Climate consultant: a tool for instigating bioclimatic design through the exhortation of adaptive strategies in the climate of Agha (Algeria)

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Abstract

The empirical study reported in this paper focuses on the Climate Consultant program as a tool for instigating bioclimatic design through the exhortation of climate adaptive strategies in Agha, a downtown Algiers neighborhood that is part of the commune of Sidi M'Hamed. The objective of this paper is to advocate pragmatic, sustainable solutions to achieve bioclimatic design in climates comparable to Algiers. In this study, we use the Energy Plus data source, as well as the Climate Consultant and Google SketchUp tools, to assess the local climate-related characteristics of Agha. The article includes psychometric diagrams and graphs that provide basic information about the climate of the urban fabric under consideration, as well as bioclimatic methods that can be applied to ensure year-round comfort.

Keywords: *Climate Consultant; bioclimatic design; climate; comfort; Agha.*

1. Introduction

The unbridled growth of cities, accompanied by reckless and unsustainable overconsumption, has led in recent years to increasingly bleak urban landscapes and progressively deplorable living conditions. The usual trajectory of the development of Western industrial civilization is one of economic expansion at the expense of the basic living conditions of humanity. If there is one thing that characterizes Western culture today, it is that, with its astonishing and revolutionary technological discoveries, it instills in people an excessive sense of arrogance and a sickly certainty that they can now live in artificial or even virtual environments far from an ever scarcer and inevitably destroyed nature.

As cities grow, so do their boundaries and populations. Uncontrolled industrialization and urbanization have impacted the number of urban buildings contributing to climate change, making the urban climate an example of human-induced climate change. According to the United Nations World Food Programme [1], climate change poses major challenges to agricultural production, species survival, urban security, and economic development. In terms of environmental damage, the contemporary structures where we live and work are almost as perilous as some businesses, contributing significantly to deforestation, water shortages, acid rain, and the danger of global warming.

Climate change is considered today to be one of the most important global problems. The urban heat island, the rise in sea level, and the greenhouse effect are the main consequences. Faced with this image of the conquering man who, without realizing it, destroys what makes him exist, humanity's proposal in the twenty-first century [2] has been to pursue a sustainable development that conserves energy and resources. Adapting to or mitigating the negative effects of climate change and creating a living environment in which humans and natural systems can coexist harmoniously are crucial issues facing global civilization.

It is fascinating to note that previous generations, while more traditional and less evolved, had a much better understanding of the obvious need to respect and protect the environment in which they lived. To prevent environmental damage and global warming, the promotion of bio-architecture has become a worldwide trend. Its fundamental characteristic is to remember that everything that this bioclimatic design produces is linked to the soil and the earth. It is as if there is an invisible umbilical cord that transfers from the ground to the building all the energy and materials necessary for its existence in space and time.

In recent years, considerable attention has been given to both ecological and bioclimatic architecture. Previous studies indicate that bioclimatic, ecological, or "green" design is an alternative type of architecture that seeks to solve the problem of current architecture that is directly related to the destruction of the ecosystem, since the environmental crisis is highlighted as the most serious threat to the existence of humanity.

Bioclimatic architecture, as its name suggests, was born out of the awareness of a close link between climate and human life. More concretely, it is a theoretical and practical discipline that focuses on the development of buildings highly adapted to local climatic conditions, making the best use of available natural resources such as sun, wind, and vegetation in order to achieve high levels of comfort with minimal energy consumption. The brothers Victor and Aladar Olgyay, American architects of Hungarian origin [3], who were the first to study the relationship between man, climate, and construction, were the first to use bioclimatics in architecture. The postulates that will establish the theoretical and practical bases of bioclimatic architecture are described in 1962 in the book by Victor Olgyay, "Bioclimatic Evaluation Method for Architectural Application" [4]. In the mid-1970s [5], the idea of bioclimatic architecture gained ground. Several researchers, including Steve Szokolay [6], Baruch Givoni, Ralph Goldman [7], and, in Latin America, Eduardo González [8], John Martin Evans [9], and Silvia de Schiller [10], to name a few, made significant modifications and additions to Olgyay's theoretical and practical framework [11]. The Climate Consultant psychrometric diagram, which is based on the work of Baruch Givoni [12] and Murray

Milne [13], can be used as an alternative to Olgyay's bioclimatic graph to estimate cooling requirements and appropriate design options.

In the late 1970s [14], several publications and research projects on bioclimatic building design and the concepts incorporated in it began to be published. In 1976, Keith Haggard [15] proposed the use of passive technologies to heat and cool buildings, as well as their integration into architectural design. In 1982, Len Warshaw and Claude Parisel [16] proposed several bioclimatic design approaches for solar energy efficiency in buildings. In 1994, Cettina Gallo [17] concluded that a bioclimatic house is inextricably linked to the environment, including wind, solar radiation, relative humidity, and climatic factors. Between 1990 and 1994, John Martin Evans and Silvia de Schiller [18], [19], and [20] attempted to bridge the gap between climate and architectural design. In 1998, Manfredi Nicoletti [21] studied the link between passive design and energy savings, and Marco Sala [22] studied the benefits of bioclimatic building design. In 2001, Alexandros Tombazis and Stefan Preuss [23] conducted research on how to construct passive solar buildings in an urban environment. In 2003, Eddy Prianto and Patrick Depecker [24] presented their research on how to improve building design in tropical wetlands. In 2004, Qingyan Yan Chen [25] used computational tools to integrate the wind factor in architectural design, and in 2007, Niki Gaitani, Giouli Mihalakakou, and Mattheos Santamouris [26], through their research, emphasized that the application of bioclimatic principles improves thermal comfort conditions.

Initially, the bioclimatic approach did not involve extensive computer calculations and simulations. However, today we have software that allows us to accurately assess the impact of bioclimatic techniques on buildings. This implies the widespread use of simulation software to create bioclimatic strategies and evaluate the performance of buildings in areas such as energy efficiency, comfort, and carbon emissions. Some of the software programs that offer simulation tools for this purpose include Climate Consultant, Google SketchUp Pro, OpenStudio, EnergyPlus, DesignBuilder, IES-VE (Integrated Environmental Solutions—Virtual Environment), and TRNSYS (TRaNsient SYStem).

Regardless of the considerations made above, climate change is impacting the cities we live in as well as the environmental systems on which we depend. Adapting to or mitigating the negative effects of climate change are critical issues for civilization. The climate study of urban fabrics should be the focus of scientific research as they can be primary sites for climate change mitigation. In this context, we explore in this study the possibility of providing insight into how climate-sensitive design by generating bioclimatic strategies can help ensure the sustainability of buildings.

Given the growing danger and concern about climate change, the objective of this study is to use simulation software to develop climate-appropriate architectural solutions for the Agha neighborhood in Algiers. The approach of this study is based on the following question: Which program should be used to assess the climatic condition of the Agha district in Algiers in order to develop buildings with sustainable characteristics? To answer this question, we propose the hypothesis that "the Climate Consultant program is an effective tool for developing guidelines for a bioclimatic design adapted to the climate of Agha (Algiers)." The approach described later in the second section of this paper is used to test the validity of this hypothesis.

To address the above question, evaluate the validity of the hypothesis, and achieve the objective of the study, this article is divided into five sections: In addition to the introductory phase (Section I), Section II discusses and explains the methods used in this study. Section III presents the experimental results. This section will show how the Climate Consultant software can be used as an instigation tool for the exhortation of adaptive strategies to the Agha (Algiers) climate. Section IV discusses and analyzes these results, and Section V summarizes and draws conclusions based on the results discussed in more detail earlier (Section III).

2. Research methodology

Climate change is underway, and Algeria is already feeling the effects: catastrophic floods are becoming more frequent and heat waves more severe. The effects already observed draw attention to the potential for future damage. Early and proactive identification and control of anticipated climate risks in Algeria would potentially mitigate the cost of future climate adaptation and fully address the issues at hand. Therefore, in this study, we examine the climate of the Agha neighborhood, which is part of the Sidi M'Hamed commune in Algiers, by analyzing EPW (Energy Plus Weather) data from the Energy Plus platform for climate study. The objective of the study is to identify different passive design strategies that would provide optimal comfort to its inhabitants without the involvement of an active design strategy or any other strategy involving the use of a mechanical device. To achieve this objective, the methodological approach of this scientific research is based on a central question: What program should be used to assess the climatic condition of the Agha district in Algiers in order to develop buildings with sustainable characteristics? Because of their expertise in three-dimensional modeling, sunlight and shadow research, and climate analysis, Google SketchUp Pro as well as Climate Consultant are chosen in this regard. These state-of-the-art software tools are selected to achieve the goal of sustainability through energy-efficient structures in the studied urban fabric.

The research hypothesis that motivates the subject of our study and that we attempt to test in this paper is whether "the Climate Consultant program is an effective instrument for the development of guidelines for a bioclimatic design adapted to the climate of Agha (Algiers)." To assess the validity of this hypothesis, a bibliometric study, conducted in an exhaustive manner, was based mainly on the work of a few authors in order to highlight the different sources that have examined our study subject. The Climate Consultant program's ability to issue proposals for adaptive strategies to the study area's climate necessitates potential relevant evaluations of recently published works.Within this framework, and in order to achieve the set objective, this article carries out a bibliographic search that includes an extensive review of some works that have investigated our study topic.

As can be seen below, a brief presentation of the two software programs mentioned in this section is provided here via a succinct synthesis of the current scientific information required on the issue.

2.1. Climate Consultant: climate analysis tool

Climate Consultant, a professional climate data analysis software, was developed by the Department of Architecture and Urban Design at the University of California, Los Angeles (UCLA) [27]. Its purpose is to gather and display information in an understandable way, focusing on the design elements needed for the climate in question. This computer program works by reading weather data as long as it is compiled in an EPW (Energy Plus Weather) format compatible with that of this software.

There are four distinct comfort levels proposed by the Climate Consultant. The first option, the "California Energy Code" comfort model, is the one we will use in our case study. According to this comfort model, a dry temperature of 20°C to 23.9°C and a maximum relative humidity of 80% are required for the comfort zone, which is meant to encompass the number of hours that residents of a location, whether indoors or outdoors, are thermally comfortable.

2.2. SketchUp Pro (shadow analysis): three-dimensional modeling, sunlight and shading tool

Three-dimensional (3D) modeling is a branch of computer graphics that attempts to simulate the appearance of real-world objects and is supported by a number of applications, the most well-known of which are SketchUp Pro, Blender, and 3DMax .SketchUp, developed by Last Software before being acquired by Google, is a program containing a collection of tools for three-dimensional modeling and can be obtained as a download from many specialized sites.

In order to build a three-dimensional model of the study area to be able to design more energy-efficient and sustainable buildings, the Agha neighborhood is built in Google SketchUp Pro and then imported into Shadow Analysis, a sunlight and shade modeling plugin, the results of which are described and illustrated in the third section of this paper.

3. Results

This article focuses on climate-sensitive (bioclimatic) design, which has proven to be one of the most effective methods for ensuring the sustainability of buildings. Identifying appropriate concepts for climate-sensitive design early in the design process can have a significant impact on the success and quality of the architectural or urban project. Because of the importance of green and sustainable construction, it is critical to assess the overall sustainability of the built and urban environment through climate to assist architects and planners in this process.

Construction and urban development are among the largest users of natural resources and have a significant effect on the environment. Throughout the twentieth century, there has been a growing awareness of the planet's environmental problems. Many people have become aware that it is possible to develop and create while building green structures and cities that will provide a better quality of life in the present while preserving resources for future generations. However, the design of sustainable green environments and the successful implementation of this agenda in construction and urban planning require a comprehensive and integrated planning approach that relies on knowledge of certain software. With this in mind, the objective of this research is to see if the Climate Consultant program can be used to provide recommendations for bioclimatic design that is appropriate for the climate of the Agha neighborhood of Algiers. In this context, this paper will primarily use this particular software as a decision-support tool to highlight its ability to predict architectural alternatives that are appropriate for the climate of the study area. This potential is measured empirically in this section.

3.1. Evaluation of the current climatic condition of the Agha district

At the time of an important rural exodus, the Agha district in Algiers experienced a rapid and uncontrolled development of urbanization. The variations of surface and ambient air temperatures were influenced by this development. The results of the two-dimensional and three-dimensional modeling of the study area via Google SketchUp Pro software appear in the figures below (Figure 1).

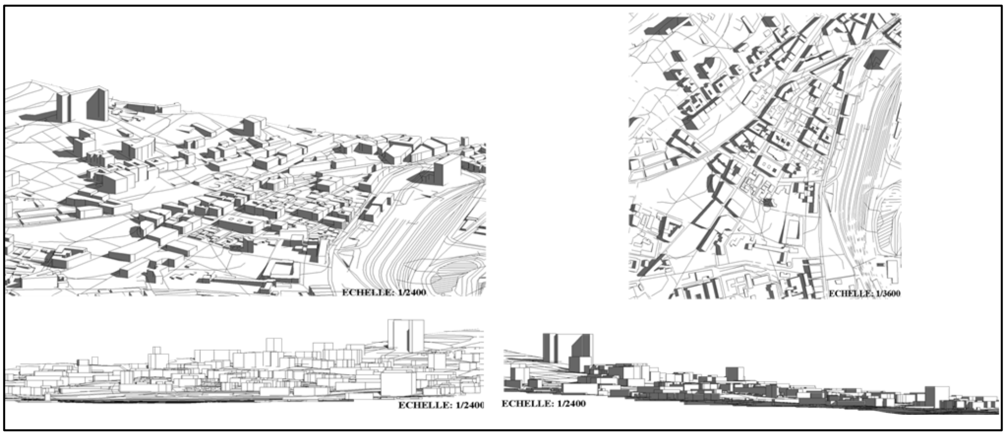

Figure 1. Modeling of the Agha district on Sketchup Pro

The analysis of our study area's weather data is the final step in the bioclimatic design process for us to determine the architectural design strategies to be used. Therefore, the climatic conditions of our study area are outlined below in order to develop architectural projects and zero-energy urban structures that are sustainable in the long term. The Climate Consultant software is used to statistically evaluate weather data in EPW format (which can be obtained for free from the Energy Plus web platform). Since the Climate Consultant program was created by Americans, all results of the analysis of climate parameters are presented in a series of graphs written in English. The results of the assessment of the current climatic condition of the Agha district are presented in the graphs below, which show, among other things, wind speed, temperature fluctuations, radiation, and sunshine levels, as well as the development of bioclimatic design requirements specific to the study area.

The Climate Consultant software interprets the EPW weather data and generates graphs of several climate variables for the area where the climate analysis is applied. Figure 2 shows the temperature range, daily radiation fluctuation, sky cover and wind for our study area after processing in the Climate Consultant software.

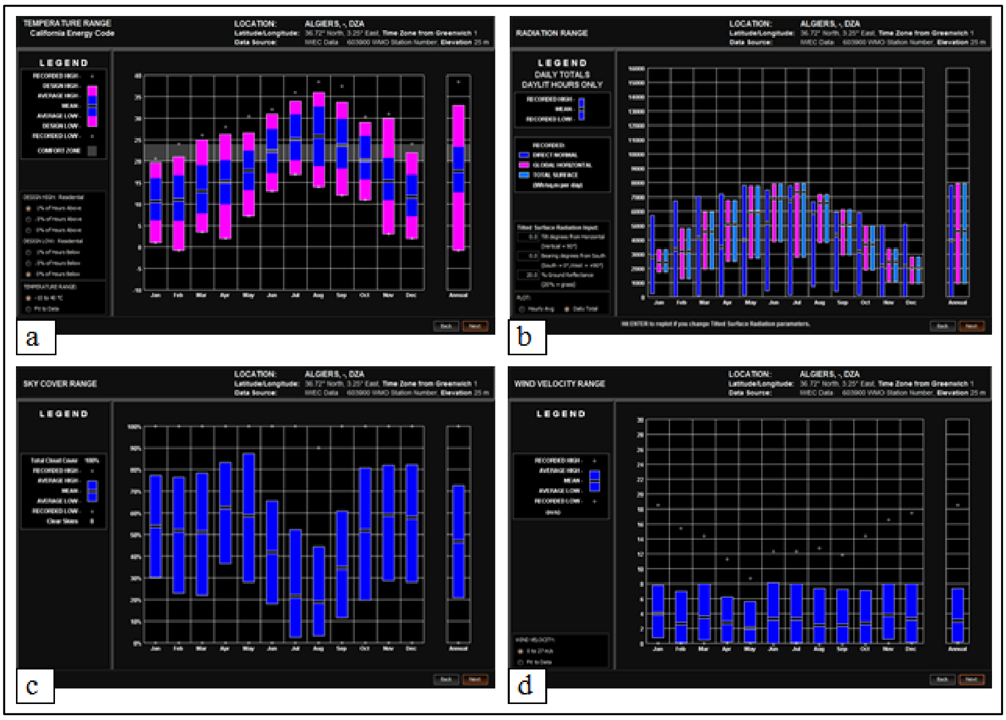

Figure 2. Climatic data for the Agha district
(a) Temperature variation, (b) Radiation intensity,
(c) sky coverage rate, (d) Wind speed

The results of the examination of the temperature variation at the study site tell us that the Mediterranean region of Agha (Algiers) has an average annual temperature of 18 °C (34 °F). The average high temperature and average low temperature (in fuchsia), which are displayed above and below the blue part of the average temperature, show that throughout the year, the temperature of the study area in the middle of winter is -1°C (February) and 36°C in summer (August).

High-intensity radiation is responsible for the rise in skin temperature and various other skin disorders. According to the Climat Consultant program, the typical direct radiation level is 4000 W/square foot per hour on an annual basis. The months of April, May, June, and July are the most irradiated, as shown in Figure 2.

Understanding how the sun travels through the sky is a prerequisite for architectural and urban interventions. It teaches us how to use the sun's heat to our advantage when heating or avoiding and protecting structures in hot weather. In a bar graph, as can be seen in Figure 2, clouds cover about 46% of the sky on average.

The light and shadows, projected onto the urban fabric of Agha, are shown in Figure 3. The Shadow Analysis plugin is used to model them in SketchUp Pro. As shown in Figure 3, the hue of the sunlight is calculated as a function of time. Regardless of distance, the simulated sunlight rays are parallel and have the same intensity. The geographical location of our research region determines the angle of the sunlight. The number of hours that the Agha district is exposed to solar radiation can be used to power sustainable energy sources such as solar photovoltaic and solar thermal.

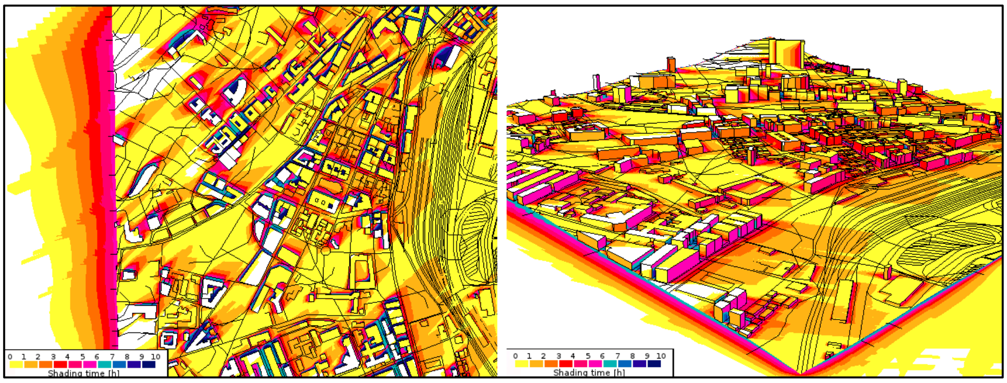

Figure 3. Simulation of the light and shadows projected on the urban fabric of Agha

Wind speed is caused by the movement of air from high to low pressure, which is usually caused by temperature differences. Wind direction is defined as the number of degrees measured clockwise from the north. In calm winds, wind direction is equal to 0. Winds in the city of Algiers can reach a maximum of 19 m/s annually; this can be seen in figure 2. The average wind speed, according to the Climate Consultant software, varies from 0 to 7.5 mph (Figure 2).

In the representation of the wind rose, we take into consideration the characteristics of wind strength, temperature, and humidity. In our case study, we found that the southwest has the lowest temperatures (ranging from 20°C to 24°C, as indicated by the red aniline color) during August, while the northeast and northwest have the highest temperatures (the turquoise blue hue indicates a temperature ranging from 24°C to 38°C). In August, the relative humidity varies between 30 and 70%. It is indicated by the color indigo blue and is concentrated mainly in the northeast and northwest. The magenta-pink color indicating humidity above 70% is noticeable in the southwestern orientation. As can be seen in royal blue, the northwest direction has the highest wind intensities, ranging from 8 to 15 m/s (Figure 4).

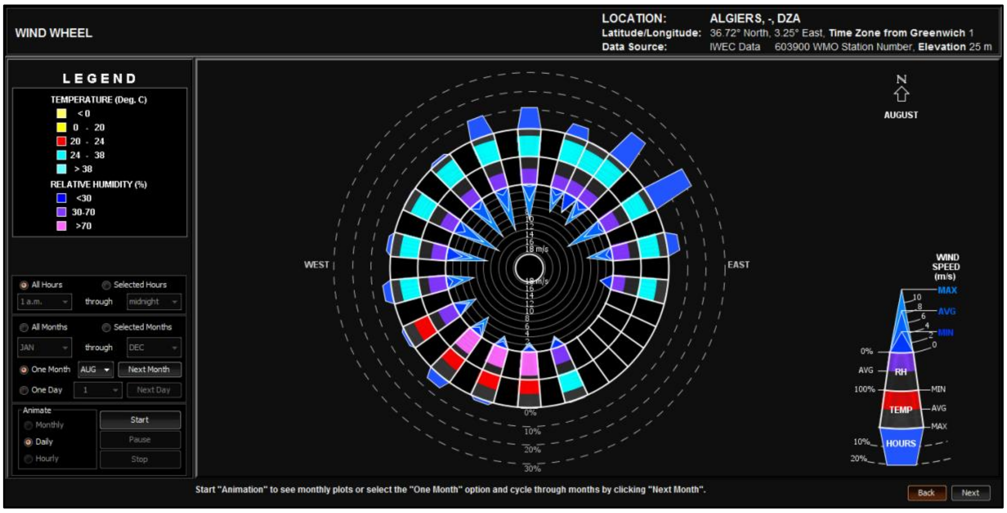

Figure 4. Simulation of the specific wind rose at Agha

3.2. Psychometric graph: a factor for optimal comfort in Agha

After analyzing the different factors that contribute to the climate change of the study area, the Climate Consultant software displays the two psychrometric graphs proposed in Figures 6 and 7, providing a general diagnosis of all the important aspects to be considered and their percentage of importance in order to achieve optimal thermal comfort. This approach integrates various design methods (active (Figure 6) and passive (Figure 7)) to provide a high degree of thermal comfort throughout the year, as indicated by the pink dots in both graphs.

Figure 5 shows that thermal comfort is achieved for only 713 hours out of a total of 8760 hours in a year when no design strategy is employed (or 8.1% of the time). In contrast, if the psychrometric graph is used to select the most relevant design strategies for the Agha climate, all hours will be potentially comfortable. The key design approaches designated in these psychometric graphs could expand the comfort zone shown in yellow in Graphs 6 and 7.

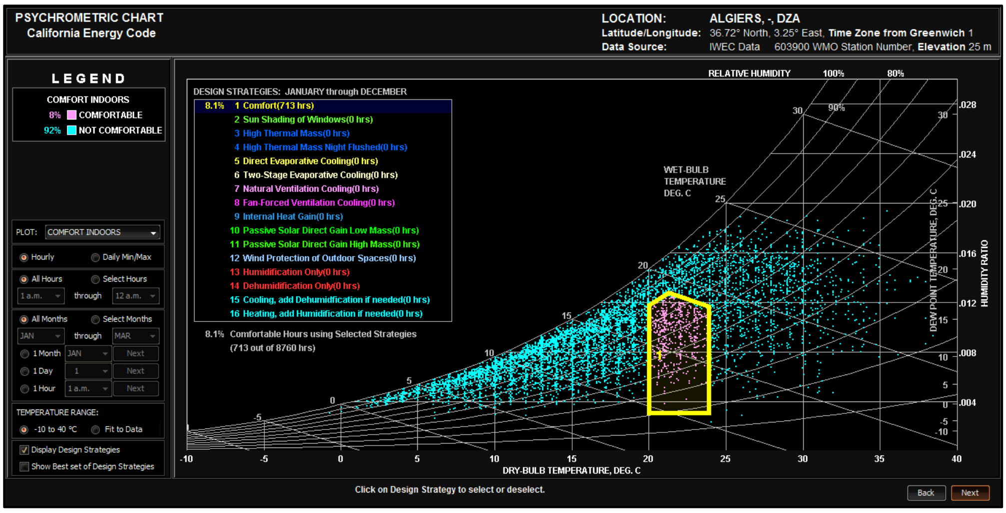

Figure 5. Psychometric graph

without bioclimatic strategies of Agha

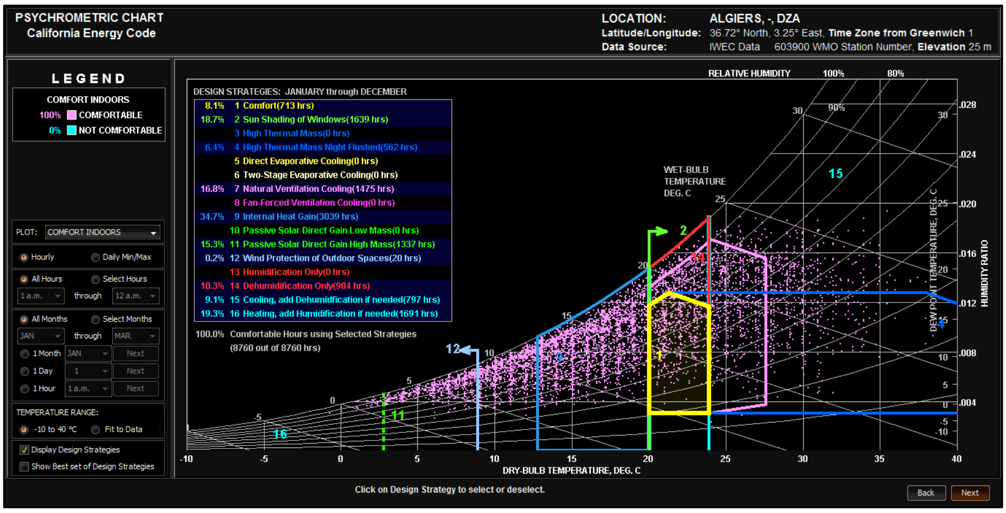

Figure 6. Psychometric graph
with active design strategies of Agha

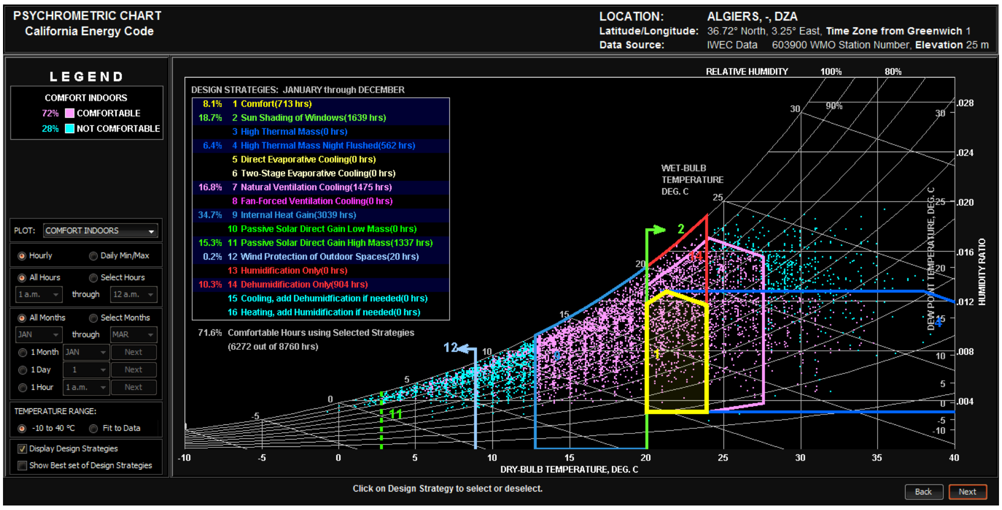

Figure 7. Psychometric graph
with passive design strategies of Agha

The active design approaches generated by the Climate Consultant software (Figure 6), which indicate the percentage of time active cooling and heating are essential, reveal that our research area requires 9.1% cooling and 19.3% heating to achieve 100% thermal comfort. For a passive design without heating and cooling, the Climate Consultant proposes, through Figure 7, seven sustainable (passive) strategies that are adaptive to the local climate of Agha. These are discussed in the next section.

4. Discussion

Understanding the climatic characteristics of a city like Algiers, as well as the thermal comfort choices available to its inhabitants, is not always obvious. To address this issue, we undertook an in-depth study of the Agha area in Algiers. This area was chosen as a case study because of the availability of meteorological data. In this study, the Climate Consultant software is used to develop bioclimatic strategies for the Agha district, which will improve user comfort, save energy, and preserve the environment. To conduct our research, a realistic two- and three-dimensional computer model of the study area is created using SketchUp Pro software (Figure 1).

This paper focuses on the environmental comfort conditions of the area selected for this study and seeks to assist in the design of projects that encourage buildings with thermal behavior appropriate to the local temperature, resulting in a pleasant built environment. To achieve the objective of this paper, which is to identify appropriate knowledge for a guideline simulation suitable for the research area of this study, temperature, humidity, wind speed, sun intensity, and even clouds are used to assess the climate. The data is analyzed using the California Energy Code comfort model, which aims to design energy-efficient buildings that maintain the same level of comfort in winter and summer.

The results of this research, outlined in the previous section of this article, argue that the use of climate-appropriate passive designs can significantly reduce energy consumption while providing adequate thermal comfort for occupants. In accordance with Climate Consultant software recommendations, Agha can be comfortable for up to 72% of the annual hours using passive design techniques shown in a psychrometric graph (Figure 7). Figure 6 shows and illustrates the proportion of time that active cooling or heating is required.

Since it is possible to artificially regulate the environment, finding an optimal climate for comfort has become a challenge. In 1996 [28], Holm and Viljoen defined the "comfort zone" as an imposed situation in which most people do not feel hot or cold. The study of climate is, therefore, essential for the development of projects that allow for the comfort of users. Climate is the result of the action of climatic variables and their mutual relations. The most important environmental variables for this work, recorded in the Agha district, are exposed in the previous section of this paper in order to generate bioclimatic strategies. The psychrometric graph is one of the Climate Consultant's most advanced features. It relates the climatic variables of temperature and relative humidity, which are represented graphically for the 8760 hours of the year. In addition, the software analyzes the graph, presenting quantitatively the efficiency of the application of different design strategies. That is, how many hours per year each strategy is required. Examples of psychrometric graphs are presented in figures 6 and 7, in which it is possible to observe that the Climate Consultant software presents ten categories (zones) of design strategies as an answer. The first corresponds to comfort, according to the California Energy Code comfort parameters, and the number of hours it can be achieved without any environmental adaptation. The other nine categories correspond to recommended bioclimatic methods (seven of which are passive and two of which are active) and their respective percentages of effectiveness in transforming the building into a comfortable environment.

In a simplified manner, the results of the Climate Consultant program, presented in the figures listed from 2 to 7, which can be used as a basis for future architectural guidelines for the city of Algiers, help us identify many suggested passive and active design methods for the study area to provide optimal thermal comfort during the summer and winter seasons. These methods are based on the fluctuations of dry bulb temperature and relative humidity in our research area, as illustrated in Figures 6 and 7.

A broad diagnosis of all the key factors for the thermal comfort of Agha and their relative importance is given in graphs 6 and 7 provided by the Climate Consultant program. The main methods that can be adapted to the climate of the Agha district have a direct impact on its thermal comfort. If buildings are not designed to provide shade, the ambient temperature will most likely increase. Therefore, to ensure optimal thermal comfort, it is necessary to shade windows from 9:00 a.m. to 5:00 p.m. to prevent the interior of the buildings from overheating. Thermal comfort improves by 18.7% when window shading is appropriate (Zone 2). Night-time flush cooling (removal of daytime heat by cold night air) is another technique (Zone 9) that should not be overlooked, as it results in a 6.4% improvement in comfort in the study area. Cooling by natural ventilation (Zone 7), cooling by internal heat gain (Zone 9), cooling by dehumidification alone (Zone 14), and active cooling (Zone 15) increase thermal comfort by 16.8%, 34.7%, 10.3%, and 9.1%, respectively.

According to Asma Khalid [29], direct-gain passive solar energy (Zone 11) is a design approach in which high thermal mass materials absorb, store, and distribute solar energy as heat. Solar energy enters the building through the south-facing windows and is absorbed by the thermal mass embedded in the floor and walls. This approach reduces the discomfort caused by Agha's climate by 15.3%. The approach to wind protection of outdoor spaces (Zone 12) can improve Agha's thermal comfort by up to 0.2% by providing wind protection to outdoor spaces such as patios, decks, and high-shade exteriors through the installation of a windscreen or windbreak and the use of a shrub hedge or windbreak. For thermal comfort, the air heating process is 19.3% efficient.

Despite what has been discussed previously, it is clear that since time immemorial, man has sought protection from the climatic elements and has also structured his living environment to meet his individual and collective needs. The goal is to build a sustainable future so that future generations can live in a clean and green environment. Furthermore, can the design and management of urban projects and structures include the concept of sustainable development and the Climate Consultant program in order to reduce environmental impact while improving our quality of life? Yes, it can! This article shows how to achieve sustainability goals through the above-mentioned methods recommended by the Climate Consultant software. This climate analysis tool helps us understand the local climate of the study area and develop appropriate solutions. The hypothesis of the paper, that the Climate Consultant program is a good tool to model architectural and urban solutions adapted to the climate of Agha (Algiers), is indeed verified.

5. Conclusion

In this paper, we present several graphs of different meteorological characteristics, such as temperature fluctuation and radiation, in bar graph form (Figure 2). The average annual temperature was found to be about 18°C. According to the sky coverage rate (shown in Figure 2), on average 46% of the sky in the Agha region is hazy. Other environmental factors, such as wind speed, which ranges from 0 to 7.5 mph, and psychrometric charts (Figures 6 and 7), are plotted and studied in this research. The psychrometric chart is used to provide various suggestions for coping with the Agha climate.

To combat climate change in the study area, some green architectural design strategies, including year-round thermal comfort, are outlined in guidelines. According to the results of the Climate Consultant simulation program, we can achieve a high level of comfort by design alone using the methods described in this article without increasing construction costs or requiring the use of complicated technologies. We can achieve a high level of comfort in a green building, which not only preserves the environment but also saves a lot of conventional energy by reducing its carbon footprint, using the methods described in this article with the help of the Climate Consultant simulation program to deal with the Agha climate. As a result, the hypothesis presented in this paper that the Climate Consultant program is an effective tool for creating bioclimatic design recommendations appropriate for the climate of Agha (Algiers) is verified.

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