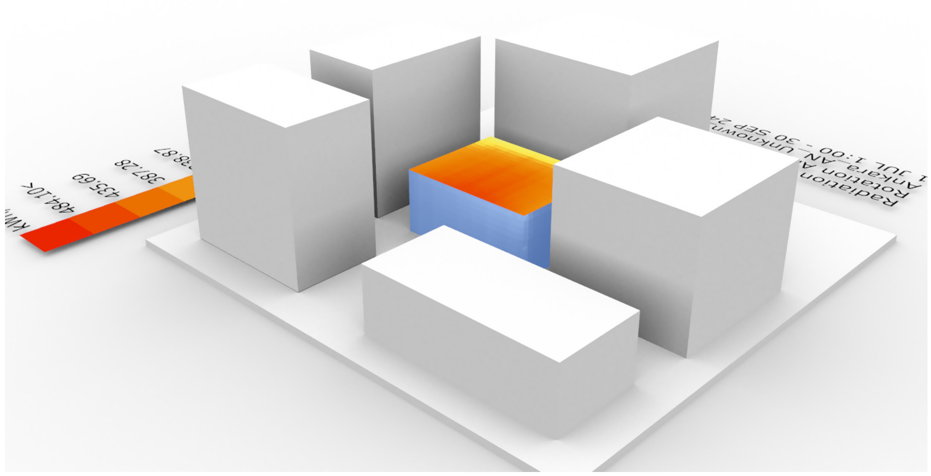

Figure 6.
Mass Modeling and Environmental Conditions.

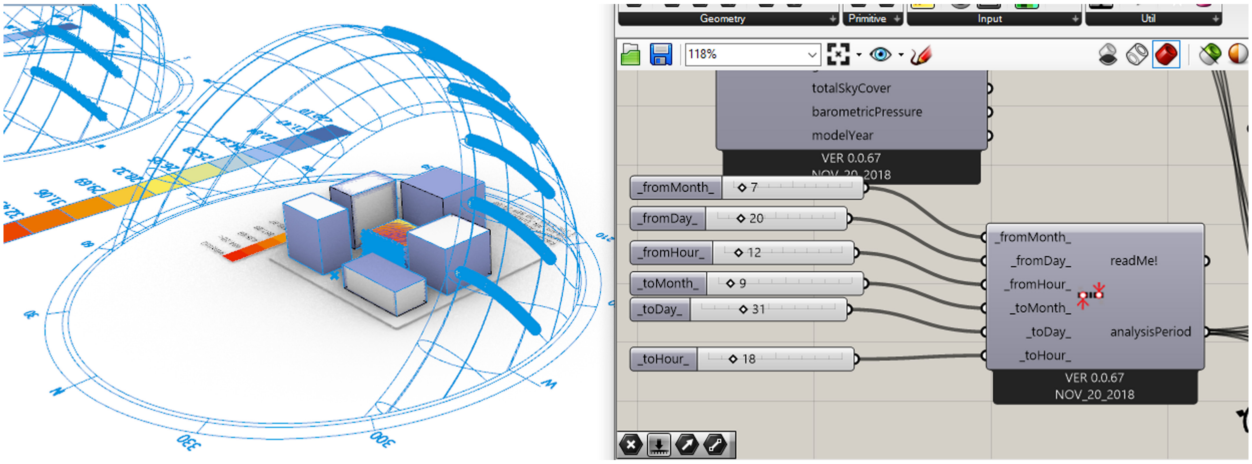

Figure 7.
Mass Modeling and Environmental Conditions With Specific Hours and Days.

model for the kinetic facade change makes it difficult for the designer, so genetic algorithms have been tried, and thus, the ideal approach has been tried to be found with the optimization method.

Evolutionary Algorithm and Optimization Process
When the kinetic facade studies are reconsidered with all their numerical data, they are limited at certain intervals. With the Galapagos plug-in, in which evolutionary algorithms in Rhino–Grasshopper are used, the integration of the design with different positions of the sun is ensured again. (Figures 10 and 11). "The common underlying idea behind all these techniques is the same: given a population of individuals within some environment that has limited resources, competition for those resources causes natural selection (survival of the fittest)"(Eiben et al., 2015).

Genetic algorithms are obtained by mutations and different combinations of populations. According to Mirjalili (2019) While each chromosome expresses the solution method, the genes formed by the chromosomes express the variable parameters. As a result of the crossovers obtained here, the best solution alternative is more dominantly shown in the simulations. In our method, change variables according to the distance of the façade opening to the position of the sun are defined as a gene, while each façade alternative defines a chromosome. As a result of the optimization obtained here, the best alternative is the facade model 6.

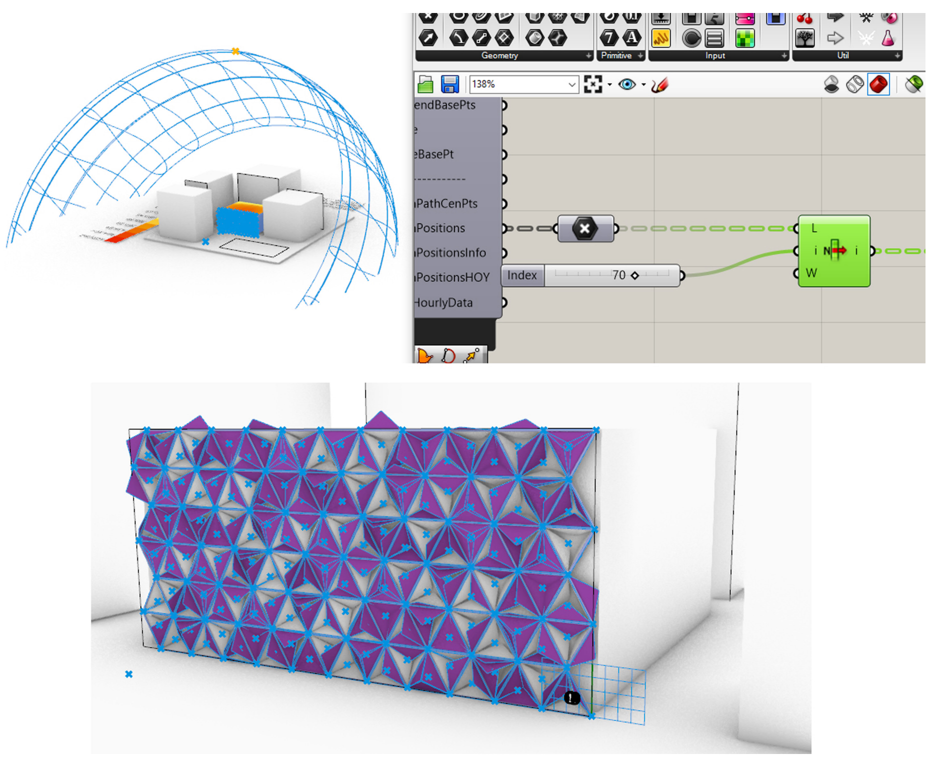

Figure 9.
Sun Position Parameter Degree "70" and Attractiveness Through Façade.

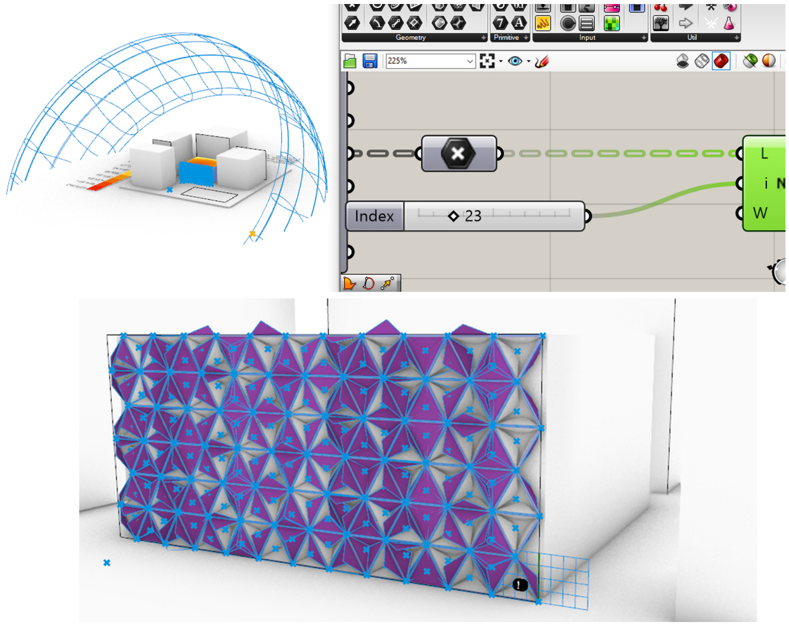

Figure 8.
Sun Position Parameter Degree “23” and Attractiveness Through Façade.

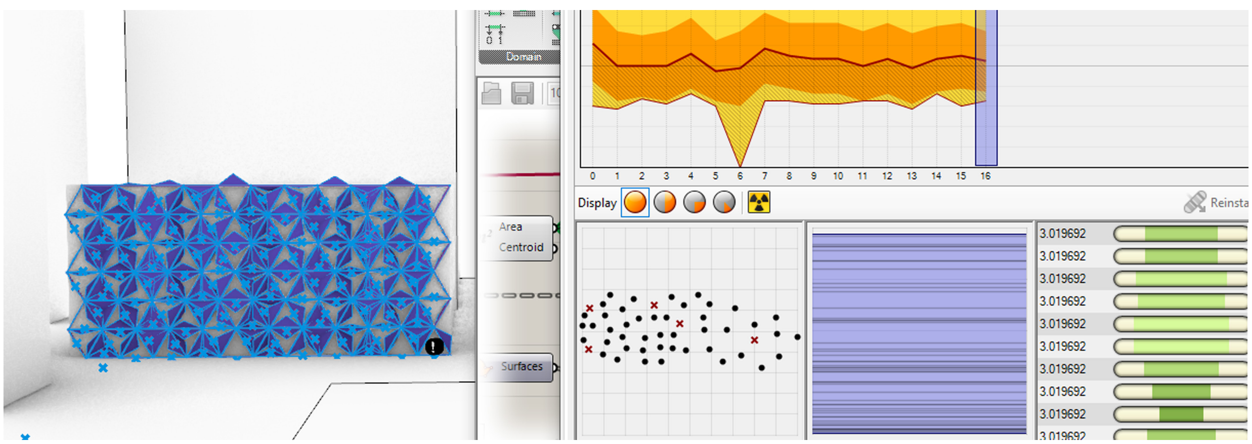

Figure 10.
Optimization Process I.

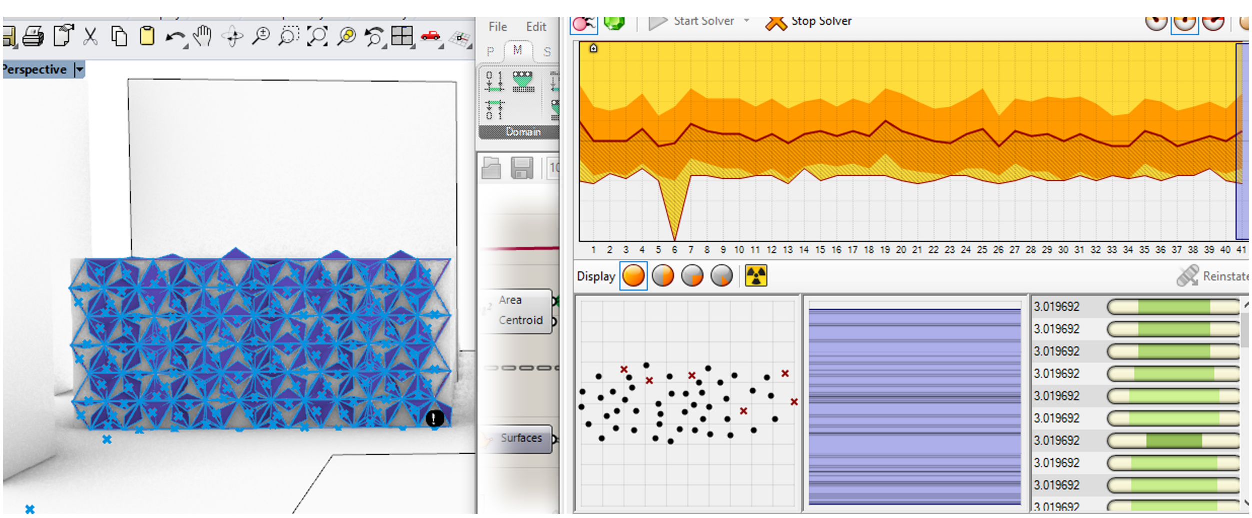

Figure 11.
Optimization Process II.

Conclusion and Recommendations

The design model was tested according to bioclimatic approaches. The study was carried out in Ankara, using environmental-climate data. In this way, all site-specific data sets were used.

The position of the sun and the area it affects and the wind direction analyses were made. The mobile facade is designed according to the temperature changes in the range determined during the summer months according to the differences in the sun's position.

To produce different alternatives to these façade models, genetic algorithms have been used in addition to the parametric design model. In this way, different alternatives have been reached.

In the later stages of the study, the relationship with the interior will be established and the effect of the position of sunlight will be measured and the optimization method will be tried.

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