University Of Salah Boubnider Constantine 3
Faculty of Architecture and Urban Design
Department Of Architecture

PARAMETRIC STUDY ON SOLAR CONTROL OF URBAN SPACES (SPACES BETWEEN BUILDINGS)

THESIS

Submitted in order to obtain the degree of
Doctor of Science in Bioclimatic Architecture and Environment

By
Amina NAIDJA

University year
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Dedication

With my deep affection, I dedicate this modest work: To those who have supported me encouraged me throughout my life. To those who always wanted me to be the best: To my mother, and my father. Symbols of sacrifice, love, encouragement, and tenderness, ... I would like to express my affection to you, and admiration.

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Abreviation list

E:East

ET : Effective Temperature

FAR : Floor Area Ratio

GIS : Geographic Information System

H/W: Height to Width ratio

L : Lenght

Lat : Latitude

N: North

OBA : Obstruction Angle

PMV: Predicted Mean Votes

PPD: Predicted Percentage Dissatisfied

PR : Plot Ratio

PSE: Parmetric Solar Envelope

PTFE: Polytétrafluoroéthylène

RSB : Residential Solar Block

S:South

SBB : Solar Bounding Box

SCE : Solar collection envelope

SET : Standard Effective Temperature

SRE : Solar right envelope

SVC: Solar Volume Coefficient

SVF : Sky View Factor

Teq : Equivalent Temperature

UTCI : Universal Thermal Climate Index

W: West

W=Width

Abstract

Spaces between buildings constitute the crucial module of the city fabric and have a great influence on the performance of the buildings abutting them. The geometrical parameters of urban spaces influence widely sun penetration, shading requirement, and outdoor thermal comfort. However, these spaces are given a little importance in the design process and urban planning. Moreover, in developing countries, urban regulations frequently are founded on imported rules and they are poorly adapted to their local climate. In this regard, the present research work attempt to assess the Algerian urban planning rules, in accordance to solar movement and outdoor thermal comfort in the main climatic zones of Algeria. The present study attempt to develop a parametric solution, which allows urban designers to determine the proper geometrical parameters of urban spaces in accordance with solar right, outdoor thermal comfort. In addition, we pursue through this research to assist urban designers in linking between fulfilling greater built density and guaranteeing solar rights of spaces between buildings. To achieve the goal of this study, an evaluation and generative method has been used. The first phase of the process, focused on the evaluation effect of obstruction angle, orientation and geographical latitudes on solar radiation dropped on ground surface of urban spaces and outdoor thermal comfort during both of times summer and winter. Whereas, in the second phase, the generative approach based on twofold steps; the application of parametric solar envelope to optimize the results of the first phase, and the application of the Comfort Cover model to determine the urban areas for future urban densification in accordance with the desirability of shade and outdoor thermal comfort (UTCI). Afterward, the parametric solar envelope is applied on the blocks reserved for future urban densification. The findings of this research reveal some guidelines; low obstruction angle safeguard solar right of urban spaces in both high and low latitudes. However, high obstruction angle mitigate outdoor thermal comfort during summer period in both high and low latitudes, while during winter periods high obstruction angle leads to drop outdoor thermal comfort in high latitudes. In addition, the generative algorithm of parametric solar envelope permits urban planners to fulfill greater built density and safeguard solar access in urban spaces and mitigate winter outdoor thermal comfort. Moreover, the generative algorithm of Comfort Cover model permits urban designers to define the area of future urban densification in accordance with shading requirement and outdoor thermal comfort.

Key words: Urban Spaces, shadings, solar rights, outdoor thermal comfort, parametric solar envelope, Comfort Cover

Résumé

Les paramètres géométriques des espaces urbains influencent largement la pénétration du rayonnement solaire, les exigences d'ombrage et le confort thermique extérieur. Cependant, ces espaces ont un peu d'importance dans le processus de conception et d'urbanisme. De plus, dans les pays en développement, les réglementations urbaines sont souvent fondées sur des règles importées et sont mal adaptées à leur climat local. A cet égard, le présent travail de recherche tente d'évaluer les règles d'urbanisme algériennes, en fonction du mouvement solaire et du confort thermique extérieur dans les principales zones climatiques de l'Algérie. La présente étude tente de développer une solution paramétrique, qui permet aux concepteurs urbains de déterminer les paramètres géométriques appropriés des espaces urbains conformément au droit solaire, au confort thermique extérieur. Pour atteindre l'objectif de cette étude, une méthode d'évaluation et de génération a été utilisée. La première phase du processus, s'est concentrée sur l'évaluation de l'effet de l'angle d'obstruction, de l'orientation et des latitudes géographiques sur le rayonnement solaire déposé à la surface du sol des espaces urbains et sur le confort thermique extérieur en été et en hiver. Considérant que, dans la deuxième phase, l'approche générative repose sur deux étapes; l'application de l'enveloppe solaire paramétrique pour optimiser les résultats de la première phase, et l'application du modèle Comfort Cover pour déterminer les zones urbaines pour la future densification urbaine en fonction de la désirabilité de l'ombre et du confort thermique extérieur (UTCI). Ensuite, l'enveloppe solaire paramétrique est appliquée sur les blocs réservés à une future densification urbaine. Les résultats de cette recherche révèlent quelques lignes directrices ; le faible angle d'obstruction protège le droit solaire des espaces urbains dans les latitudes hautes et basses. Cependant, un angle d'obstruction élevé atténue le confort thermique extérieur pendant la période estivale dans les hautes et basses latitudes, tandis qu'en hiver, un angle d'obstruction élevé entraîne une baisse du confort thermique extérieur dans les hautes latitudes. De plus, l'algorithme génétique de l'enveloppe solaire paramétrique permet aux urbanistes d'atteindre une plus grande densité bâtie et de protéger l'accès solaire dans les espaces urbains et d'atténuer le confort thermique extérieur hivernal. De plus, l'algorithme génétique du modèle Comfort Cover permet aux urbanistes de définir la zone de densification urbaine future en fonction des besoins d'ombrage et du confort thermique extérieur.

Mots clés : Espaces urbains, L'ombre, Droit au soleil, Confort thermique extérieur, L'enveloppe solaire paramétrique, ComfortCover model.

الملخص

تشكل المساحات بين المباني الوحدة الأساسية لنسيج المدينة ولها تأثير كبير على أداء المباني المجاورة لها. تؤثر الخصائص الهندسية للمساحات الحضرية على تغلغل اشعة الشمس على نطاق واسع ومتطلبات التظليل والراحة الحرارية الخارجية. ومع ذلك ، يتم إعطاء هذه المساحات أهمية قليلة في عملية التصميم والتخطيط الحضري. علاوة على ذلك ، في البلدان النامية ، كثيراً ما تقوم اللوائح الحضرية على قواعد مستوردة وهي غير متكيفة بشكل جيد مع مناخها المحلي. في هذا الصدد ، يحاول العمل البحثي الحالي تقييم قواعد التخطيط العمراني الجزائري ، وفقًا للحركة الشمسية والراحة الحرارية الخارجية في المناطق المناخية الرئيسية في الجزائر. تحاول الدراسة الحالية تطوير حل حدودي ، والذي يسمح للمصممين الحضريين بتحديد المعلمات الهندسية المناسبة للمساحات الحضرية وفقًا للراحة الحرارية الخارجية المناسبة للشمس. بالإضافة إلى ذلك ، نطمح من خلال هذا البحث لمساعدة مصممي المدن في الربط بين تحقيق كثافة مبنية أكبر وضمان الحقوق الشمسية للمساحات بين المباني. لتحقيق هدف هذه الدراسة ، تم استخدام طريقة التقييم والتوليد. ركزت المرحلة الأولى من العملية على تقييم تأثير زاوية الانسداد والتوجيه وخطوط العرض الجغرافية على الإشعاع الشمسي الساقط على سطح الأرض للمساحات الحضرية والراحة الحرارية الخارجية خلال فترات الصيف والشتاء. حيث أنه ، في المرحلة الثانية ، النهج التوليدي القائم على خطوات مزدوجة , تطبيق مظروف شمسي معياري لتحسين نتائج المرحلة الأولى وتطبيق نموذج ComfortCover لتحديد المناطق الحضرية للتكثيف الجضري والمستقبلي . تكشف نتائج هذا البحث عن بعض الارشادات , زاوية الانسداد المنخفضة تحمي الحق الشمسي في الأماكن الحضرية في كل من خطوط العرض العالية والمنخفضة ومع ذلك فإن زاوية الانسداد المرتفعة تخفف الراحة الحرارية الخارجية خلال فترة الصيف في كل من خطوط العرض العالية والمنخفضة , بينما تؤدي زاوية الانسداد المرتفعة خلال فترات الشتاء الى انخفاض الراحة الحرارية الخارجية في خطوط العرض العالية بالإضافة الى ذلك تسمح الخوارزمية التوليدية للمعلف الشمسي المعياري للمخططين الحضريين بتحقيق كثافة مبنية أكبر وحماية الوصول إلى الطاقة الشمسية في المساحات الحضرية وتخفيف الراحة الحرارية في الهواء الطلق في فصل الشتاء علاوة على ذلك تسمح الخوارزمية التوليدية لنموذج ComfortCover للمصممين الحضريين بتحديد منطقة التكثيف الحضري المستقبلي وفقا لمتطلبات التظليل والراحة الحرارية الخارجية .

الكلمات المفتاحية: المساحات بين المباني , الظل , الحق الشمسي , الراحة الحرارية الخارجية , المغلف الشمسي المعياري , نموذج ComfortCover

CHAPTER I : INTRODUCTIF CHAPTER

Chapter 1 : Introductif chapter

Introduction

The town is more than a simple juxtaposition of buildings; it is more than an enlarged architecture. It consists of structuring modules that can also be called urban morphology modules, appear in the plan of a city in various forms and geometries: as a strip, islands, courtyard, urban street, blocks, squares etc. The geometrical parameters of the urban morphology modules have a wide influence on the urban climate. The urban climate of the built environment has a large effect on energy consumption, human thermal comfort and air quality. The quality of urban climate can be affected by three main elements of urban land use: Green ways, city structure (urban density-sky view factor- and prospect); and building materials (Volker Heidt, Marco Neef, 2008 , P.92-93). Generally urban city generates higher values of air temperatures compared to their nearby rural areas. This phenomenon known as Urban Heat Island (UHI). This phenomenon is due to many factors: such as the street geometry of Town, heat kept in the fabric of the city, anthropogenic heat (combustion, etc.), less evaporative cooling by vegetation, less wind cooling within street. In colder climates the (UHI) has a beneficial effect, while it leads to decrease heating requirement. Cities like Trondheim have generated artificial heat island by casing all streets. However, in warmer climates the opposite strategy is requested. Since, this latter (UHI) leads to drop outdoor thermal comfort and the energy efficiency of buildings (P J Littlefair , et al , 2000,P.4). In this regard, the integration of climatic knowledge into urban planning strategies is mandatory to obtain sustainable urban development. According to M. Alcoforado et al (2009):

Both planners and the public should bear in mind that taking the climate into account in the selection of the planning procedures may also have a number of economic and social consequences, namely with respect to energy consumption and the health of the urban dwellers. (M. Alcoforado et al, 2009, P.64).

In another statement, F. De Luca (2016) said that:

"Planning requirements in terms of energy efficiency and day lighting strongly contribute to shaping the layout of cities." (F. De Luca, 2016, P.195).

The advent of bioclimatic and solar urban planning made it possible to incorporate climatic and physical environmental factors in the field of urban design. In this way, many studies erupt to deal between urban fabrics, urban density and energy efficiency. Urban density affects widely outdoor thermal comfort and building’s energy performance through its effect on sun penetration, surface temperature and wind cooling. It was found in earlier studies that the highest sky view factors gave the lowest surface temperatures (P J Littlefair, et al, 2000, P.47). Spaces between buildings constitute the main module of the urban fabric and also influence the performance of the constructions that abut them. They can be comfortable or uncomfortable spaces dependent on their detailed design (P J Littlefair, et al, 2000, P.60). Shading and solar access have a crucial effect on the thermal behavior of an open space, and for the internal spaces next to it. Shading leads to decrease the convective heat transmission from sunlight, buildings and ground surfaces. The geometrical parameters of spaces between buildings affect widely the mutual shading and sun penetration. Unfortunately design of geometrical parameters of spaces between buildings can make shading as a serious problem in winter, since it prompts uncomfortable conditions inside the buildings and outdoors, as it generates cold urban public spaces and increases the energy consumption for warming of adjacent buildings in addition to daylight lacks (P J Littlefair, et al, 2000, P.73). Therefore, the respect of solar rights in urban design is vital in order to permit passive heating of buildings during winter and to enhance the comfort conditions of people in open spaces, streets, and sidewalks (Guedi Capeluto, 2006). In this approach, Knowles (1980), invented the solar envelope method, to bridge the gap between solar access and urban density. The solar envelope allows sun penetration to the buildings and surrounding areas (I. G. Capeluto and B. Plotnikov, 2017, P1). According to F. De. Luca (2016),when planning the volume of new building that has to safeguard sun hour’s requirement of its nearby existing buildings, the solar envelope method determine the maximum allowed volume that does not cast shade to its neighborhood. However, it was found that the solar envelope created by Knowles (1980) has some degree of lack. Because it is generated for a specific period of a single façade, it can’t safeguard the same right to light for the other orientations. Therefore, it is unable to ensure a specific requirement of direct solar access of different facades, especially when, it is conceived in an articulated urban environment (F. De Luca, 2016, P.196). In this regard, I. G. Capeluto and B.Plotnikov (2017) used a parametric tool (Rhinoceros/Grasshopper/Ladybug) to generate the parametric solar envelope. The parametric solar envelope is an improved method for reconciling between increasing the amount of solar access though ensuring greater built density. The parametric solar envelope is considered as an innovative filtering process focused on specific needs during the year such as weather data, site geometry and mixed programmatic requirements (I. Guedi and

B.Plotnikov, 2017, P.3). Nevertheless, solar rights and shading requirement of the built environment depend on the climatic zone. Algeria, characterized by a variety of climate environments. However, their urban planning rules are not established conferring to primary climatic analysis. Therefore, the urban development in Algeria cannot enhance the energetic performance, since it does not respect the climatic constraint of each region. In this way, the researchers attempt over this doctorate thesis entitled "Parametric study on solar control of urban spaces –spaces between buildings-"to find a procedure which allows them to bridge the gap between urban planning rules, climatic zones of Algeria, solar rights and shading requirement. The researchers used a parametric tool Rhinoceros/Grasshopper/Ladybug, to assess the effect of the existing urban planning rules on solar radiation and outdoor thermal comfort in different latitudes of Algeria. Afterward, a parametric analysis has been done to improve the existing urban planning rules according to the outdoor thermal comfort. Subsequently, the parametric solar envelope has been applied to enhance the best results of the parametric analysis. In order to help the urban planners in the design phase of urban forms of future urban densification the parametric solar envelope has been also associated with the Comfort Cover model.

Problématic:

The sun is considered as the most imperative climatic parameter in the field of solar design architecture. Solar design strategies are known on the relative movement of sun and its impacts on human environment (Birol Topaloglu 2003). Solar rights is a notion that many countries, regions or towns use in urban rules (Capeluto et al., 2006). The causes for regulating conferring to solar rights can both be associated to public purposes of guaranteeing sunny and daylight outdoor environments and to keep active solar potential. The latter both safeguard private property and allow legislative goals to reach environmental aims within renewable energy. Towns as New York, Toronto, San Francisco and Tel Aviv all employ solar rights as a strategy to keep public places (Capeluto et al., 2006). Though, the notion of shading right is not yet well researched on urban planning for hot,arid and semi-arid climates .Generally, in hot arid or semi-arid climates where Maghreb countries are located, applied urban regulation does not take into account the climatic context (Raboudi and Ben Saci 2017). In Algeria, urban outdoor spaces are given little importance in planning and design processes. Urban regulations frequently are based, on imported rules and they are poorly adapted to the local climate. Often urban regulations worsen the climatologically situation and consequently urban areas often become unnecessarily uncomfortable. Under these conditions, the inadequacy of the existing urban rules must be highlighted, also evaluated in comparison with solar rights and outdoor thermal comfort in different latitudes of the climatic zones of Algeria. According to Littlefair ,J. et al (2000), Maryléne Montavon (2010), the geometrical parameters of urban spaces and urban density have a big impact on solar rights and shading requirement of buildings and spaces around them. In this regard some questions arise.

-What are the optimum geometrical parameters of urban spaces (obstruction angles) which safeguard adequate solar access and outdoor thermal comfort in each climatic zone of Algeria?

-How can urban planners merge between achieving greater built density and ensuring solar rights of spaces between buildings and outdoor thermal comfort?

- How can urban planners determine the area of future urban densification in accordance with shading requirement and outdoor thermal comfort?

Statements of thesis

Four distinct hypotheses are put forward

-Low obstruction angle safeguard solar right of urban spaces in both high and low latitudes.

-High obstruction angle mitigate outdoor thermal comfort during summer period in both high and low latitudes, while during winter periods high obstruction angle leads to drop outdoor thermal comfort in high latitudes.

-The generative algorithm of parametric solar envelope allows urban planners to achieve greater built density and safeguard solar access in urban spaces as well as mitigate winter outdoor thermal comfort.

-The generative algorithm of ComfortCover model allows urban planners to determine the area of future urban densification in accordance with shading requirement and outdoor thermal comfort.

Chapter 1 : Introductif chapter

Thesis objectives:

Through this research we attempt to achieve the following purposes:

- Evaluate urban planning rules in comparison with solar rules and outdoor thermal comfort in each climatic zone of Algeria.

- Develop parametric investigation which allows urban designers to determine the proper geometrical parameters of urban spaces in accordance with solar right, outdoor thermal comfort and latitudes.

-Improve energy efficienty and outdoor thermal comfort, by founding clear and flexible guidelines, that ensure solar rights, and shading requirements for each building, and spaces between them.

Methodology of research

This research is emphasized on a parametric study of solar control of urban spaces (Spaces between buildings).The hypothesis formulated in the context of this research are in fact only provisional answers to the fundamental questions, then, they require confrontation with reality. In order to verify the hypotheses, a methodological approach has been established. In this way, the current thesis report is made of two main parts such as theoretical and analytical parts. The modelling simulation has been done by using parametric tool (Rhinoseros/Grasshopper/Ladybug). Weather data were obtained from Meteonorm 7.

-Theoretical part

This part is focused on the presentation of an overview of theories related to solar and shading control of urban spaces, as well as urban planning rules and the geometrical parameters of urban spaces. To understand our research subject we refer to many bibliographical references (papers, books, theisis,..etc).

-Analytical part

Concerns an analytical study, it will be developed under the guidance of the first part in particular the recommendations of the second chapter.

The first step of this part is based on a process which deals between a parametric evaluation and a parametric solar envelope. The parametric evaluation is focused on the assessment of the effect of obstruction angle, orientation, and latitudes on solar radiation received on ground surface of urban spaces and outdoor thermal comfort during summer and winter times. Then, to optimize the recent urban rules the parametric solar envelope will be applied on the best results of the parametric assessment. However the process applied in the second step of the analytical part deals between the ComfortCover model to determine the area of future urban densification and the parametric solar envelope to determine the proper value of the solar volume coefficient of future urban densification.

Structure of thesis

This manuscript is divided into five main chapters, preceded by an introductory chapter, and followed by a general conclusion. It is structured as follows:

Introductory chapter: includes the problematic, and the research hypothesis, the objectives, as well as the structure of the dissertation.

Chapter 1:

Presents the meaning of solar access in urban spaces. Then, it highlights the importance of solar access, the history of solar rights and the geometrical parameters of solar control in urban spaces. Afterward, it presents the importance and the means of shading control in urban spaces.

Chapter 2:

This chapter summarizes an overview of the main approaches (Evaluative and Generative) related to solar and shading control of urban spaces. These approaches dealt with obstruction angle, aspect ratio (H/W), street orientation, building outlines, urban density, and solar volume coefficient. Then, it explains the research methodology.

Chapter 3

The first section of this chapter presents the evaluation of the effect of prospect urban rules on solar radiation and outdoor thermal comfort at different latitudes in Algeria during summer and winter times. While, the second section of this chapter presents a simulation of fictious fabrics of urban street to find clear and flexible guidelines which ensure outdoor thermal comfort during summer and winter periods in each climatic zone of Algeria.

Chapter 4

This chapter presents the application of the parametric solar envelope to determine the proper geometry of urban spaces and street profil based on the desired density level, latitude and orientation.

Chapter 5

A process which deals between an inverted approach (ComfortCover) model and a generative algorithm of parametric solar envelope has been applied in this chapter to overcome the uncomfortable conditions caused by solar access in spaces between buildings of future urban densification.

General Conclusion:

Concludes the thesis by summarizing the main achievements. It advocates several application fields and other ways for a further development of this research.

CHAPTER II : SOLAR CONTROL AND OUTDOOR THERMAL COMFORT

Chapter 2: Solar control and outdoor thermal comfort

Introduction:

Solar control and shading are crucial factors in shaping architectural and urban forms. In this regard, the present chapter is made of three main sections. The first section explains the significance and the importance of solar access in urban spaces. It underlines the geometrical parameters of solar control in urban spaces and its development. While, the second section focused on the importance of shading control in urban spaces. It underlines the several means of shading control in spaces between buildings (static and dynamic means). Finally, this section display recent applications of Bio-inspired design of kinetic shading strategies. Whereas, the third section focused on the most important theories that are related to outdoor thermal comfort on one hand and on the other hand emphasized on the effect of solar and shading control on pedestrian's thermal comfort.

1- Solar control in urban spaces:

Solar access is recognized as the sunlight passage through the neighboring properties and its obstruction by constructions or vegetation (Anna Kapnoullas 2010).In addition, it has an imperative impact on the global appearance and on the quality of the development of urban areas (Littelefair 2000). Solar control considerations have a great importance in shaping urban and architectural forms (Birol Topaloglu 2003). In this regard the meaning of solar access in the built environment must be highlighted.

1-1-Aspects of solar access:

Sunlight is the result of geometrical interactions between objects and direct solar radiation in the built environment. These interactions lead to appear sunspots or shadow spots. According to Siret these spots can procure various values (energetic and aesthetic…etc.).In order to show the importance of solar exposure of buildings, we note in the following statement the different implications of sunlight.

1-1-1-Energy aspect of solar access

Sunlight importance in building has been reviewed since the energy crisis of the 1970. In this regard, many attempts have been taken by several architectural tendencies (solar architecture, bioclimatic architecture, and ecological architecture,etc) to counter the energetic requirements in various ways. To cope with the standards that are the result of modern movement doctrine, the construction mode must be regionally adapted.

The need of comfort and energy-efficient constructions is the driving force to many architectural solutions.

Solar energy is used either passively or actively. Among the known and applicable active solar energy systems, we note solar collectors, photovoltaic panels, power towers, solar ponds. However, hydrogen generating solar centrals and ocean thermal conversion centrals are only theoretical methods of energy generation. The buildings` energy performance has to be enhanced in three procedures (heating, lighting and cooling) so that the passive energy can be applied. The passive and active solar design strategies are founded on solar access as a precondition (Birol Topaloglu 2003).

1-1-2- Visual comfort aspect

Sunlight is considered the source of energy and illumination. Good light have to be described with sufficient quantity and good quality. In all climates, the requirement for both natural lighting and thermal comfort has to be balanced.

Natural light pierces the insides of buildings in various forms: as diffused by the sky and clouds, as direct solar radiation and as reflected by the environment. The most efficient source of natural light is the one, which is derived from solar radiation due to its characteristics of quality, quantity, and distribution. The quality is essential to the property to render colors appropriately to make the insides more enjoyable for the tenants. The quantity is the amount required to achieve many tasks and to perceive the surroundings comfortably. The distribution is the ability to light the insides at a significant depth due to its intensity and to be consistently diffused where it is more beneficial by appropriate window, floor, or facade layout.

1-1-3- Physical comfort aspect:

In practice designers, attempt to offer environments that are conventional to a majority of the occupants. Comfort is subjective. There are many factors that affect comfort we mainly note: clothing, the individual`s age and gender, the activity,; as well as aspects of the internal environment such as air temperature, air movement, noise, humidity, surface light, temperature, and odors. Therefore, comfort is divided into thermal comfort and visual comfort, indoor air quality and acoustic quality. First two of them are directly depended to solar exposure since the sun is recognized as light and heat source.

Thermal comfort designates the sense of satisfaction with respect to temperature. Givoni expand the meaning by adding the human body temperature and states that the preservation of thermal equilibrium between the human body temperature and its environment is vital. It contains conserving the temperature of the core tissues of the body in narrow range, irrespective of the relatively large variations in the outdoor environment. (Birol Topaloglu 2003).

1-1-4- Aesthetic aspect of solar access

The seasonal and daily dynamism of the sun may result with aesthetic consequences that coincide with the functional necessities. According to Daniel Siret (1997), the best-known research on the aesthetic value of sunlight is that of twarowski (1967). In a theoretical and practical study devoted to the sun and architecture, Twarowski recommends the helioplastics theory. He then studies the dynamics of the shadows and sun spots produced on the gable of a building. Twarowski attests that the plastic effects are reproductible and can be foreseen or conceived in an architectural project. Twarowski proposals have to be understood in the context of the "radiant" modernity; he expresses his belief in an urban solar enchantment.

1-2- Solar right development:

The importance of solar insolation in winter has been studied in many research works (Arnfield (1990), M.M.E.van Esch, et al (2012), A.Vartholomaios (2015), L.Koubaa, et al (2018)). Throughout history, one of the key generators of urban form is the right to solar access. Nowadays, solar access inspires urban planners and several architects, (Eugenio Morello, Carlo Ratti-2009). According to Anna Kapnoullas (2010), the Romans were the first to develop solar control law in the second century A.D. In Roman times, if a building or a tree blocks a neighbor`s access to sunlight, it would be demolished by the court`s order.

Boston architect William Atkinson (1912) in his book entitled “The orientation of buildings, or Planning for sunlight” stated solar direction for sanitary reasons and argued that the building heights have to be limited because of the healthy benefits of sunlight access. Furthermore, access to sunlight has become a matter for strict urban rules in recent era by regulations. Many world dense cities like New York attempt to safeguard daylight and sunlight through the idea of “Obstruction angles”. Knowles

(1974) has developed the obstruction angle rule in order to present the well-known concept of the "Solar envelope" (See figure2.1).According to Knowles (1980)

> *"The solar envelope can be defined as a zoning device to achieve solar access by regulating development within limits derived from the sun's relative motion. Buildings within its boundaries will not shadow surrounding properties during critical energy-receiving periods of the day and year. Guaranteed solar access, thus, offers to society a chance to develop a renewable energy source; to architects it extends aesthetic possibilities based on the dynamics of sunlight."* (Knowles (2003),P.25)

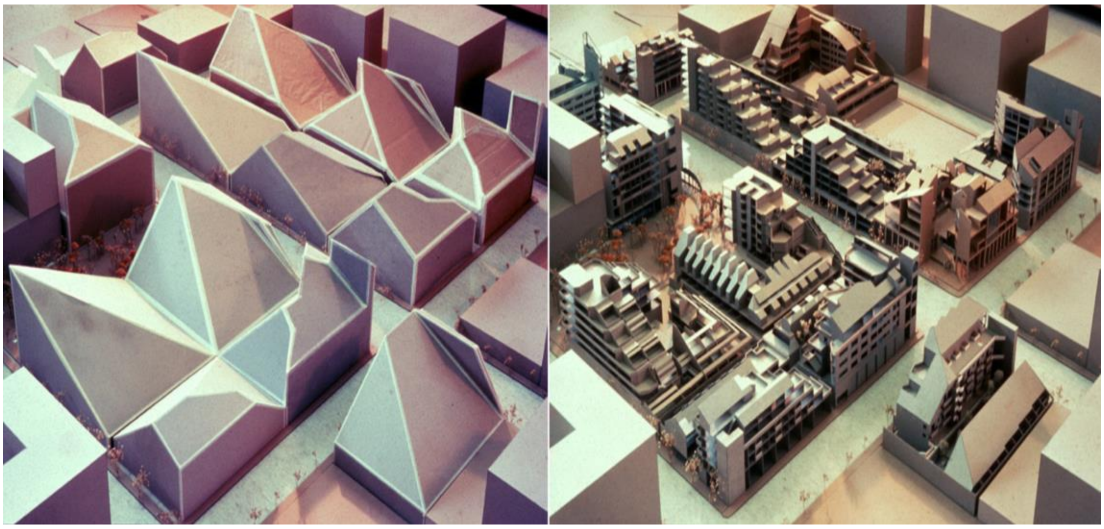
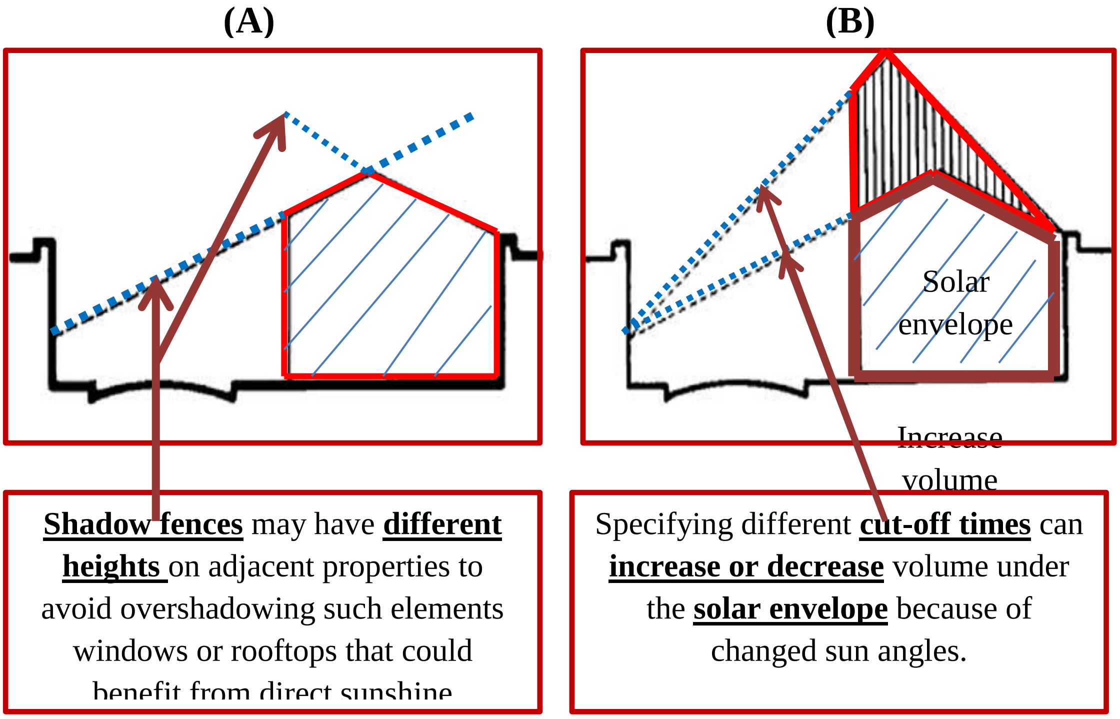


Figure2.1: Knowles' solar envelope applied to an urban plan
https://www.metropolismag.com/sustainability/ralph-knowles-pioneer-solar-design/

The solar envelope is related to: First, the space construct which means the physical boundaries of surrounding properties. Second, it is related to the construct of time which is related to the period of the surrounding properties` assurance of sunshine access. Therefore, the final size and shape of the solar envelope will be determined by the combination of these two measures. First, the shadow fences or undesirable shadows above designated boundaries are restricted by the solar envelope. The height of the shadow fences is related to both the surrounding conditions like windows or party walls; and adjacent land-uses for example commercial or industrial uses need higher shadow fences than houses. Thus, this variation in shadow fence heights led to differentiation in shapes and sizes of the solar envelope (Figure. 2.2 (A). Second, at a restricted time known as the cut-off time, the envelope generates dominant amount. This amount has been achieved through identifying the largest theoretical container of space, which is characterized by preventing off-site shadows between precise periods of the day. In comparison to shorter periods of assured solar access, greater periods will be more restricted on the solar envelope (Figure.2.2 (B)) (Ralph L. Knowles 2003).



Shadow fences may have **different heights** on adjacent properties to avoid overshadowing such elements windows or rooftops that could benefit from direct sunshine

Specifying different **cut-off times** can **increase or decrease** volume under the **solar envelope** because of changed sun angles.

Figure2.2 (A; B): Space–time constraints (Ralph L. Knowles-2003-)

Capeluto and Shaviv (1997) have distinguished between “Solar rights envelopes” (SRE) and “Solar collection envelopes” (SCE). The Solar Right Envelopes is the maximum height of a building in which it doesn`t prevent the surrounding buildings from the solar exposure during a given period of the year (See Figure2.3).

While, the solar Collection Envelope (SCE) defines the lowest possible locations of passive solar collectors and windows, on the elevation of the construction, such that they will not be shaded through a given period of winter, but will not be exposed to the sun in summer (see Figure 2.4). In fact, this envelope defines the shading cone casts by present edifices that create the urban built. The prescribed examined period determines the shading cone size which simplifies the calculation of the volume included between both envelopes. This volume is consisted of all the building heights. Those building heights do not prevent the neighbouring buildings from sunlight. In turn, the surrounding buildings do not exert any shade on them (Birol Topaloglu 20003).

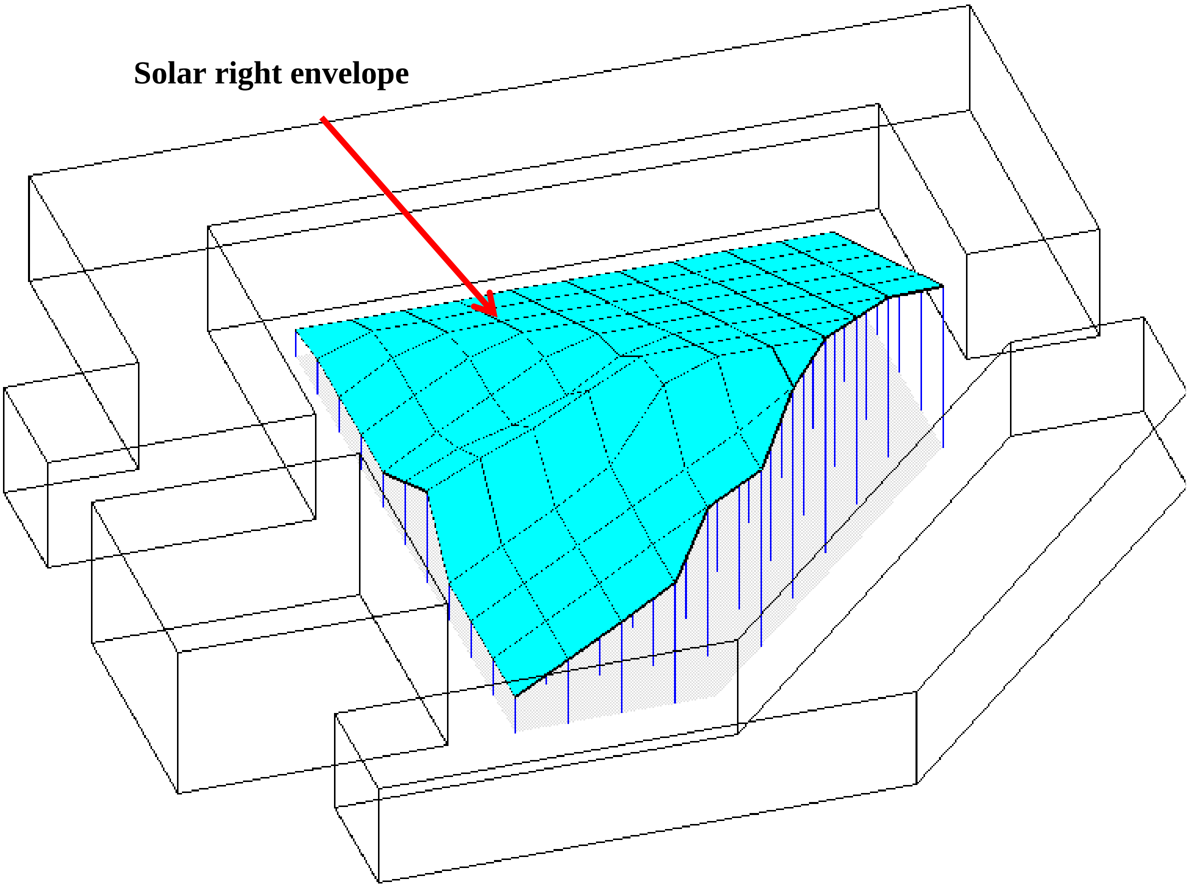


Figure 2.3: Solar right envelope (Capeluto and Shaviv-1997)

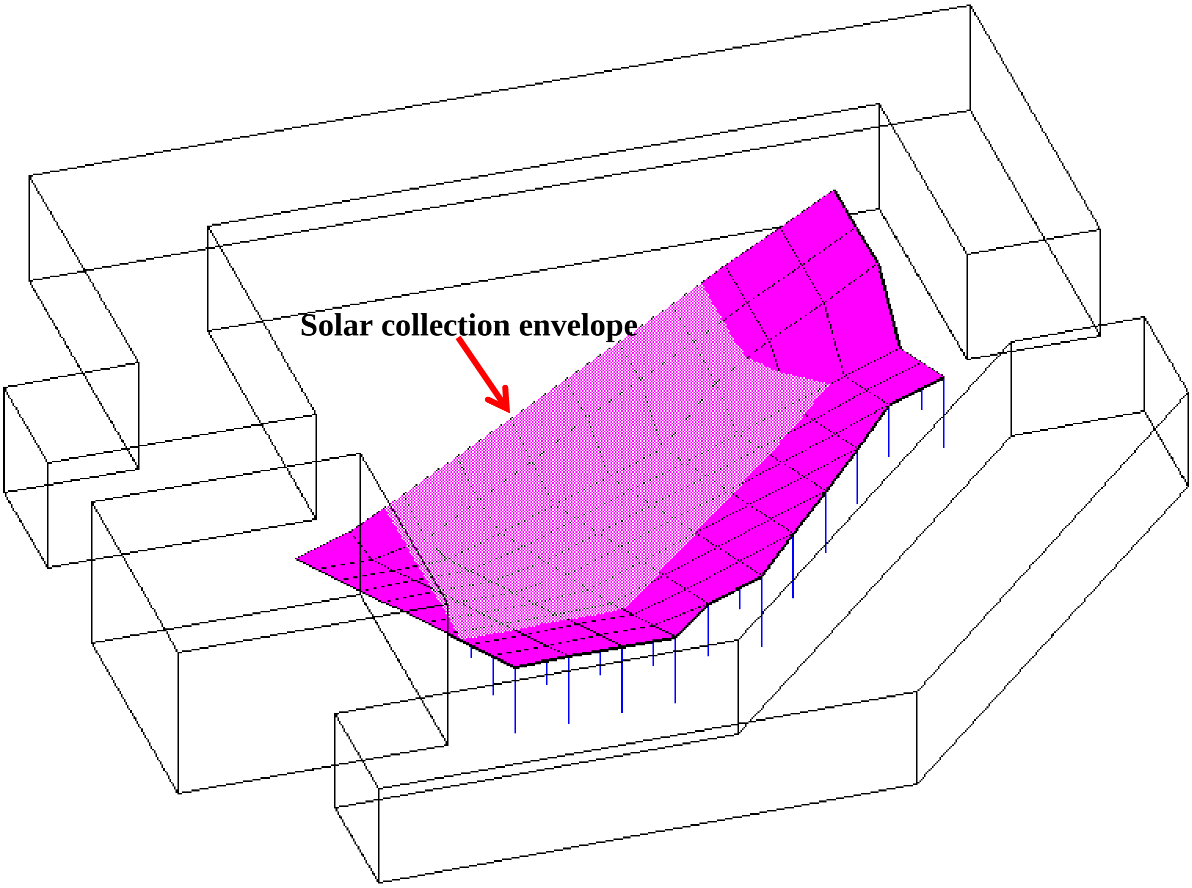
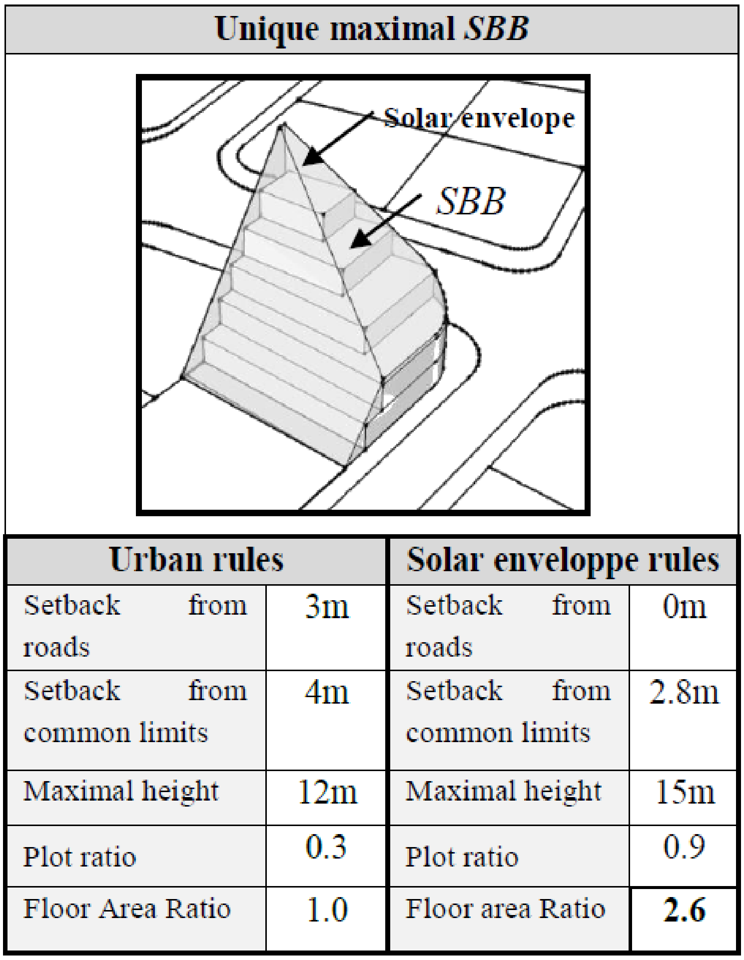


Figure 2.4: Solar collection envelope (Capeluto and Shaviv-1997)

More recently, the concept of Solar Bounding Box (SBB) has been introduced by khaoula Raboudi in her paper entitled “A morphological generator of urban rules of solar control”. The solar bounding box (SBB) is the optimum volume determined by both the solar envelope rules and urban rules of form. The urban zoning regulations of the city determine those urban rules. During critical periods of solar access, the largest volume that doesn’t prevent nearby buildings from solar exposure is identified by the solar envelope (See figure2.5).According to Khaoula Raboudi (2013), the SBB, allows urban planners to found urban morphological rules of solar control.


Unique maximal *SBB*

Urban rules		Solar enveloppe rules	
Setback from roads	3m	Setback from roads	0m
Setback from common limits	4m	Setback from common limits	2.8m
Maximal height	12m	Maximal height	15m
Plot ratio	0.3	Plot ratio	0.9
Floor Area Ratio	1.0	Floor area Ratio	**2.6**

Figure2.5: maximal Solar Bounding Box conditioned by both the urban rules of form and solar envelope rules (Khaoula Raboudi -2013-)

Hence, after this historical overview, we can say that, since the ancient time right to solar access has always been considered as one of the key generators of urban form, also has been the source of inspiration for several architects, and urban planners in recent times.

1-3-Geometrical parameters of solar control in urban spaces

The building and its nearby morphology have widely influenced the solar energy access. Several studies were emphasized on the effect of urban block form on solar access. Littlefair, for example, tried to discover the relationship between urban geometry and individual building’s solar access. Moreover, Okeil (2010) generated a generic built form pattern called the residential solar block (RSB). The RSB is considered as an exciting form of improving the amount of solar rays on facades and roofs and on the ground in the cities located at latitude of 25^0. Kampf and Robinson (2010) concentrated on the creation of novel urban forms and applied a multi objective optimization algorithm to reduce the energy needed of buildings in an urban space and to increase the incident solar radiation whereas accounting for thermal losses. Their process can also be beneficial to existing forms (Haniyeh Sanaieian,et al -2014-). There are several parameters related to building form and neighborhood that affect solar access. Harzallah (2007) summarized these parameters in three groups: Urban Density; Building form and orientation; Building outlines and street’s orientation (Thibaut Vermeulen -2014-).

1-3-1-Urban density

Urban density is considered one of the crucial parameters that affect solar access because it increases shading by neighboring buildings. According to Caroline Hachem et al (2011) some important points have to be considered:

- Since solar access is affected by urban density, it is important to design the urban morphology in accordance to shading requirements.
-It is very important to determine the right place for implementing buildings to avoid shading.
-The geometrical parameters of urban street have to be taken into consideration. They have to be designed to improve the outdoor thermal comfort.

In order to determine the optimum distance between building, building height, and orientation, Yn Kyu yi et al (2015) used a computer aided design tool (Rhinoceros-Grasshopper) and a genetic algorithm (Galapagos) to develop a new approach of solar control in a given density. This process based on an agent based geometry system that sets parameters to control a building in a ranked way.

In this approach, the agent point which controls the location of child points has a significant effect in simplifying the building`s geometrical parameters. The change in the position of agent points from a (x,y) to b (x,y), leads the child points to change their locations .The conceptual idea of introducing an agent point within the geometry control is presented in Figure (2.6). Instead of requiring several individual points, this method permits the morphing of geometry with a few agent points.

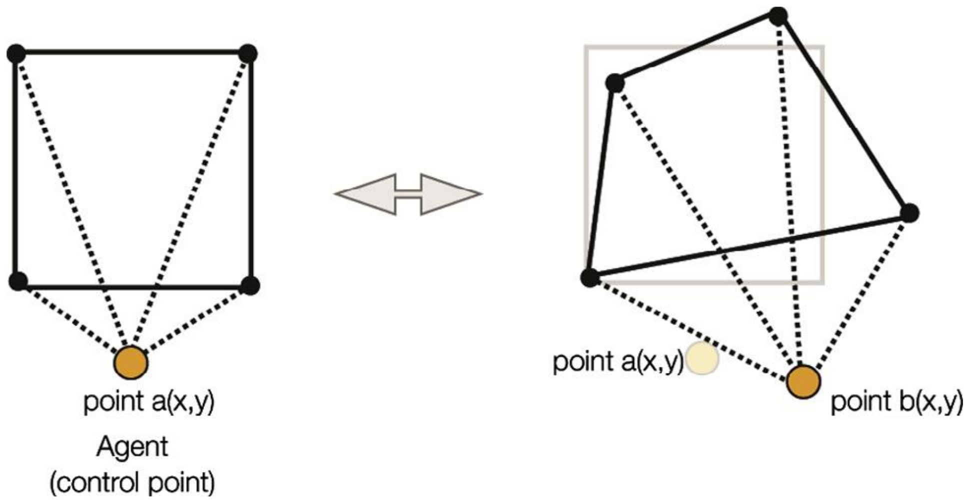


Figure2.6: Conceptual idea of suggested method to control geometry (Yun Kyu Yi.2015., P.239 according to Yi and Malkawi, 2009).

The child points (point 1, 2, 3, 4 . . . n) which are controlled by sub agent points are used to construct each building. Thus, building layouts are efficiently handled. In (figure 2.7) each building is illustrated by a sub agent points whereas, several buildings are controlled by one agent point.

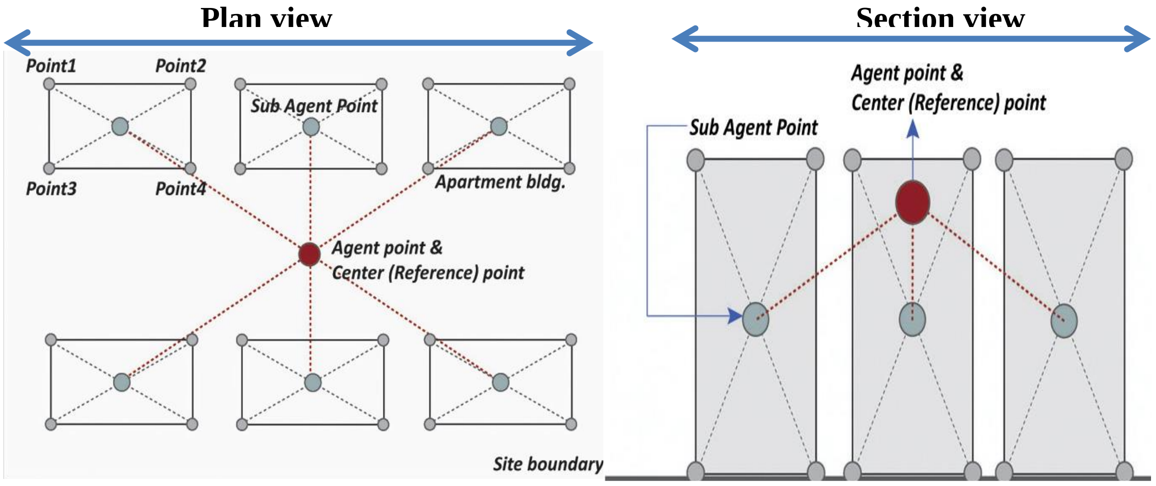
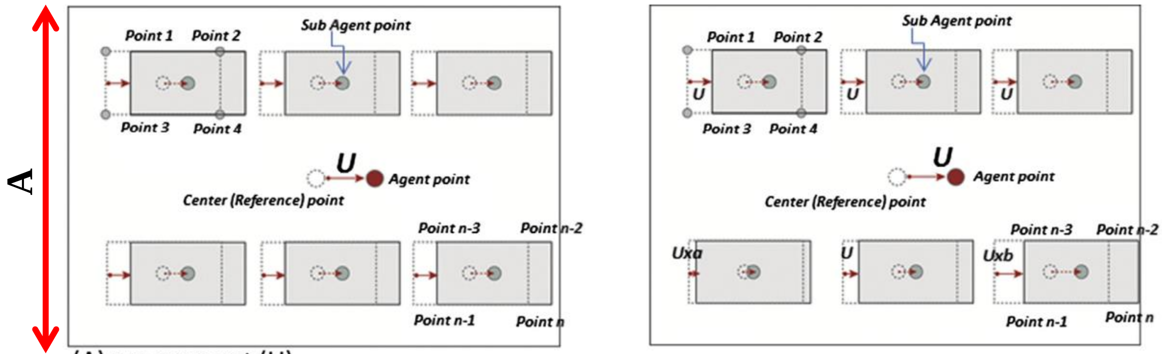


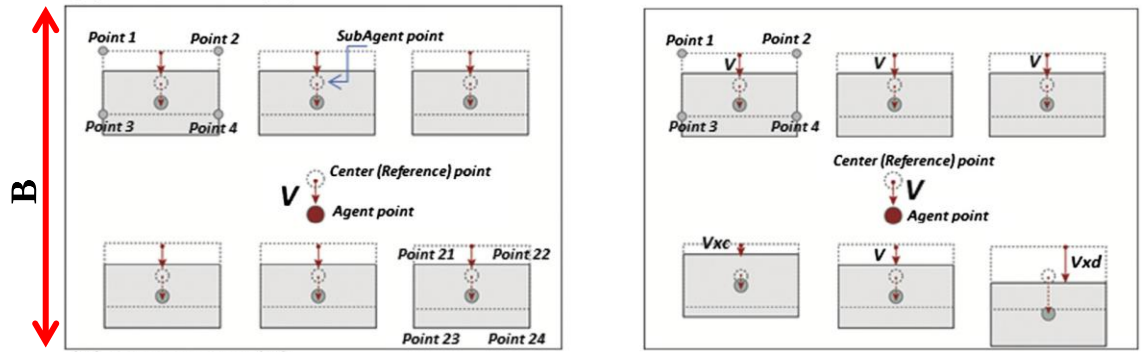
Figure 2.7: Hierarchical agent point control systems (Yun Kyu Yi.2015.P.240)

With the horizontal movement of an agent point (x) the displacement magnitude (U) will dynamically change the geometry and apprises the sub agent points. Therefore, the child points, which relocate the building, will change (Figure2.8. A).

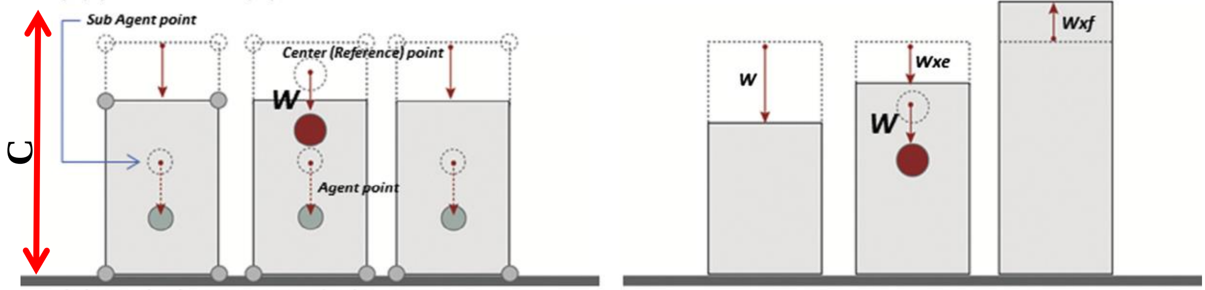
Founded on a user’s strategy, movement (U) can be overstated with diverse weights (a and b) for each single or collection of sub agent points (building). This will differ the movement of each building inversely whereas still controlling numerous buildings with one agent point. The similar process can be applied to y and z displacement – as V relocates the building relocates with the y-axis and weights (c and d). The aforementioned workflow can be applied to vary the movements of each individual or group of buildings (Figure2.8.B), and as W relocates, the building displaces along the z axis with weights (e and f) varying the movements of the buildings (Figure2.8.C). Without controlling all child points, the building can be controlled by the use of the three variables (U, V and W).



(A) x movement (U)



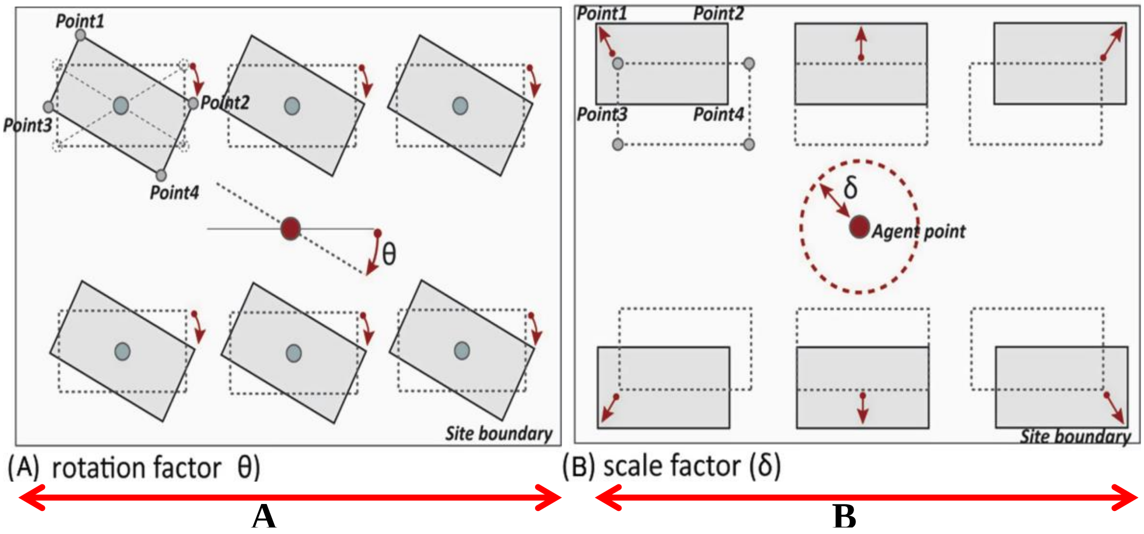
(B) y movement (V)



(C) Vertical movement (W)

Figure 2.8: Agent point controls for buildings (Yun Kyu Yi.2015., P.240)

With the rotation of agent (h), every building is rotating with diverse weights (Figure2. 9. A). The building distance is altered by the scale factor (δ) as in Figure2. 9B.



(A) rotation factor θ) (B) scale factor (δ)

Figure 2.9: Additional agent point control for buildings (Yun Kyu Yi.2015., P.241)

The required sunlight hours determine the change of hierarchical agent point control.

1-3-2-Building form and orientation

According to Leylian et al. 2010

> " *The layout, form and orientation of the buildings in addition to spacing between them are the most important strategies affecting indoor thermal comfort. Also, building envelope has a great influence as it separates the outdoor and indoor environment*"

(Elaiab, Fatima M -2014- P.21).

-The effect of building form:

When heat is considered an essential condition, choosing the building form is attributed to its capacity in increasing solar collection and decreasing heat losses through buildings envelope. However, when cooling is the essential condition, the main principle is reducing undesirable heat transmission. This can be fulfilled through the improvement of building`s thermal performance by decreasing the ratio between the surface and the volume (Goulding et al. 1992) (See Figure2.10). Since some forms of buildings (H-type or L-type) may offer self –shading, their distribution on the urban layout has a wide effect on reducing the direct solar rays impinged on urban surfaces (Elaiab Fatima, 2014).

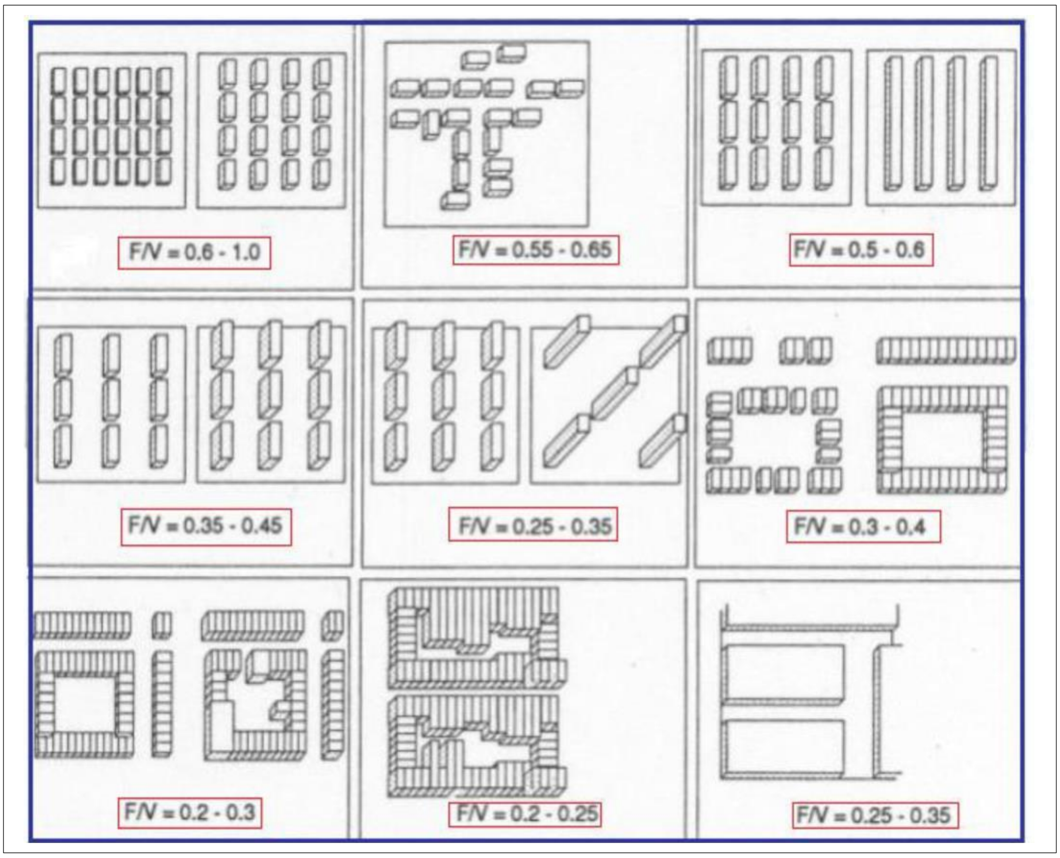
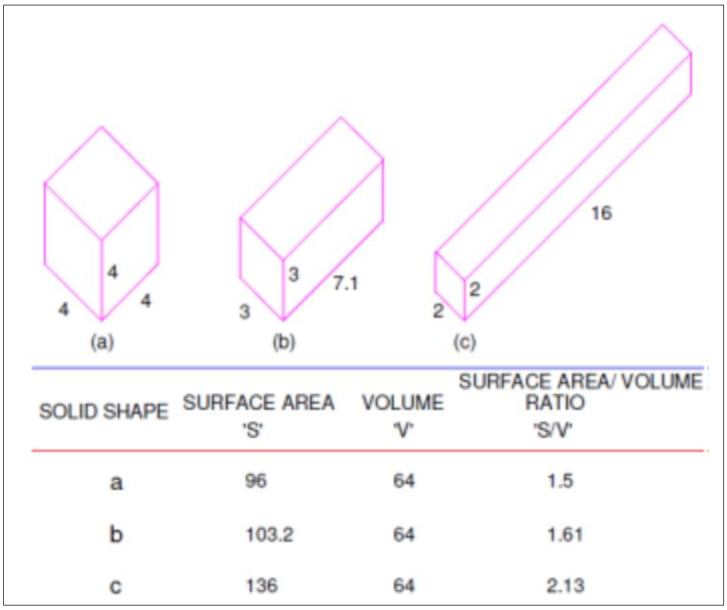


Figure2.10: Site layouts displaying several surface area (F) to volume (V) ratios .Source: Goulding et al. (1992)

In high-rise buildings, self-protected form is among the ways that prevents the effects of solar rays. Self-shading strategies is a crucial way, which decreases solar radiation on vertical surfaces (Nikpour et al. 2011). The geometric shape is largely influenced by the the width to length ratio and surface-to-volume ratio.

Behsh (2002) stated that forms with several geometric shapes of the same enclosed volume have diverse surface area. This is generally presented by surface to volume ratio. The surface to volume ratio is also considered as a rough indicator of urban grain dimension, signifying the volume of open ‘covering’ of the constructions, and so, their potential for interrelating with the climate through day lighting and natural ventilation, etc. (Elaiab Fatima-2014-).

However, the high surface to volume ratio has two counter-indications; the increase in heat loss during winter and heat gain during summer. (Ratti et al. 2003), see Figure (2.11) and Figure (2.12).



SOLID SHAPE	SURFACE AREA 'S'	VOLUME 'V'	SURFACE AREA/ VOLUME RATIO 'S/V'
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

Figure 2.11: Surface area to volume ratio (S/V ratio) for a few building shapes Source: Elaiab Fatima-2014-P.23, according to Nayak and Prajapati, (2006)

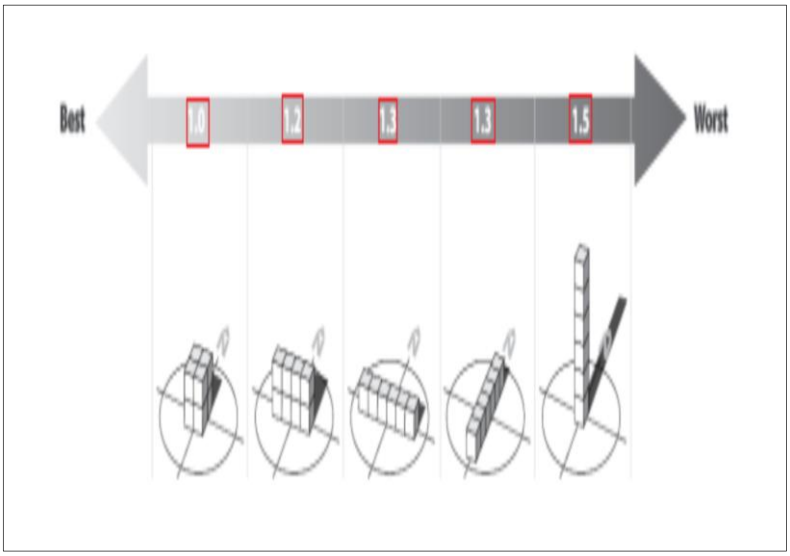


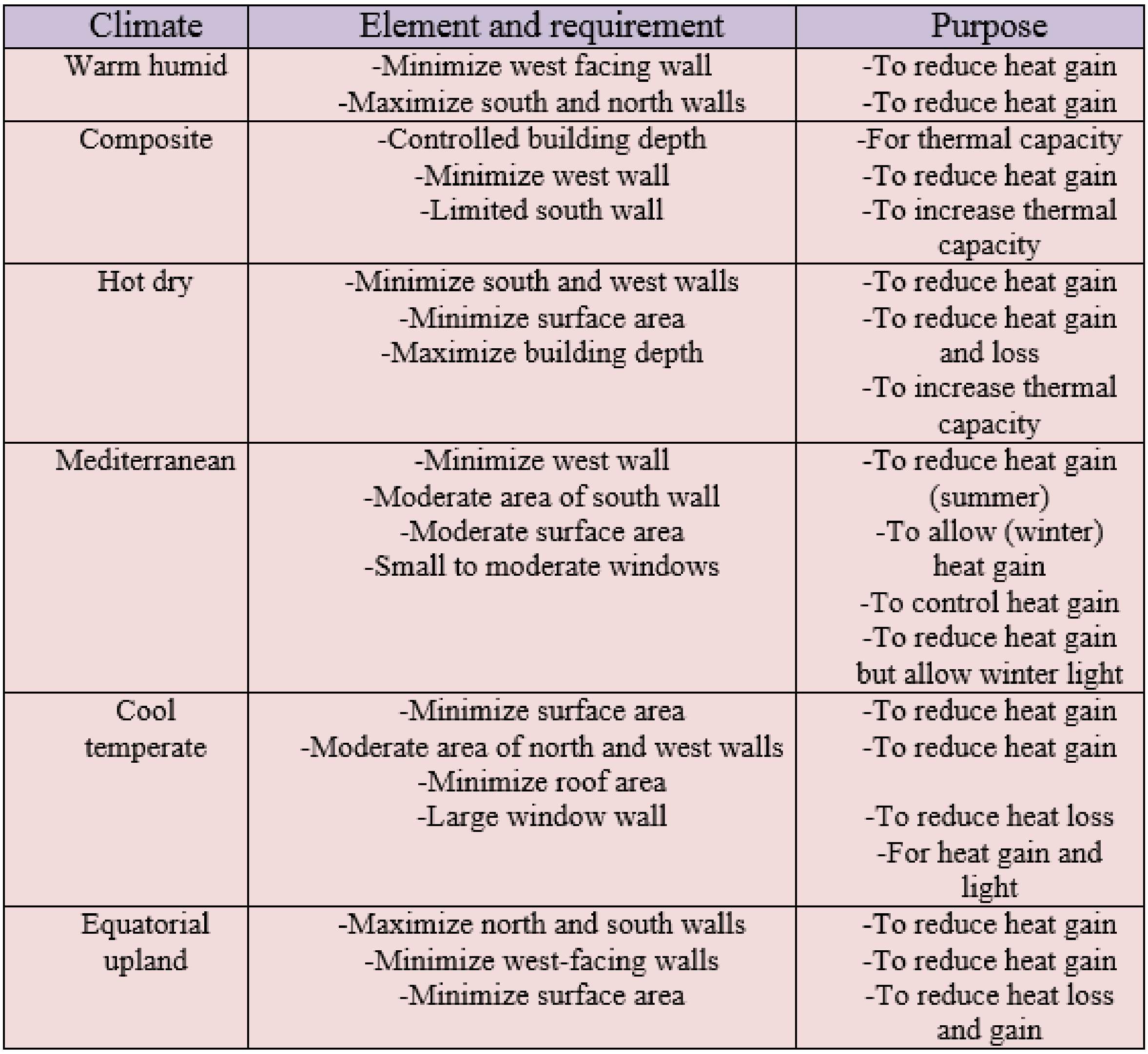
Figure 2.12: The influence of envelope to volume ratio on energy efficiency Source: Elaiab Fatima-2014-P.24, according to Mikler et al. (2008)

According to Ling et al. (2007)

"*The exposed surface-to-volume ratio (S/V ratio) for geometric shape depends on the width to length W/L ratio. Geometric shapes with higher value of W/L ratio contained lower value of S/V. He indicated that main factors that determine the relationship between solar insolation level and building shape are W/L ratio and building orientation*". (Elaiab Fatima -2014-P.24).

In order to minimize the energy consumption of the building environment Hyde (2000) has adapted the geometrical parameters of the building envelope (shape, proportion, orientation) in accordance to the climatic region (see table 2.1) (Elaiab Fatima M-2014)

Table2.1: The preferred requirements for building form in different climate zones (Elaiab Fatima-2014-P.24, according to Hyde (2000))



Climate	Element and requirement	Purpose
Warm humid	-Minimize west facing wall -Maximize south and north walls	-To reduce heat gain -To reduce heat gain
Composite	-Controlled building depth -Minimize west wall -Limited south wall	-For thermal capacity -To reduce heat gain -To increase thermal capacity
Hot dry	-Minimize south and west walls -Minimize surface area -Maximize building depth	-To reduce heat gain -To reduce heat gain and loss -To increase thermal capacity
Mediterranean	-Minimize west wall -Moderate area of south wall -Moderate surface area -Small to moderate windows	-To reduce heat gain (summer) -To allow (winter) heat gain -To control heat gain -To reduce heat gain but allow winter light
Cool temperate	-Minimize surface area -Moderate area of north and west walls -Minimize roof area -Large window wall	-To reduce heat gain -To reduce heat gain -To reduce heat loss -For heat gain and light
Equatorial upland	-Maximize north and south walls -Minimize west-facing walls -Minimize surface area	-To reduce heat gain -To reduce heat gain -To reduce heat loss and gain

- Orientation of buildings

The direction of facades has a great influence on the potential capture of incident solar radiation. It is clear that west facades receive more solar radiation, thus, creating less shadow at the hottest time of the day. In contrast to the west facades, the north ones would be less vulnerable to sun radiation (Elaiab Fatima-2014). The orientation has an important role in figuring out the received amount of radiation (Givoni 1969).

According to (Rosenlund, 2000), the solar rays' penetration can be avoided by orienting the main facades to the north south (NS). For instance, during summer this façade can be protected from solar rays. However, during wintertime the aforementioned orientation (NS) permits the penetration of solar access because the path of the sun is lower.

Goulding et al. (1992) has introduced some strategies for the building`s direction in order to increase the potential for solar collection. One of those strategies is focused on facing the longest side of building to the south. In addition, the effects that the facades orientation has in multifamily housing have been discussed. They have found that the heat loss in apartments, which have more than one external wall, is less than that in apartments with only one external wall. In a conventional block, the apartment which is situated at the northwest corner of the top floor losses twice amount of heat than an apartment which is situated in the middle of the south façade as shown in Figure(2.13.).

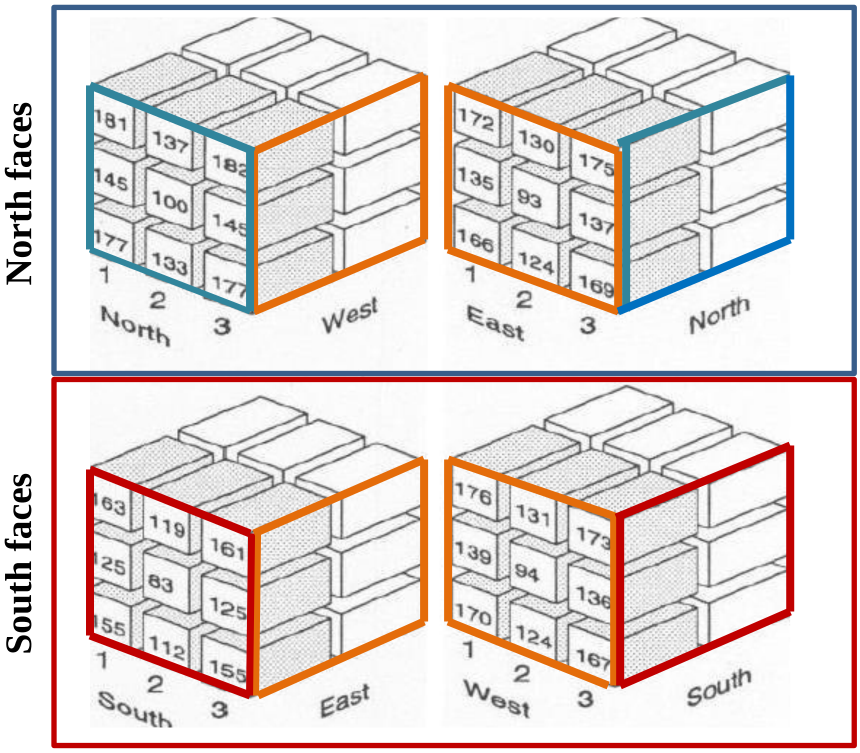


Figure2.13: Heat losses from rooms with different positions and orientations
Source: Goulding et al. (1992)

1-3-3-Building outlines and streets

The virtual volume that buildings have to respect is known as the building outline. According to Meir et al. (1995), vertical and horizontal surfaces of urban spaces will be deprived of direct sun exposure by the buildings, which have higher height beside a given axis. Moreover, Gupta (1984) attributed the variety of solar energy access of some forms to a set of parameters namely building height, street width and orientation in hot and dry climates. Also, the relationship between sunlight per square meter façade and the energy that a building consume for warming and cooling has been investigated in his study (Haniyeh Sanaieian et al 2014).

2- Shading control of urban spaces:

The main factor that influences shading requirement in buildings and spaces between them is the site layout. Neighboring buildings have crucial role in overshadowing. If the buildings are designed inappropriately, they deprive the spaces between them from solar exposure almost all the year. The variation in shading requirement depends on the latitude of the climatic region. Sunlight out of door is preferable in the far north of Europe. However, in the South shade becomes more and more desirable, particularly in summer.

2-1-Importance of shading control:

According to Belakehal and Tabet (1996), shading is the interactive concept that links solar control and aesthetics. Otherwise, J Littlefair and Al (2000) assumed that mutual shading between buildings is crucial for outdoor and indoor thermal comfort. In this regard Dulce Marques de Almeida (2014) has conducted a study in order to determine the shading effects on outdoor activities and business such as café esplanades during hot period. In addition, he assessed the relationship between shopping preferences and street shade. He interviewed people in the downtown of Portuguese town (Braganca, Lat 42^0 N). The study has revealed that the presence or the absence of shade determines the desire to walk for shopping in summer.

Another study at a pedestrian mall on Arizona State University’s Tempe campus was carried out by Ariane Middel (2016) in which the effect of photovoltaic canopy shade and tree shade on thermal comfort has been assessed. The methodological process of this study is based on meteorological observations and field surveys. The results reveal that because of the shade, the thermal sensation votes were lowered by nearly one point on a semantic dissimilarity nine-point scale. Therefore, the thermal comfort has decreased in winter in contrast to the other seasons.

In order to disaggregate and evaluate the impact of mutual reflection and mutual shading in a network of buildings, the idea of Inter-Building Effect (IBE) was presented in (2012) by Pisello. Han Taylor (2017) studied the effect of Inter-Building Effect (IBE) on energy consumption. The results confirmed that shading has moderately a wider influence compared to reflection on energy consumption, mainly in hot climatic regions. . Obviously, after presenting the synopsis of the results of some research on the importance of shade in urban built; we can say that without any doubt, shading control has a significant effect on the energy consumption for cooling, the aesthetic values for lighting, and the physical comfort of human being.

2-2- Means of shading control in urban spaces:

2-2-1-Static means of shading control

ImSik Cho, Chye-Kiang Heng, and ZdravkoTrivic (2015) argued that the presence or the absence of shade determines the use of the urban spaces in which some people prefer enjoying sunlight but others do not. In those urban spaces, the shade that affects the well-being of users can be produced by either hard or soft means.

-Hard means of shading

The neighboring buildings and additional built structures, such as, colonnades, or various kinds of canopies are responsible of producing hard shade. Those are considered as hard means of shading (See figure2.14). During the day, a variety of shading circumstances are generated by well-designed spatial layouts while around noon, additional built structures play an important role in creating shade.

Figure2.14: Hard shading means, tall buildings around the Raffles place park in Singapore (provide shady conditions in the mornings and afternoons). Source: ImSik Cho et al (2015)

- Soft means of shading

The shade, which is casted by transparent canopies tall trees, and pergolas, is referred to as soft or unstable shade (See figures2.15; 2.16).This soft shading permits some light to pierce while offering protection from the direct sun.

Figure 2.15 : Soft shading provided by tall trees and pergolas, as at the Meridian Roof Garden, Singapore (enables activities during noon time).Source: ImSik Cho et al (2015)

Figure2.16: Transparent and semi- transparent canopies in Clarke Quay, Singapore. Source: ImSik Cho et al (2015)

2-2-2- From static to kinetic strategies of shading control in urban spaces:

Soft shading and permanent hard means provide one static solution that has to be appropriate for all possible situations. Recently, technological inventions are creating new generation of adaptive shading elements. Those elements are able to provide enhancing designs that are associated to the solar rights, and shading requirements of a built environment. Another advantage of creating an adaptive shading solutions is offering aesthetic opportunities which defines the building`s architectural appearance.

-Parametric design of kinetic shading elements based on curved-line folding:

According to Aline Vergauwen et al (2013), set of parameters is intricate in the design process of adaptive shading elements founded on curved-line folding: parameters describing the kinematic behavior, parameters relative to the morphology of the construction and parameters affecting the energy flow over the facade.

The Japanese art of paper folding, origami can be a source of inspiration for generating new shading solutions. Curved-line folding techniques provide the opportunity to create a transformation procedure that can be fulfilled in the generation of adaptive shading elements.

Therefore, comprehending the parameters that clarify and affect this process is crucial to employ it in the best way (AlineVergauwen et al -2013).

-Recent applications of shading elements based on folding technique

In this statement we attempt to explore how architects and urban designers used responsive folding techniques to create kinetic surfaces those can modify their configuration according to the desirability of shade in urban built. In this way, some noteworthy contemporary examples of kinetic shading element based on folding techniques will be analyzed.

a)- Kinetic Roof Structure of the central square of the heart of Doha (Barahat Al Nouq)

Msheireb Heart of Doha is among the noteworthy contemporary projects generated by the architects Mossessian and Partners. Barahat Al Nouq is the main square of the core of capital of Qatar (Doha). Ensuing traditional Arabic architecture, the novel roof construction is imitating ancient building elements that already worked adaptive and reacting (See figure 2.17). This is likewise the situation with the new folding roof with its detachable skin shielded shading panels. In Doha, daytime temperatures certainly increase to 50°C. The idea of Barahat Al Nouq is to safeguard temperatures under 32°C. This is attained by a shading arrangement of the folding roof 30 m beyond ground together with conventional skin covers on the ground.

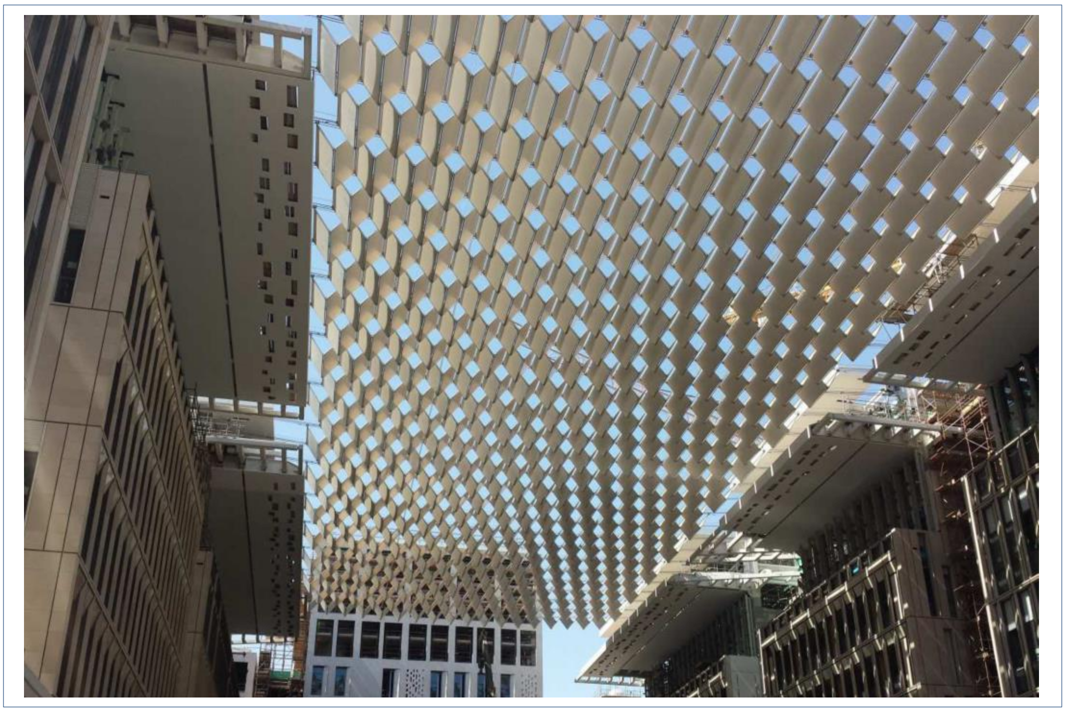


Figure2.17: View from Barahat Al Nouq square against un-folded roof structure. (Gregor Grunwald et al-2016-)

b)-Automated shading system, with umbrella-like , structure, Prophet's holy mosque, Al-Madinh Al-Monawara.

According to Naglaa A. Megahed (2018)

" *In recent architectural practices, several responsive structures tries to apply umbrella-like structures. In the words of the architects, they came up with the idea from umbrellas, which are the most common object used by people for shading themselves from the sun*". (Naglaa A. Megahed -2018-P.10)

In addition, the folding of different skins is also inspired from the umbrella principle (See figure2.18). A wonderful example is the adaptable cover of the two patios of the Prophet's holy mosque, Al-Madinh Al-Monawara. It contains 12 big umbrellas approximately 17m X 18m in exposed configuration. These sunshades deliver shading throughout the day, cooling, and ventilation over the night.

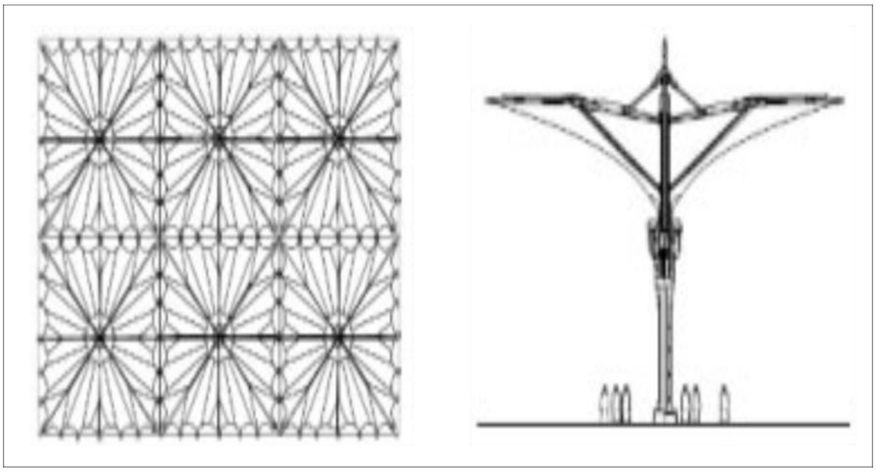


Figure2.18: Principle of adaptive umbrella in the Prophet's holy mosque, Al-Madinh Al-Monawara (Naglaa A. Megahed -2018-P.11)

The superb umbrellas work together to create the adaptable shading roof of either of the mosque's patios, having 143,000 m^2, which is wider than the floor surface of the mosque itself. To get the predictable product and offer hajis with appropriate shade and atmosphere, the high tech sunscreens are created of an exceptional material called polytétrafluoroéthylène (PTFE) fabric, which fulfills the rigorous criteria, needed by the customer and struggle the violent UV radiation. Moreover, the material has a very high tensile strength due to colorfastness, wind load, maximum flexibility, fire resistance, as well as appropriate light transmission. Moreover, effective shading. This super tough PTFE fabric is a sand-colored, which allows the penetration of the light through the sunscreens.

Moreover, the umbrellas are characterized by beautiful columns and adjusting patterns constructed of the blue PTFE ribbons that were used in the umbrella bottom. The translucent sunshades produced an ambient temperature with a reduction of at least 8 °C. The umbrella` s moving parts which are inspired from the blooming flowers are set to open and close simultaneously in minutely delayed sequence in order to avoid collision between them. The procedure, which takes three minutes, provides an extraordinary scene. (See figure2.19).

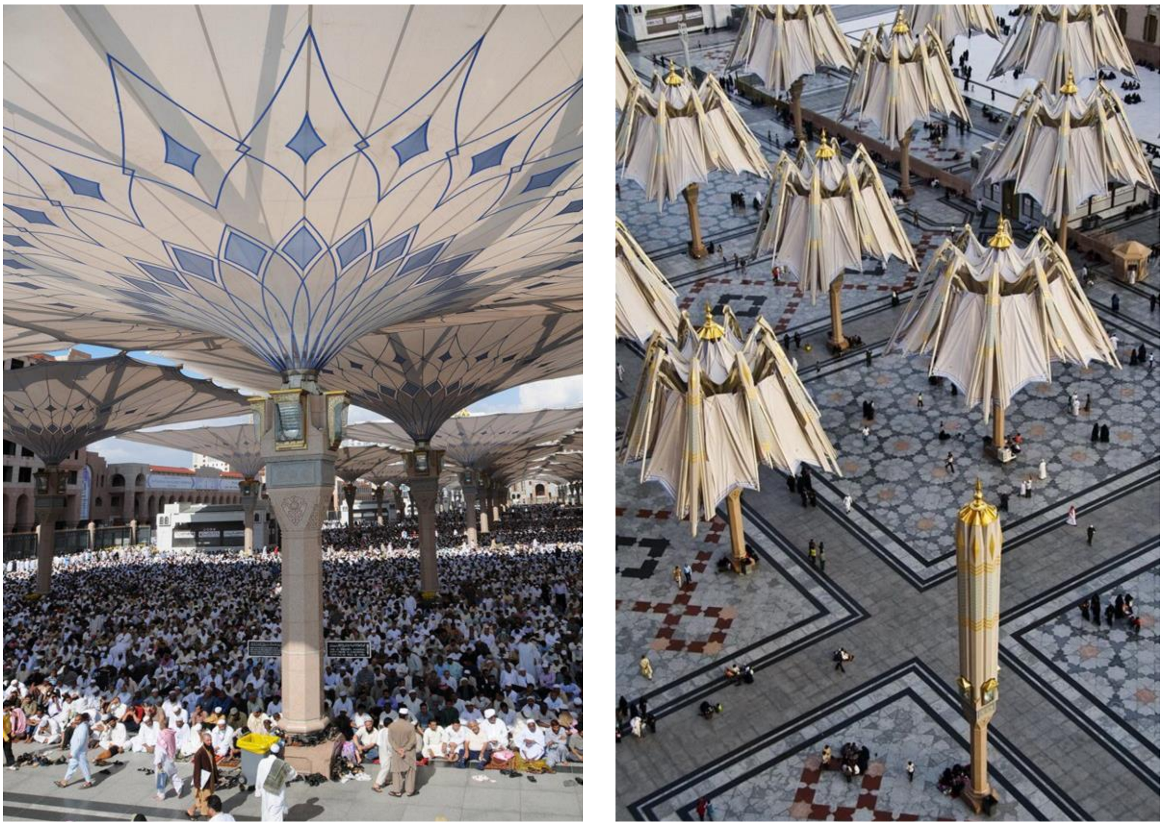


Figure2.19 : close and open adaptive umbrella in the Prophet's holy mosque, Al-Madinh Al-Monawara (**http://designlike.com/high-tech-giant-umbrellas-improve-al-masjid-al-nabawi-mosques-natural-micro-climate/**)

2-2-3- Bio-inspired design of kinetic shading elements:

From an architectural perspective, researchers are trying to find solutions for decreasing energy consumption in the built environment. However, this solution may be provided by nature since it has already resolved many problems, which we are striving with nowadays throughout a long period of trial and error. According to Nick Taylor Buck(2017).

"*In problem solving, it has been argued that exposure to biological examples increases the novelty of solutions generated in contrast to human-engineered examples, which decrease variety*". (Nick Taylor Buck-2017-P.123)

Hence, to conceive strategies for folding surfaces, nature is a good place to look. In some flowers and leaves, a collapsible procedure is applied competently to improve their outlines incessantly (Marco Pesentia et al 2015).

Biomimicry (from bios, ‘life’, and ‘mimesis’, to imitate) is one method to design stimulation from the nature. It is a pragmatic discipline that imitates nature’s processes, forms, and ecosystems to response human design problems; using schemes developed over 3.8 billion years of progression (Nick Taylor Buck, 2017). Biomimicry has been used in engineering architecture and urban design through problem based - approach and a solution – based approach. First, when the source of inspiration is related to the biological knowledge, the solution-based approach is used to find solution through new technologies or systems. An important point has to be stated is that the particular characteristic of an organism or ecosystem must be clarified by biological research before transforming it into a useful design. However, in the problem-based approach clarifying the problem is the first step. Then, designers can investigate the ways (methods/techniques/approach) that natural organisms consider in order to figure out those problems. There is no need for a detailed biological understanding (Yilong Han et al 2015).

- Recent applications of Bio-inspired design of kinetic shading strategies

The strategies provided by Biomimicry enable professionals of the built environment to make buildings and spaces between them more responsive to shading that human being need. In order to recognize how architects and urban designers have used biology as a source of inspiration to shape kinetic shading strategies, it is appropriate to show some noteworthy contemporary examples of bio-inspired design of kinetic shading strategies.

a)- Elytra filament pavilion (Victoria and Albert Museum, London, 2016)

The Elytra Filament Pavilion represents an integrative approach to design and engineering. The structure is the product of four years of exploration on the assimilation of biomimetic principles, engineering, and architecture. It discovers how biological fiber systems can be conveyed to architecture. The 200m² pavilion structure is stimulated by lightweight building values found in nature – the fibrous structures of the forewing shells of flying beetles recognized as elytra.

According to figure (2.20), two principle cells, which are the canopy and the column, construct the fibrous composite structure of the installation. The column cell connects the inhabitable ground and the canopy, which is in turn equipped with transparent roof panels.

The cells production that is developed by Achim Menges team considered as a creative robotic winding process. The reason is that the cells are made of load-bearing fiber material that is composed of transparent glass fibers and black carbon fibers.

Figure (2.20): Elytra filament pavilion (Victoria and Albert Museum, London, 2016). Source: http://www.achimmenges.net/?p=5922

Fiber optical sensors, which are able to detect the forces in the structure, are using in the canopy because there exists no deliberate final state. Thus, the additional growth and adaptation of the canopy that caused the alteration of the structural systems is going to be detected. Depending on the images that are obtained by thermal sensors, the shading is determined based on the visitors' utilization of the shading spaces. The obtained data are clarifying in accordance to the calculation of environmental parameters including temperature, radiation, ambient humidity and wind. The canopy has possessed a learning system and evolving structure by the combination of real-time sensing and the onsite fabrication. Based on the visitors` behavior and their favorable places to walk, stroll, rest or meet, the canopy will grow and redesigned over the displayed time.

b)- Sun shade (sunflowers) canopy

In order to supply cities with climate adaptation and digital shading, Future Museum of Dubai in association with International design and innovation office Carlo Ratti Associati, have elaborated a dynamic, reflecting canopy. At the museum of the future and as part of the "Reimagining Climate Change" exhibit; "Sun and Shade" which is the first practical example has been exposed in Dubai during the 2017 World Government Summit (See figure2.21).

Figure2.21:"Sun and Shade", a digitally–controlled cover that combines the solar power generation with cooling of outdoor areas (Carlo Ratti-2017-)
https://carloratti.com/project/sunshade/

The Shade and Sun canopy is based on an arrangement of mirrors that follow the path of the sun. Considerably as a sunflower, every mirror can reflect the sun's rays away from the ground and displace on a double axis – permitting the exact control of the preferred level of shading and natural cooling underneath. Reflected rays, in turn, are focused on a photovoltaic receiver, positioned a safe distance away, which produces electric power.

3-Outdoor thermal comfort

Regarding pedestrian`s health in urban spaces, outdoor thermal comfort is considered an important contributor which must be understood in order to design attractive outdoor spaces and enhance the outdoor life quality. Since 1980`s, the increasing desire of pedestrians in urban canyons, plazas and squares, have increased the number of studies on thermal comfort in the outdoor environment. Therefore, numerous researches about microclimate design parameters based on pedestrians' thermal comfort have been conducted. (Mohammad Taleghani 2015). Based on the information presented earlier in the previous sections of this chapter, it is found that the external thermal comfort is strongly associated to shading and solar control. In this regard we attempt through this section to highlight the most important theories that are related to outdoor thermal comfort on one hand, and on the other hand we try to understand how we can analyze the effect of solar and shading control on pedestrian's thermal comfort based on comfort range.

3-1-Assessment of outdoor thermal comfort

The evaluation of outdoor thermal comfort is represented by the combination of several factors mainly we note: weather parameters including air temperature, relative humidity, wind speed, and solar radiation; personal heat balance parameters; clothing and metabolic activity; and distance. In order to better clarify the boundaries of thermal comfort, various studies have taken place in which all related factors are combined (fused) into a single index (Edgar Eugenio Samano Baca -2015-).

In this regard, numerous indices incorporating heat balance of the human body and thermal environmental factors are developed for evaluating thermal comfort. Howard (1833) was the leader who recommended considering the impact of urban form on microclimate (Mills, Gerald.-2006-). In 1914 Hill, Griffith prepared a huge thermometer, which designated the effect of air temperature, air velocity, and mean radiant temperature. Furthermore, Dufton elucidated the equivalent temperature (Teq) in 1929. In addition, ASHRAE suggested and used the effective temperature (ET) since 1919 until 1967. In 1971, Gagge presented ET* which was more precise than ET as it simultaneously enclosed evaporation, radiation, and convection. During the same period, Fanger (1970) advanced ideas of human body heat exchange founded on PPD (Predicted Percentage Dissatisfied) or PMV (Predicted Mean Votes). Far along on, this theory became the foundation for indoor thermal comfort standards such as ASHRAE 55-1992 and ISO 7730-1984. Thermal indices has been subdivided by Tahbaz (2011) and Cohen, Potchter (2013) into hot and cold climates:

a) Hot climates: Heat Stress Index (HIS) (1955), Wet Bulb Globe Temperature (WBGT) (1957), Discomfort Index (DI) (1959), Index of Thermal Stress (ITS) (1962), New Effective Temperature (ET*) (1971), SkinWettedness (1972), Heat Index (HI) (1979) and Tropical Summer Index (TSI) (1986).

b) Cold climates: Wind Chill Index (WCI) and Wind Chill Equivalent Temperature (WCET) (1993).

Afterward, the requirement for appropriate indices for all climates and periods gives several universal indices such as the Standard Effective Temperature (SET) (1986), Perceived Temperature (PT) (1997).Outdoor Standard Effective Temperature (OUT_SET) (2000), Physiological Equivalent Temperature (PET) (1999) and Universal Thermal Climate Index (UTCI) (2012).

3-1-1- Outdoor thermal comfort indices:

In hot and cold conditions, thermal comfort is evaluated by more than 100 indices (Wendy Walls et al (2015). Although the indices complexity has risen in recent years, many of them are simplified versions of air temperature combined with a secondary parameter (Krzysztof Blazejczyk et al., 2012; Johansson et al., 2014).

The using of thermal comfort indices in the design of outdoor space can offer significant information of the relationships between the main variables that influence thermal sensation.

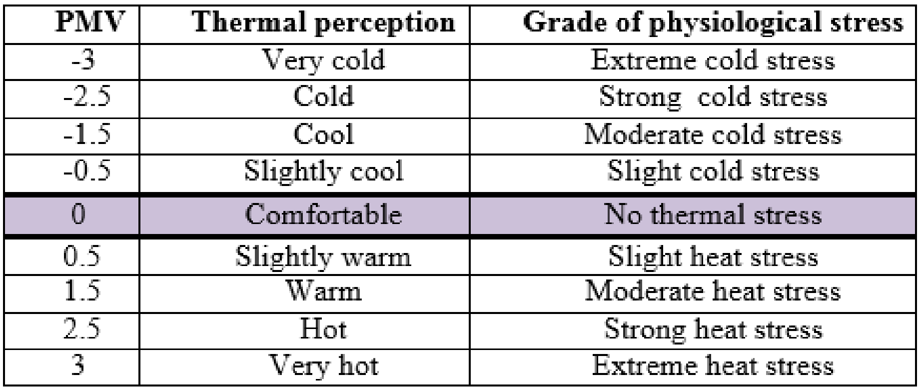
Some outdoor thermal comfort indices were previously presented. Then we are intending to illustrate the most used ones.

- Predicted mean vote (PMV)

PMV, which was proposed by Fanger in 1970, is one of the important temperature-physiological indices that are recurrently used in both regional planning and urban studies as well as meteorological research projects (Matzarakis, 2001). This index is applied to predict the opinions of a group of individuals from the same environment (Bła_zejczyk, 2013). In order to calculate PMV six factors (relative humidity, dry temperature, metabolic rate, mean radiation temperature, wind speed, and clothing insulation) are employed.

The value of this index is conveyed on a seven-point measure that ranges from -3 to +3, by 0 being the perfect value designating neutral thermal perception (Bła_zejczyk, 2013). Table (2.2) illustrates the categorization of PMV (Matzarakis et al., 1999).

Table2.2: Thermal sensation and different groups of PMV (Sajad Zare et al 2018, p.51).

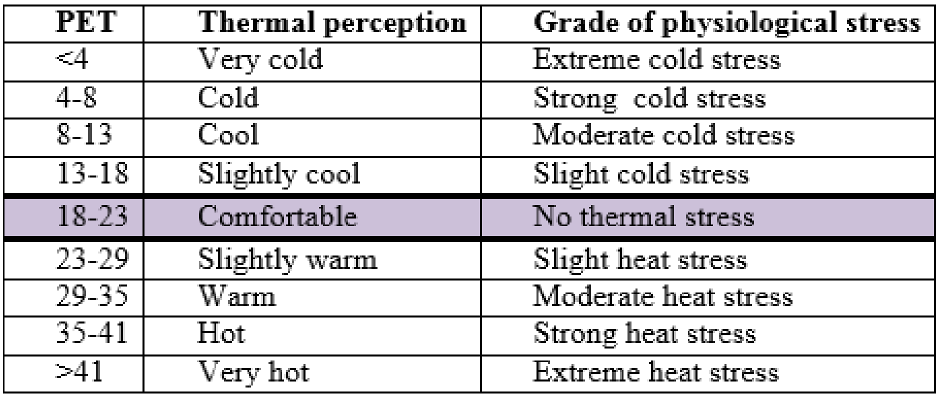


PMV	Thermal perception	Grade of physiological stress
-3	Very cold	Extreme cold stress
-2.5	Cold	Strong cold stress
-1.5	Cool	Moderate cold stress
-0.5	Slightly cool	Slight cold stress
0	Comfortable	No thermal stress
0.5	Slightly warm	Slight heat stress
1.5	Warm	Moderate heat stress
2.5	Hot	Strong heat stress
3	Very hot	Extreme heat stress

-Physiological equivalent temperature (PET)

The Physiologically Equivalent Temperature (PET) that is specially presented for outdoor environments is defined as the needed air temperature in the outdoor environment to reproduce a standardized indoor setting, for a standardized individual. It is also defined by Höppe, 1999; Tzu-Ping Lin, (2008) as the required air temperature that equilibriums human body heat with the membrane and core temperatures in complex exterior conditions. The index PET that is obtained from the equation of human energy balance is estimated by relative humidity, wind speed, dry temperature, and mean radiant temperature (Hoppe, 1999). PET values for different levels of physiological stress and thermal perception are presented in Table (2.3) (Matzarakis et al., 1999).

Table (2.3): Thermal sensation and different groups of PET (Sajad Zare et al 2018, p.51).



PET	Thermal perception	Grade of physiological stress
<4	Very cold	Extreme cold stress
4-8	Cold	Strong cold stress
8-13	Cool	Moderate cold stress
13-18	Slightly cool	Slight cold stress
18-23	Comfortable	No thermal stress
23-29	Slightly warm	Slight heat stress
29-35	Warm	Moderate heat stress
35-41	Hot	Strong heat stress
>41	Very hot	Extreme heat stress

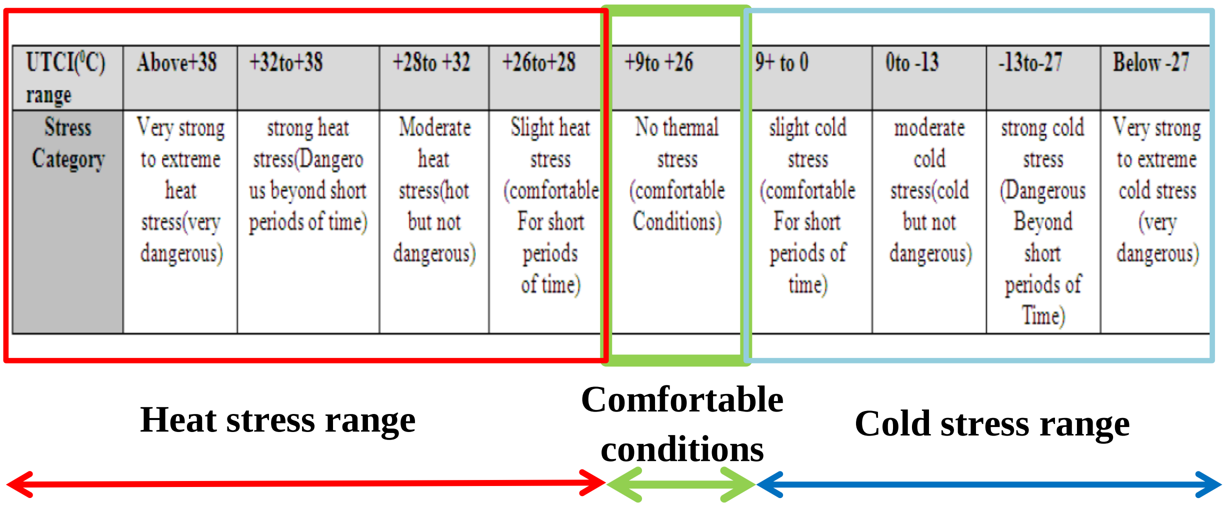
- Standard Effective Temperature SET* and OUT_SET*

The standard effective temperature (SET) is advanced for interior spaces, it is a model for assessing the dry-bulb temperature which links the existent conditions of an environment to the (effective) temperature supposing standard clothing, metabolic rate and 50% relative humidity (Blazejczyk et al., 2012). This evaluation provides an equal air temperature measurement in order to compare thermal sensations in a wide variety of conditions. In this regard, the subjective thermal response determines the effectiveness of a temperature. The outdoor environment is evaluated by Out standard effective temperature (OUT_SET*). Based on a well-known indoor thermal comfort index SET*, the OUT_SET* was developed (Pickup and de Dear, 2000; Jendritzky et al., 2012). Solar radiation is the main difference between indoor and outdoor settings. Thus, when the outdoor mean radiation temperature is calculated, the model incorporates direct radiation fluxes, however; it diffuses the shortwave radiation fluxes.

-Universal Thermal Climate Index (UTCI)

UTCI is the equivalent temperature for the environment resulting from a reference environment. It is recognized as the air temperature of the reference environment that gives the equivalent strain index value in appraisal with the reference individual's need to the real environment. It is considered as one of the main comprehensive indices for assessing heat stress in exterior areas (Blazejczyk, 1994). This index was advanced to have a standard measure for calculating heat stress in the light of human meteorology (Blazejczyk, 2012). The input data for assessing UTCI contains meteorological and non-meteorological (metabolic rate and clothing thermal resistance) data (Farajzadeh et al., 2016). The parameters that are taken into account for evaluating UTCI include relative humidity, dry temperature, mean radiation temperature, wind speed, and the pressure of water vapor. (at the elevation of 10 m). The wind speed has to be ranged from 0.5 to 17 m/s in order to assess the UTCI (Froehlich and Matzarakis, 2015).In the study of Blazejczyk (2012), some of the prevalent thermal indices were compared with UTCI. It was revealed that existent indices express bioclimatic circumstances practically only below explicit meteorological conditions, whereas the UTCI denotes particular climates, location, and weather much better (Dragan Milosevic et al -2016-). UTCI values are subdivided into 9 groups reaching from very strong to extreme cold stress to very strong to extreme heat stress (Table2.4).

Table (2.4): Thermal sensation and different groups of UTCI (Author 2018 according to Ladybug00062).



UTCI(^{0}C) range	Above+38	+32to+38	+28to +32	+26to+28	+9to +26	9+ to 0	0to -13	-13to-27	Below -27
Stress Category	Very strong to extreme heat stress(very dangerous)	strong heat stress(Dangerous beyond short periods of time)	Moderate heat stress(hot but not dangerous)	Slight heat stress (comfortable For short periods of time)	No thermal stress (comfortable Conditions)	slight cold stress (comfortable For short periods of time)	moderate cold stress(cold but not dangerous)	strong cold stress (Dangerous Beyond short periods of Time)	Very strong to extreme cold stress (very dangerous)

3-2-The effect of shading control on outdoor thermal comfort

Shading is among the regulated factors of thermal stress as it decreases the convective heat transfer from the ground surfaces and the sunlit building (Spronken-Smith and Oke, 1999). As solar radiation can be blocked by shading, the effects of shading on thermal environment have been the subject of several studies. According to Ali-Toudert and Mayer (2006) several studies revealed that there is a strong correlation between outdoor thermal comfort, the short wave and long wave radiation fluxes surrounding human actions. They proved that shading and street orientation have a crucial role in the process of heat moderation during hot times.

Makaremi et al. (2012) confirmed from their study that the Space I (A) which was prepared with a transparent roofing without any effective shading casted by environments, is less comfortable most of the time. It can be observed that throughout the investigated time, mainly during noon, the stated cover was incapable to shelter the area from solar radiation. On the other hand, the Space II (A) which had a pergola bounded by vegetation and plants particularly offered an improved thermal situation compared to Space I (A).They proved that vegetation and trees shading leads to decrease PET index values (See figure2.22). Accordingly, the positions, which were sheltered by the shade of plants and nearby buildings, reveal trend to be slightly cooler than the others owing to their lesser disclosure to direct solar radiation. Hence, high shading level is needed in urban areas to maximize thermal comfort and prolong the permanency of the suitable thermal condition throughout the day.

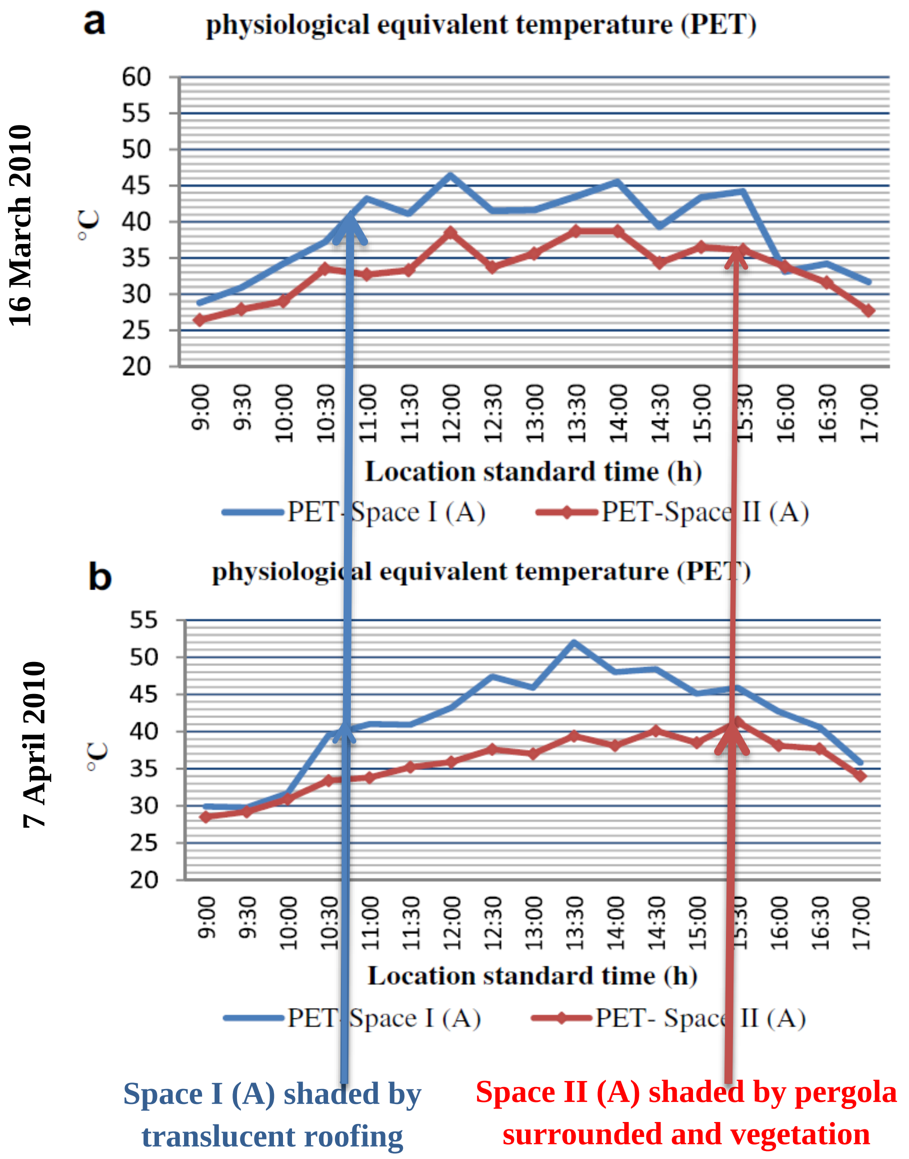


Figure (2.22): The effect of shading strategies on PET values (Nastaran Makaremi, 2012, p.10)

Shinichi Watanabe et al (2014) appraised outdoor thermal comfort throughout summer in a humid subtropical region (Nagoya, Japan). Meteorological assessments were directed in sunlight, building shade, and pergola shade. The sky view factors (SVF) of the aformentioned areas were 0.65; 0.02; and 0.05 respectively (See figure2.23). They also confirmed from their outputs that decreased value of SVF leads to minimize the universal effective temperature (ETU). In clear conditions (sunlight during summer) in humid subtropical regions with total solar radiation of 800 W/m2, it was found that there is an ETU reduction of 18.4 °C and16.2 °C, respectively because of the cooler environment, which is provided by the building and pergola shades. However, the building and pergola have provided shades with ETU diminutions of 9.3 °C and 6.8 °C, correspondingly in cloudy conditions and solar radiation of 300 W/m2.Therefore, the variation in temperature reveals that pergolas bears the characteristic softly avoiding solar radiation.

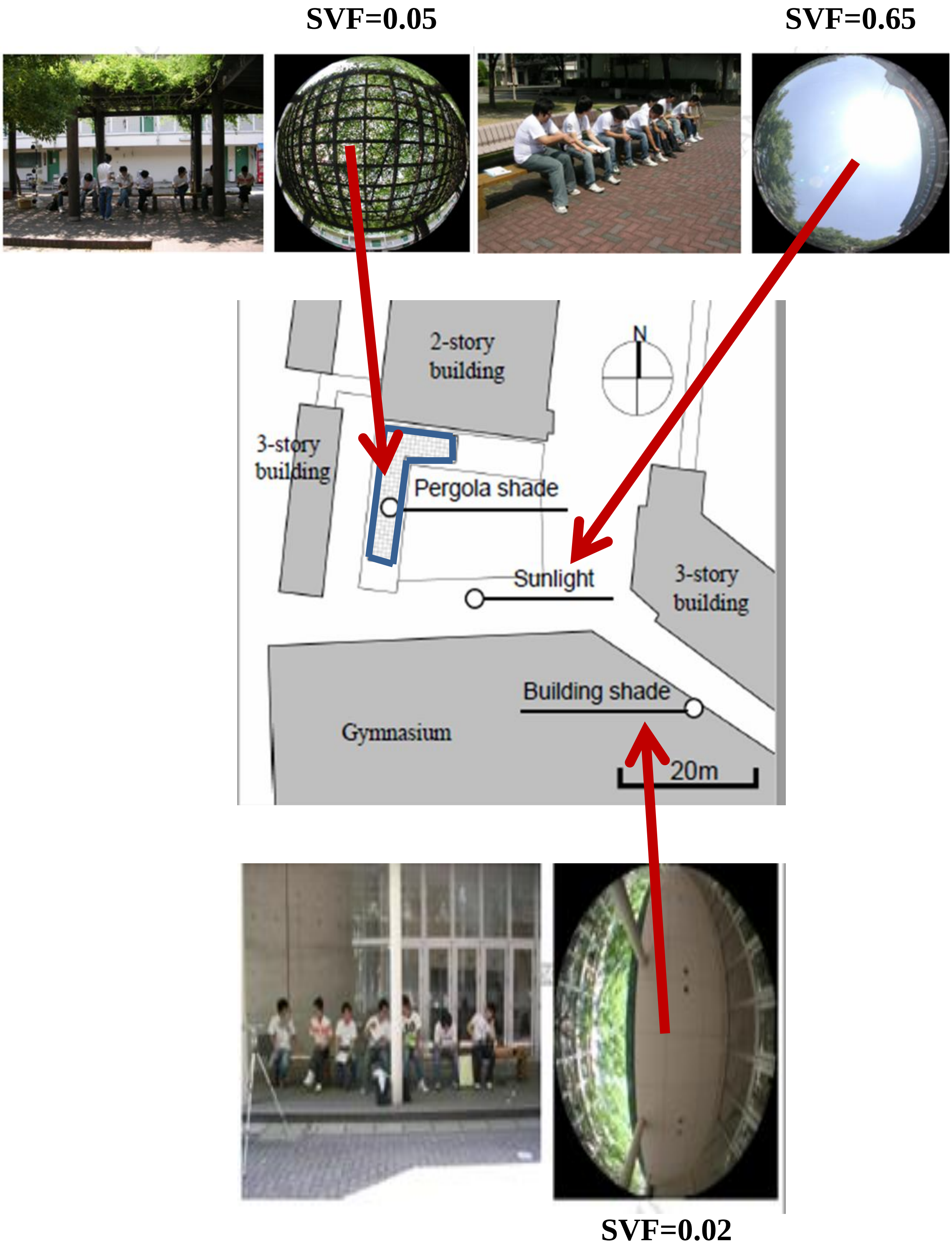


Figure 2.23: Evaluation of outdoor thermal comfort during summer in a humid subtropical region (Nagoya, Japan)(Shinichi Watanabe et al (2014), p.25.,26)

Referring to what came by Martinelli et al. (2015), the hourly trend of the index PET for the shaded and unshaded locations represented the relationship between the hourly shading patterns and thermal comfort as shown in Figure (2.24). A particular change in the PET values indicates the difference in the direct solar radiation between shaded and unshaded areas.

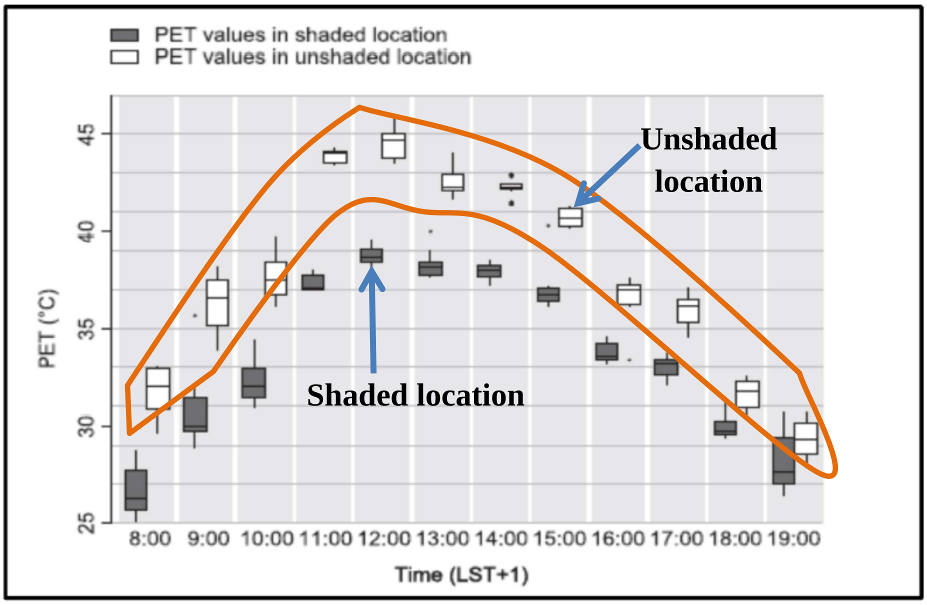


Figure (2.24): Hourly values of PET for shaded and unshaded locations from 8:00 to 20:00 (Martinelli et al., 2015,p.30)

Conclusion

Through the first section of this chapter we have clarified the elements needed to understand the development of solar control. Afterward; we have underlined the importance of taking into account solar access to ensure the energy consumption, architectural aesthetics, visual and thermal comfort. Then we have presented the effect of geometrical parameters of urban spaces on solar access. There have been several studies that focused on the impact of geometrical parameters of spaces between buildings on solar access. Harzallah (2007) summarized these parameters in three groups: Urban Density; Building form and orientation; Building outlines and street's orientation (Thibaut Vermeulen -2014-).

Shading is among the counteracting measures to thermal stress since it decreases the convective heat transfer from sunlit building, and ground surfaces. In arid climate, shadow casting has a decisive effect on the thermal comfort of human beings. The literature overview presented in the second section of this chapter displays that shading control has a significant effect on the energy consumption for cooling, the aesthetic values for lighting, and the physical comfort of human being. Over the second section of this chapter, we have also depicted that there are three kinds of shading control strategies; Static, Kinetic and Bio-inspired design of kinetic shading strategies.

The third section of this chapter, explains the assessment of outdoor thermal comfort ; it also displays that many researchers assess the effect of solar and shading control on pedestrian’s thermal comfort based on comfort range such as ; Ali Toudert et al (2006) ; Makaremi et al (2012) ; Shincichi Watanabe et al (2014); Martinelli et al (2015).

CHAPTER III: APPROACHES AND METHODS OF SOLAR AND SHADING CONTROL OF URBAN SPACES

Chapter 3: Approaches and methods of solar and shading control of urban spaces

Introduction

After clarifying the meaning of solar and shading control in urban spaces in the previous chapter, it seems crucial to overview the different approaches and methods of solar and shading control of urban spaces in the present chapter. In this regard, the present chapter is made of three main sections.

The first section of this chapter is focused on a literature overview on the evaluation methods of solar and shading control of urban spaces. These methods attempt to evaluate the relationship between the geometrical parameters of urban spaces, sunlight, and shading. Through the second section of this chapter we present a literature overview of the generative methods of solar and shading control of urban spaces. These methods aim to determine the proper geometrical parameters of urban spaces and to generate optimal urban forms that enhance outdoor thermal comfort. The third section of the present chapter presents the process, which will be useful to control solar access and shading in the case study.

1-Evaluation methods:

According to Capeluto I. G. and Shaviv E. (1997)

> *"During the conceptual design phase of urban spaces, the designer deals with different geometrical characteristics related to the building's height in relation to the orientation, width of the open spaces, and the pedestrian sidewalks. These include the determination of the proportion of the buildings, the open spaces and land subdivision. Each one of these topics is complex by itself, and the determination of the best design solution becomes specially complicated due to mutual influences. For example, the size of the open spaces influences the exposure of the buildings to winter sun, or can create the required summer shading. Therefore, the design of spaces between buildings without considering their geometrical parameters from the very beginning may cause discomfort conditions inside the buildings, in the sidewalks, and in the open spaces".*

Through this section, we attempt to present a literature overview of the researches that evaluate the relationship between the geometrical parameters of urban spaces, sunlight, and shading. These researches analyze the performance of a given design.

1-1-Evaluation methods of solar control

1-1-1-Aspect height to width ratio (H/W) and orientation:

Urban canyon proportions are described by the aspect ratio. The aspect ratio signifies the ratio between the average width of the space (The wall-to-wall distance across the street) and the average height of nearby vertical elements (such as building facades) (See figure 3.1).

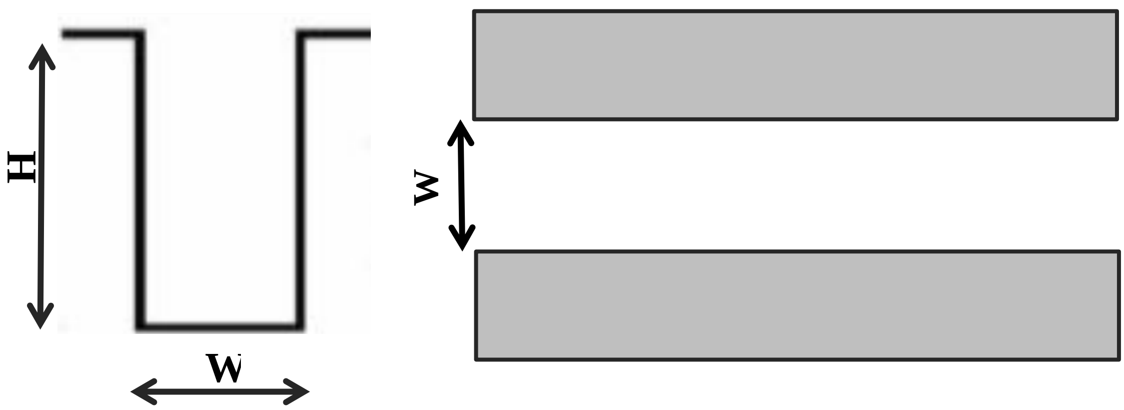


Figure (3.1): The aspect Height to Width ratio (Jeffrey Raven, 2011, p.10)

Various studies have been conducted in order to evaluate the effects of the aspect ratio (H/W) and orientation on solar right in an urban canyon. In order to assess the correlation between the aspect ratio (H/W), orientation and the amount of solar radiation impinged on canyon surfaces (Facades and ground), Arnfield (1990) examined the amount of solar radiation dropped in several urban canyon configurations of different aspect ratios (H/W ratio was ranged between 0.25 and 4). The urban canyons examined were oriented to EW and NS directions. The study was carried out throughout the whole of the year in all the latitude. The results designate that the sum of solar radiation impinged on urban canyon surfaces augmented when the aspect ratio (H/W) reduced (See figure3.2).However, the solar radiation fallen on ground surface is more than the quantity of solar radiation dropped over building facades. Furthermore, Arnfield comprehended that the effect of orientation is more considerable during summer time than during winter time. The result of this study also prove that the effects of aspect ratio (H/W) and direction of urban streets on solar radiation received on urban canyon surfaces (ground and facades) are more considerable in latitudes (20^0-40^0) during all the seasons.

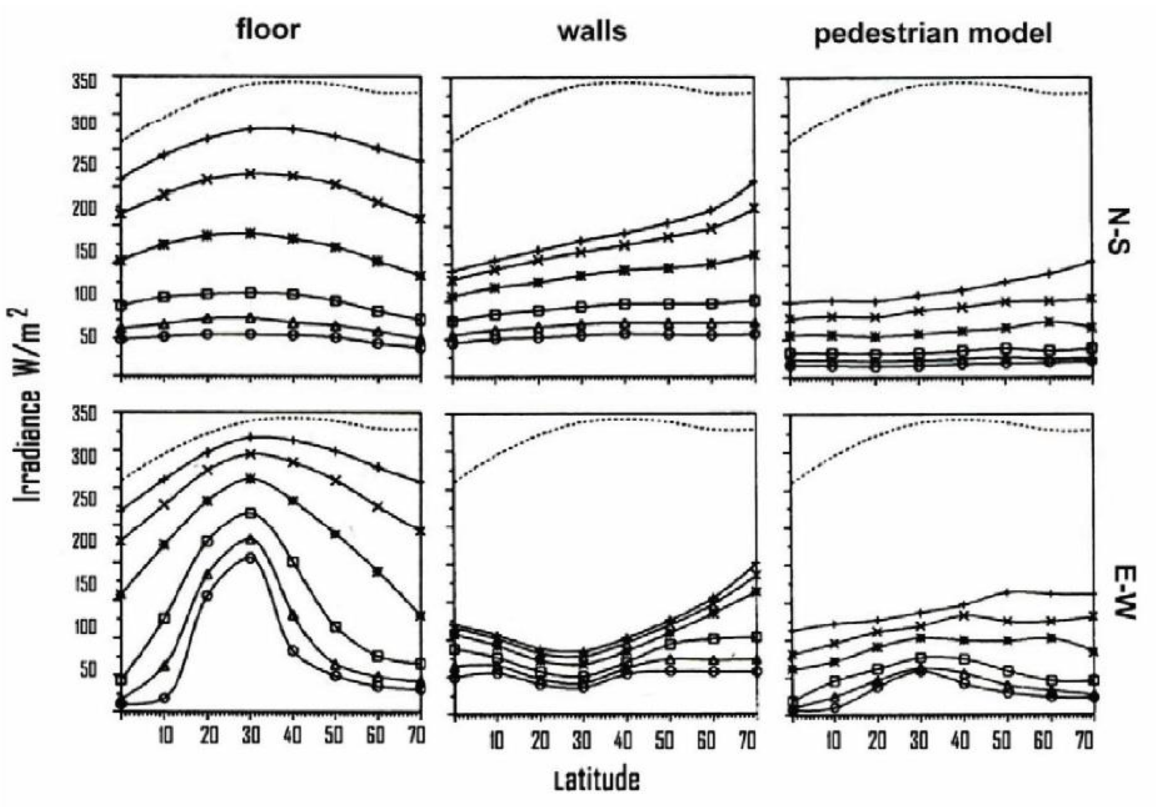
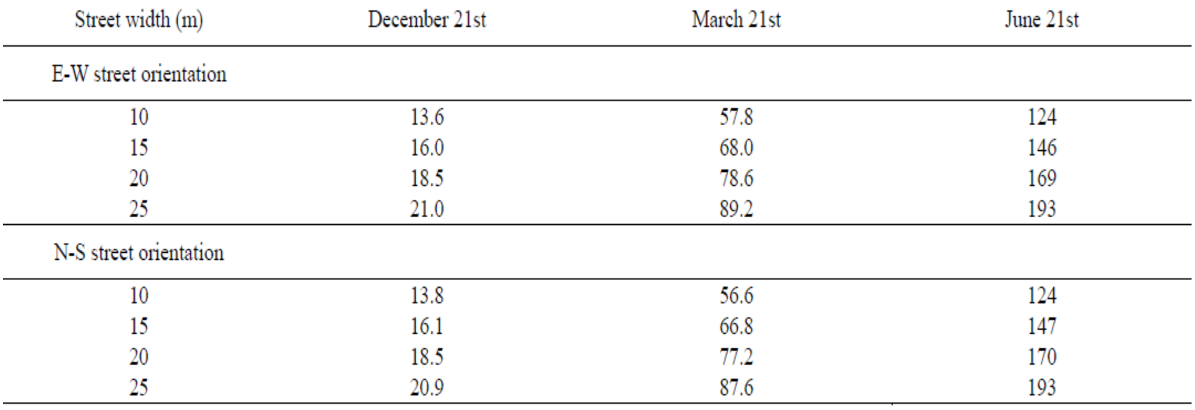


Figure 3.2: Monthly mean canyon irradiances simulated for June for E-W and N-S canyons and different aspect ratios. The symbols +, x,* , □, Δ , ○ correspond to H/W = 0.25, 0.5, 1, 2, 3, and 4 respectively .
(Nastaran Shishegar (2013), p54)

In another investigation, PJ Littlefair et al (2000) assessed sunlight dispersion for four possible street directions in Rome (42^0N) and Athens (38^0N), for a long street, of (H/W) ratio 2. The results reveal that east-west streets are to be avoided in warm climates. They have considerably higher annual sunlight perception than the other street directions, and all of this happens in the summer period. In mid -summer the sun can reach the north side of the street for approximately all the warmest period of the day. The except barring to this is if the street is so deep. For Athens H/W would require to be at least four, for Rome and H/W of 3.5 would be best to avoid sun perception. North-south streets have the least sun dispersion, and around a third of it happens in the winter period when it will be more needed. The sunlight is intense during the middle of the day, while at other times of day the entire of street will be in shade. Throughout the summer period, sunlight perception is less than half that for an east-west street. In another investigation, the influence of the geometrical parameters of urban street (width and orientation) on solar access received by the urban canopy has been assessed by Van Esch et al (2012). The urban street canyons examined were directed to the East-West and North-South orientations, their width were ranged between10 and 20 meters. The simulations were carried out during both solstices summer and winter, also during the equinox of spring in De Bilt, the Netherlands (52^{0}06 N and 5^{0} 11E). The findings indicated that maximizing street width leads to increase the solar radiation dropped on the urban street canyon with 17%-20% (See table 3.1).

Table (3.1): Total radiation yield of the canyon in Kwh/m for diverse street orientations, typical dates, and street widths with flat roofs
(Nastaran Shishegar (2013), p55)



Street width (m)	December 21st	March 21st	June 21st
E-W street orientation			
10	13.6	57.8	124
15	16.0	68.0	146
20	18.5	78.6	169
25	21.0	89.2	193
N-S street orientation			
10	13.8	56.6	124
15	16.1	66.8	147
20	18.5	77.2	170
25	20.9	87.6	193

1-1-2-The Sky View Factor (SVF)

When we look up to the sky, the view we are seeing is known as the sky view factor. The SVF determines the openness or reticence of a given area. When there are no buildings or high objects obstructing the view, it is said that the area is entirely open with a SVF equal to1. However, the area is said to be closed if its SVF is 0. From an environmental engineering and architectural perception, the SVF is defined as a quantitative standard to measure the vastness of open air, or at a point in a street (Brown et al., 2001) (See figure3.3). Among the crucial morphological factors that widely affect the urban climate, we note the SVF.

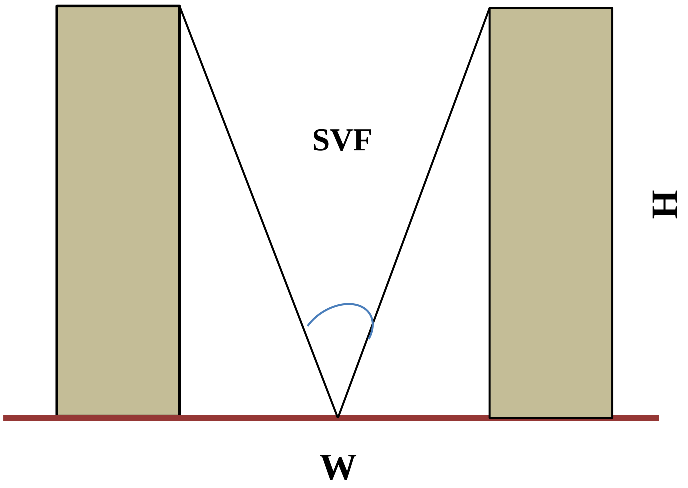
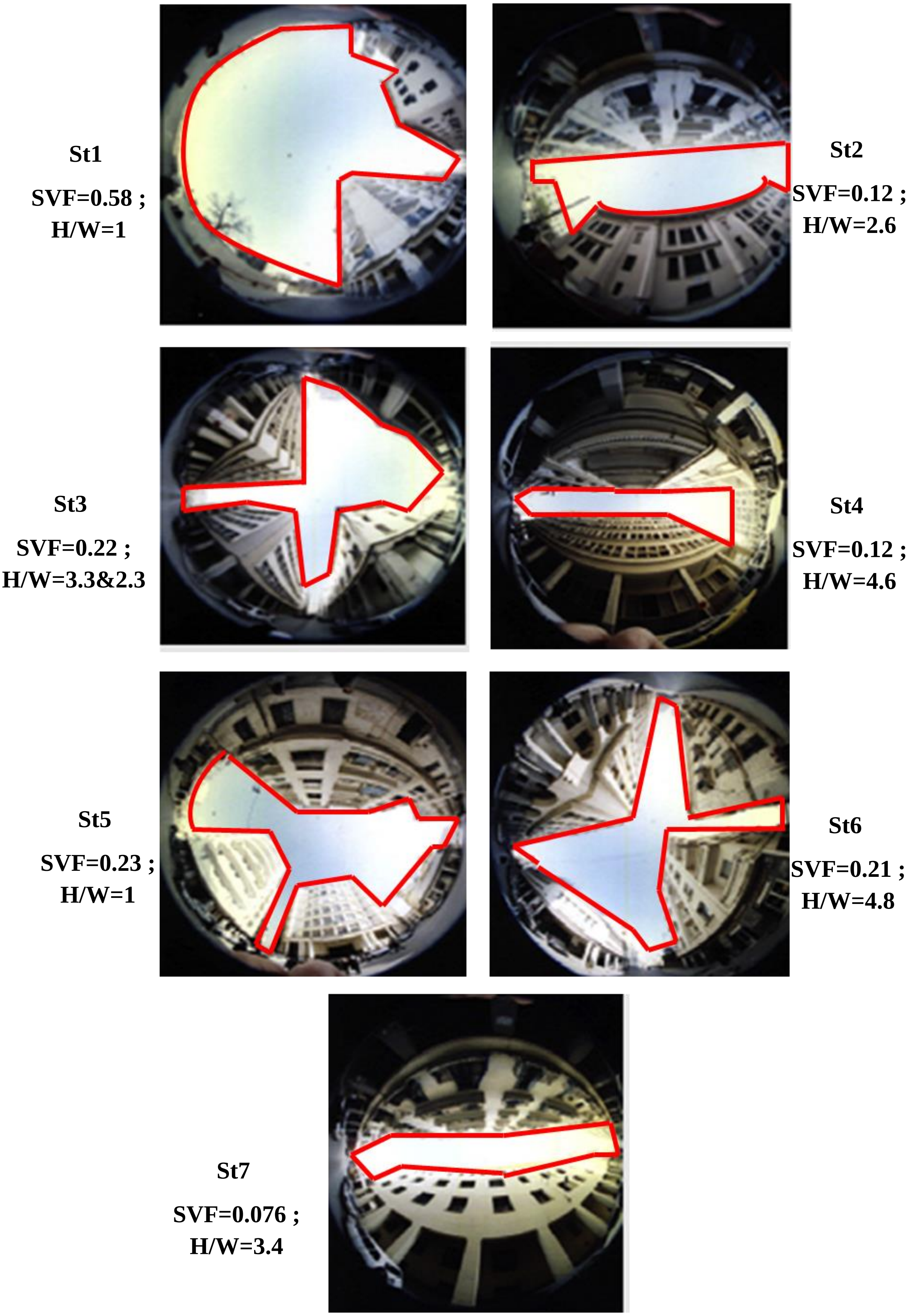


Figure 3.3: The Sky View Factor (Brown et al., 2001)

According to P J Littlefair et al (2000), several studies have been carried out in order to reveal the correlation between the (SVF), the heat island intensity and the surface temperature.

Yamashita et al (1986) find a clear correlation between the urban air temperature and sky view factor for some Japanese cities. Another study that was carried out by **Barring** et al (1985) in Malmo, Sweden revealed a correlation between the street surface temperature and the SVF. The results proved that the surface temperature pattern is strongly dependent to the street geometry in which with the increasing value of the SVF, the surface temperature increases.

Bourbia and Boucheriba (2010) explored the correlation between air temperature and the sky view factor. To achieve this aim a set of measurements were obtained from seven stations that were designated based on variation of the H/W ratio, SVF, and the orientation. The investigation was done in summer during the month of July 2007, representing the warmest period (See figure3.4). The obtained measurements show that the air temperature is strongly affected by the SVF especially from 12 am to 6 pm with an R^2=0.46. Nevertheless, the values of air temperature are tending to be identical between 6 pm and 4 am, in all stations. (See figure3.5).



St1

SVF=0.58 ; H/W=1

St2

SVF=0.12 ; H/W=2.6

St3

SVF=0.22 ; H/W=3.3&2.3

St4

SVF=0.12 ; H/W=4.6

St5

SVF=0.23 ; H/W=1

St6

SVF=0.21 ; H/W=4.8

St7

SVF=0.076 ; H/W=3.4

Figure (3.4): SVF and H/W ratio of station measurement (Bourbia and Boucheriba 2010, p.345, 346)

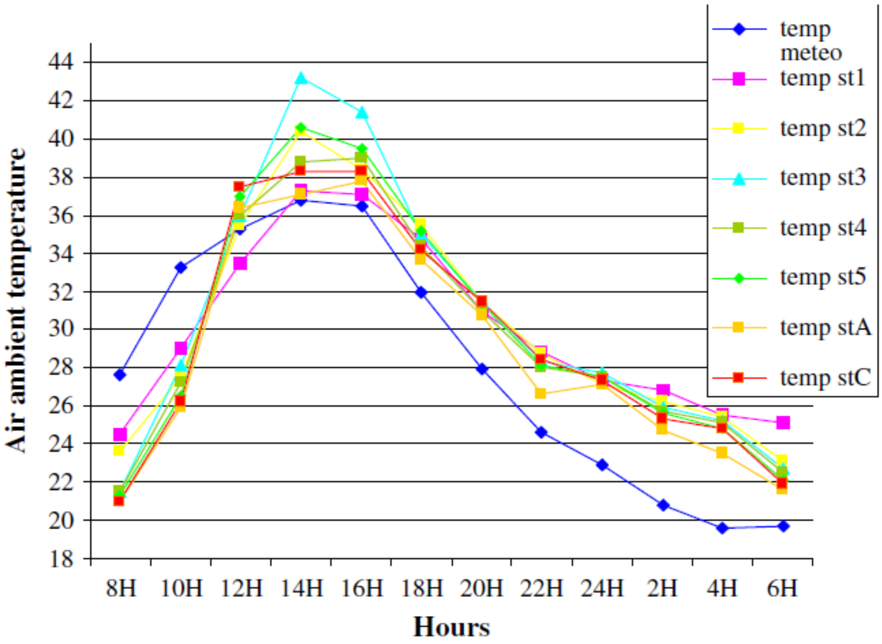


Figure (3.5): Air temperatures at the measurement stations. (Bourbia and Boucheriba, 2010, p.346)

In another exploration, Yupen Wang and Hashem Akbari (2014) examined the correlation between the urban heat island and the sky view factor. To fulfil this aim they evaluated the impact of SVF on air temperature (Ta) and mean radiant temperature (MRT). The existence or lack of the archaic vegetation cover largely affects the SVF. Thus, the SVF during summer differ from the SVF in winter. For that reason, four locations with distinctive SVF in Montreal have been the subject of this study (See table 2.2).Through this study, they proved that higher values of SVF leads to give beneficial thermal sensation at night during summer time. However, during winter period higher values of SVF give colder temperature, which leads to increase the energy consumption. Finally, in order to mitigate the urban heat island they recommended low sky view factor values, because it leads to reduce urban temperatures and maximize outdoor thermal comfort.

Table (3.2): Local SVF in each area (Yupen Wang and Hashem Akbari (2014), p.280)

Areas	Concordia	Berri-UQAM	Joliette	Snowdon
SVF Summer	46.6%	74.6%	83.3%	76.5%
SVF Winter	46.3%	74.7%	88.9%	91.0%

1-1-3- The urban form:

In its simplest definition, urban form is the physical description of the city`s characteristics. At the regional scale or expansive town, urban form has been simplified as the spatial structure of static components (Anderson et al., 1996 in Nicola Dempsey et al 2008, p21). Aspects of urban form at this level would contain urban settlement sort, such as a central business district, market town, or suburbs. Though, urban form depends to scale and has been designated as the 'morphological characteristics of an urban space at all scales' (Williams et al., 2000 in Nicola Dempsey et al 2008, p21). Attributes therefore vary from, at a very restricted scale, structures such as construction materials, façades and fenestration, to, at a larger level, housing category, street form and their spatial organization, or plan (Nicola Dempsey et al 2008). The urban form and sunlight exposure of urban spaces are interrelated.

Thus, they are the focus of several studies like Ye Kang Ko (2012) study, and Jouri Kanters and Miljana Horvat (2012) study. In order to reveal the effects of urban forms on solar exposure of urban spaces, Steemers (1996) has investigated the impact of three various urban forms (the tower, the courtyard and the bar types) on the solar rays impinged on ground surfaces and over building facades (See figure 3.6). The findings of this investigation have demonstrated that:

-At the urban scale, solar radiation has a large effect over the management of urban forms and has to fulfill the conciliations between the aim of sunlight and the dispersal of the building.

- When the three forms were compared in term of affecting the solar access of urban forms, it was found that: the tower prevents the walls and the spaces on the roofs form solar exposure. Whereas, the courtyard and the bar type seized fewer solar radiation on the walls because they partially block it.

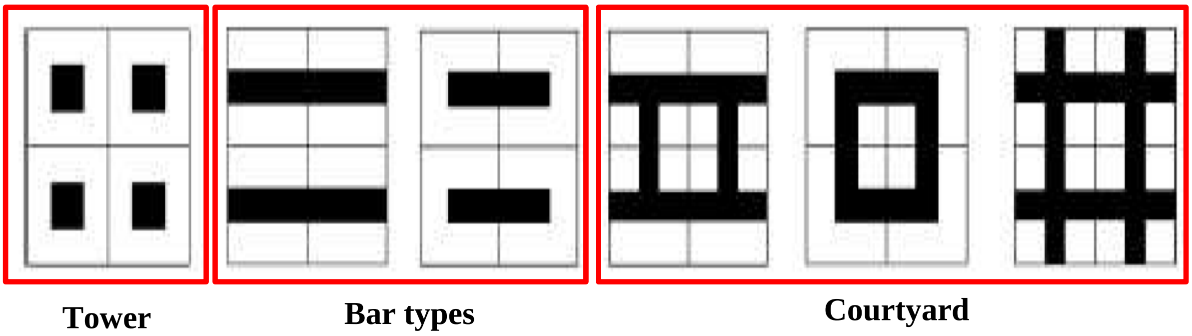


Figure 3.6: Three different urban forms investigated (Steemers ,1996)

Another study was carried out in Athens by Eirini Tsianaka (2006) .The study aims at exploring the benefits and shortcomings of open space. Courtyards, which are the opened middle spaces within a block of buildings and streets, were the examined urban forms in this study. The investigation of urban morphology and air temperature is the cornerstone of this study. The clusters of Amerikis and Omonias (See figure 3.7), which are tow various cases study sites are taken into consideration in morphology analysis. In the examining of air temperature, the prediction model is applied in order to calculate air temperature and the Cluster Thermal Time Constant (CTTC). This investigation intended to reveal the advantages of courtyards in providing natural ventilation, which in turn has benefits in decreasing cooling consumption. The obtained results have demonstrated that the temperature rise is largely affected by urban geometry. For instance, in contrast to the floor opposite to the streets, the floor, which is opposite to the courtyards, is much cooler even if they are designed improperly. Therefore, it can be concluded that courtyards are considered an important space in the city of Athens because they are able to decrease the energy consumption for cooling in the buildings. Whereas, the streets are hot, noisy and polluted.In the spaces with high building density, narrower courtyards are more valuable than the larger ones.Temperature assessment also displayed that courtyards can decrease the energy consumption for cooling in the constructions. The apartments facing the street are able to transform the fresh air of the courtyard through the apartments facing it. This is achieved only through the ventilation of buildings, which can be produced by the airflow through the entrance between the street and the courtyard.

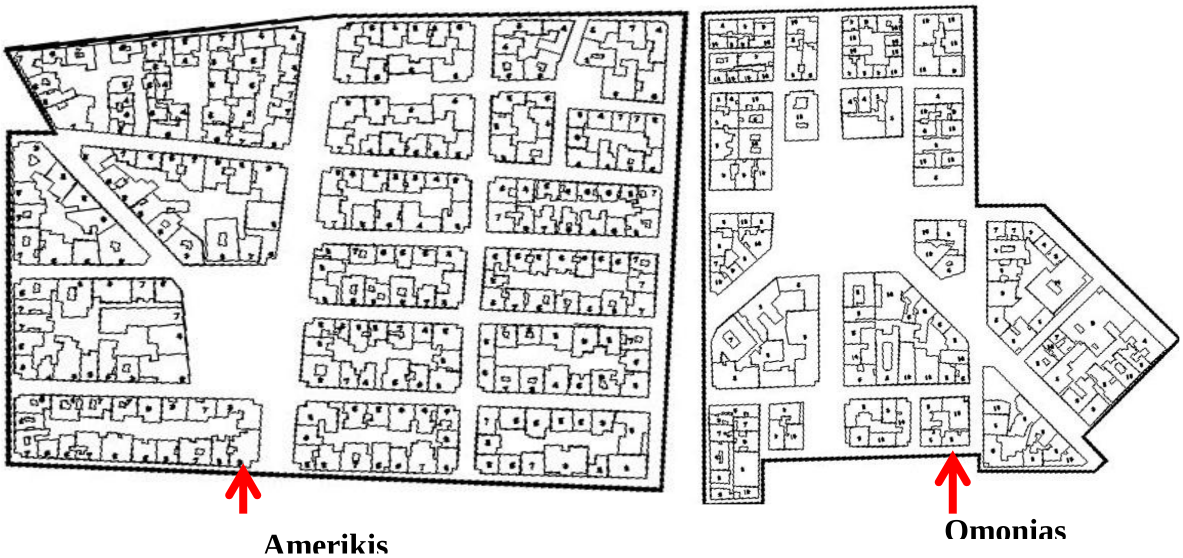


Figure 3.7: two different case study sites investigated (Eirini Tsianaka ,2006)

1-1-4-Urban density

In contrast to the physical meaning of density (mass divided by volume), the term is more complicated when it is used in the city (Kim Dovey and Elek Pafka 2014).The urban density, which is a crucial variable of urban form, is strongly related to the variable of spatial configuration. This correlation should be presented to establish a sufficient planning context (Balint Halasz 2015). Both urban density and some determinants of urban form have great impact on making local environmental conditions for instance; the quality of the air, the ability to walk, and the access to green space. All of those conditions are crucial for the thermal comfort of urban residents. Urban density notably influences the quality of life of urban residents and urban energy use (Burak Güneralp et al 2017). In order to reveal this fact, Vicky Cheng et al (2006) have evaluated the relation between built forms, density, and solar radiation fallen on urban surfaces by attributing it to a set of design factors:

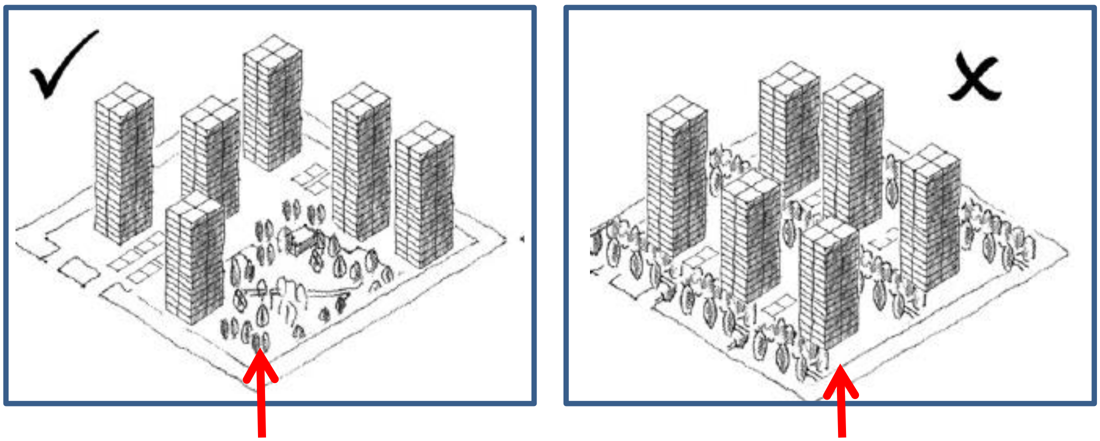
-The first factor is associated with the ground level openness that is greatly linked to pedestrian comfort.

-The second factor is related to the building façade and their access to daylight. It is important to mention that they are crucial in assuring solar access for the buildings.

-The last factor is Photovoltaic impending on the building envelope. It illustrates great part about the utilization of renewable energy at the urban scale.

The study, which was carried out by Vicky Cheng et al (2006), was based upon the coefficients of soil coverage and land use calculations in order to evaluate the urban density. The results has clarifies some useful perceptions to design cities with high solar density.

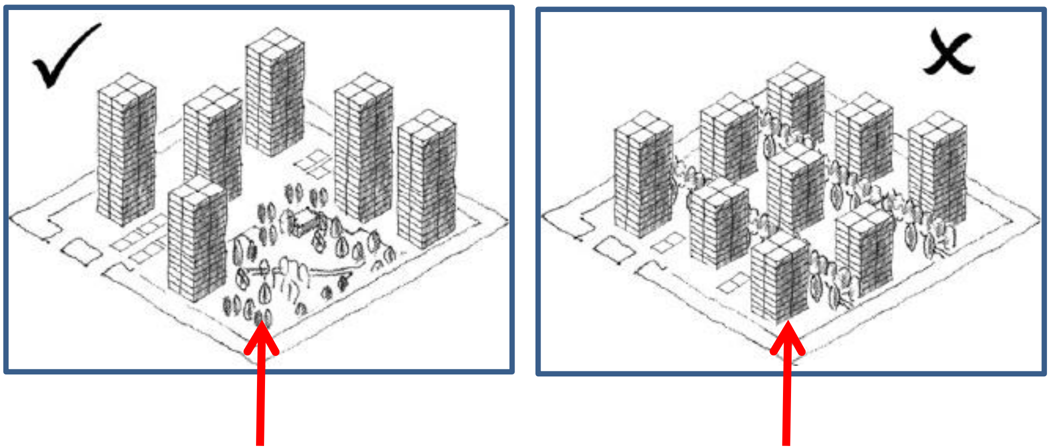
- The random horizontal layout is strongly advisable. Taken into consideration the equal amount of the utilized floor area, the scattered layouts arrangement of the building blocks is more preferable than arranging them in uniform arrays (See figure 3.8).



Scattered layout **Uniform arrays**

Figure 3.8: Scattered layout and uniform arrays (Vicky Cheng et al (2006))

-The most desirable arrangements consists of higher buildings, having more open space with less coverage of site rather than having higher site coverage and lower buildings (See figure 3.9).



Higher buildings, less site coverage **Lower buildings and higher site coverage**

Figure 3.9: Higher building, less site coverage is preferable (Vicky Cheng et al (2006))

- Randomness in vertical layout has to be stimulated. In order to make this occur, construction and planning rules on building elevation would have to be made more supple (See figure 3.10).

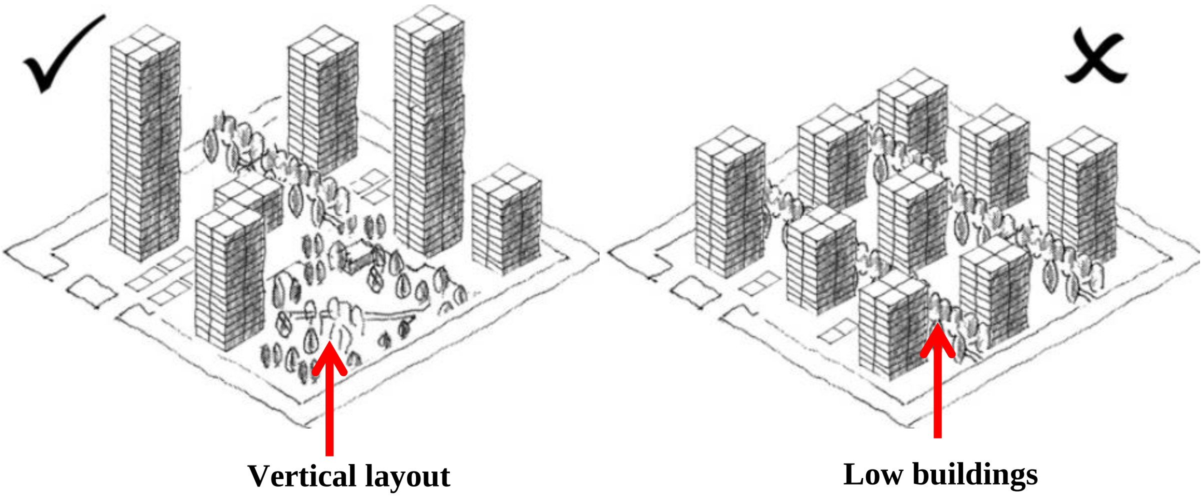


Figure 3.10: Vertical randomness is preferable (Vicky Cheng et al (2006))

In another investigation, Milos Mirkovic and Khaled Alawadi (2017) evaluated the impact of urban density on solar gains and cooling request for Abu Dhabi. Three various urban cases were verified, all of which had various number of levels. In this investigation, the space between the edifices was varying, beginning with the base-case distance of 15m (See figure3.11). The study has demonstrated that high urban density has great role in enhancing energy performance and decreasing solar gains. Therefore, it is preferable for the building to be bounded by constructions, which have smaller plots and many floors.

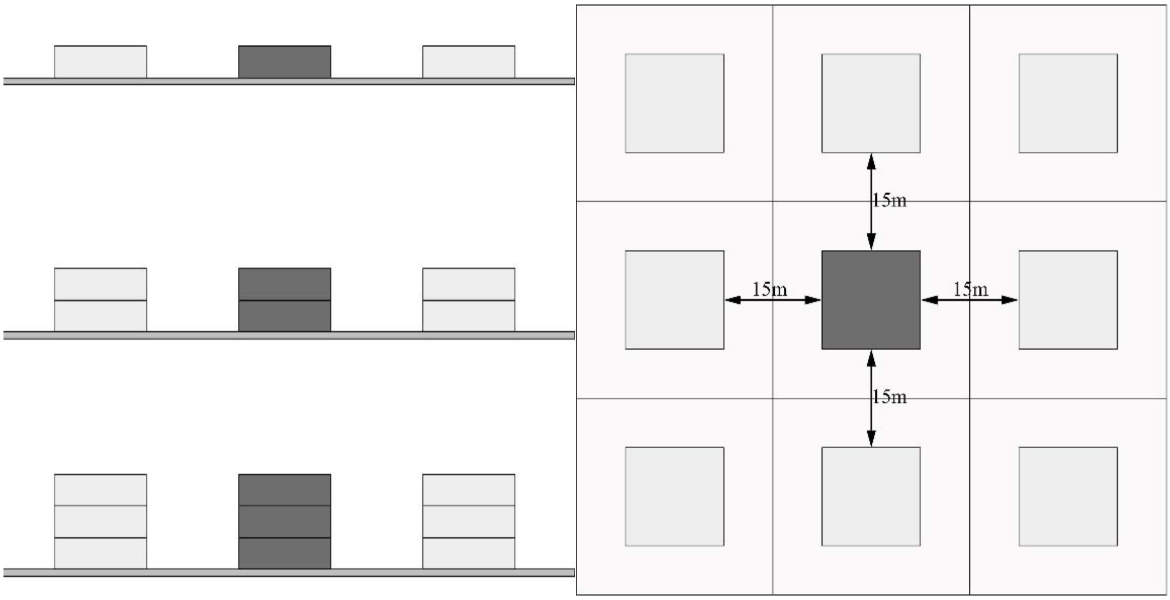


Figure 3.11: Three different urban cases tested (Milos Mirkovic and Khaled Alawadi (2017), p.279)

1-2-Evaluation methods of shading control

Bourbia, and Awbi (2004) employed a simulation program (Shadowpack PC code version 2), to check, and to assess the impact of aspect ratio (H/W) on the average values of shading fraction dropped on street surfaces and ground for several direction. The investigation was carried out in El Oued city of latitude (33^0). The findings of this research revealed the following recommendations:

1- In summer and winter, there is a negative correlation between the aspect ratio (H/W) and the floor shading fraction in which the rising of the first one leads to the reduction of the second (see figure 3.12).

2- The shading and urban microclimate is considerably impacted by the direction of the urban street canyon.

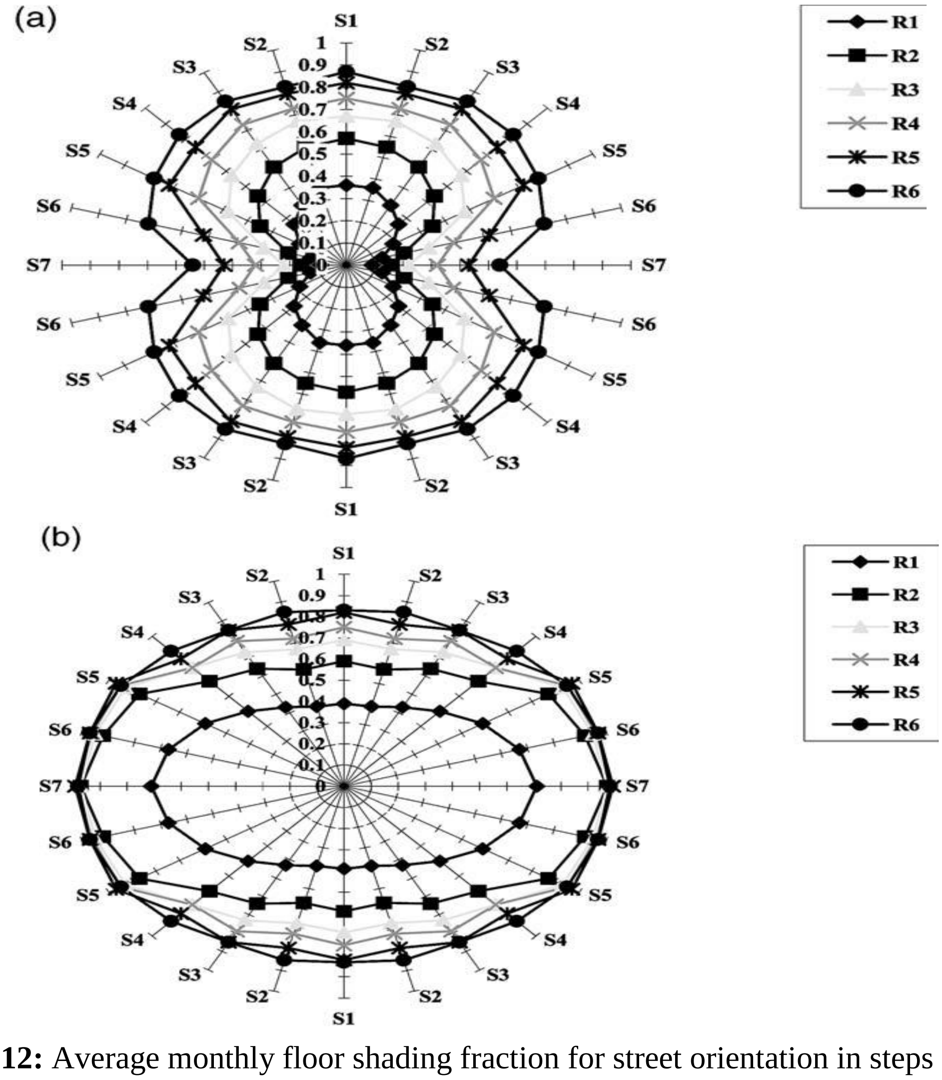


Figure 3.12: Average monthly floor shading fraction for street orientation in steps of 15° from the north (S1) to the east and west (S7) for latitude 33°N.

(Bourbia and Awbi (2004), p295)

In another investigation Naidja Amina et al (2017) have elaborated a workflow in which they incorporated the modeling parameters (Grasshopper-Ladybug) (See figure 2.13), and statistic tool SPSS.20. The process aimed at revealing the effects of the urban geometry including the street length (L), street canyon aspect ratio (H/W), and street orientation on the values of the shade net effect during summer period in hot arid climate (Biskra). The findings of this investigation reveal that in contrast to the other configurations, the urban street of length (2L) and aspect ratio (H/W=4) needs less shading (See figure 3.14). Furthermore, this investigation has revealed that shading requirement, and the geometrical parameters of urban street are inversely related. Nevertheless, the length influences shading requirement of ground surface more than the H/W ratio. Moreover, all canyon configurations, which are mainly oriented to the NS direction, need less shade than the other orientations. However, the EW orientation needs less shade in comparison with all other directions.

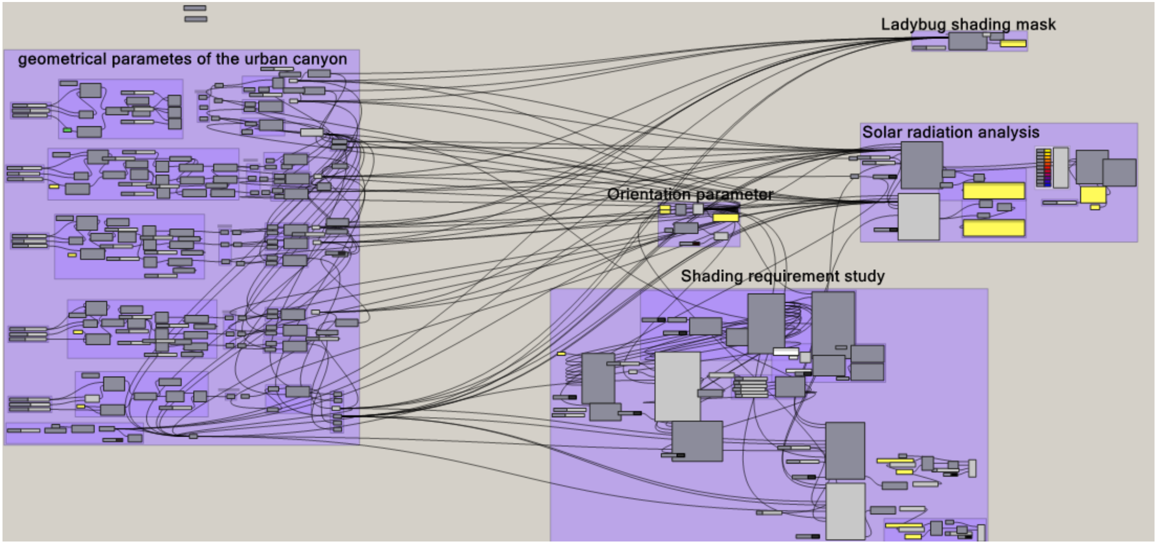


Figure3.13: The parametric definition of geometrical profile of the study canyon and shading requirement study (Naidja et al 2017)

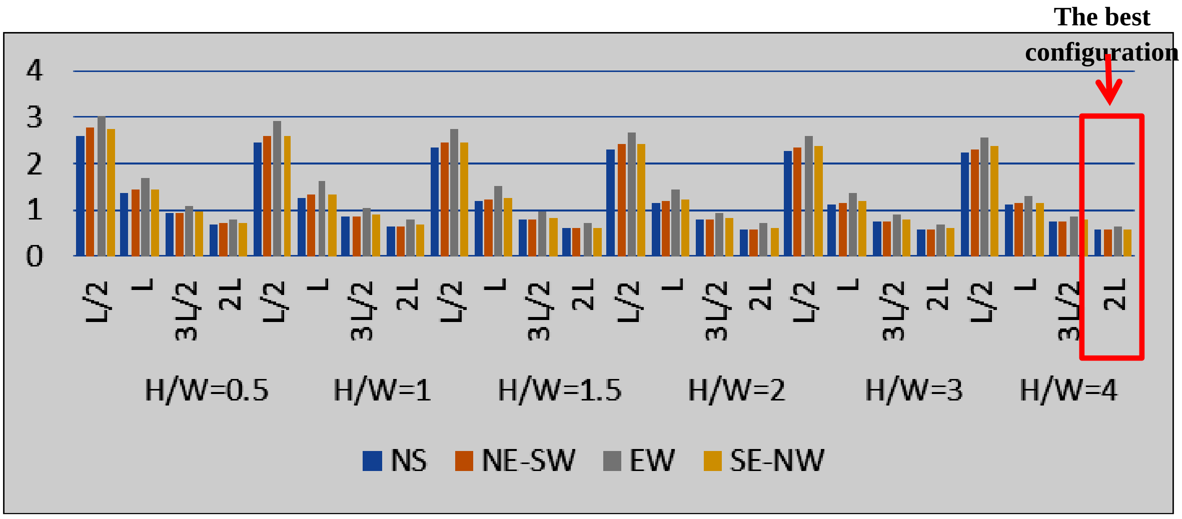


Figure 3.14: Shade net effect values on ground surfaces during summer period (21stJuin-21st September) (Naidja et al 2017)

1-3-Evaluation methods of solar and shading control

For a visual and quantitative assessment of solar rights and shading requirements, Yezioro and E.Shaviv (2004) elaborated a workflow that deals with both an evaluation tool SHADING and a RayTracinng algorithm. The emphasis of this process is to permit architects and urban designers to define quantitatively the ratio between shaded and insolated zones.

In another study, Khaoula Raboudi and Abdelkader Ben Saci (2017) employed a parametric design tool Rhinoceros-Grasshopper, to elaborate a component of volumetric and radiative assessment of solar and shading requirement **(See figure 3.15)**. On one hand, the volumetric assessment is founded on the coefficient of volumetric shading satisfaction, which is the ratio between the volume of the **shadow envelope** and the volume of the solar control envelope. More the coefficient of volumetric shading satisfaction approaches 1 more shading will be fulfilled, because when the volume of shadow envelope overlapped with the solar control envelope shading is fulfilled **(See figure 3.16)** . The volumetric assessment is also focused on the coefficient of volumetric satisfaction of solar access that is the ratio between the volume of the solar envelope and the volume of the solar control envelope. More the coefficient of volumetric satisfaction of solar access approaches 1 more solar access will be satisfied, because when the volume of solar envelope Overlapped with the solar control envelope solar access is satisfied. On the other, hand the radiative appraisal based on two coefficients: the radiative efficiency coefficient of shading, and the radiative efficiency coefficient of solar access. The radiative efficiency coefficient of shading is defined as the ratio of the cumulative solar irradiance provided by the shadow envelope to the cumulative solar irradiance provided by the solar control envelope. Solar irradiance is calculated during the solar cut-off time for the entire summer season. More the radiative efficiency coefficient of shading approaches 1, more the volume of solar control protects the surfaces of neighboring buildings against solar irradiance. Whereas, the radiative efficiency coefficient of solar access is the ratio between the cumulative solar irradiance provided by the solar control volume and the cumulative solar irradiance provided by the solar envelope. In this case, the solar irradiance is calculated during the shading cut-off time for the entire winter season. More the radiative efficiency coefficient of solar access approaches to 1, more the solar control envelope allows the solar irradiance of neighboring buildings. According to Khaoula Raboudi (2017) the volumetric evaluation is based on solar geometry while, the radiative evaluation allows a quantification of solar radiation received. This latter, aims to study the impact of solar control, on the direct solar irradiance received by the surfaces (vertical and horizontal surfaces) of neighboring buildings throughout the cold, and the hot seasons.

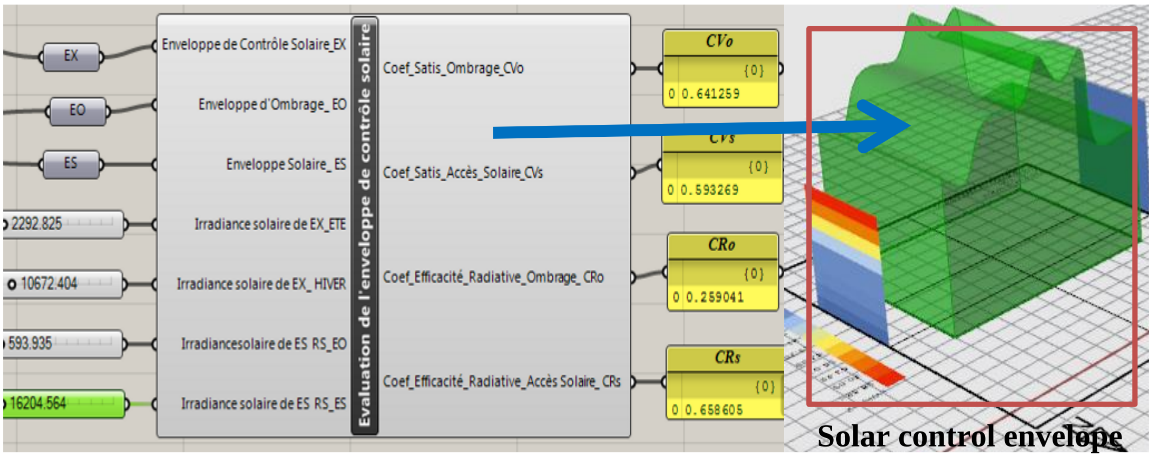
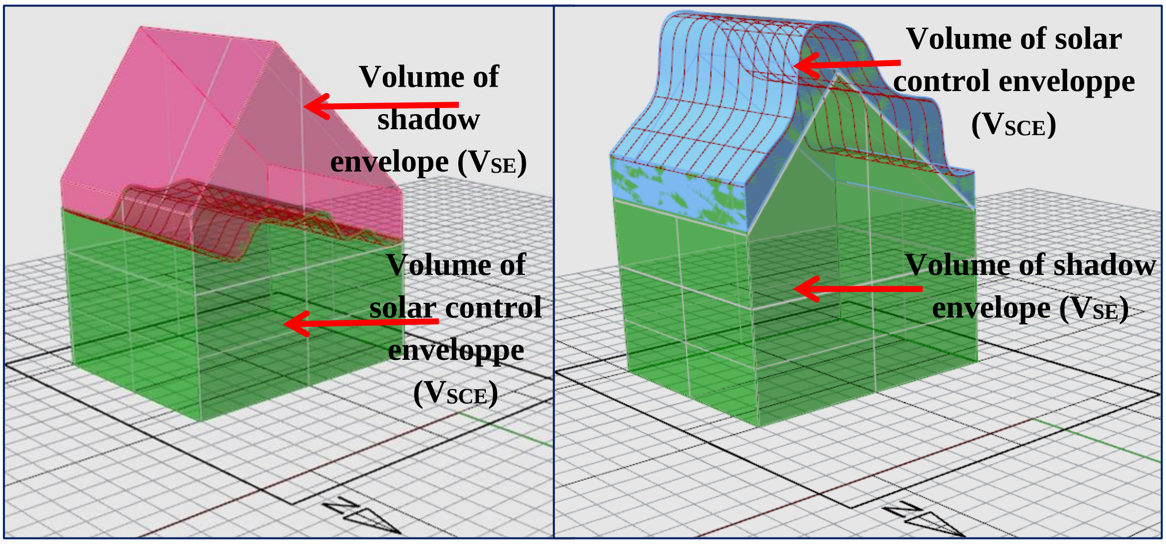
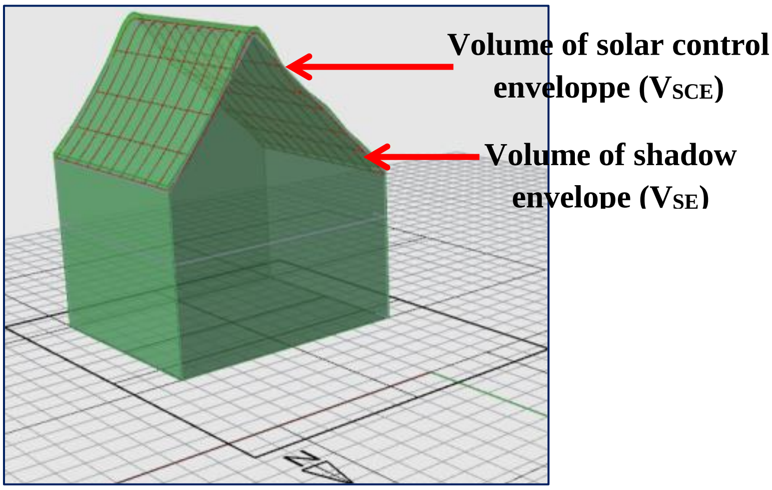


Figure (3.15): developed component of volumetric and radiative evaluation of solar and shading requirement (Raboudi and Ben Saci 2017)

(A) **(B)**



$V_{SCE}<V_{SE}$ (Shading is unsatisfied) **$V_{SCE}>V_{SE}$ (Shading is undesirable)**



$V_{SCE}=V_{SE}$ (Shading is satisfied)

(C)

Figure (3.16): The relationship between the volume of shadow envelope and the volume of solar control envelope (Raboudi and Ben Saci, 2017, P.132-134)

Recapitulation

After reviewing the main researches related to solar control of urban spaces, we conclude that the main parameters which affect the thermal comfort of urban spaces are: Aspect ratio(H/W), Orientation, street length, Sky view factor (SVF), Urban density, Coefficient of volumetric shading satisfaction, Coefficient of solar access satisfaction, Ratio between insolated and shades areas (See table3.3).

Table 3.3: The main researches related to solar control of urban spaces, and the main parameters which affect the thermal comfort of urban spaces (Author,2017)

Evaluation methods	Parameters												Performance studied	Bibliography
						Urban density								
	H/W ratio	**Orientation**	**Lenght**	**SVF**	**Urban form**	**Height (H)**	**Distance (L)**	**Soil coverage Coefficient**	**Land use Coefficient**	**Coefficient Of volumetric Shading satisfaction**	**Coefficient Of volumetric Satisfaction of Solar access**	**Ratio between insolated and shades areas**		
Solar access	●	●											energetic performance	Arnfield(1990), Littlefair (2000), Van Esch (2012)
						●	●							Milos Mirkovic (2017)
				●									energetic performance	Yamashita, Barring,Yupen Wang and Hashem Akbari (2014),Bourbia and Boucheriba(2010)
					●								energetic performance	Steemers (1996),Eirini Tsianaka (2006)
								●	●				energetic performance	Chang et al(2006)

Shading	●	●											energetic performance	Bourbia and Awbi (2004)
	●	●	●										energetic performance	Naidja et al (2017)
Solar access and shading												●	energetic performance	Yezioro and Shaviv (2004)
										●	●		energetic performance	Raboudi and Ben Saci (2017)

2-Generative approaches:

Generative approaches have provided a new simulation process in environmental design. Instead of measuring the status of a phenomenon, they intend to recommend ' all possible ' (buildings/structures) that fulfill a given state of a phenomenon for a given environment. Therefore, in a given environment the generative computer tools focused on identifying the type of building that meets the desired properties instead of identifying the properties of the building. Thus, since 1991 R. Woodbury recommended that the generative tool is adaptive to design practice (D.Siret, 1996). Jacob Riiber (2011) has defined the generative approach as following:

> *"A generative approach can be observed to construct a design process around the idea of departing from a topological schema defining the relations of a non-representational organization. This organization is a virtual construct allowing a variety of actualized structures. As an example of this conceptual framing the architect Lars Spuybroek (2004) defines two main phases of a generative design process, a convergent phase of selection and a divergent phase of design".* (Jacob Riiber -2011- P.93)

In another statement Lorenzo Villaggi and Danil Nagy (2020) defined the generative process for architecture as following :

> *"Generative design integrates artificial intelligence into the design process by using metaheuristic search algorithms to discover novel and high-performing results within a given design system. Its framework is dependent on three main components: 1) a generative geometry model that defines a 'design space' of possible design solutions; 2) a series of measures or metrics that describe the objectives or goals of the design problem; 3) a metaheuristic search algorithm such as a genetic algorithm which can search through the design space to find a variety of high-performing design options based on the stated objectives. Generative design (GD) belongs to a wider ecosystem. It is preceded by a phase we call 'pre-generative design' (pre-GD) and followed by one called 'post-generative design' (post-GD)."* (Lorenzo Villaggi and Danil Nagy (2020) https://www.autodesk.com/autodesk-university/article/Generative-Design-Architectural-Space-Planning-2020)

In this regard, we will emphasize through the following statement to develop an understanding of the generative approach for solar control of urban spaces.

2-1-Generative methods of solar control

The generative approach of solar control includes both of the following methods; the descriptive method and performance method.

2-1-1-The descriptive methods

The descriptive methods are focused on the study of the geometrical parameters of solar access, excluding the energy related to it. These methods that can be graphic or numerically aided are emphasized on the computation of solar trajectories and obstruction angles. The descriptive methods are useful in estimating the geometry of the constructions and their realization. Through this section, we will see some applications of the descriptive method related to of the purpose of this study.

- The section lines to keep solar rights

Capeluto, Yezioro, Tamar Bleiberg and Edna Shaviv (PLEA,2006), introduced a simple design tool for taking solar rights in urban design that permits the creation of building outlines safeguarding solar rights of each adjacent building, as well as the exposed areas between them, by employing the idea of section lines. The section lines recognized for the descriptive method are focused on the solar envelopes that were generated conferring to the needed hours of insolation for each direction. The section lines characterize the critical (lowest) sun angle for the time period required. Constructions that are lower than these section lines will not block solar rays mainly throughout the needed hours. The procedure of these section lines is diverse for maintaining solar rights of each edifices, sidewalks or public open spaces.

The section lines angles for each direction permit the clear description of building elevations. The base point of the lines has to be at the lower part of the housing floor (See figure 3.17). This indicates that in vital areas, where lower floors may be employed for commercial purpose the base point of the section lines will increase up, and allowing higher constructions.

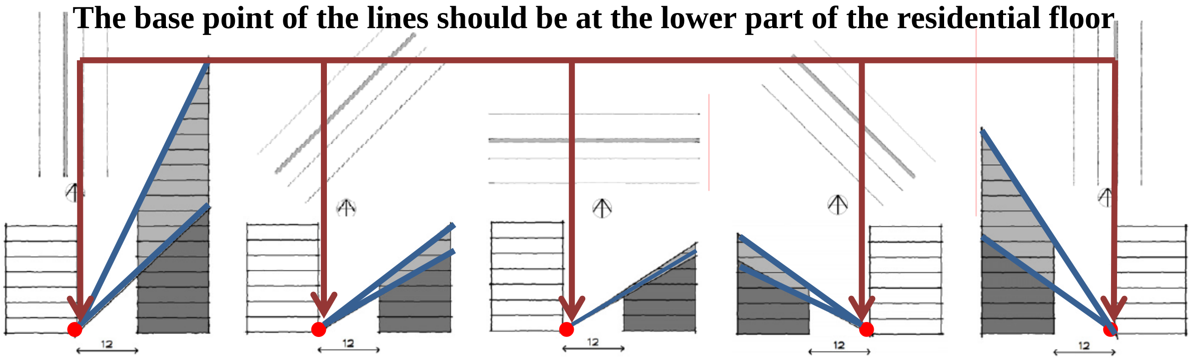

The base point of the lines should be at the lower part of the residential floor

Figure 3.17: Building heights allowed in differently oriented streets in Tel Aviv for keeping solar rights of building’s façades. The distance between buildings is 12m. The first floor is residential. The dark spot is for the peripheral areas and the light one is for the central areas. Capeluto,Yezioro, Tamar Bleiberg and Edna Shaviv (PLEA 2006)

The application of the section lines for sidewalks is similar to the buildings, but the base point has to be located one or two meters from the building (See figure 3.18).

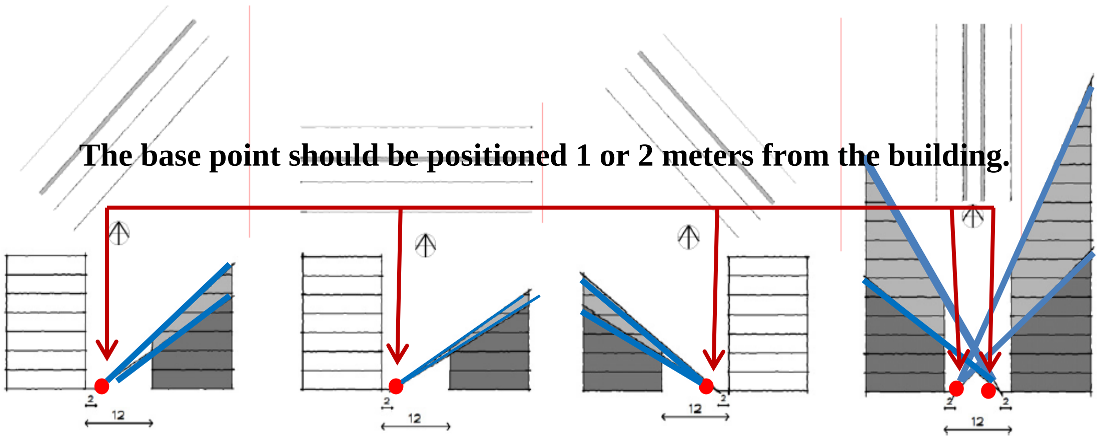

The base point should be positioned 1 or 2 meters from the building.

Figure 3.18: Building heights allowed in differently oriented streets in Tel Aviv for keeping solar rights of sidewalks. Capeluto,Yezioro, Tamar Bleiberg and Edna Shaviv (PLEA 2006)

The application of the design tool for preserving solar rights of open spaces is more intricate than for walkways and constructions (See figure 3.19). This is owed to the fact that the buildings bound the open areas from all orientations. Safeguarding solar rights of open areas is fulfilled in three stages as follows:

a. Determining the area that require to be exposed to sunlight in the North-East and North-West side of it. This would be a triangle with the surface of 30% (for central locations) or 40% (for peripheral locations) of the exposed area. The triangle's hypotenuse should be parallel to the open space's diagonal.

b. Describing the base points for the section lines in the central of the triangle's hypotenuse.

c. Generating the section lines from the base points, employing the angle of the south to border the buildings on the east, south and west sides of the area.

In cases where the exposed spaces are situated 45^0 from the principles directions, there would be only single triangle in the north, and the section lines of the south would border the edifices on the south-east and south-west sides.

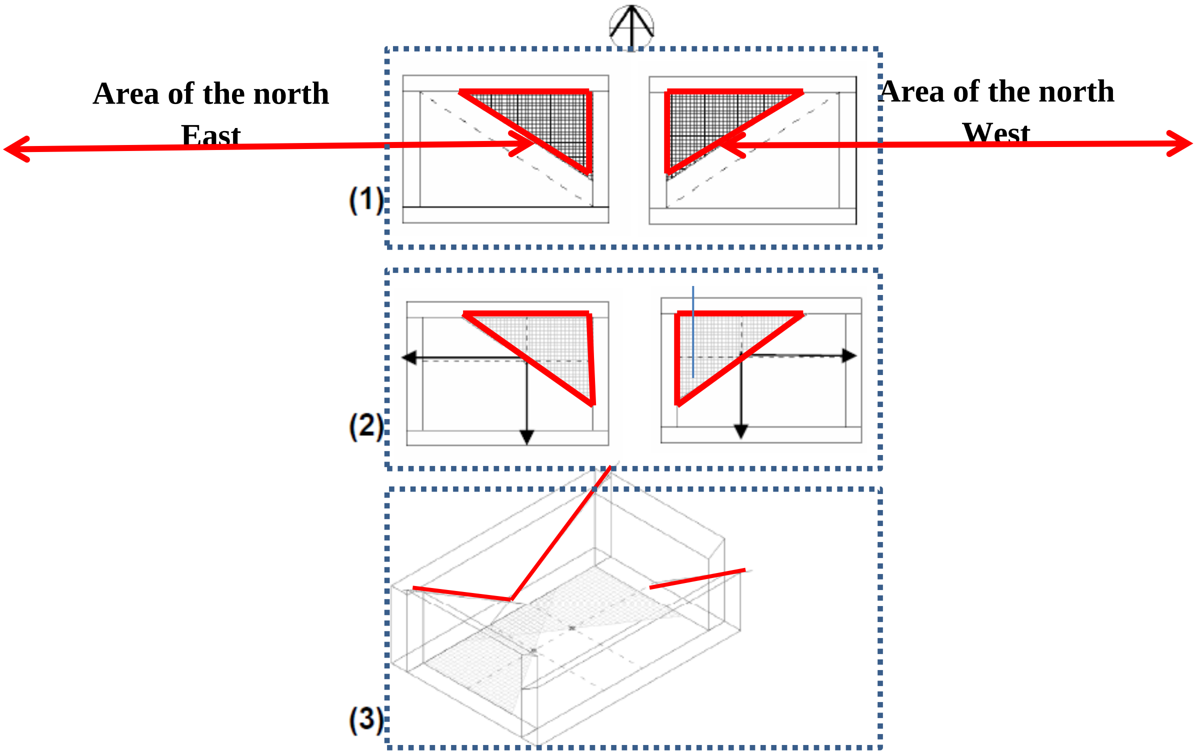


Figure 3.19: Three steps of keeping solar rights in open spaces: 1)defining the area of exposure, 2)defining base points for section lines, and 3) limiting building heights on the east , south and west sides. Capeluto, Yezioro, Tamar Bleiberg and Edna Shaviv (PLEA2006).

The findings revealed that regulating buildings elevations employing the proposed section lines could leads to realize quite high Floor Area Ratio (FAR) rates in all directions, while permits the sun exposure needed.

- Obstruction angles

The obstruction angles utilization has been considered as a device of town designing regulation and a factor for architectural design performance. In Northern Europe, the obstruction angle model has widely been employed as an architectural design tool for designing houses since 1920`s.The aim is to fulfill sun penetration to the habitable rooms through windows; the problem being to confirm that a block is not overshadowed by it's adjacent. This is why it is very important to provide as much sunlight as can be for the buildings of countries that characterize with less solar rays.The obstruction angle should then be designated in agreement with the sun path, the relevant latitude, direction of the buildings, and time of year. According to William Fawcett (1983), the non-sun-starved regions, which are located at lower latitude, can apply the steeper obstruction angle model (α) of 76^0, 63^0, and 45^0 that are identical to the aspects ratios (A) of 4, 2, and 1 respectively.

Evans (1980) produced the following table (2.4) which gives for each type of climate depending on the latitude, the minimum angle of obstruction between two opposite buildings. The interest of this table (3.4) is its consideration of different types of climates (S.Mazouz 2007).

Table 3.4: The empirical rules of Evans (S.Mazouz (2007), p.181)

Climate	Latitude (^{0})	Minimum angle of obstruction
Hot and Wet	0-10	40
Composed	15	45
Composed/Desert	20	50
Mediterr/Desert	30	45
Mediterranean	35	40
Mediterr/Temperate	40	35
Temperate	45	30
Temperate	50	25
Temperate Cold	60	22

According to Littlefair (1998), setting criterion values for obstruction angles appears instinctively clear however, there are three difficulties:

a) - Selecting a date and time.

b) - Identifying the angle of measurement

c) - The final subject is that of facade direction.

For this cause, Littlefair (2001), has employed the idea of regulating obstruction height inside a specific angular region on plan .The most significant surface to safeguard lightly obstructed is in 30^0 either side of due south of a solar collecting façade (See figure3.20).

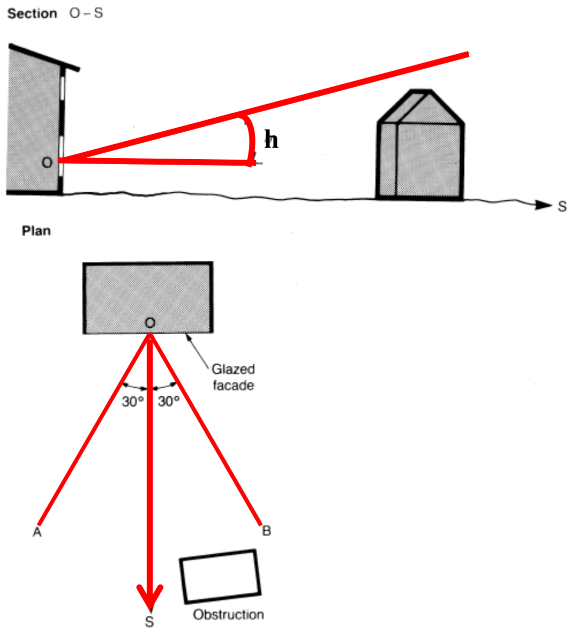


Figure 3.20: For passive solar gains in winter the sector AOB 30^0 either side of due south is important. To guarantee winter sun from this sector obstruction within it should not subtend more than the critical angle h when measured in section (Littlefair 2001, p184)

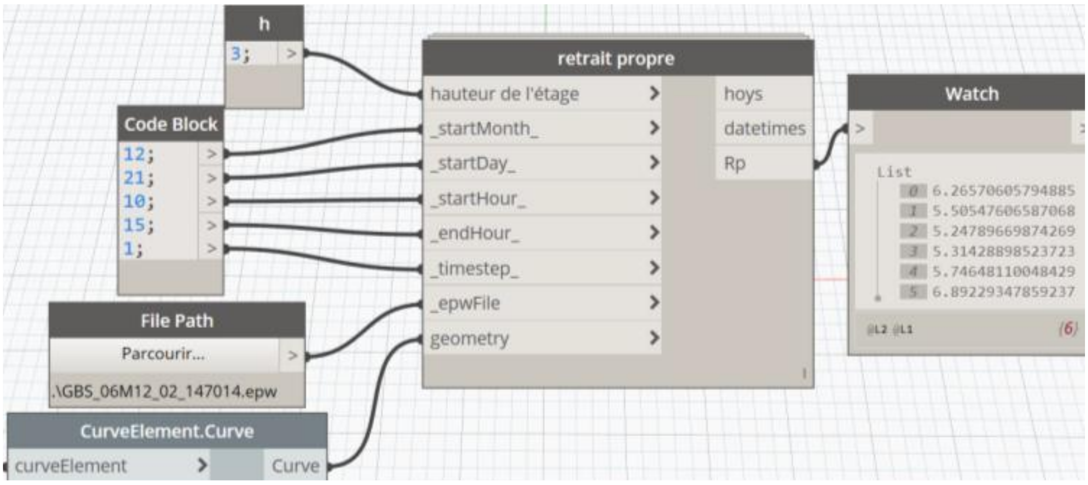
According to S.Mazouz, and S.Zeroula (1999), to safeguard shading requirement the obstruction angle of a representative street should have a range of values that avoid solar rays from penetrating the street throughout the overheated period. For such aim, several values of obstruction angles had been investigated for warm arid climate (mean latitude of 32^0) (See table3.5). The results of the simulation demonstrate that a range of spacing angles of 60^0 to 70^0 seems to be the best answer in warm arid climate.

Table3.5: The effect of angle of obstructions on sun ray's penetration for hot arid climate (Author -2018-according to S.Mazouz, S Zeroula -1999-)

A mean latitude of 32^0;most of the ksours being located between latitude 31^0 and 33^0	
angles of obstruction	**Sun ray's penetration**
45^0	Undesired sun of the overheated period from May to October
55^0	August for 03hours, June and July for 04 hours.
60^0	August for 02 hours, June and July for 04 hours.
65^0	03 hours in June, 01 hour in July, less than hour for august
70^0	Prevents sun rays penetration in all times except June for a less than three hours.

- Prospect strategies of solar rights

By the using of parametric tool Dynamo, Laila Koubaa et al (2018) define prospect strategies with modalities that preserve solar rights of each building and spaces surrounding them (See figure2.21). Laila Koubaa (2018) distinguishes twofold prospect strategy. The first one concerns the appropriate withdrawal, to limit the shade in the parcel during a shade cut-off time. The second one concerns the proper withdrawal mutualized by negotiation between neighbors optimizes solar potential, and density (See figure2.22).



```
3;
```

```
12;
21;
10;
15;
1;
```

```
List
  0 6.26570605794885
  1 5.50547606587068
  2 5.24789669874269
  3 5.31428898523723
  4 5.74648110048429
  5 6.89229347859237
```

Figure (2.21): Component for the calculation of the proper withdrawal on Dynamo (Laila Koubaa et al (2018), p5)

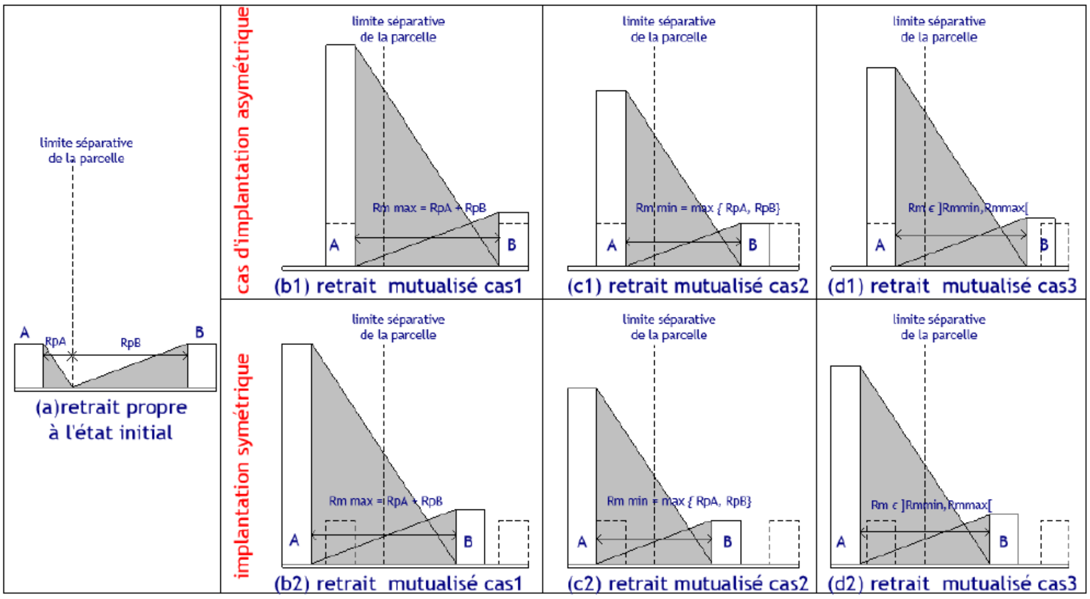
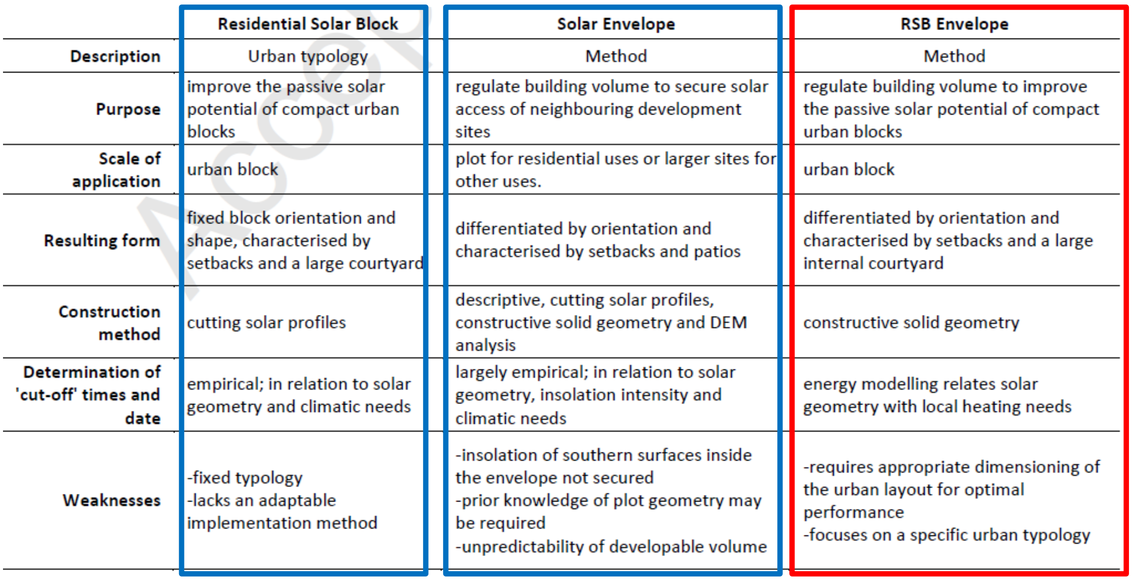


Figure (2.22): Strategies for calculating the proper withdrawal mutualized between two parcels A and B. (symmetrical implantation variant and asymmetrical implantation variant) - Laila Koubaa et al (2018), p.8-

-Building volume and solar rights

Aristotelis Vartholomaios (2015) inspired from the works of Knowles on solar envelopes and Okeil on the Residential Solar Block (RSB) typology to suggest the RSB envelope (See table3.6). Therefore, the suggested RSB envelope is derived from the solar envelope that allows the universal application of the RSB typology in high-density housing and mixed residential quarters. It keeps the insolation of southern building surfaces both outdoor and indoor of the urban block. This is accomplished through the integration of solar envelope and solar fan[1], or in some cases solar fans, in which the solar envelope assures solar rights of the surrounding blocks, whereas, solar fan assures solar access for the building itself by avoiding block self-shadowing. A constraint of the RSB envelope is that it can be accurately applied where blocks and streets have right proportions and form. These restrictions are not common, but rather depend on the development context and local climatic. According to Aristotelis Vartholomaios (2015) the use of RSB envelope in a Mediterranean city reveals that the building layout created by the RSB envelope outperforms by far the present building layout in terms of captured winter insolation.

Table3.6: Comparison between Okeil's RSB, Knowles' solar envelope and the proposed RSB envelope.
Aristotelis Vartholomaios (2015), P7



	Residential Solar Block	Solar Envelope	RSB Envelope
Description	Urban typology	Method	Method
Purpose	improve the passive solar potential of compact urban blocks	regulate building volume to secure solar access of neighbouring development sites	regulate building volume to improve the passive solar potential of compact urban blocks
Scale of application	urban block	plot for residential uses or larger sites for other uses.	urban block
Resulting form	fixed block orientation and shape, characterised by setbacks and a large courtyard	differentiated by orientation and characterised by setbacks and patios	differentiated by orientation and characterised by setbacks and a large internal courtyard
Construction method	cutting solar profiles	descriptive, cutting solar profiles, constructive solid geometry and DEM analysis	constructive solid geometry
Determination of 'cut-off' times and date	empirical; in relation to solar geometry and climatic needs	largely empirical; in relation to solar geometry, insolation intensity and climatic needs	energy modelling relates solar geometry with local heating needs
Weaknesses	-fixed typology -lacks an adaptable implementation method	-insolation of southern surfaces inside the envelope not secured -prior knowledge of plot geometry may be required -unpredictability of developable volume	-requires appropriate dimensioning of the urban layout for optimal performance -focuses on a specific urban typology

Residential solar block **Solar envelope** **Residential solar block envelope**

---

[1] Solar fans mainly display the volume that should be clear of shading in order to offer solar access to a test area for a specified set of sun vectors. Solar fans are typically used to safeguard solar access for park vegetation in the midst of wide developments created around it. It can be also used to safeguard solar access for windows that might want to use the sun for heating for certain hours of the year (Ladybug 0062).

The building process of the residential solar block envelope is the following (See figure3.23):

1. Creation of solar volumes by extruding the surrounded surfaces through the tops of the surrounding building blocks. Concerning the period and the number of times, the surfaces were extruded once per each direction of the solar rays vector at the beginning, the middle and the end of stated time.

2. Surfaces which are surrounded by the front and back building line of the investigated block (at the maximum allowed height) are vertically extruding in order to produce the gross block volume.

3. Boolean connection of the four volumes formed in step (1) and (2).

4. The creation of the solar fan (or fans if necessary) which has the ability to avoid self-shading of the block. Almost cases only one solar fan is effective to ensure solar access of the southern areas directing the courtyard.

5. Removal of the solar fan(s) from the solid created in step (3). If no surfaces lacking insolation are indicated so phases (4) and (5) are omitted.

6. Correction of the created solid so that in any point of the buildable area a minimum elevation is guaranteed. A volume is created by vertically extruding the buildable surface at a minimum elevation and is added to the solid created in step (5). This minimum elevation depends on the aspect ratios (W/H) Width-to-Height of the adjacent street segments.

7. As a last elective stage the created solid can be elevated overhead a limited elevation employing a supplementary ‘solar fence’ when sun penetration to the ground level of nearby blocks is not needed.

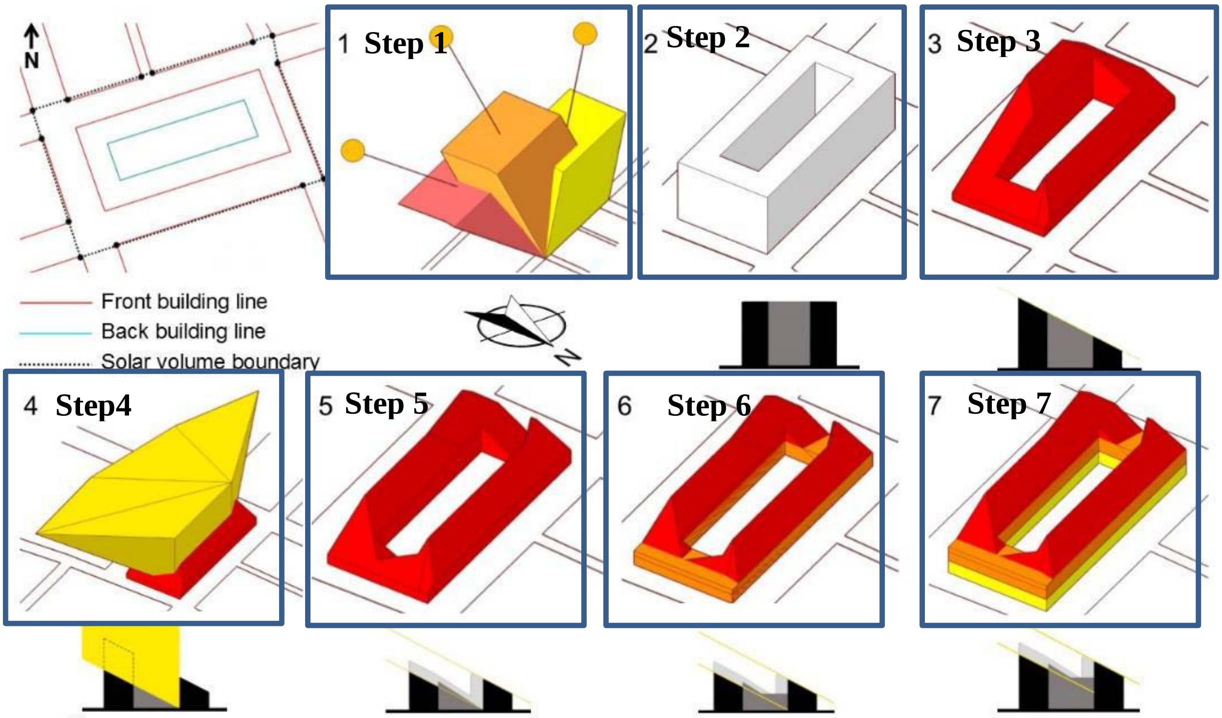


Figure 3.23: The RSB envelope construction steps (Aristotelis Vartholomaios (2015), P10).

2-1-2-The performance methods:

The performance method is the method that clarifies the supplies that should be met such as the number of insolation required, elucidated for example in Constantine.

-Genetic urban design algorithm of solar control

In order to guarantee a sufficient solar access at the street level, Marko Jovanovic (2016), applied a genetic algorithm for urban design and planning that joins parametric design tool within Rhino-Grasshopper software overall with sustainable design analysis software Ecotect. The linking between the parametric software Rhino-Grasshopper and performance analysis software Ecotect is elaborated by Grasshopper add-on, Geco that deals data between both of programs suitably. The algorithm is applied with twofold purposes; first to evaluate the impact of geometrical parameters of urban street (width to height ratio, corner height ratio, and floor space index) on solar access, second to improve these parameters until increasing the daily average sun hours on street level. The algorithm is relevant to all geographical locations and climate areas, offered with proper weather file. Applying such a process in the initial phases of urban planning can help the design of all of the related buildings, in terms of solar rights. The algorithm confirmation is shown through a case study application approach. A small urban portion of Grbavica, situated near the town centre of Novi Sad, Serbia is selected for the application of the previous workflow.

The insolation assessment of the present state of Grbavica, including four buildings, bounding streets and adjacent buildings, displays that the daily amount of sunlight periods for this section is averaging at about 2.5 hours. Complemented by the section's south direction deviation of 35 degrees, almost of these streets are not receiving suitable or some sunlight hours, mainly throughout the winter, as can be perceived in the certain parts, shaded in blue colour (Figure3.24).

Applying the algorithm on the unoccupied portion disposition, the urban planning optimization (Figure3.25) offers a resolution that produces an average of 4.8 average sunlight hours daily, which is an increase of 2.3 daily averages of sunlight hours.

Figure (3.24): Grbavica current state analysis grid (Marko Jovanovic,2016, P.37)

Figure (3.25): Grbavica optimal parcel disposition and building analysis grid (Marko Jovanovic, 2016, P.37)

-Parametric solar envelope:

Isaac Guedi Capeluto and Boris Plotnikov (2017) introduced the idea of parametric solar envelope as an enhanced tool for reconciling between safeguarding solar rights of each building and spaces bounding them, while reaching greater built density. According to Capeluto and Plotnikov (2017),

> "*The calculation of the parametric solar envelope starts off with a question for which conditions do we want or need to allow direct sun access? The parametric solar envelope presented a flexible and advanced filtering mechanism based on specific requirements throughout the year such as weather data, site geometry and mixed programmatic requirements, horizontal incidence angles of sun vectors which can be neglected when they are large due to the insignificant benefit they may have on solar access and total radiation collected on the facade and the potentially significant*

reduction on the resulting SV" (Capeluto and Plotnikov -2017-P.1-4). (See figures3.26; 3.27).

In order to make the suggested workflow largely obtainable, it is free like an open source tool as part of the Ladybug analysis tools suite in Rhino/Grasshopper Isaac Guedi Capeluto and Boris Plotnikov (2017).

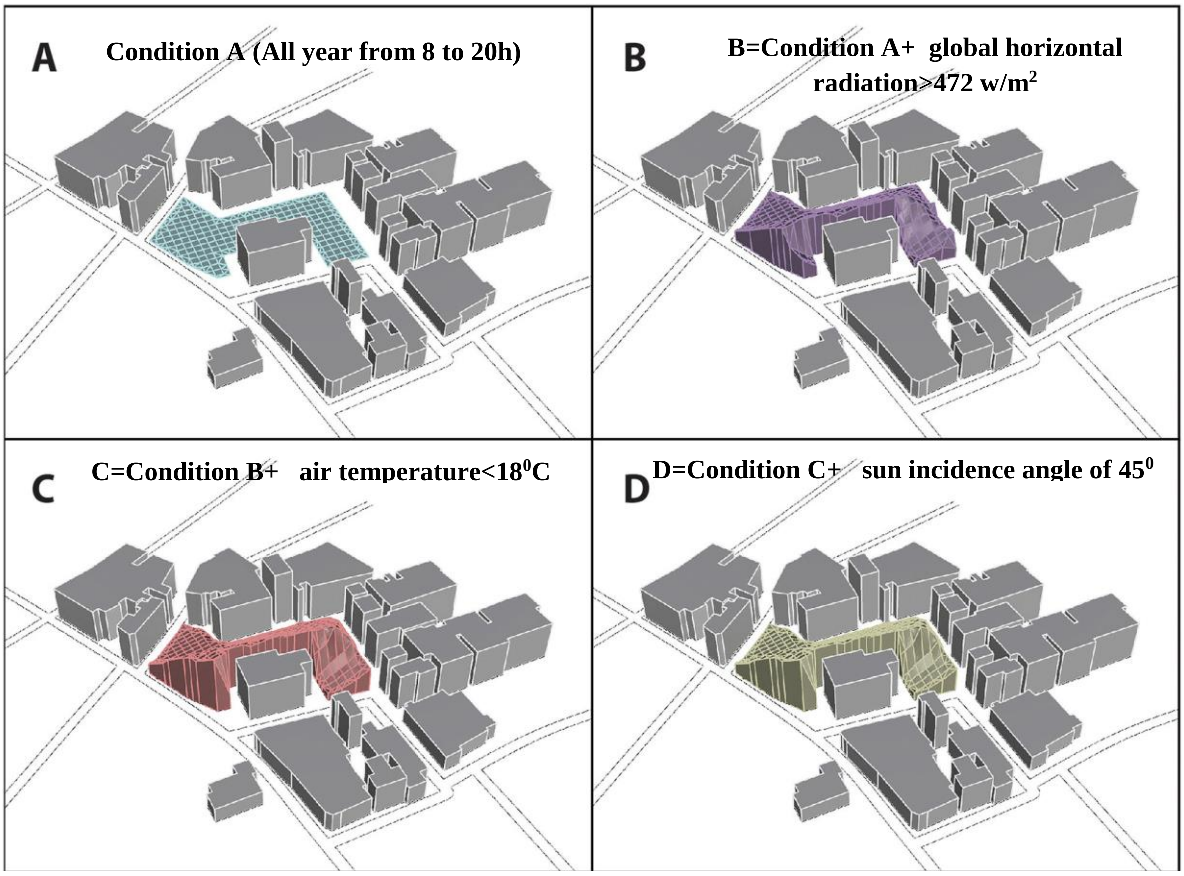


Figure3.26: Four simulated solar envelops s showing the change and increase in total developable volume as the initial criteria is refined (Isaac Guedi Capeluto and Boris Plotnikov 2017, p.11)

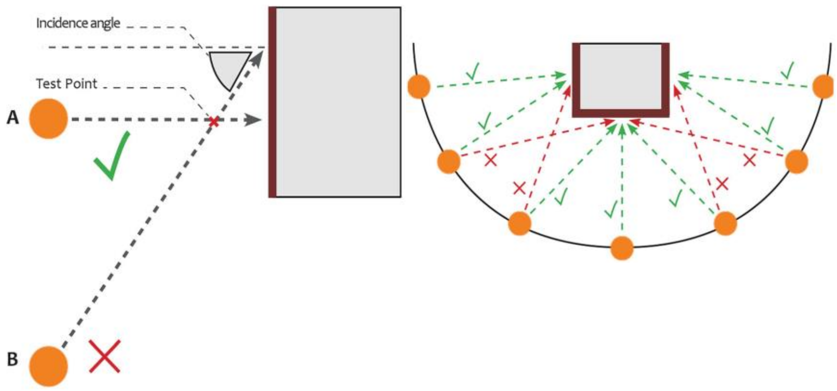


Figure (3.27): Filtering out suns whose impact is insignificant as a function of a large

(Isaac Guedi Capeluto and Boris Plotnikov 2017, p.7)

2-2-Generative methods of shading control

Rohinton (1993) hypothetically advanced the idea of shadow umbrella for radiation-reduction in the outsides throughout the day. In order to reply to the necessity for high density living and mitigate the urban heat island, the shadow umbrella is developed as an urban mass model for thermal comfort in the equatorial tropical (See figure 3.28).

This urban mass is generated by CAD software (Microstation) founded on the computation of shadow angles throughout a scheduled cut-off time. In order to guarantee shading requirement of a surface, the deepest shadow angles of all directions are selected to limit the minimum summit of the edifices around the area to shading.

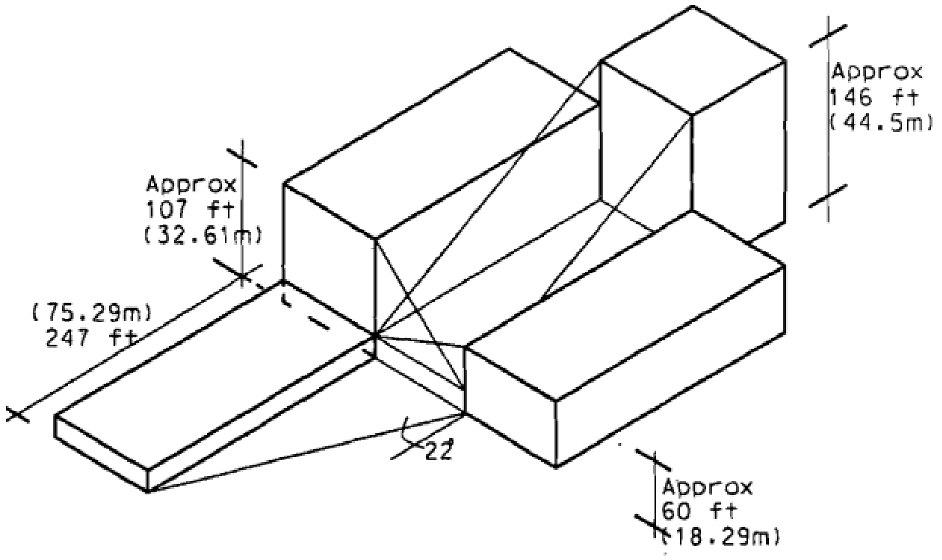


Figure 3.28: Total shadow construction for a commercial block (cut-offis8am). The north and east are to be covered with tall buildings; the south is to have medium-high buildings; the south-west could be open.

(Rohinton Emmanuel (1993), p.180).

I.Guedi Capeluto (2003) advanced the idea of self-shading envelope to elude the sun's perception throughout summer period. The application of the self-shading envelope is pertinent for buildings where the designer decided to fulfill a self-shading geometry for a needed period. The required period is the time in which the edifice must be self-shaded. The designer has to define the length of the needed period of self-shading conferring to climatic and programmatic reflections. The self-shading envelope can also be employed at an urban level with the aim of defining the outline of the streets to get shadowed sidewalks and facades through a needed period at summer.

William Suyoto, Aswin Indrapratha, Heruw Purbo (2014) used a parametric approach to regulate shading in the design of office tower in Kebayoran Lama Jacarta. Likewise parametric tool Grasshopper is employed to inscribe an explicit formula which takes into account legal parameters of building's massing (Building Coverage Ratio, Floor Area Ratio, Building Setbacks, Road setbacks, clearance between buildings), and shading between buildings. This method permits the urban designer to pursue the potential of nearby building's shade in generating a comfortable environment in project's site.

2-3-Generative methods of solar and shading control

2-3-1-The inverted approach: solar access for pedestrians

Estefania Tapias, and Shubham Soni (2014) suggested a method for adjusting solar access, like the 'solar envelope', however for eluding shading in prospective amusing open areas, rather than evading shading for nearby buildings. The method named 'inverted' approach is advanced by means of parametric modeling in Rhinoceros-Grasshopper, where a set of constituents are settled in order to create urban envelopes founded on the 'inverted' method.

This method is proposed for urban areas under development, as the final purpose is to generate conceivable spaces for future urban densification founded on the creation of urban open spaces that improve pedestrian outdoor comfort. Therefore, the case study for the application of the method was the Thälmann- Park in the centre of the Prenzlauer Berg district in Berlin.

The diverse processes discovered for the 'inverted' approach method are founded on generative and parametric modelling techniques that permit the systematic foundation of novel urban forms conferring to several solar access and urban limits criteria. According to these criteria, the method is organized on **three successive stages;**

The first part of the method attempts to institute a ground-level geometry of the conceivable building spaces conferring to the bound space between buildings and on the urban block limits (city normative). This is achieved first by taking the urban block surface as a surface for possible extensions. Subsequently, determining the least distance between building (city normative) from the existing buildings and extracting this surface from the urban block area. At this point, a region for possible future expansions is generated as shown in figure (3.29).

The second part is focused on the execution of the shadow range analysis for the both of solstices summer and winter. The area of winter solstice shadow range is presented by blue color,

While the red color revealed summer solstice shadow range (See figure 3.30).The modelling simulation has been done by employing parametric tool Rhinoceros-Grasshopper and Geco that is a practice constituent for Grasshopper that provides a direct association between Rhinoceros Grasshopper models and Autodesk Ecotect.

Finally, the area which has shadows during summer but not during winter is selected to be the surface of future urban densification. Afterward, this latter will be extruded according to the city normative (maximum height of the building) (See figure3.31).

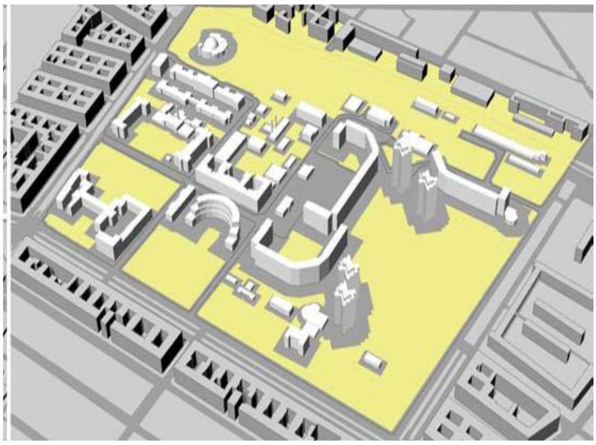


Figure3.29 : Delimitation of development areas

(Estefania Tapias,and Shubham Soni (2014),p.131)

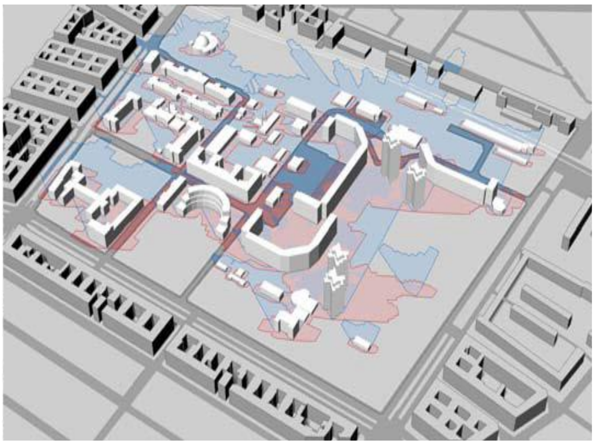


Figure 3.30 : Shadow range generation, (blue) winter solstice shadow range and (red) summer solstice shadow range.

(Estefania Tapias,and Shubham Soni (2014),p.132)

Figure3.31: Selection of recreational urban areas and generation of volumes for future densification.

(Estefania Tapias,and Shubham Soni (2014),p.133)

2-3-2-The morphological generator of urban rules for solar control

Khaoula Raboudi, and Abdelkader Ben Saci (2017), used a parametric design tool Rhinoceros-Grasshopper to create a constituent of morphological generator of urban rules for solar control (See figure 3.32). The generator is founded on a modeling approach of the solar control volume. This volume is constrained by the shading envelope rules and the solar envelope rules. The shading envelope is the lowest volume to shade the nearby buildings through overheating hours in summer. The Solar envelope is the supreme volume to keep the sunshine of the adjacent buildings throughout beneficial hours in winter. Hence, Khaoula Raboudi (2017) suggested a methodology for incorporating solar control purposes (solar access and shading) in the design procedure of the built environment morphologies and the institution of urban rules. Moreover, the generator offers urban planners with one or more optimum volume(s) that assist as a medium for the creation of urban morphological rules for solar control in a specified geographical, climatic and urban context. It also offers architects with optimum solar control keys.

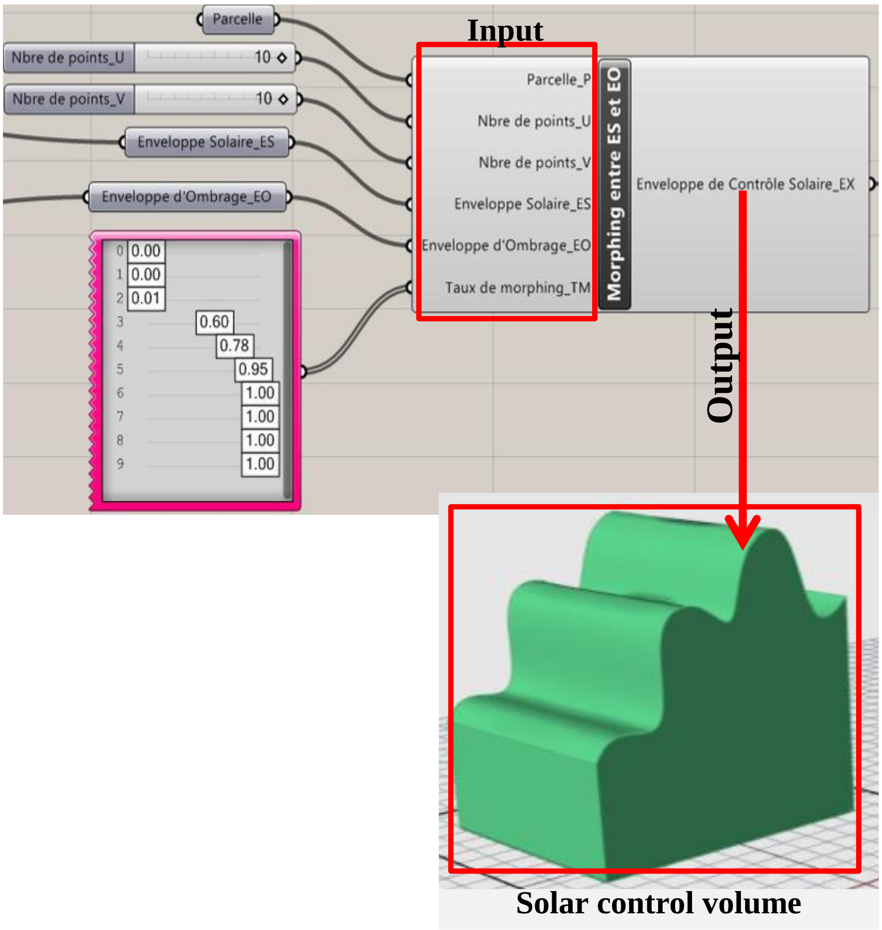


Figure3.32: Component of solar volume control
Khaoula Raboudi and Abdelkader Ben Saci (2017), p.154

2-3-3-ComfortCover model

The ComfortCover model is presented by Christopher Mackey et al (2015), in order to offer a high-accuracy proposal of where outdoor shading should be delivered, and where it should be evaded. The ComfortCover model starts by evaluating the radiation dropping on a person and calculating solar-adjusted radiant temperature for all hours of the year. Afterward, this temperature is put in an hourly calculation of Universal Thermal Climate

Index (UTCI). Lastly, this UTCI is put in an algorithm that projects sun vectors for each hour of the year from the location of an individual over an area where shade design is being reflected. Every vectors is allied with a UTCI, and a temperature change from a “Comfort temperature” that is anticipated up for each division of the test shade to color it with shade helpfulness (blue), shade harmfulness (red) and no main of shade (See figure3.33). Christopher Mackey et al (2015) combines the above-mentioned stages together by incorporating them over the Grasshopper visual scripting platform, making all phases accessible as a distinct Grasshopper module (See figure3.34).

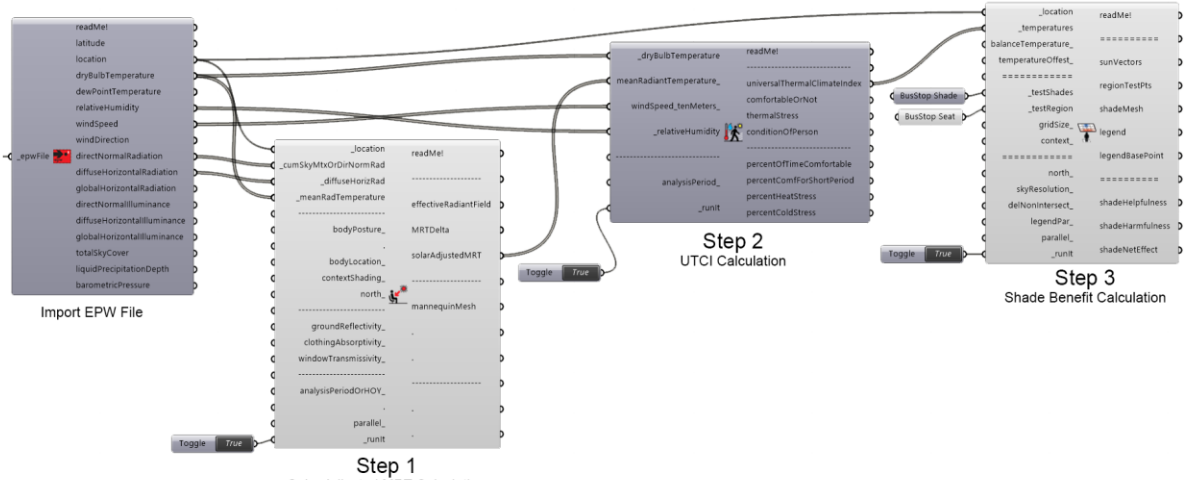


Figure3.34: The component-based interface of the ComfortCover workflow.
(Christopher Mackey et al (2015).

Recapitulation

In this section, we have reviewed some generative methods under the constraint of solar rights or shading requirements of urban spaces (See table 3.7). These methods aim to determine the proper geometrical parameters of urban spaces and to generate optimal urban forms that enhance outdoor thermal comfort. The overall method used is based on the modeling and evaluation of a small sample of theoretical configurations and hypothetical forms. These forms are not related to an existing city. They are used in the context of a prospective work. Through this section, we have also perceived that few studies have stressed both the importance of shading during hot periods as well as the number of insolation needed to warm people in colder conditions. Nevertheless, solar rights and shading requirement of the built environment depend on the latitude of the climatic zone. Therefore, it is mandatory to take into account the both constraints (solar and shading) throughout the earliest stage of the design process to reduce the unwanted solar gain peaks in summer on one hand ,and to curb cool conditions of cold climates during winter time on the other hand.

Table. 3.7: The main generative approaches of solar and shading control (Author,2017)

Generative approaches	**Solar control**		**Shading control**	**Solar and shading control**	**Bibliography**
	Descriptive	**Performance**			
Section lines	●				Yezioro Tamar and Edna Shaviv (2006)
Obstruction angles	●				William Fawcett (1983) Evans (1980) Said Mazouz and Zeroualа (1999) Littlefair (1998)
Prospect strategies	●				Laila Kobaa and Ben Saci (2018)
Residential solar block envelope	●				Aristotelis Vartholomaios (2015)
Genetic urban design algorithm of solar control		▲			Marko Jovanivoc (2016)
Parametric solar envelope		▲			Guedi Capeluto and Boris Plotnikov (2017)

Shadow umbrella			⬬		Emanuel Rohinton (1993)
Self Shading envelope			⬬		I.Guedi Capeluto (2003)
Inverted approach				⬢	Estefania Tapias and Shubham Soni (2014)
Morphological generator rules for solar control				⬢	Khawla Raboudi And Ben Saci (2017)
ComfortCover model				⬢	Christopher Mackey et al (2015)

3- Workflow of evaluative and generative approaches (the analytical model adopted)

After reviewing on approaches and methods of solar and shading control of urban spaces in the previous sections of this chapter, it seems essential to us to establish our method of analysis. According to Boucheriba (2017), in Algeria recent prospect urban rules are not established according to a climatic analysis which covers all the national territory. To overcome the uncomfortable conditions caused by their application, recent prospect urban rules must be evaluated and enhanced in regard to solar rights, shading requirement and outdoor thermal comfort. To achieve this aim, the present study seeks a process which deals between an evaluation method and a generative approach (See figure3.35). The first step of the process is focused on the assessment of the effect of angle of obstruction, orientation, and latitudes on solar radiation received on ground surface of urban spaces and outdoor thermal comfort during summer and winter times. However, the generative approach is based on two methods;

1-The application of parametric solar envelope to optimize the results of the first step

2- The application of the ComfortCover model to determine the urban areas for future urban densification in accordance with the desirability of shade and outdoor thermal comfort (UTCI).

This workflow is established because it integrates both the constraints of solar access and shading. The aim of its application is to offer architects and urban planners a space of forms defined from the synthesis of these two constraints. The generative algorithms of parametric solar envelope and the ComfortCover model have been chosen to be applied because we manage their application. Also, in comparison with the other methods of solar control (aformentioned in the previous sections of this chapter) the generative algorithms of parametric solar envelope and ComfortCover model, are considered as the most recent methods in the field of solar and shading control of urban spaces.

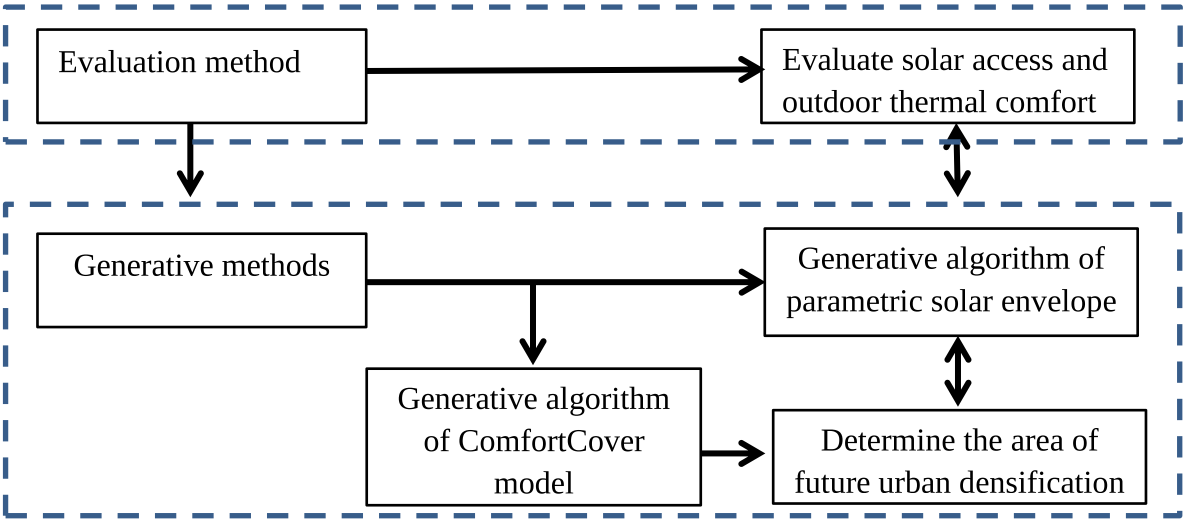


Figure 3.35: The process of the analytical part (Author,2017)

Conclusion

To overcome the discomfort conditions inside the buildings and in the space surrounding them, urban planners and designers develop many approaches and methods which take in consideration during the design phase, solar rights and shading requirement of the built environment. The methods of solar and shading control are classified according to their aim of research in tow types, such as evaluation and generative methods. The evaluation methods assess the performance of a given design. This assessment serves to understand and identify the main geometrical parameters and urban rules that influence the thermal comfort of human being. The geometrical parameters of urban spaces which influence solar access and shading are summarized in the first section of this chapter. While the second section of this chapter presents the main generative methods of solar and shading control which are classified in tow types such as the descriptive and the performance methods. The descriptive methods are based on the search of the geometrical parameters of solar access, without taking into account the energy associated with it. Whereas, the performance method is the method that describes the necessities that should be encountered such as the number of insolation required. Through the third section of this chapter the analytical process of the second part of this research is established. This process deals between an evaluation method and a generative approach.

CHAPTER IV: THE EFFECT OF URBAN STREET CONFIGURATION AND LATITUDE ON SOLAR RADIATION AND OUTDOOR THERMAL COMFORT

Chapter 4: The effect of urban street configuration and latitude on solar radiation and outdoor thermal comfort

Introduction:

After underlining the main concepts and theories related to solar control and shading in the first part of this research, we attempt through this chapter to optimize the performance of recent prospect urban rules in Algeria in accordance to solar control and outdoor thermal comfort. In this regard, the present chapter is made of two main sections. The first section is focused on the evaluation of the inadequacy of the prospect urban rules with solar radiation and outdoor thermal comfort in different climatic zones of Algeria. In order to enhance outdoor thermal comfort, a simulation of fictious fabrics by varying the values of obstruction angle of urban street canyon has been done over the second section of this chapter.

1- Modeling and evaluation of prospect urban rules in relation to solar radiation and outdoor thermal comfort

Urban areas are crucial to sustainable towns, outdoor spaces contribute to urban livability and vitality; they also ensure outdoor activities and pedestrian traffic. The use of urban spaces is largely depend on the degree of comfort sensed in these spaces (P J Littlefair et al, 2000). Solar control has an important influence on human thermal comfort. Geometrical parameters of the urban built, orientation of buildings and topology influence solar access in outdoor spaces. Solar rights and shading requirement vary according to the latitude of the climatic zone. In Algeria, unlike vernacular urban geometries heritage, which shows a real concern and perception in planning with climate, the present urban design geometry, consists of new urban rules application, which are not usually in harmony with the climatic context desired for a given region (Maatouk Khoukhi and Naïma Fezzioui, 2012). The executive decree (n^{0}91-175 of 28/05/1991) is as following:

> "*In the same property, the planned buildings must be located in such a way that the openings illuminating the living dwellings are not obscured by any part of the building seen at an angle of more than 45^0 degrees above the horizontal plane considered the support of these openings*". (Fouzia Boucheriba,2017,P.21).

Hence, the content of this decree, cannot be generalize to all the national territory, because it does not specify for which climatic zone latitude will be applied, especially for Algerian territory which has different climatic zones where the duration of insolation is different from one zone to another. Moreover there is no rigorous or even approximate climatic analysis which covered all the national territory (Fouzia Boucheriba 2017). Under these circumstances, we attempt through this section to highlight and evaluate the shortcoming of the existing prospect urban rules in comparison with solar rights and outdoor thermal comfort in different latitudes. In order to achieve this aim, a contemporary urban geometry must be analysed. The urban geometry of a town is described by a repetitive component named the Urban Street Canyon. Urban Street Canyon is known as the three dimensional spaces surrounded by a street and, the constructions that border the street (Rohinton Emmanuel 2005). Therefore an urban street canyon of obstruction angle equal to 45^0, represent a model of the recent prospect urban rules, and buildings length equal six times its height[2] will be investigated. The investigation was conducted during summer and winter periods in different latitudes related to the different climatic zones of Algeria.

1-1- Parametric modelling of urban street canyon (Using Grasshopper plugin)

Urban design and planning are under a large impact of computation and use of digital tools. Utilization of algorithms has been recognized as an effective method to sustainable development, and multi criteria optimization difficulties. Application of genetic algorithms helps in determining the best solution, by operating certain range of parameters (Marko Jovanović 2016). On this basis a Generative Algorithm Aided Design Tool (Rhinoceros/Grasshopper) has been used for this research study. Rhinoceros/Grasshopper is considered as a parametric design tool that provides a very dynamic design environment, where the designer can always discover answers by varying parameters (José Beirao et al 2012).

The investigated geometrical parameters of the urban street canyon are referenced into Grasshopper (0.9.0076) plugin. As shown in figure (3.2). The Grasshopper plug-in is considered as a visual programming tool which employs visual nods instead of written computer language code, thus simplifying the code generation and connection of parameters (Marko Jovanović 2016). The scene of Rhinoceros 5 software, allows the user to visualize the algorithmic definition of the geometrical parameters of the urban street canyon investigated (See figure4.1). In tandem, to the purpose of this study which is the evaluation and optimization of the used prospect urban rules in relation to solar rights and outdoor thermal comfort. Table (4.1) summarizes the manageable parameters for the algorithm workflow.

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[2] The building length equals six times its height to meet the dimension of an urban canyon (Fazia Ali Toudert,P75-2005-)

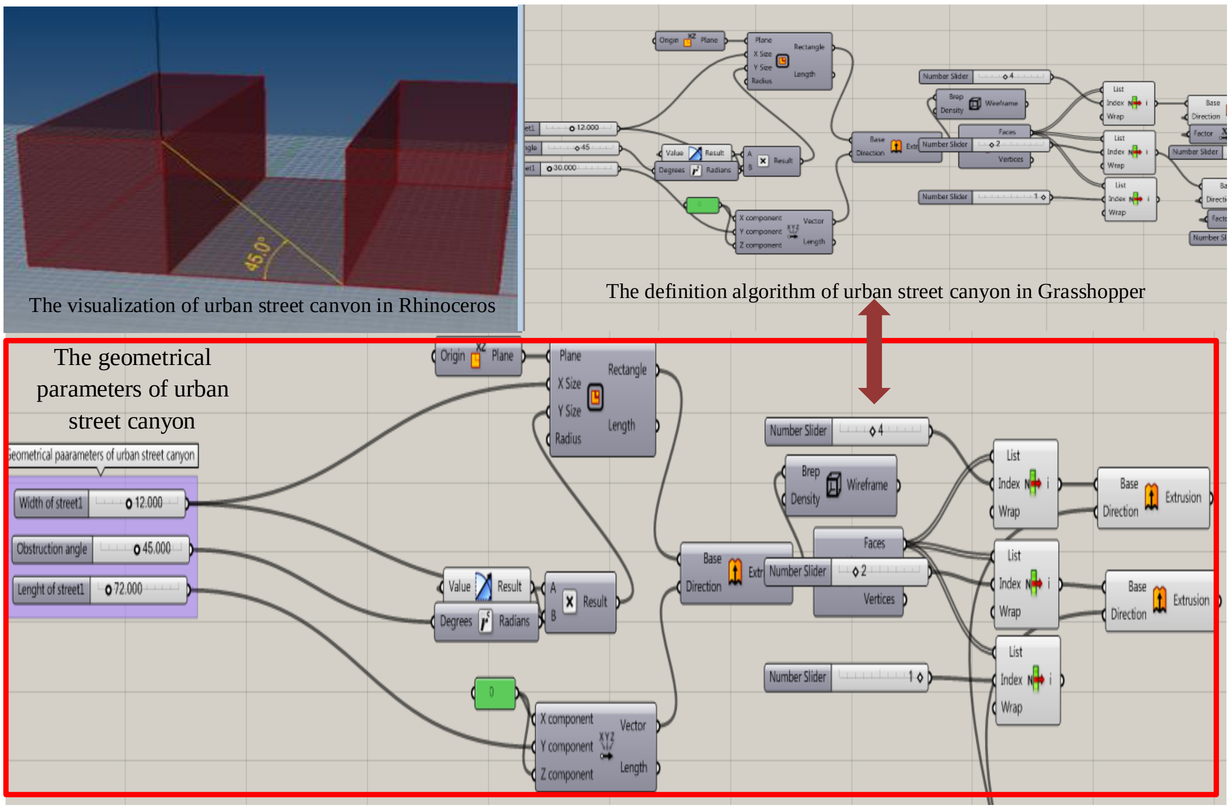

Figure (4.1): The parametric definition of geometrical profile of the study urban street canyon(Author,2018)

Table (4.1): The manageable parameters for the algorithm workflow (Author, 2018)

Parameters	Value type	Range of parameters values
Angle of obstruction (α)	Float	**α ∈[26.6^0,76^0]** (This range is chosen because it will be used in the second section of this chapter-performance simulation-)
Street width (W)	Integer	**12 m** (wide street from the thermal point of view is that can include streetscape elements to promote shading and good comfort conditions-P J Littlefair (2000)-
Building length (L)	Float	6(Building height) **6W(tang α)**

1-2- Case study:

City and climate are two systems with close interactions. The purpose of climate conscious design is to offer protection from the undesirable factors of climate and take the benefit of the helpful factors in order to decrease energy consumption and environmental effect caused by buildings design and offers thermal comfort of the dwellers. As mentioned earlier, in Algeria urban planning and design process give a little importance to urban climate and outdoor thermal comfort. To mitigate this problem, a rigorous evaluation of recent prospect urban rules must be done in association with solar radiation analysis, outdoor thermal comfort and latitudes. This evaluation has an important amenity value. Since, it helps urban designers in the formulation of adapted urban design guidelines to the local climate for the Algerian climatic zones. According to Ould Henia (2003), more than 85% of the total area of Algeria is characterized by a hot and dry climate, subdivided into three summer climatic zones (E3, E4 and E5) and a winter climatic zone divided into three sub-zones (H3a, H3b and H3c). On the other hand Said Mazouz (2007) subdivided the national territory of Algeria on four climatic zones (Marine coast, Backshore mountain littoral, Highlands, Pre-Sahara and Sahara). A.J.Arnfield (1989), and PJ. Littlefair (2000) demonstrate the dependence of the solar access within the urban street canyon on the latitude. For this research, we have subdivided the Algerian national territory into six climatic zones according to the latitude (See figure4.2). Afterward, a specimen representing each zone of analysis has been chosen see table 4.2. Furthermore, in order to visualize the climatic subdivision on the Algerian Map, and to found a geo-database which relates prospect urban rules and latitudes, a geographic information system tool[3] (ArcGis 10.3) has been used.

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[3] "***A Geographic Information System** (**GIS**) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations*" (Clarke, K. C., 1986).

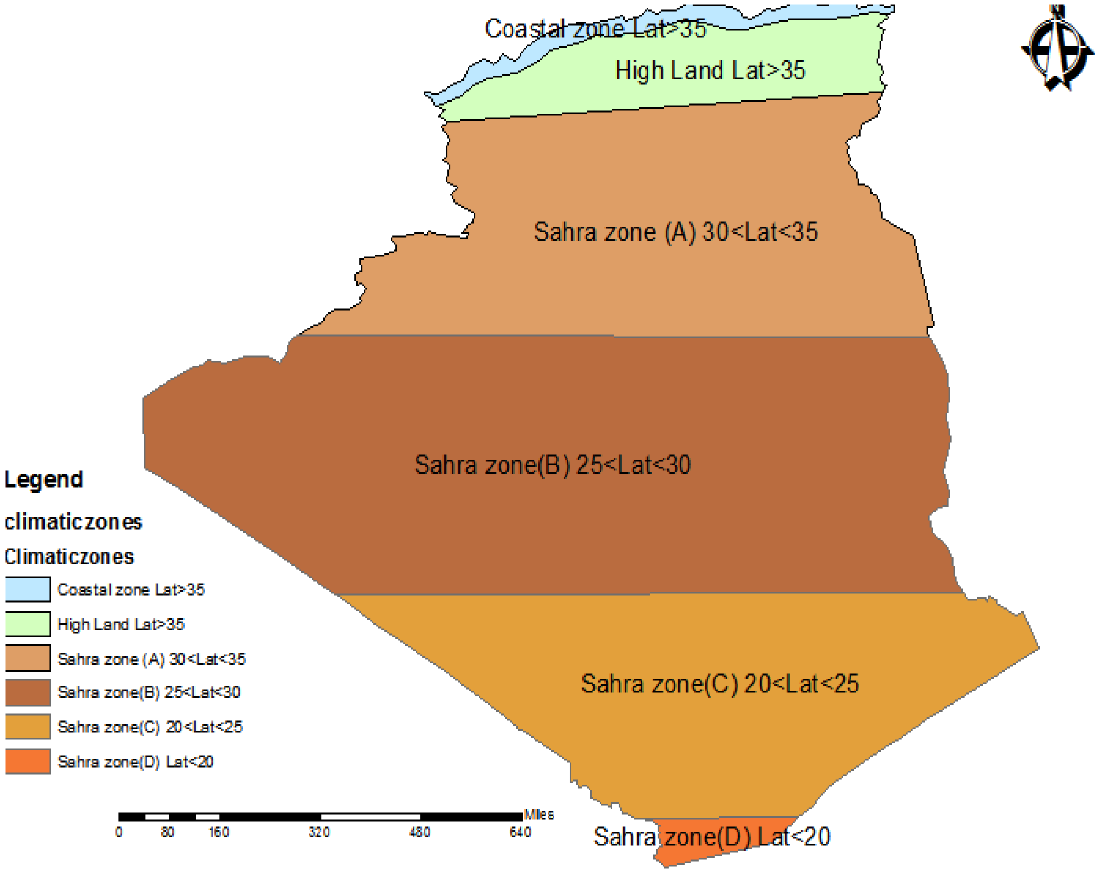

Figure 4.2: The subdivision of the Algerian national territory according to the latitudes (Author,2018).

Table 4.2: Specimens of analysis according to the latitude (Author, 2018).

Climatic zones	Latitudes	Spécimens of analysis
Coastal zone	**Lat>35^0**	**Oran**
High Land	**Lat>35^0**	**Constantine**
Sahra (zone A)	**30^0<Lat<35^0**	**Ouarguela**
Sahra (zone B)	**25^0<Lat<30^0**	**Illizi**
Sahra (zone C)	**20^0<Lat<25^0**	**Tamanrasset**
Sahra (zone D)	**Lat^0<20^0**	**Ain Guezzam**

1-3- Evaluation of solar radiation and thermal comfort in urban street canyon model at different latitude

As mentioned in the previous statement, in Algeria the accordance of prospect urban rules with solar rights or shading requirement is not confirmed by a climatic analysis which covers all the national territory. Hence, we attempt over this part to evaluate the effect of obstruction angle according to the chosen latitude on solar radiation and outdoor thermal comfort. The investigation was conducted during both seasons, summer and winter. A parametric design software (Grasshopper (0.9.0076)/Ladybug[4] (0.0.62)) was used to found the algorithmic definition of solar radiation analysis and outdoor thermal comfort assessment. This latter was added to the algorithmic definition of the urban street canyon model (See figure4.3). The developed procedure can be used for any urban environment. Weather data were obtained from Meteonorm 7.

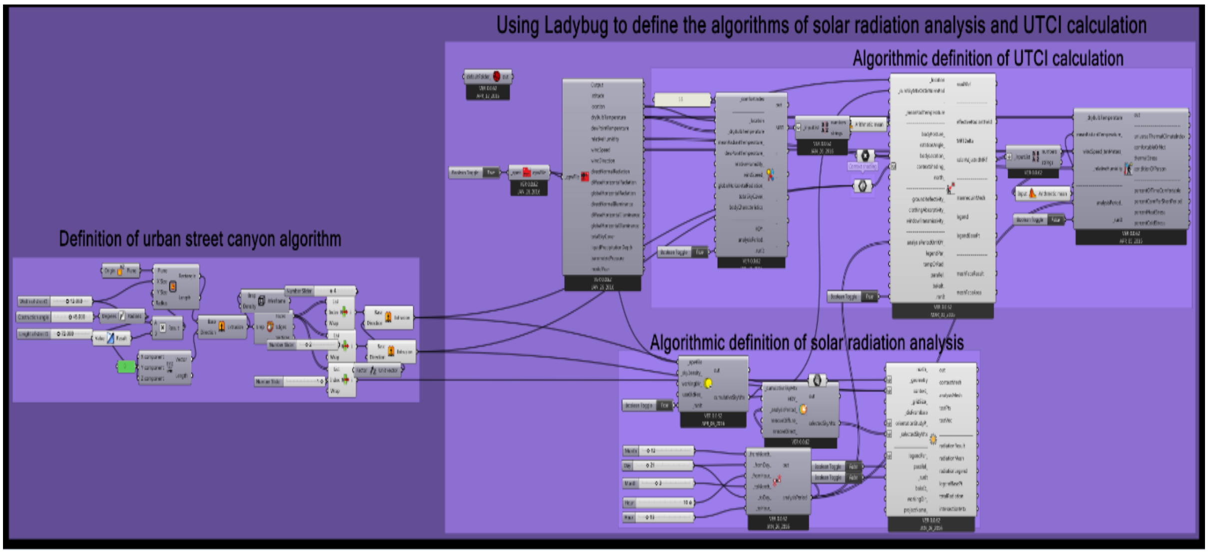

Figure 4.3: algorithmic definition of solar radiation analysis and outdoor thermal comfort evaluation (Author,2018).

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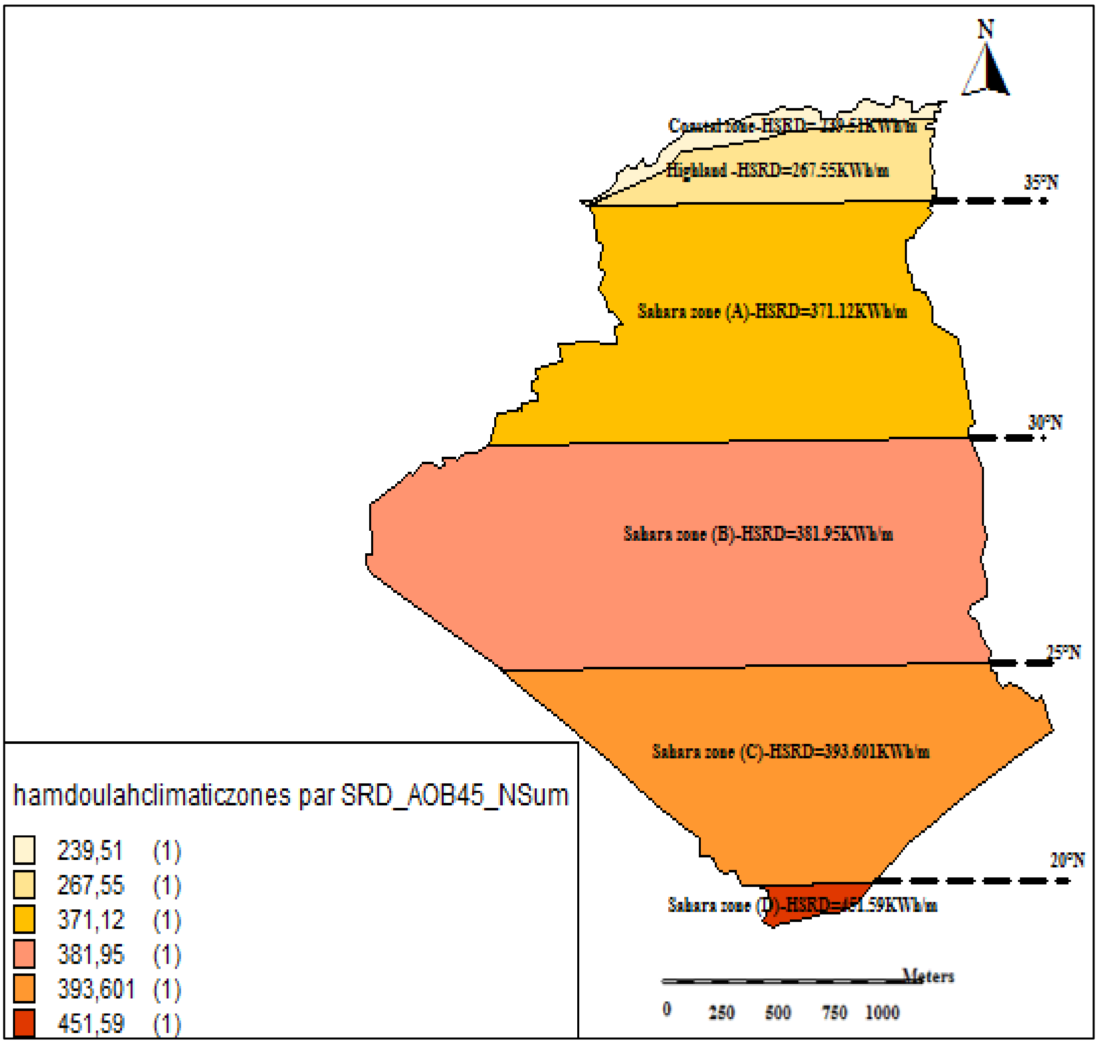
[4] *Ladybug (0.0.62) is a plug- in of the Grasshopper (0.9.0076) (graphical algorithm editor) software for generating parametric procedures. Ladybug software allows the user to discover and survey direct relationship between elements of 3D model and environmental data over numerical and graphical data* （Dragan Milošević et al, 2016).

1-3-1-Solar radiation assessment

Figures (4.4; 4.5) display the average values of solar radiation impinged on urban street canyon of OA = 45^0 (prospect of urban street mode used as urban planning rules) for all latitudes. The output of the present assessment reveal that there is a negative correlation between the latitude and the average values of solar radiation dropped on the horizontal surfaces of urban street models (OA=45^0). Hence, the previous figures display that during both of period's summer and winter the average values of solar radiation reduced when latitude increased. Since, the ground surface of urban street canyon located on the climatic zone (Sahara zone D) of latitude under 20^0 (Lat<20^0) which is presented by Ain Guezzam's weather data, is the most exposed to direct solar radiation about 451.59 Kwh/m^2 during summer period and reaching 109.58 Kwh/m^2 during winter time (See figures 4.6; 4.7). Accordingly, the ground surface of urban street canyon located in low latitude (Sahara zoneA,B,C,and D) received more solar radiation than the horizontal area of urban street situated in high latitude (Caostal and highlands). The finding of this assessment is in accordance with the results of the evaluation of the global solar irradiance carried out by the center for the development of renewable energies (André Joffre, 2013). These results confirm that the value of obstruction angle **(α)** must be given in terms of site latitude. In order to determine in which range of latitude the prospect urban planning rule (Angle of obstruction equal 45^0) is more adapted, an outdoor thermal comfort assessment must be done.



The effect of latitude on solar radiation dropped on ground surfaces

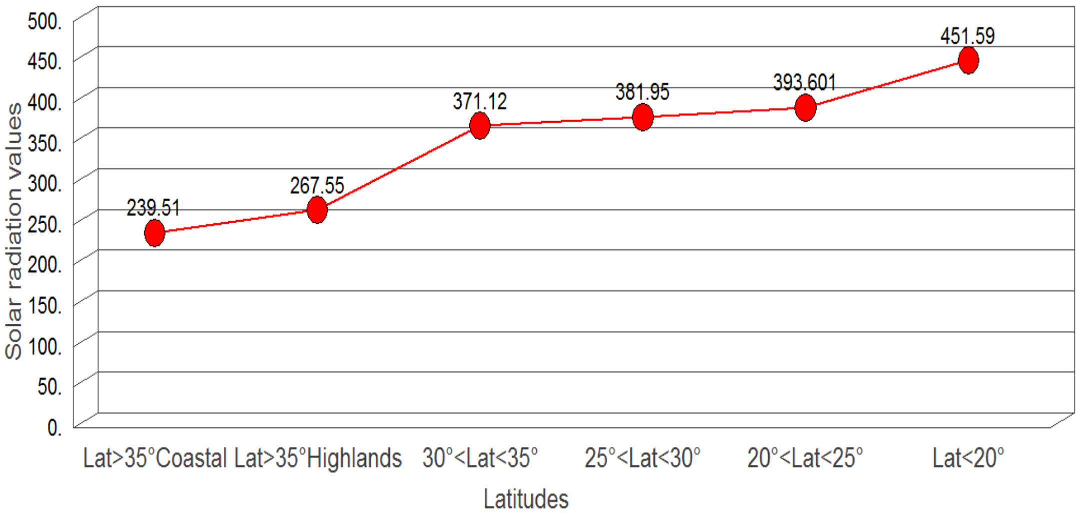


Figure 4.4: The effect of urban prospect rule (angle of obstruction=45^0) on solar radiation during summer period at different latitudes (Author, 2018).

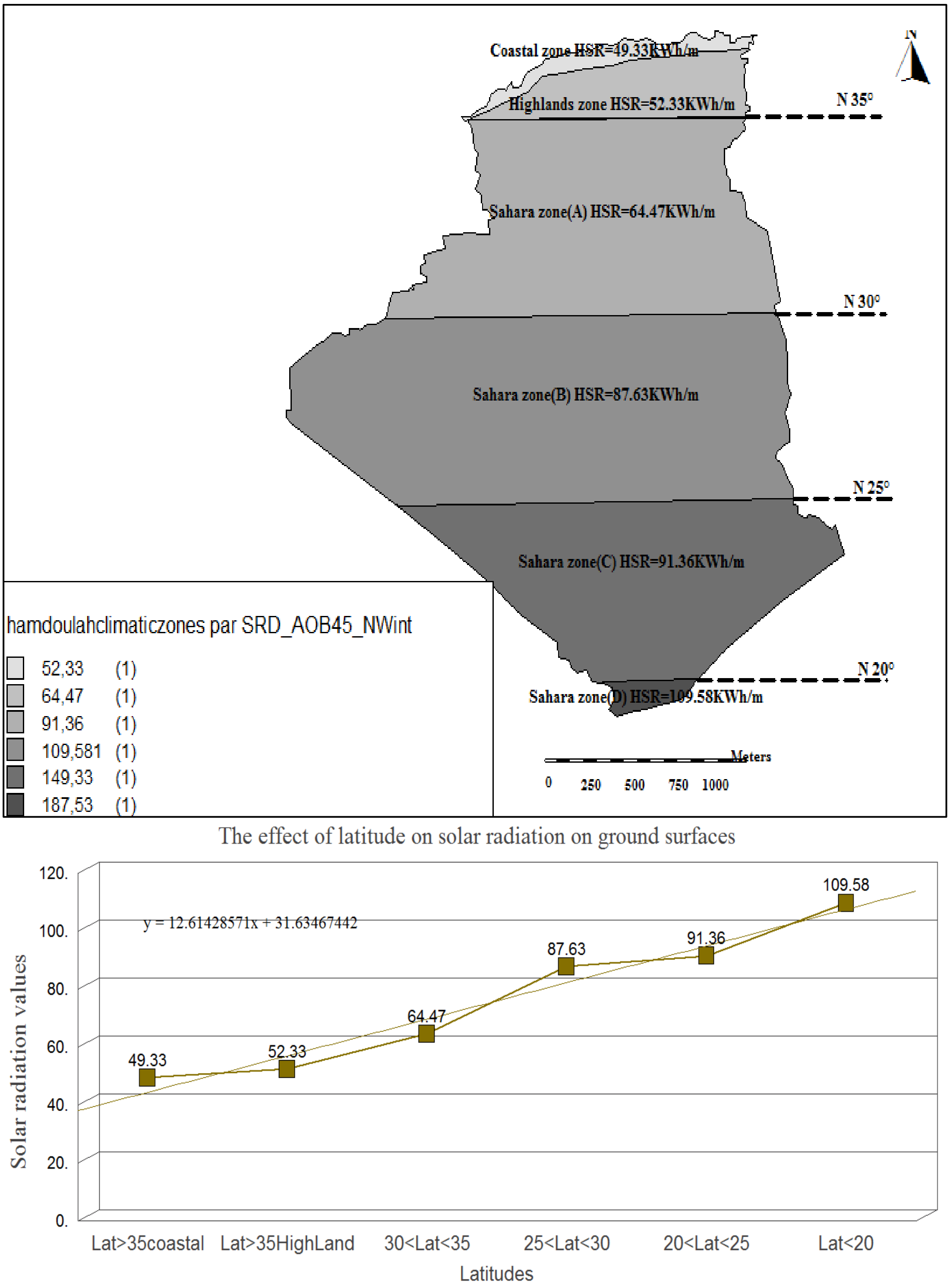
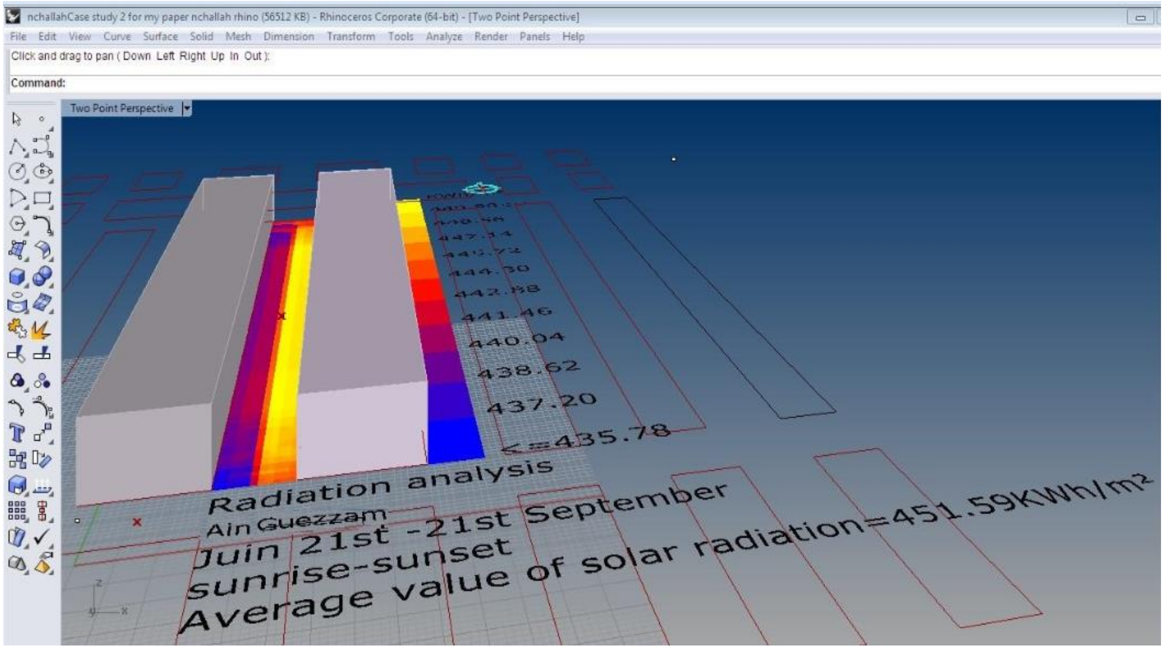


Figure 4.5: The effect of urban prospect rule (angle of obstruction=45^0) on solar radiation during winter period at different latitudes (Author, 2018).

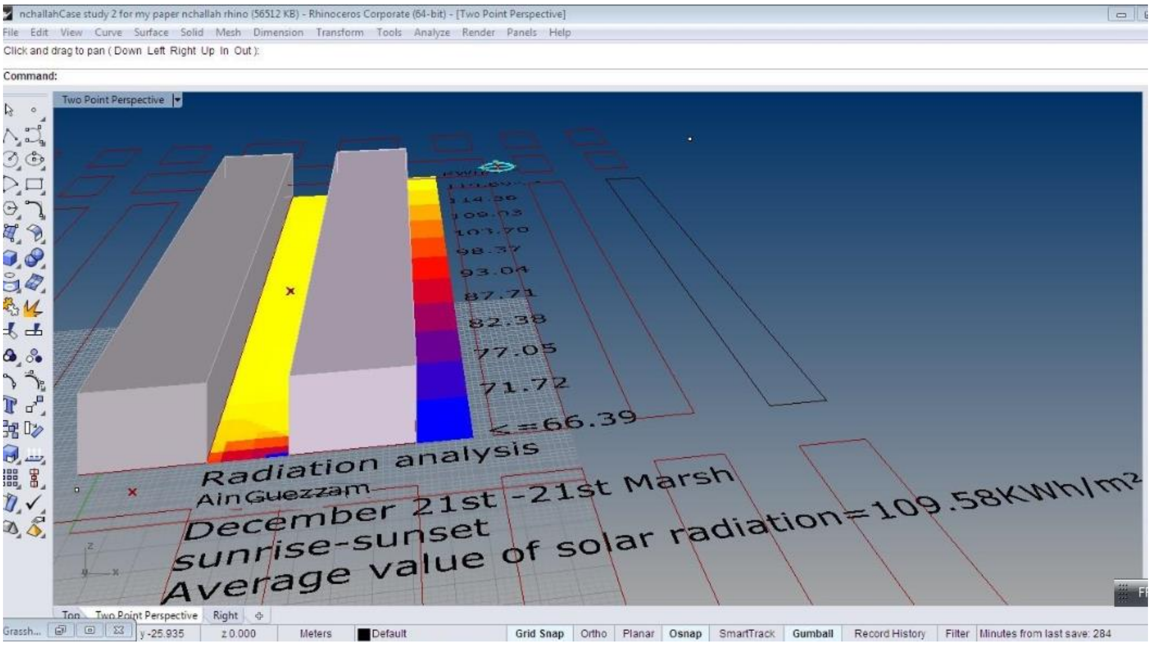


Click and drag to pan (Down Left Right Up In Out):

Command:

Radiation analysis
Ain Guezzam
Juin 21st -21st September
sunrise-sunset
Average value of solar radiation=451.59KWh/m²

Figure 4.6: The average value of solar radiation received during summer time on ground surface of urban street canyon (located in Ain Guezzam) of angle of obstruction 45^0(Author, 2018).



Click and drag to pan (Down Left Right Up In Out):

Command:

Radiation analysis
Ain Guezzam
December 21st -21st Marsh
sunrise-sunset
Average value of solar radiation=109.58KWh/m²

y -25.935 z 0.000

Minutes from last save: 284

Figure 4.7: The average value of solar radiation received during winter time on ground surface of urban street canyon (located in Ain Guezzam) of angle of obstruction 45^0(Author,2018).

1-3-2-The assessment of outdoor thermal comfort

Outdoor thermal comfort in urban environmental is a complex issue with multiple layers of concern. Outdoor thermal comfort is a composite function of atmospheric conditions, and physical, physiological, psychological, and behavioral factors (Ariane Middel et al, 2016). Therefore, the principles for creating thermally comfortable urban site are intricate and sometimes contradictory. They contain solar control in summer and solar gains in winter. The geometrical parameters of urban spaces can have a significant effect on the outdoor thermal comfort, and energy performance of an urban environment (P J Littlefair et al 2000). Through this investigation we attempt to assess the effect of latitude and prospect urban rule (obstruction Angle equal 45^0) on outdoor thermal comfort. To achieve this aim the Universal Thermal Climate Index (UTCI)[5] has been calculated (See figures 4.8; 4.9).

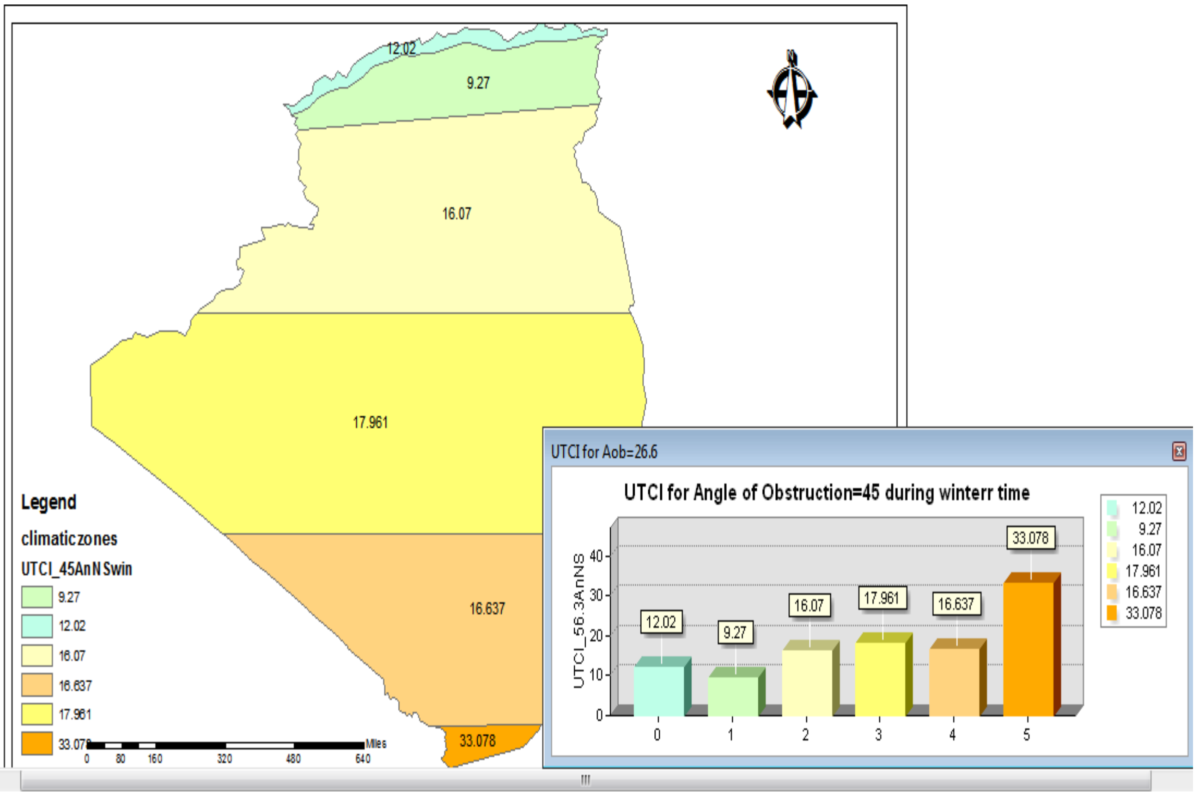


Figure 4.8: The effect of urban prospect rule (angle of obstruction=45^0) on UTCI during winter period (Author,2018)

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[5] See chapter 2 page 37

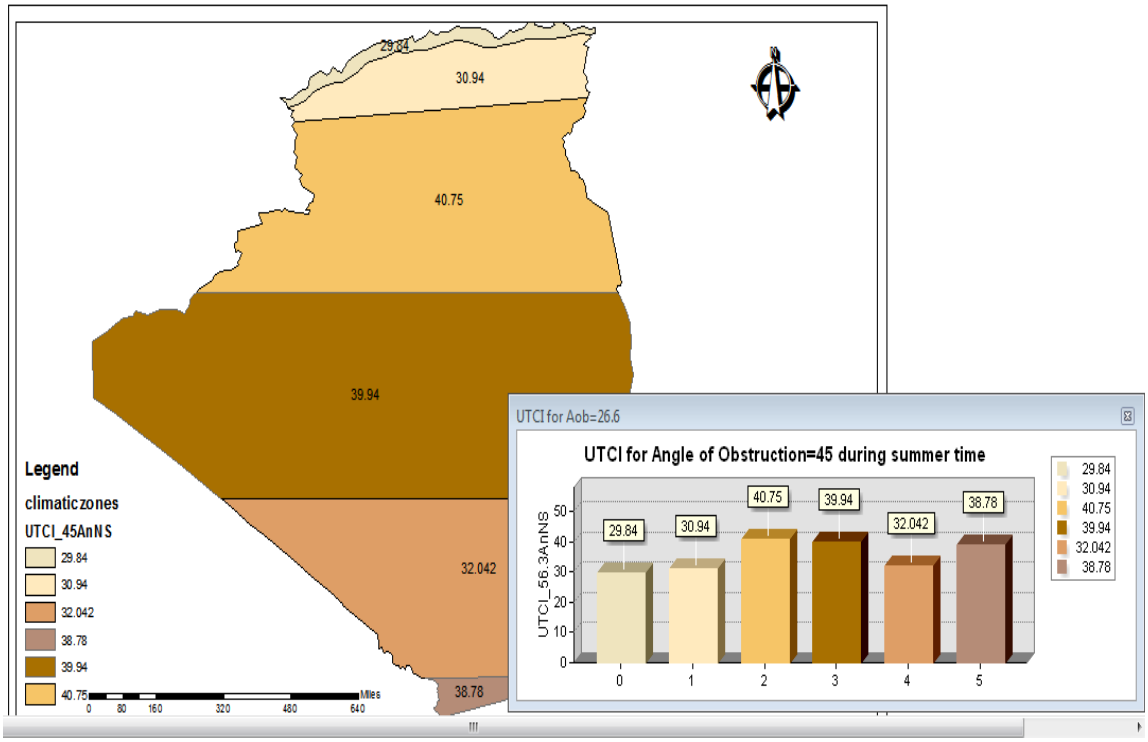


Figure4.9: The effect of urban prospect rule (angle of obstruction=45^0) on UTCI during summer period (Author, 2018).

As shown in figure (4.8; 4.9; 4.10; 4.11), the average values of UTCI in high latitudes of Coastal and Highland zones during summer period are reaching respectively 29.84^0C, 30.94^0C. These values indicate that the thermal sensation of walkers under those conditions is characterized by moderate heat stress (hot but not dangerous). Therefore, the application of prospect urban rule (**$\alpha=45^0$**) in high latitudes (Latitude>35^0) cannot ensure comfortable conditions of walkers during summer period. However, it provides comfortable conditions (no thermal stress) during winter time. Since the average values of UTCI in Coastal and Highlands zones are respectively as following; 12.02^0C, 9.27^0 C (See figure4.12; 4.13).

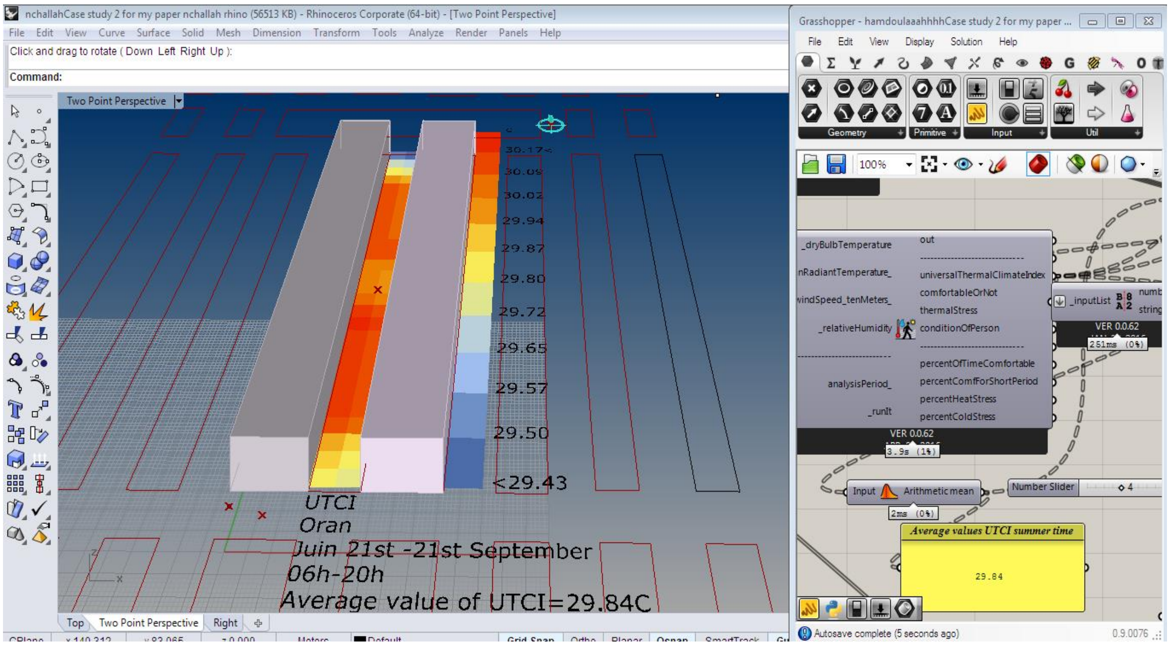


Figure 4.10: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Oran (Author, 2018)

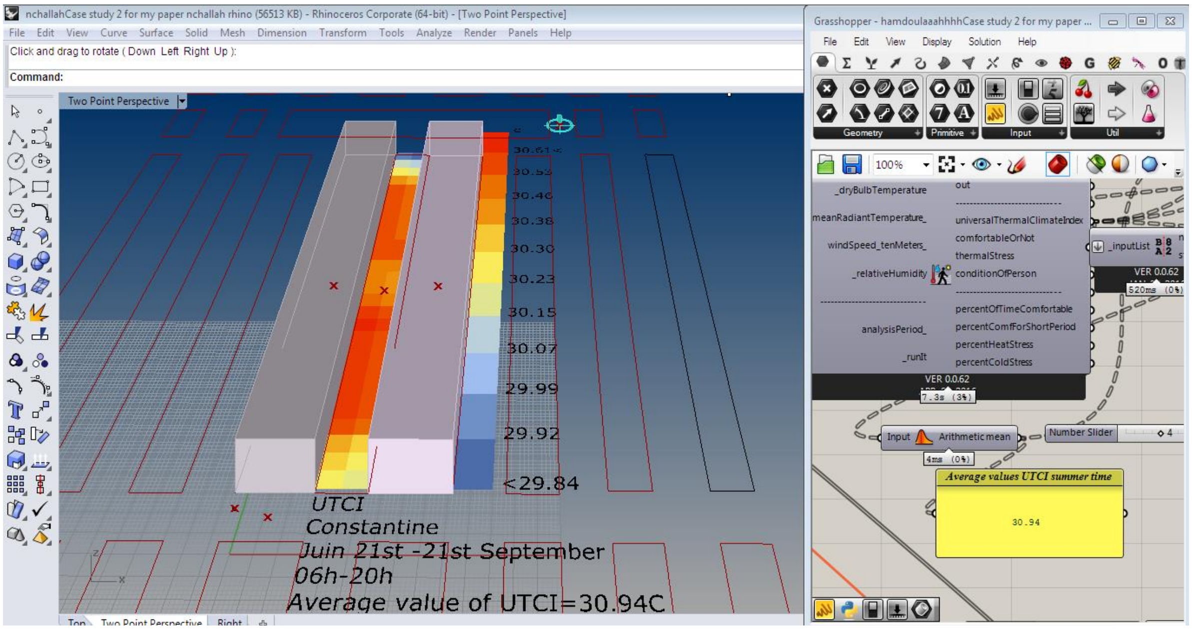
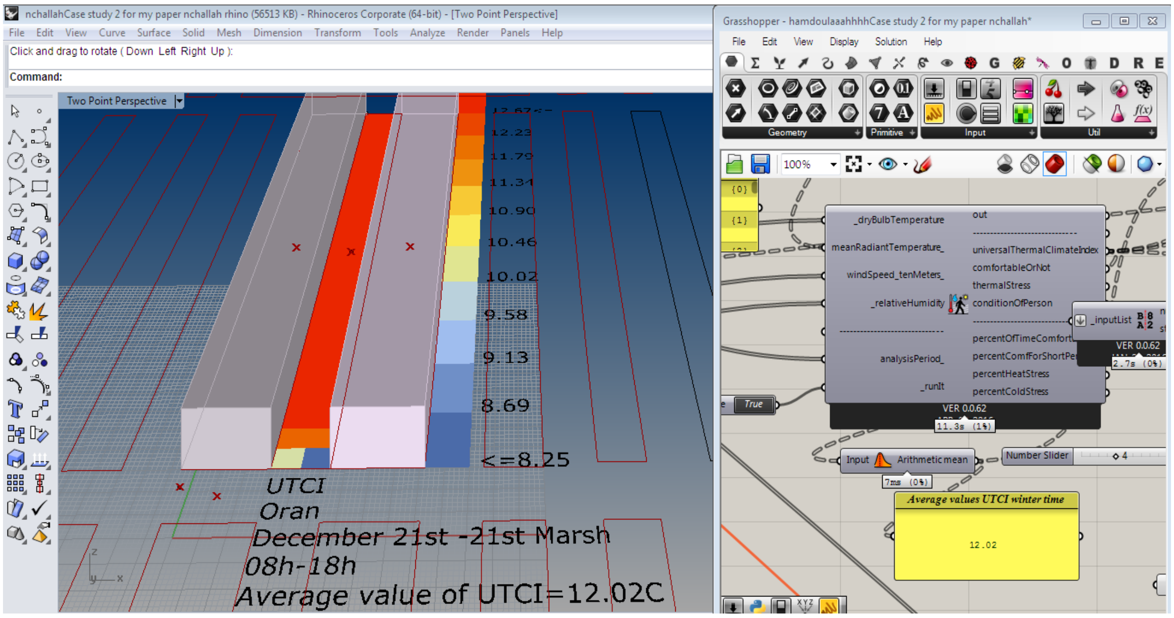


Figure 4.11: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Constantine (Author,2018)



Click and drag to rotate (Down Left Right Up):

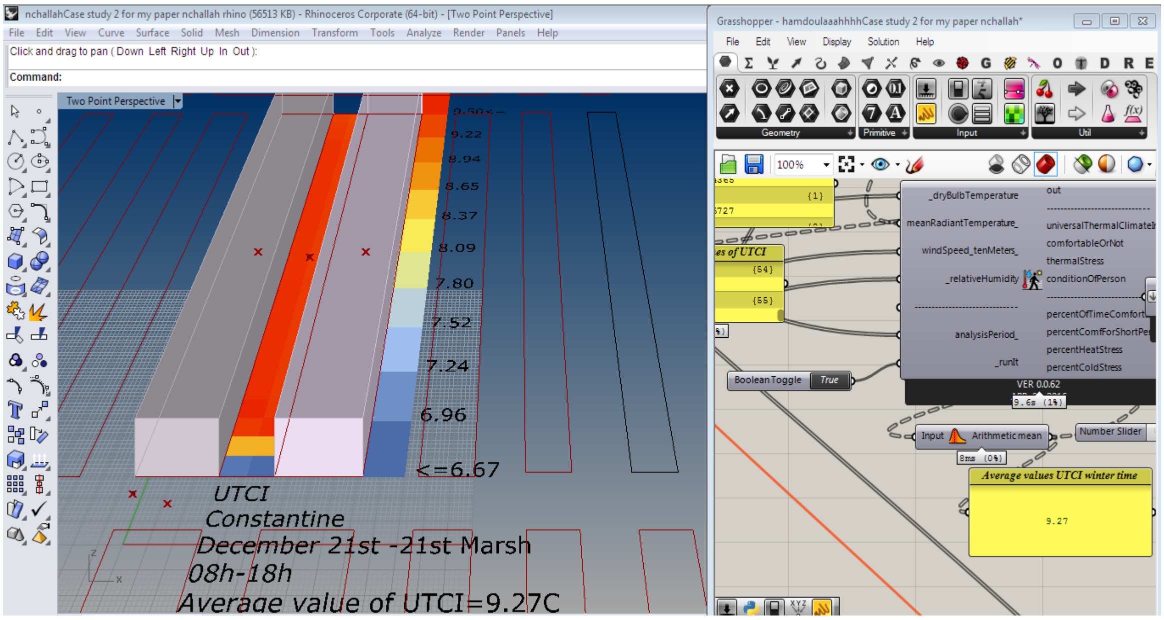
Command:

UTCI
Oran
December 21st -21st Marsh
08h-18h
Average value of UTCI=12.02C

Average values UTCI winter time

12.02

Figure 4.12: The average value of UTCI during winter period in urban street of angle of obstruction 45^0 located in Oran (Author, 2018)



Click and drag to pan (Down Left Right Up In Out):

Command:

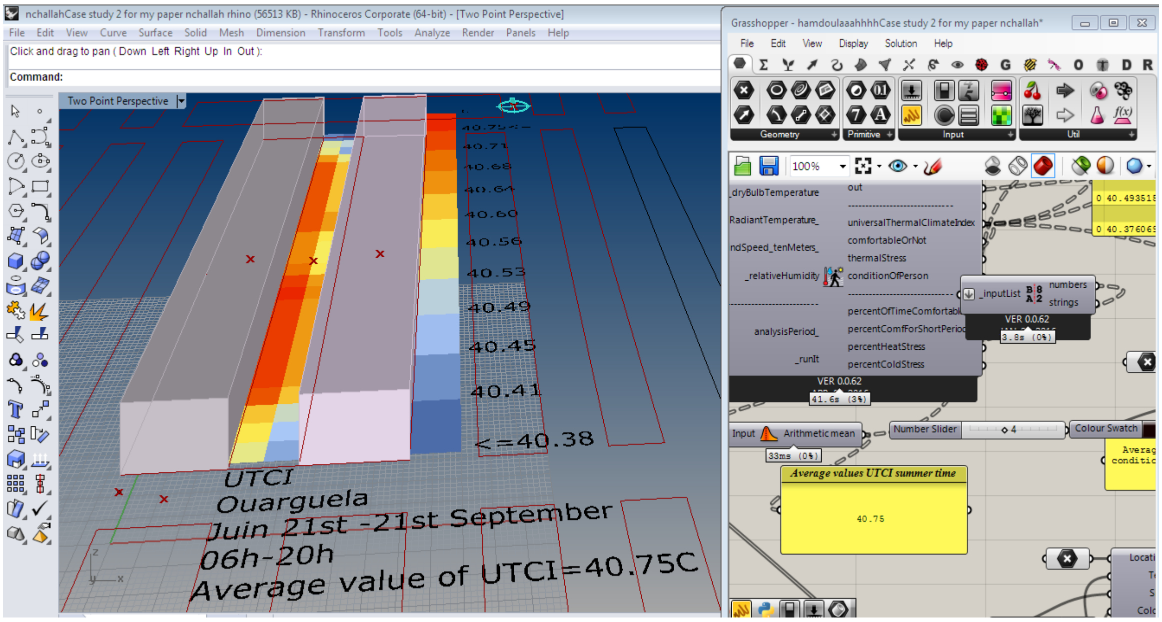
UTCI
Constantine
December 21st -21st Marsh
08h-18h
Average value of UTCI=9.27C

Average values UTCI winter time

9.27

Figure 4.13: The average value of UTCI during winter period in urban street of angle of obstruction 45^0 located in Oran (Author, 2018)

On the other hand, in low latitudes (Sahara Zone A, B, C, D) the average values of UTCI during summer period for obstruction angle **α** equal to 45^0 are reaching respectively 40.75^0C, 39.94^0C, 32.04^0C,38.78^0C (See figures4.14;4.15;4.16;4.17). These values indicate that the thermal sensation of walkers is characterized by very strong to extreme heat stress (Very dangerous) in Sahara zone (A, B, D), and described by strong heat stress (Dangerous beyond short periods of time) in Sahara zone (C). Therefore, the application of urban prospect rule (obstruction angle **α** equal to 45^0) is advisable in low latitudes. However, this latter ensures outdoor comfortable conditions in Sahara zone (A, B, C) during winter time. Though, during the same period thermal sensation of the walker in Sahara zone (D) kept the character of strong heat stress (dangerous beyond short periods of time). From these results, and after this analysis we can confirm that the application of prospect urban rule (obstruction angle **α** equal 45^0) safeguard outdoor thermal comfort during winter time, but it cannot ensure it during summer period especially in low latitudes, where the thermal sensation is described, as very strong to extreme heat stress (very dangerous). In order to optimize these results a simulation of fictitious fabrics by varying the values of the obstruction angle and orientation of urban street model will be done in the next part of this chapter.



nchallahCase study 2 for my paper nchallah rhino (56513 KB) - Rhinoceros Corporate (64-bit) - [Two Point Perspective]

Click and drag to pan (Down Left Right Up In Out):

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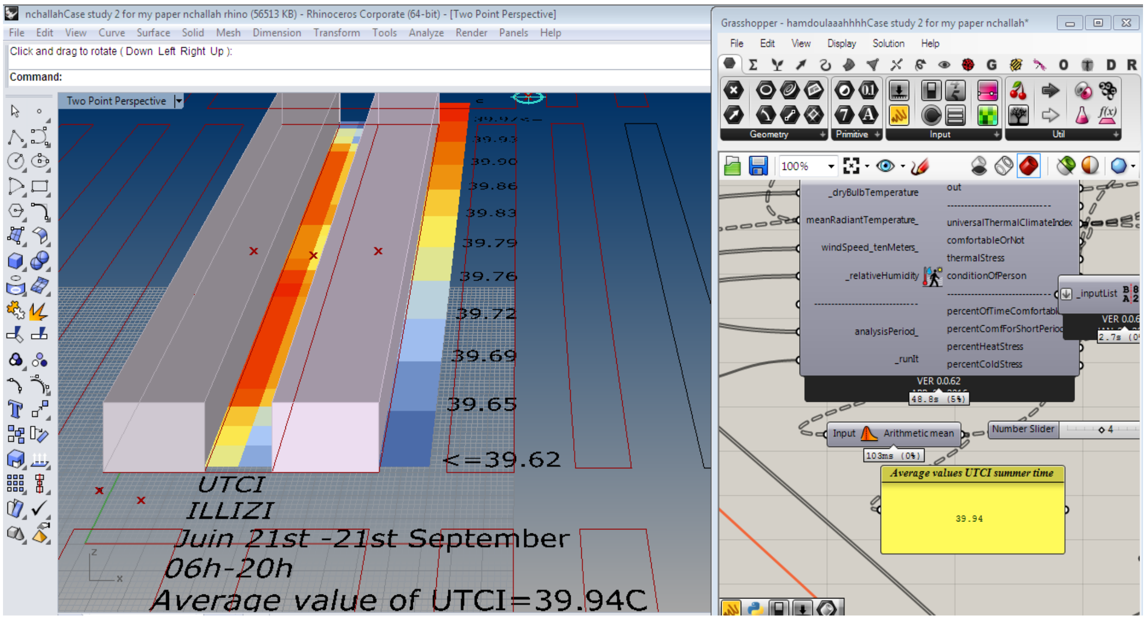
Grasshopper - hamdoulaaahhhhCase study 2 for my paper nchallah*

Figure 4.14: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Ouarguela (Author, 2018)



Click and drag to rotate (Down Left Right Up):

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Figure 4.15: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Illizi (Author,2018).

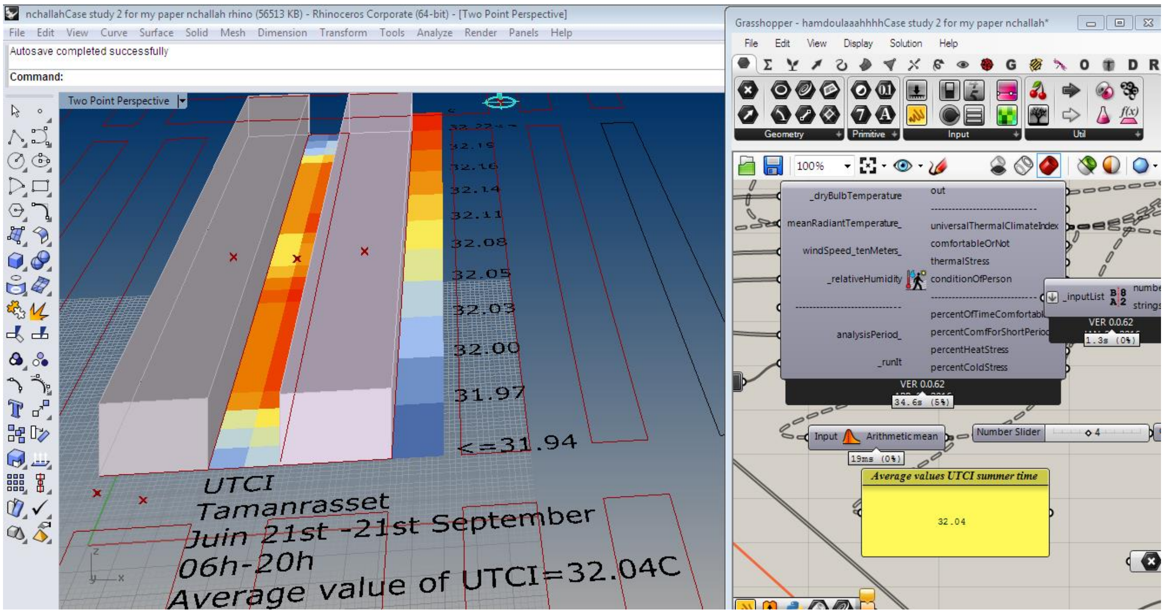

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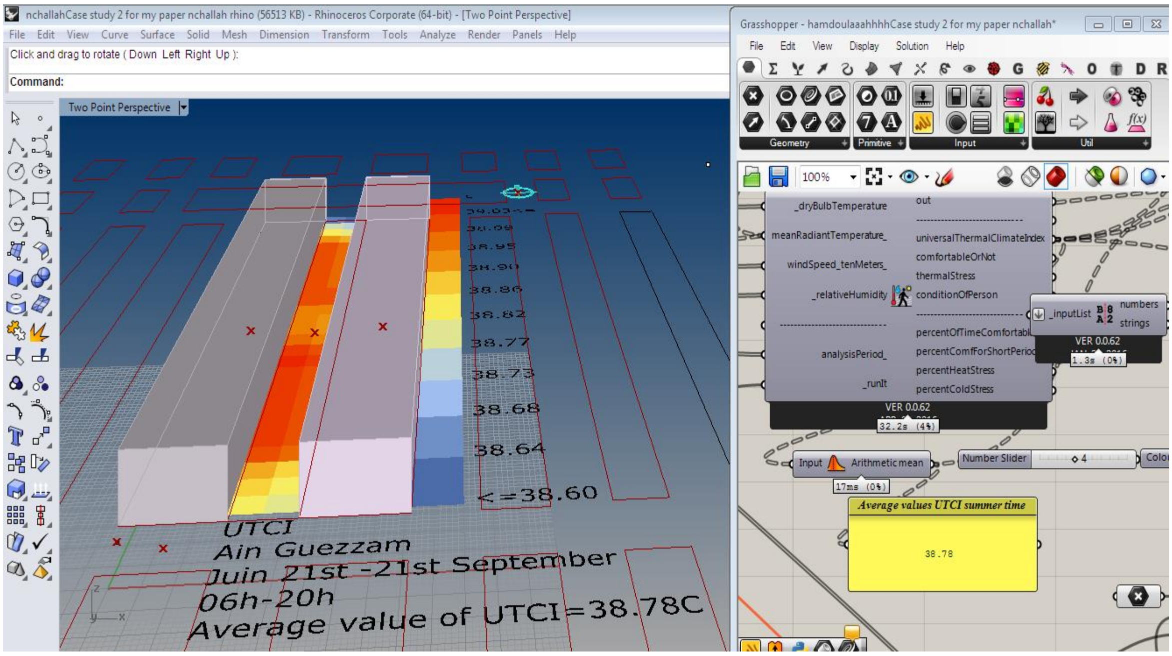
Figure 4.16: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Tamanrasset (Author,2018).



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Click and drag to rotate (Down Left Right Up):

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Grasshopper - hamdoulaaahhhhCase study 2 for my paper nchallah*

Average values UTCI summer time

38.78

Figure 4.17: The average value of UTCI during summer period in urban street of angle of obstruction 45^0 located in Ain Guezzam (Author,2018).

2- Simulation of fictitious fabrics of urban street canyons

Planning guidelines must be settled for each climatic zone, toward increasing solar access for buildings and spaces surrounding them in cold climates, also maximizing shading for buildings and urban spaces in hot climates. According to Ahmed Okeil (2010):

> *"Temperatures in cities at latitude 25^0 drop below comfortable limits in winter. In summer, temperatures in cities at latitude 45^0 rise above comfortable limits…… In recent years, cities such as Los Angles (Lat 34^0), Tokyo (Lat 35.7^0), New York (Lat 40.8^0) and Toronto (Lat 43.7^0) have launched programs aiming at reducing the city temperatures in summer through mitigation the urban heat island".* (Ahmed Okeil (2010), P.1437-1439)

In this regard the main aim of this part is directed towards, showing how the geometrical parameters of urban street (Orientation and Obstruction angle) affect solar radiation and outdoor thermal comfort within this later during summer and winter. Also making clear and flexible guidelines, which ensure outdoor thermal comfort during summer and winter periods in each climatic zones. In order to achieve this aim a simulation of fictious fabrics by varying the above geometrical parameters of urban street canyon (Obstruction angle and orientation) has been done. The obstruction angle (**α**) was varied relative to the fixed street width to create urban canyon obstruction of **α**=26.6^0; 45^0; 56.3^0; 63.4^0; 71.6^0; 76^0 (See figure4.18). These values of (**α**) correspond to the values of building height/street width ratios (R=H/W) or urban canyon ratios of R=0.5; 1; 1.5; 2; 3; and 4. These ratios cover a wide range of traditional and contemporary buildings in North Africa (Bourbia and Awbi 2004). Correspondingly, street orientations are taken in steps of 45^0 from the north (S1) to east (S4) (See figure4.19).

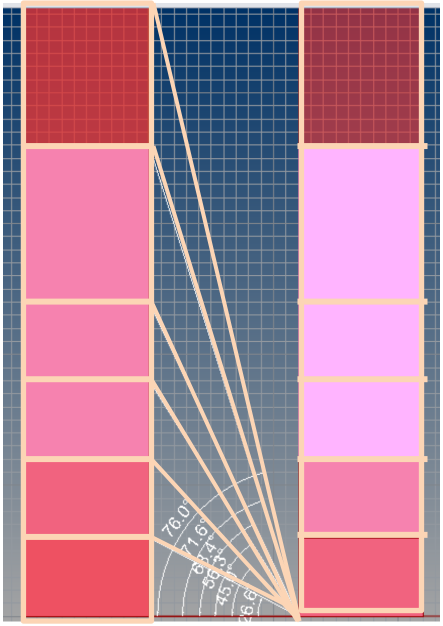


Figure4.18: Urban street canyon profil investigated (Author,2018)

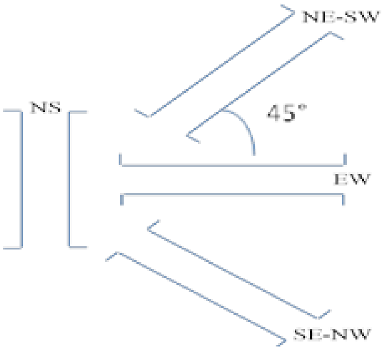


Figure4.19 : Street orientations investigated(Author,2018)

2-1-The effect of obstruction angle and orientation on solar radiation at different latitudes

A numerical comparison of the effect of obstruction angle and orientation on the average values of direct solar radiation received during summer and winter periods at ground level surface of urban street canyons in different latitudes can be seen from figure (4.21) and figure (4.22) respectively. The results shown that for all urban canyon configurations investigated, the average values of solar radiation diminishes as the obstruction angle (**α)** increases**.** This finding is in agreement with other previous results studies; such as Bourbia and Awbi (2004), Erik Johansson (2006), Stromann-andersen et al (2011), Shishegar (2013).

According to Givoni, (1997)

> *"Narrow streets provide better shading by buildings for pedestrians on sidewalks than wide streets".* Givoni (1997), P.369

Since, the peak values of solar radiation are found in shallowest urban canyon with obstruction angle of ($\alpha=26.6^0$). While, the deep urban canyons of obstruction angle ($\alpha=76^0$) receive less solar radiation in comparison with the shallow urban canyons (See figures 4.21; 4.22). The results also depict that the orientation has a significant effect on the solar radiation impinged on the ground surface of urban street canyons. According to Givoni, (1997)

> *"The direction of the streets in relation to the north determines the conditions of shade and sunshine on the face of buildings that are parallel to the street and on the sidewalks lining the streets. This affects the temperature and conditions within the buildings as well as the possibilities of protecting the pedestrians on the sidewalk from the sun in summer or of providing sunlight in the streets in winter".* Givoni, (1997), P.374.

As shown in figure (4.21), during summer time the values of solar radiation dropped on the urban street canyons which are mainly oriented to the East-West direction are higher than those for other orientations, urban streets which are oriented to the north south (NS) direction giving the lowest values. On the contrary, during winter time the ground surfaces of urban street canyons which are oriented to the North-South direction have better solar access than the urban street canyon of the East-west direction. Therefore, the east-west direction must be avoided during summer period. After a comparative study on the effect of street orientation on street shade patterns, Knowles (1981) concluded the following statement:

> *"A street grid in "diagonal orientation: northeast-southwest and northwest-southeast was found to be a preferable pattern from the solar exposure aspect. It provides more shade in summer and more sun exposure in winter".* (Givoni, p.373)

In another investigation, Bourbia et al (2004) concluded that diagonal street orientation NE-SW may often be a second best orientation. In another research Ali-Toudert and Mayer (2006) agree that diagonal urban streets could provide better comfort conditions. Since, during winter period the North-East or North-West streets allow more penetration of solar access compared to the North-South urban streets. However, during summer the NE-SW or NW-SE orientations provide more shade compared to the East-west urban street.

Subsequently, figure (4.22) illustrates that during summer time urban streets which are oriented to NE-SW directions received less solar radiation in comparison with East-West street orientation. Then, figure (4.21) shows that during winter time the amount of solar radiation dropped on diagonal street orientation (NE-SW) more than the quantity of solar radiation fallen on North-South streets which not exceed 222.96 KW/m^2 for obstruction angle of 26^0 in Sahara zone D (Ain Guezzam) (See figure4.20). It is important that the average values of solar radiation received during summer and winter periods at the ground level of urban street canyons are dependent on latitude. According to Arnfield, (1994):

> *"For higher latitudes, the sun position is lower in the winter and creates strong obstacles. Thus, the irradiances reduce for high latitudes and this is especially obvious for the E-W orientation".* Arnfield, (1994), P243.

Figures (4.21;4.22) show that during both summer and winter periods, the average value of solar radiation received on ground surface of all urban street canyons investigated in coastal zone, highland zone and Sahara zone (A,B,C,D), increase as latitude decreases.

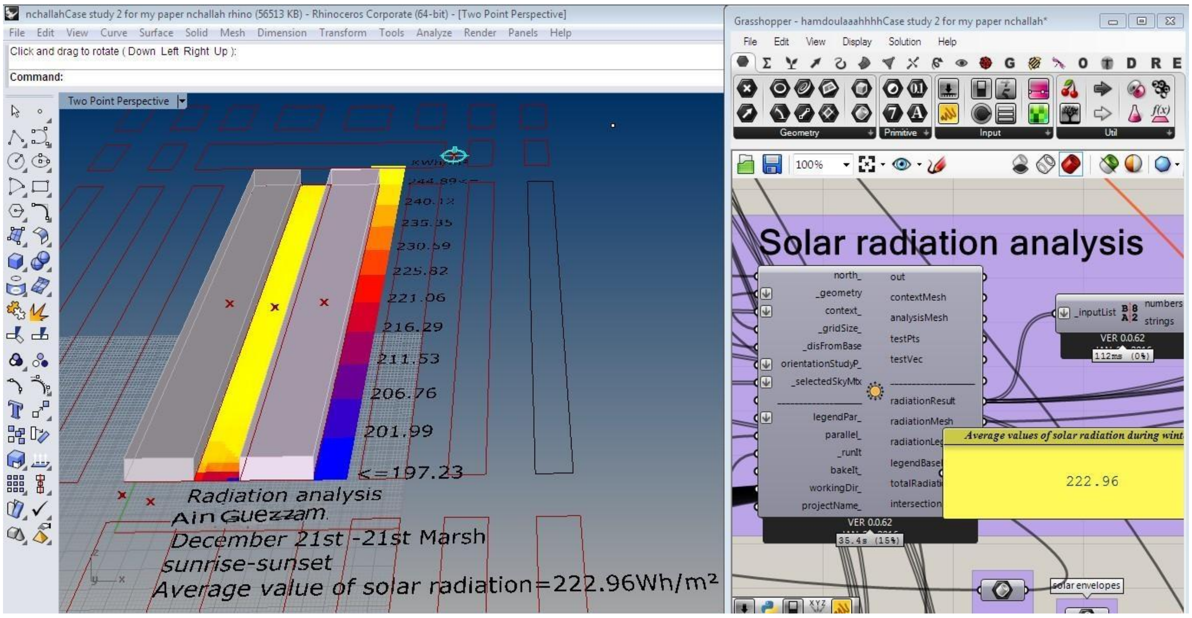
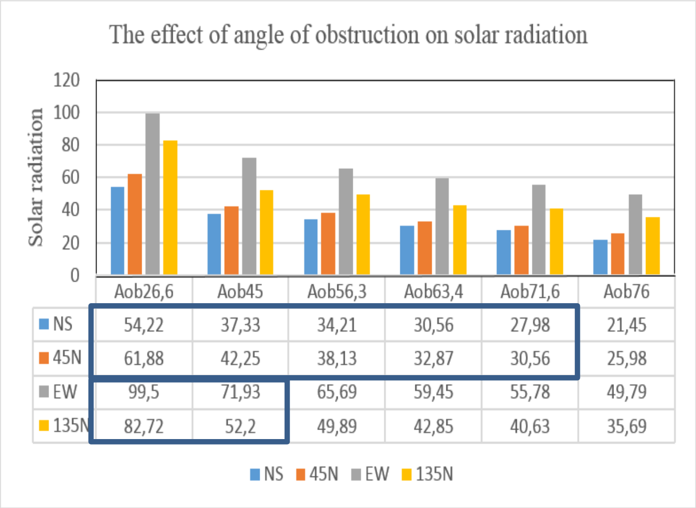


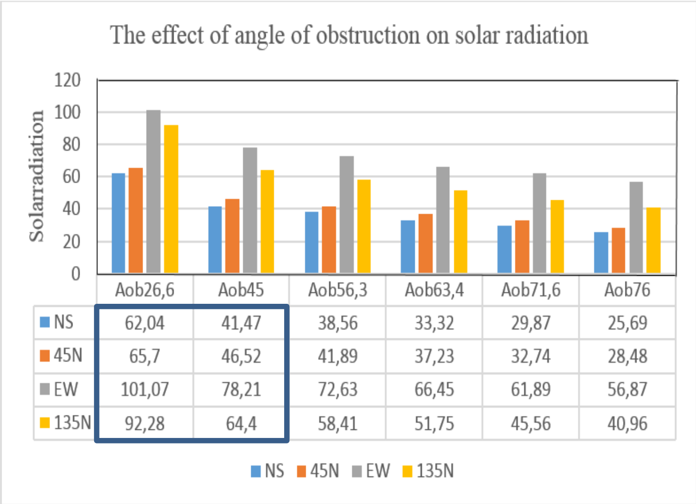
Figure 4.20: The average value of solar radiation during winter period in urban street of angle of obstruction 26^0 located in Ain Guezzam (Author,2018)

Latitude $>35^0$ Coastal zone (Oran)



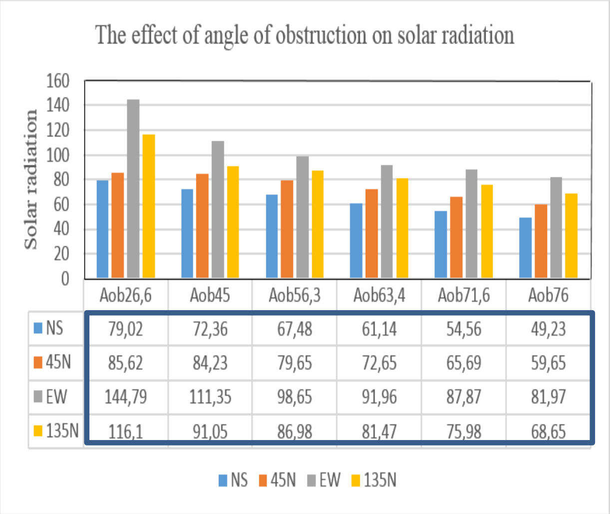
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	54,22	37,33	34,21	30,56	27,98	21,45
45N	61,88	42,25	38,13	32,87	30,56	25,98
EW	99,5	71,93	65,69	59,45	55,78	49,79
135N	82,72	52,2	49,89	42,85	40,63	35,69

Latitude $>35^0$ Highland zone (Constantine)



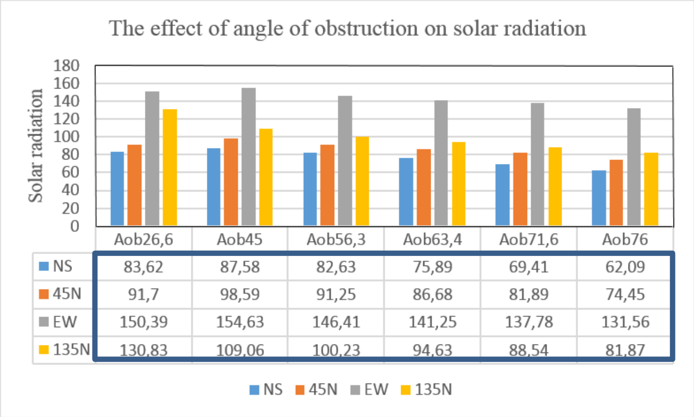
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	62,04	41,47	38,56	33,32	29,87	25,69
45N	65,7	46,52	41,89	37,23	32,74	28,48
EW	101,07	78,21	72,63	66,45	61,89	56,87
135N	92,28	64,4	58,41	51,75	45,56	40,96

30^0<Latitude<35^0 Sahara zone A(Ouarguela)



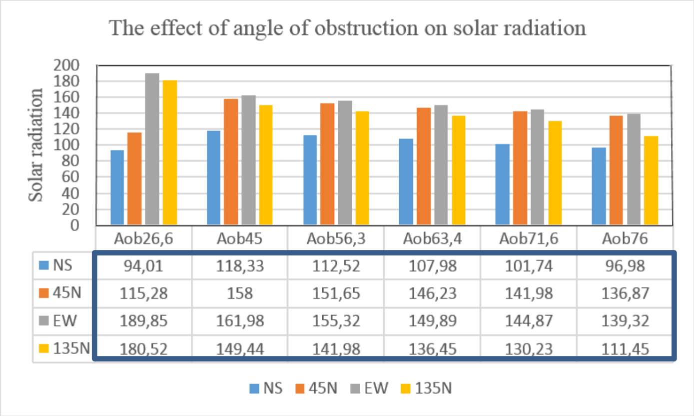
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	79,02	72,36	67,48	61,14	54,56	49,23
45N	85,62	84,23	79,65	72,65	65,69	59,65
EW	144,79	111,35	98,65	91,96	87,87	81,97
135N	116,1	91,05	86,98	81,47	75,98	68,65

25^0<Latitude<30^0 Sahara zone B(Illizi)



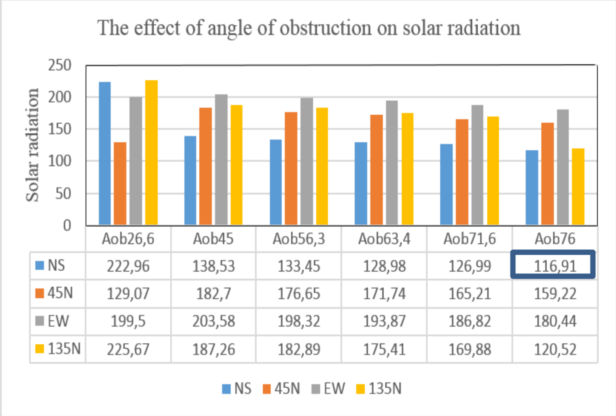
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	83,62	87,58	82,63	75,89	69,41	62,09
45N	91,7	98,59	91,25	86,68	81,89	74,45
EW	150,39	154,63	146,41	141,25	137,78	131,56
135N	130,83	109,06	100,23	94,63	88,54	81,87

20^0<Latitude<25^0 Sahara zone C(Tamanrasset)



	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	94,01	118,33	112,52	107,98	101,74	96,98
45N	115,28	158	151,65	146,23	141,98	136,87
EW	189,85	161,98	155,32	149,89	144,87	139,32
135N	180,52	149,44	141,98	136,45	130,23	111,45

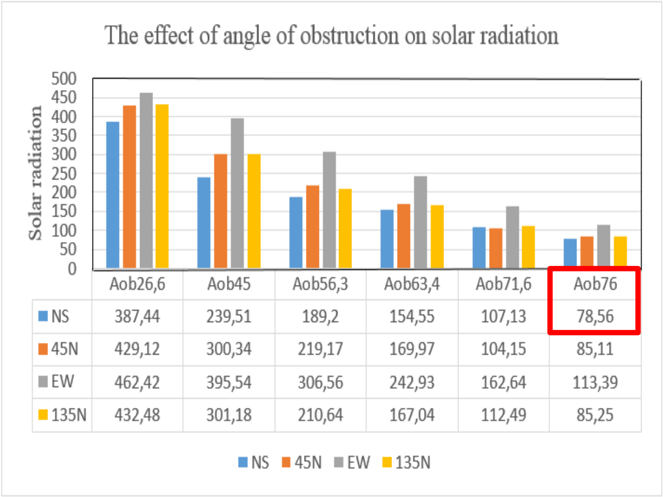
Latitude< 20^0 Sahara zone D (Ain Guezam)



	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	222,96	138,53	133,45	128,98	126,99	116,91
45N	129,07	182,7	176,65	171,74	165,21	159,22
EW	199,5	203,58	198,32	193,87	186,82	180,44
135N	225,67	187,26	182,89	175,41	169,88	120,52

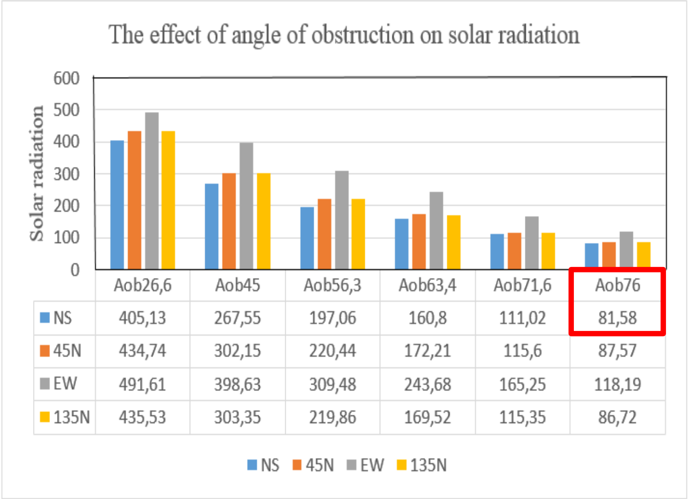
Figure 4.21: The effect of angle of obstructions and orientation on solar radiation during winter period at different latitudes (Author, 2018)

Latitude >35^0 Coastal zone (Oran)



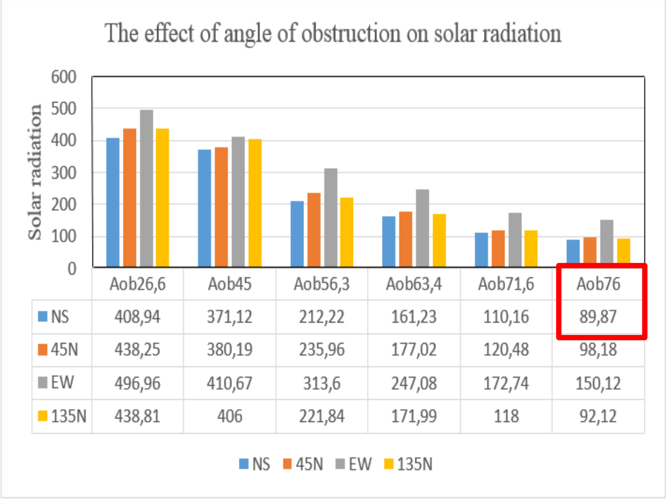
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	387,44	239,51	189,2	154,55	107,13	78,56
45N	429,12	300,34	219,17	169,97	104,15	85,11
EW	462,42	395,54	306,56	242,93	162,64	113,39
135N	432,48	301,18	210,64	167,04	112,49	85,25

Latitude >35^0 Highland zone (Constantine)



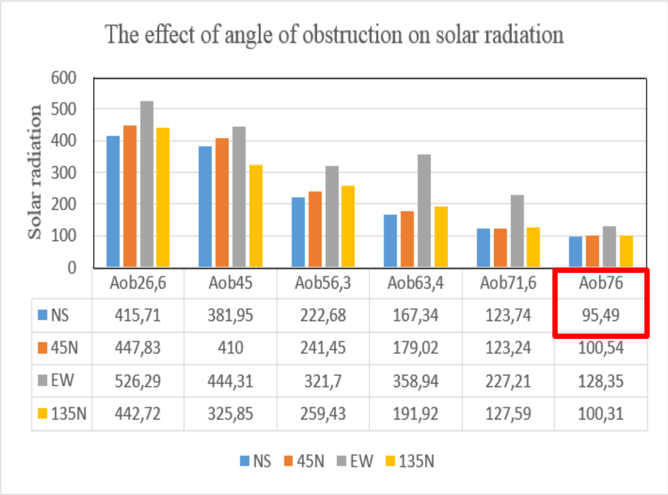
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	405,13	267,55	197,06	160,8	111,02	81,58
45N	434,74	302,15	220,44	172,21	115,6	87,57
EW	491,61	398,63	309,48	243,68	165,25	118,19
135N	435,53	303,35	219,86	169,52	115,35	86,72

30^0<Latitude<35^0 Sahara zone A(Ouargula)



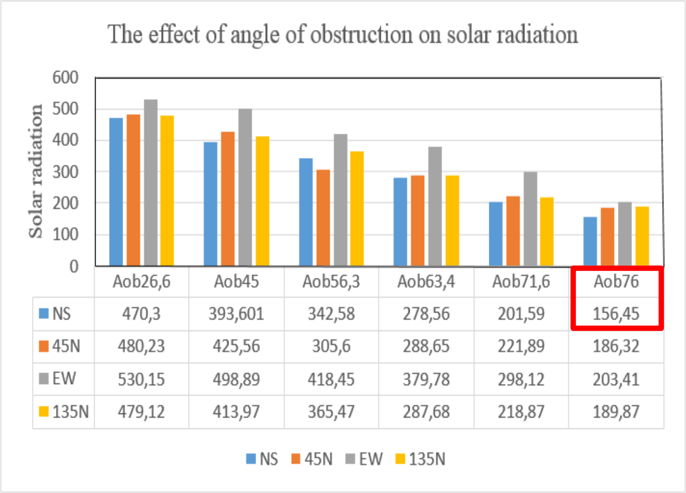
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	408,94	371,12	212,22	161,23	110,16	89,87
45N	438,25	380,19	235,96	177,02	120,48	98,18
EW	496,96	410,67	313,6	247,08	172,74	150,12
135N	438,81	406	221,84	171,99	118	92,12

25^0<Latitude<30^0 Sahara zone B(Illizi)



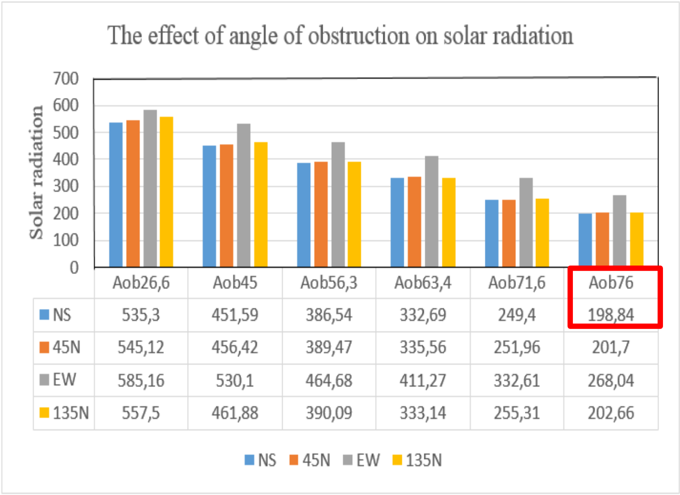
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	415,71	381,95	222,68	167,34	123,74	95,49
45N	447,83	410	241,45	179,02	123,24	100,54
EW	526,29	444,31	321,7	358,94	227,21	128,35
135N	442,72	325,85	259,43	191,92	127,59	100,31

20^0<Latitude<25^0 Sahara zone C(Tamanrasset)



	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	470,3	393,601	342,58	278,56	201,59	156,45
45N	480,23	425,56	305,6	288,65	221,89	186,32
EW	530,15	498,89	418,45	379,78	298,12	203,41
135N	479,12	413,97	365,47	287,68	218,87	189,87

Latitude< 20^0 Sahara zone D (Ain Guezam)



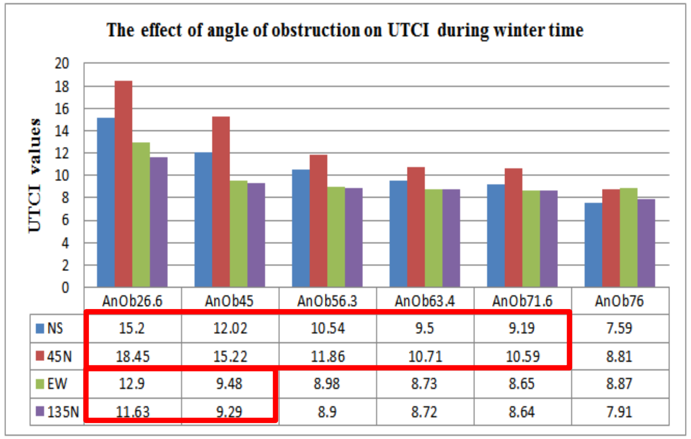
	Aob26,6	Aob45	Aob56,3	Aob63,4	Aob71,6	Aob76
NS	535,3	451,59	386,54	332,69	249,4	198,84
45N	545,12	456,42	389,47	335,56	251,96	201,7
EW	585,16	530,1	464,68	411,27	332,61	268,04
135N	557,5	461,88	390,09	333,14	255,31	202,66

Figure 4.22: The effect of angle of obstruction and orientation on solar radiation during summer period at different latitudes (Author, 2018)

2-2-The effect of obstruction angle and orientation on the universal thermal climate index (UTCI) at different latitudes

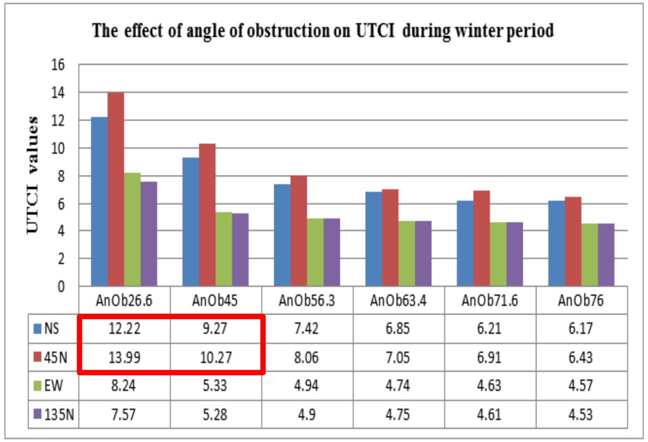
The universal thermal climate index (UTCI),was calculated, for four street orientations (NS, 45^{0}N, EW,135^{0}N), in Littoral zone(Latitude>35^0), Highland zone (Latitude>35^0), Sahara zone A (35^0<Latitude<30^0) , Sahara zone B (30^0<Latitude<25^0) , Sahara zone C(25^0<Latitude<20^0), Sahara zone D (Latitude<20^0), for urban street canyons of obstructions angles α, equal to 26.6^0, 45^0, 56.3^0, 63.4^0, 71.6^0, 76^0 . Figures (4.23; 4.24) reveal the effect of urban street configuration on UTCI values during both of periods, summer and winter. Basically, UTCI decreases with the increase of the obstruction angle From the simulation results, shown in the previous figures (4.23;4.24) , it can be concluded, that urban street canyons which are oriented to the East-West direction, must be avoided especially during summer period in low latitudes. Since, the UTCI values were ranged between 45.73^{0}C in the shallowest urban canyon (Obstruction Angle of 26.6^0) located in Ouarguela (35^0<Latitude<30^0), and about 32.31^{0}C in the deepest urban street canyon (Obstruction Angle of 76^0) located in Tamanrasset (25^0<Latitude<20^0). These values indicate that the thermal sensation of the walker for such conditions is classified between moderate heat stress and very strong to extreme heat stress (very dangerous) (See table2.4chapter2 page37). It is also important to note that during summer and winter periods outdoor thermal comfort in all urban street canyons investigated show large change with latitudes. The findings of this investigation also display that, urban street canyon which is oriented to the NS direction and has an obstruction angle of 76^0 gives average values of UTCI of 27.2^{0}C, 28.68^{0}C during summer period in high latitudes (Lat>35^0) coastal and highlands zones respectively. Hence, in comparison with the profil of current prospect urban rules (Obstruction angle of 45^0) the results were better for 2.64^{0}C, 2.26^{0}C, i.e. 8.84%, 7.30% in coastal and highlands zone respectively. Although, this deep profil is considered as the coolest one during summer period in comparison with the other investigated profiles, it remains uncomfortable despite its high obstruction angle, since the thermal sensation in it is oscillated between slight heat stress (comfortable for short periods of time) in coastal zone (Oran), and moderate heat stress (heat but not dangerous) in highlands zone (Constantine). It is worthy of note that during winter period the thermal sensation in the deep profile of obstruction angle (76^0) which is oriented to NS direction is ranged on slight cold stress (comfortable for short period of time) (See figure 4.23). Since, the average values of UTCI recorded during winter period in this case were 7.59^{0}C, 6.17^{0}C in coastal and highlands zones respectively. These values were worse of 4.43^{0}C, 3.1^{0}C, i.e. 35.77%, 33.44% in coastal and highland zones respectively, in comparison with the average values of UTCI recorded in the urban street canyon of urban prospect rule (obstruction angle 45^{0}), in which winter outdoor thermal comfort is safeguarded (Comfortable conditions). On the other hand, in low latitudes during winter period outdoor thermal comfort is ensured in the deep profile of obstruction angle 76^{0} which is oriented to NS direction. Furthermore, this latter is considered as the coolest one during summer period. Since, the average values of UTCI during summer period for urban street canyon of urban prospect rule (Obstruction angle equal 45^{0}) were as following 40.75^{0} C, 39.940C, 32.04^{0}C, 38.78^{0} C in Ouarguela, Illizi, Tamanrasset, Ain Guezam respectively, while for deep profile of obstruction angle equal to 76^{0} values of UTCI were 38.84^{0}C, 37.93^{0}C, 30.02^{0}C, 35.81^{0}C in Ouarguela, Illizi, Tamanrasset, Ain Guezam respectively. Hence the results were better for 1.91^{0}C, 2.01^{0}C , 2.02^{0}C , 3.68^{0}C , i.e. 4.68% , 5.03%, 6.30%, 9.48% in Ouarguela, Illizi, Tamanrasset, Ain Guezam respectively. However, these results show that despite the high obstruction angle, UTCI values are still over the comfort level in low latitudes. From the summary of this analysis we conclude that the performance of winter outdoor thermal comfort in high latitudes and summer outdoor thermal comfort in low latitudes still needs more investigation. In this regard, the parametric solar envelope will be applied in the next chapter on the best results of winter and summer outdoor thermal comfort of both high and low latitudes. To achieve this step, we summarize the best results of both winter and summer outdoor thermal comfort of each latitudes in tables (4.3; 4.4).

Latitude >35^0 Coastal zone (Oran)



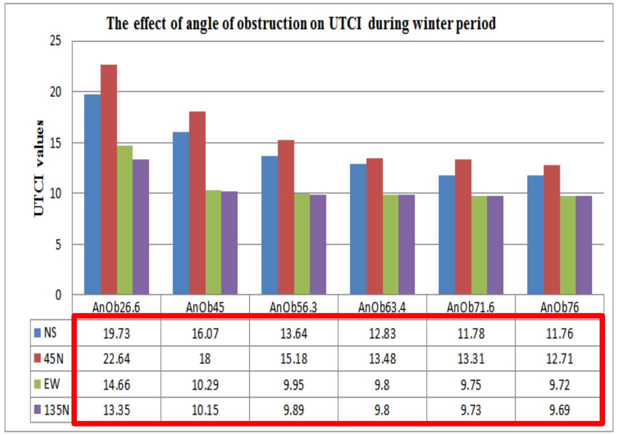
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	15.2	12.02	10.54	9.5	9.19	7.59
45N	18.45	15.22	11.86	10.71	10.59	8.81
EW	12.9	9.48	8.98	8.73	8.65	8.87
135N	11.63	9.29	8.9	8.72	8.64	7.91

Latitude >35^0 Highland zone (Constantine)



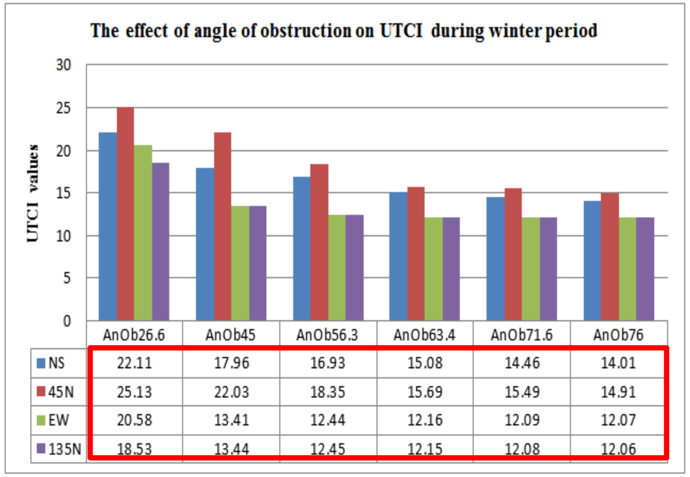
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	12.22	9.27	7.42	6.85	6.21	6.17
45N	13.99	10.27	8.06	7.05	6.91	6.43
EW	8.24	5.33	4.94	4.74	4.63	4.57
135N	7.57	5.28	4.9	4.75	4.61	4.53

30^0<Latitude<35^0 Sahara zone A(Ouargula)



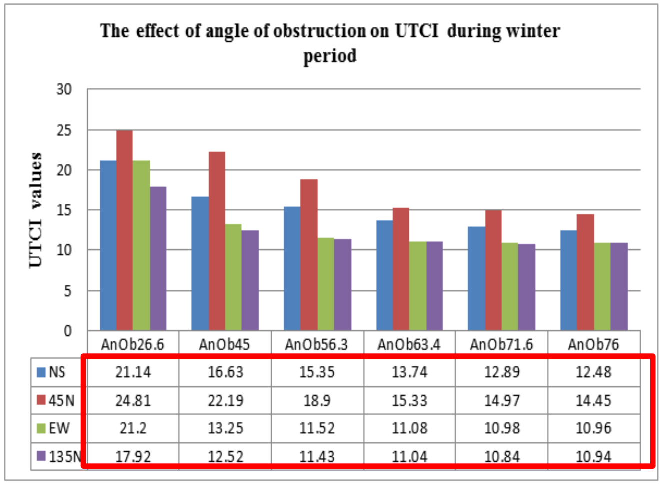
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	19.73	16.07	13.64	12.83	11.78	11.76
45N	22.64	18	15.18	13.48	13.31	12.71
EW	14.66	10.29	9.95	9.8	9.75	9.72
135N	13.35	10.15	9.89	9.8	9.73	9.69

25^0<Latitude<30^0 Sahara zone B(Illizi)



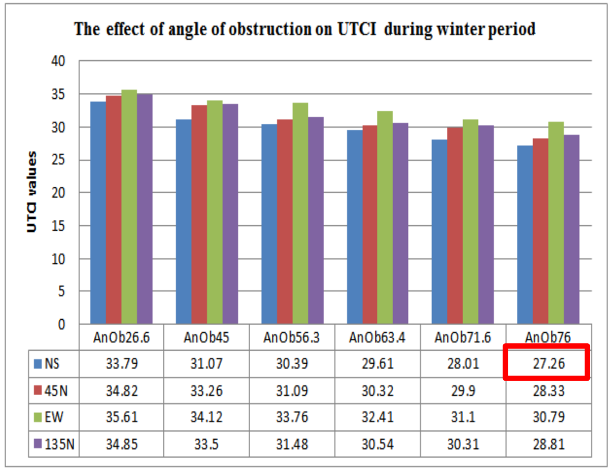
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	22.11	17.96	16.93	15.08	14.46	14.01
45N	25.13	22.03	18.35	15.69	15.49	14.91
EW	20.58	13.41	12.44	12.16	12.09	12.07
135N	18.53	13.44	12.45	12.15	12.08	12.06

20^0<Latitude<25^0 Sahara zone C(Tamanrasset)



	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	21.14	16.63	15.35	13.74	12.89	12.48
45N	24.81	22.19	18.9	15.33	14.97	14.45
EW	21.2	13.25	11.52	11.08	10.98	10.96
135N	17.92	12.52	11.43	11.04	10.84	10.94

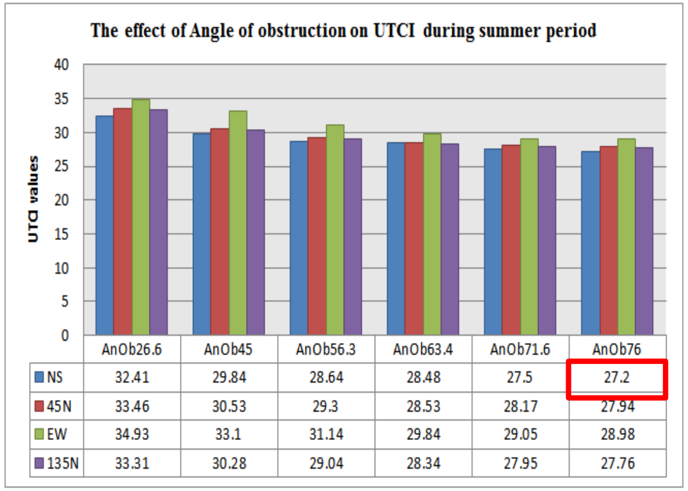
Latitude< 20^0 Sahara zone D (Ain Guezam)



	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
NS	33.79	31.07	30.39	29.61	28.01	27.26
45N	34.82	33.26	31.09	30.32	29.9	28.33
EW	35.61	34.12	33.76	32.41	31.1	30.79
135N	34.85	33.5	31.48	30.54	30.31	28.81

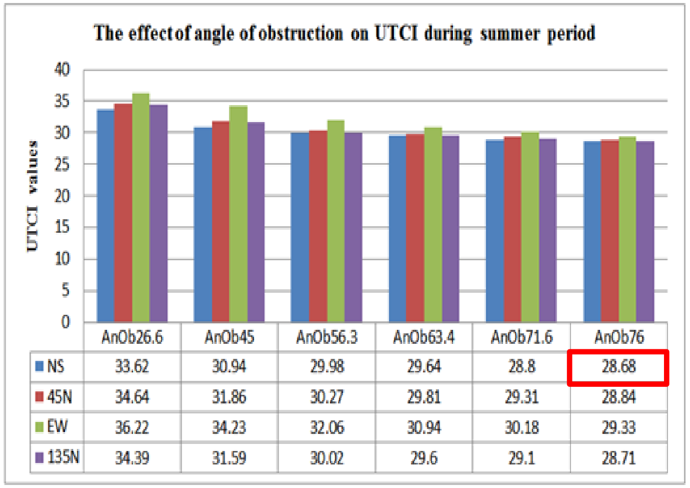
Figure 4.23: The effect of angle of obstruction and orientation on UTCI during winter period at different latitudes (Author,2018).

Latitude >35^0 Coastal zone (Oran)



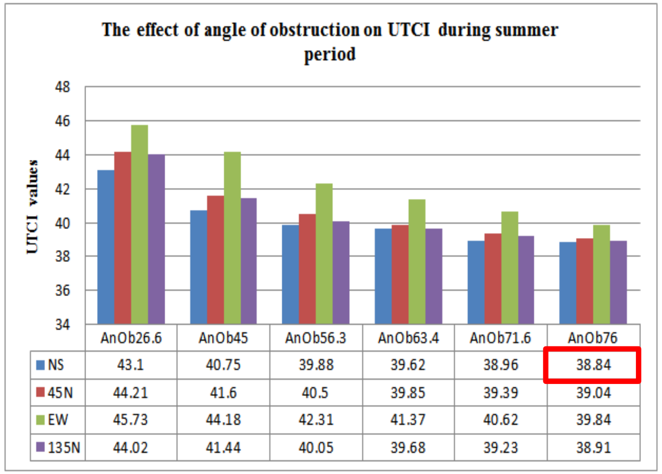
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	32.41	29.84	28.64	28.48	27.5	27.2
🟥 45N	33.46	30.53	29.3	28.53	28.17	27.94
🟩 EW	34.93	33.1	31.14	29.84	29.05	28.98
🟪 135N	33.31	30.28	29.04	28.34	27.95	27.76

Latitude >35^0 Highland zone (Constantine)



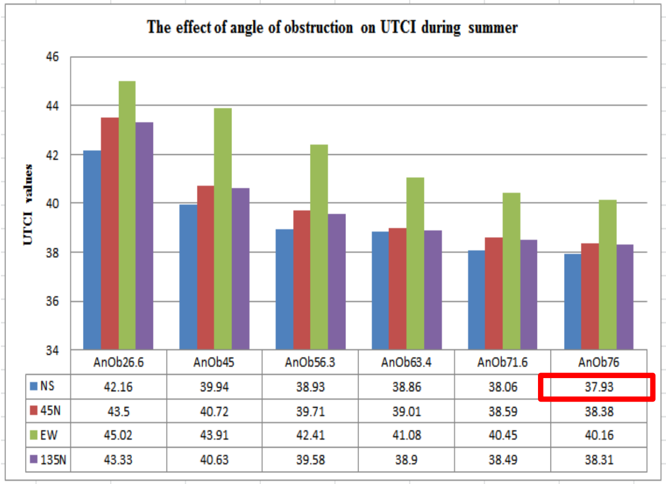
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	33.62	30.94	29.98	29.64	28.8	28.68
🟥 45N	34.64	31.86	30.27	29.81	29.31	28.84
🟩 EW	36.22	34.23	32.06	30.94	30.18	29.33
🟪 135N	34.39	31.59	30.02	29.6	29.1	28.71

30^0<Latitude<35^0 Sahara zone A(Ouargula)



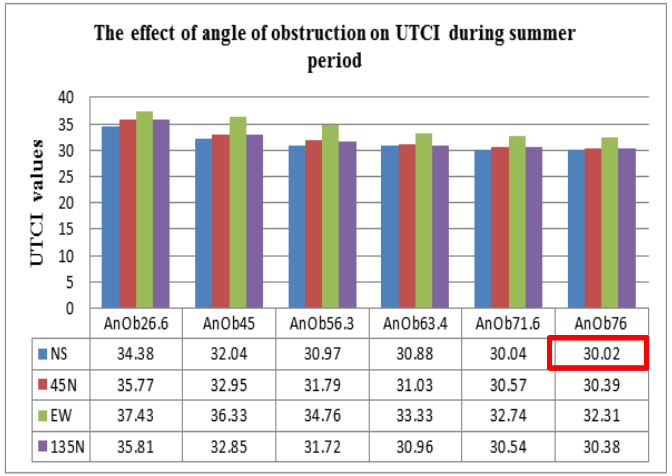
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	43.1	40.75	39.88	39.62	38.96	38.84
🟥 45N	44.21	41.6	40.5	39.85	39.39	39.04
🟩 EW	45.73	44.18	42.31	41.37	40.62	39.84
🟪 135N	44.02	41.44	40.05	39.68	39.23	38.91

25^0<Latitude<30^0 Sahara zone B(Illizi)



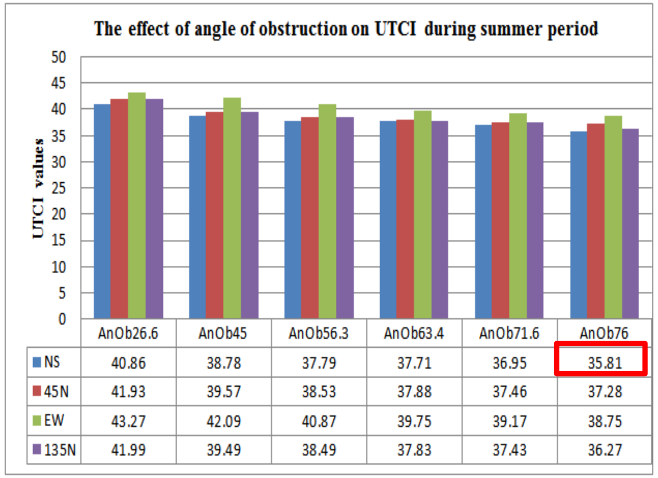
	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	42.16	39.94	38.93	38.86	38.06	37.93
🟥 45N	43.5	40.72	39.71	39.01	38.59	38.38
🟩 EW	45.02	43.91	42.41	41.08	40.45	40.16
🟪 135N	43.33	40.63	39.58	38.9	38.49	38.31

20^0<Latitude<25^0 Sahara zone C(Tamanrasset)



	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	34.38	32.04	30.97	30.88	30.04	30.02
🟥 45N	35.77	32.95	31.79	31.03	30.57	30.39
🟩 EW	37.43	36.33	34.76	33.33	32.74	32.31
🟪 135N	35.81	32.85	31.72	30.96	30.54	30.38

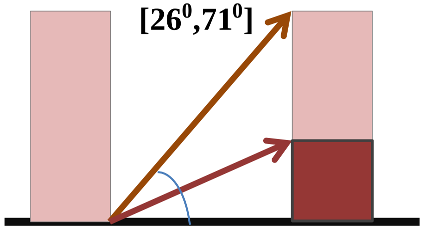
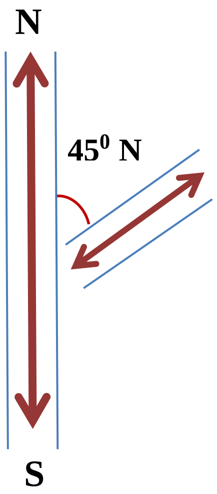
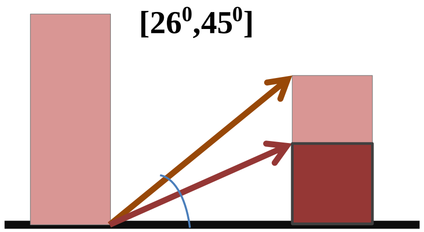
Latitude< 20^0 Sahara zone D (Ain Guezam)



	AnOb26.6	AnOb45	AnOb56.3	AnOb63.4	AnOb71.6	AnOb76
🟦 NS	40.86	38.78	37.79	37.71	36.95	35.81
🟥 45N	41.93	39.57	38.53	37.88	37.46	37.28
🟩 EW	43.27	42.09	40.87	39.75	39.17	38.75
🟪 135N	41.99	39.49	38.49	37.83	37.43	36.27

Figure 4.24: The effect of obstruction angle and orientation on UTCI during summer season at different latitudes (Author, 2018).

Table 4.3: Optimum obstruction angles and orientations for winter thermal comfort (Author, 2018).

Latitudes	**Optimum obstruction angle for winter thermal comfort**	**Optimum street orientation**	**UTCI values**		**Thermal sensation**	
			Winter	**Summer**	**Winter**	**Summer**
Lat>35^0 **Littoral**		NS, 45^0N 	[9.19^0C,….18.45^0C]	[27.5^0C,….33.46^0C]	**Comfortable conditions** [+9;+26]	Slight heat stress to strong heat stress [+26;+38]
Lat>35^0 **High land**			[9.27^0C,….13.99^0C]	[30.94^0C,….34.64^0C]	**Comfortable conditions** [+9;+26]	Moderate heat stress to strong heat stress [+28;+38]

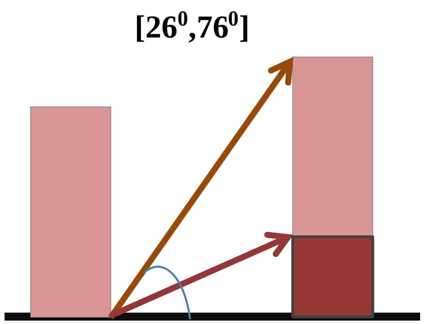
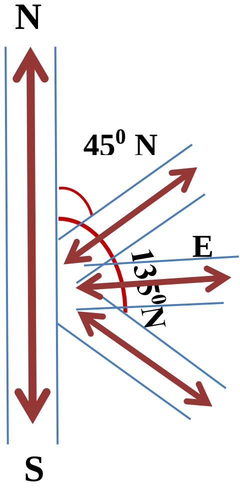
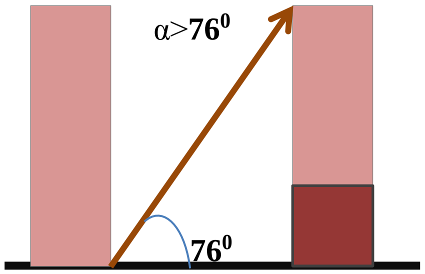
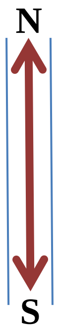
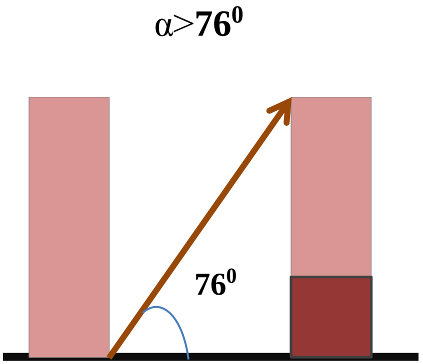
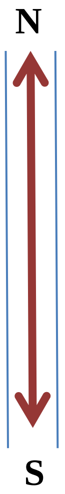
$30^0<Lat<35^0$		NS,45^0N, 135^0N 	[9.69^0C,….22.64^0C]	[38.84^0C,….45.73^0C]	**Comfortable conditions** [+9;+26]	Very strong to extreme heat stress (very dangerous) Above $+38^0$
$25^0<Lat<30^0$			[10.84^0C,….24.81^0C]	[30.2^0C,….37.43^0C]	**Comfortable conditions** [+9;+26]	Moderate heat stress to strong heat stress [+28;+38]
$20^0<Lat<25^0$			[12.06^0C,….25.13^0C]	[37.93^0C,….45.02^0C]	**Comfortable conditions** [+9;+26]	Strong heat stress, very strong heat stress to extreme heat stress [+32;+38[
$Lat<20^0$			27.26^0C	35^0C	**Slight heat stress Comfortable for short periods of time** [+26;+28]	Strong heat stress [+32;+38]

Table 4.4: Optimum obstruction angles and orientations for summer thermal comfort (Author, 2018)

Latitudes	Optimum obstruction angle for summer thermal comfort	Optimum street orientation	UTCI values		Thermal sensation	
			Summer	Winter	Summer	Winter
Lat>35^0 Littoral			27.2^{0}C	7.59^{0}C	Slight heat stress [+26;+28]	Slight cold stress [0;+9]
Lat>35^0 High land			28.68^{0}C	4.57^{0}C	Moderate heat stress [+28;+32]	Slight cold stress [0;+9]
30^0<Lat<35^0			38.84^{0}C	11.76^{0}C	Very strong to extreme heat Above +38^{0}C	Comfortable conditions [+9;+26]
25^0<Lat<30^0			30.02^{0}C	12.48^{0}C	Moderate heat stress [+28;+32]	Comfortable conditions
20^0<Lat<25^0			37.93^{0}C	14.01^{0}C	Strong heat stress [+32;+38]	Comfortable conditions [+9;+26]
Lat<20^0			35^{0}C	27.26^{0}C	Strong heat stress [+28;+32]	Slight heat stress [+26;+28]

Chapter 4: The effect of urban street configuration and latitude on solar radiation and outdoor thermal comfort

Conclusion

Over this chapter, we attempt to establish a rigorous analysis on the effect of geometrical parameters of urban spaces on solar access and outdoor thermal comfort. This analysis covers all the national territory, it will be considered as a guideline during the design process. Since, it aids urban designers to shape sustainable urban forms adapted to the local climate of each climatic zone in Algeria. To achieve this aim the Algerian national territory has been subdivided on six climatic zones according to the latitude. Afterward, a specimen of analysis has been chosen from each zone to be investigated. In order to visualize the climatic subdivision on the Algerian Map, and to constitute a geo-database which relates the geometrical parameters of urban spaces and latitudes, a geographic information system tool (ArcGis 10.3) has been used. The modelling simulation has been done by using a parametric tool (Rhinoceros/Grasshopper/Ladybug). The results of the first part of this chapter was focused on the evaluation of current prospect urban rules show that urban street canyons of obstruction angle (**α** equal to 45^0) which are located in low latitudes received more solar radiation than those which are located in high latitude. Also the results of the first part demonstrate the application of prospect urban rule (AOB= 45^0), safeguard outdoor thermal comfort during winter time, but it cannot ensure it during summer, especially in low latitudes, where the thermal sensation is described by very strong to extreme heat stress (very dangerous). In order to enhance these results a simulation of fictious fabrics varying the values of obstruction angle and orientation of urban street model has be done in the second part of this chapter. The results of this section prove that for all urban canyon configurations investigated the average values of solar radiation diminishes as the obstruction angle (**α)** increases**.** The results also show, during winter period the average values of solar radiation received on ground surface of all urban street canyons investigated increase as latitude decreases. It is also worthy of note that during summer and winter periods outdoor thermal comfort in all urban street canyons investigated show large change with latitudes. The results of the second part of this chapter also demonstrate that deep profiles of urban street canyons of obstruction angle (α) equal to 76^0 which are oriented to north south direction can mitigate outdoor thermal comfort during summer period in both high and low latitudes, however they drop it during winter period mainly in high latitudes (Coastal and Highlands zones). Based on these results we can say that the performance of outdoor thermal comfort still needs more investigation. In this regard, to enhance outdoor thermal comfort the parametric solar envelope will be applied in the next chapter.

CHAPTER V: PARAMETRIC SOLAR ENVELOPE AS A TOOL TO CONTROL SOLAR ACCESS IN URBAN STREET CANYON

Introduction

We have demonstrated earlier in the previous chapter that deep profil of urban street canyons which are oriented to the north south direction can mitigate outdoor thermal comfort during summer period in both high and low latitudes, however they drop it during winter period mainly in high latitudes (Coastal and Highlands zones). To overcome this lack, the parametric solar envelope will be applied on deep profiles which are oriented to the north south direction. The parametric solar envelope is considered as a better tool to bridge the gap between high urban density and required amount of solar radiation. The parametric solar envelope is determined by filtering sun vectors according to the condition of a real requirement. In this regard, the present chapter is made of two main sections. Through the first section, we present the generative process of the parametric solar envelope in the case study and the effect of filtering process of sun vectors on solar volume coefficient. While, the second section is emphasized on the effect of solar volume coefficient on solar radiation and outdoor thermal comfort.

1-Parametric solar envelope application:

Solar urban planning is an intricate procedure which desires to cogitate the interplay between multiples aspects and variables depending on urban form and solar energy inputs (Miguel Amado, Francesco Loggi, 2014). In order to enhance energy efficiency and outdoor thermal comfort, several famous architects and urban planners designed their buildings by drawing an envelope based on the daily sun course. R. Knowles (1980) defined the solar envelope as the maximum volume which safeguards solar rights of each buildings and spaces surrounding them during beneficial hours of winter. According to Isaac Guedi Capeluto and Boris Plotnikov (2017):

> *“A recent study of Niemasz, Sargent and Reinhart (2013), indicates that at least under some climate conditions and building types,* ***the use of traditional solar envelopes has a negative effect on total energy use including transportation as well as larger negative impact on developable density. This is partially dependent on lower densities leading to increased distance travelled which leads to increased energy use.*** *“(*Isaac Guedi Capeluto and Boris Plotnikov (2017), P.397).

In this regard, Isaac Guedi Capeluto and Boris Plotnikov (2017) presented the concept of parametric solar envelope as a better tool for reconciling between maximizing solar access while attaining greater built density (See page72, chapter 3). In another statement, Francesco De Luca and Timur Dogan (2019) said:

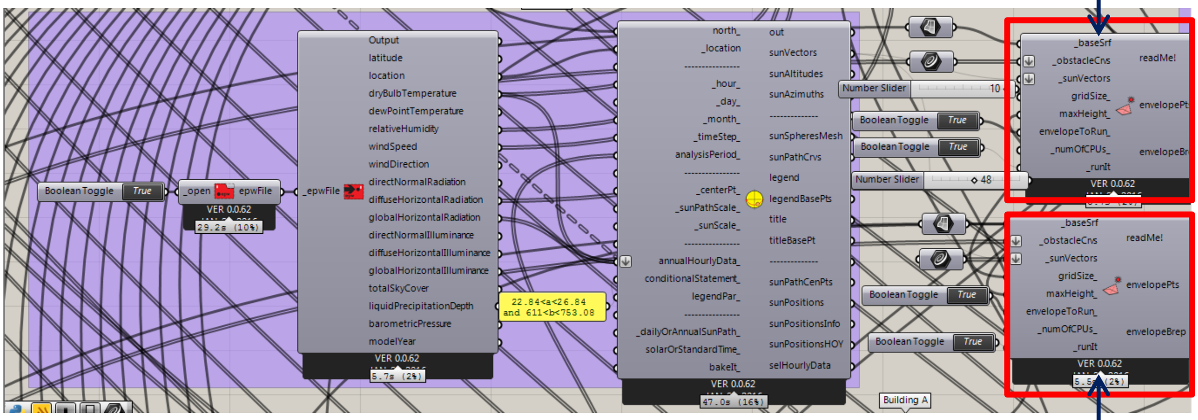
> *"The solar envelope is a method used during the schematic design phase to determine the maximum volume that buildings cannot exceed to guarantee good access to direct sunlight in streets and on neighboring facades.* ***However, two major shortcomings exist that prohibit the use of existing solar envelope techniques in practice: They don't include the neighboring buildings in the overshadowing calculation, and they utilize a fixed start-and-end time inputs for the selection of specific hours of direct solar access****".* (Francesco De Luca and Timur Dogan (2019), P.817).

In this way, to overcome the lack of recent prospect urban rules related to solar access and outdoor thermal comfort, we attempt through this chapter by applying the parametric solar envelope to determine the proper geometry of urban spaces and street profil based on the desired density level, latitude and orientation. We have demonstrated earlier in the previous chapter that deep profiles of urban street canyons of obstruction angle (α) equal to 76^0 which are oriented to north south direction can mitigate outdoor thermal comfort during summer period in both high and low latitudes, however they drop it during winter period mainly in high latitudes (Coastal and Highlands zones). Therefore, the parametric solar envelope will be applied on deep profiles which are oriented to north south direction and have an obstruction angle ($\alpha=76^0$). The investigation will be conducted during summer and winter periods in the following latitudes of each climatic zone in Algeria: Latitude>35^0 Coastal zone; Latitude>35^0 (Highlands); 35^0<Latitudes<30^0 (Sahara zone1); 30^0<Latitude<25^0 (Sahara zone2); 25^0<Latitude<20^0 (Sahara zone3); Latitude<20^0 (Sahara zone 4).

1-1- Generating parametric solar envelope

According to Capeluto and Plotnikov (2017, P.398), the design of the parametric solar envelope begins off with a query for which conditions do we require or want to allow direct sun access? The parametric solar envelope is determined by underlining the situations which create a violation of solar rights, so giving a model which more exactly simulates real-world necessities and permits increasing of the resulting solar volume. The parametric design offers advanced building design which is more adaptive and interactive by actively retorting to prevailing weather conditions. On this regard, Sadeghipour Roudsari and Pak (2013) used parametric design tool (Rhinoceros/Grasshopper/Ladybug) to outline the algorithm of the parametric solar envelope (Capeluto and Plotnikov, 2017, P.396) (See figure 5.1). The previous figure (5.1) shows the inventive modules in Grasshopper. Module A considers as inputs a base area which assists as the site boundary, obstacles curves which are the neighboring edifice limits, a filtered list of sun vectors from Ladybug's SunPath module and a few more configuration parameters and outputs a 3D polysurface which is the solar envelope. Weather file (EPW) is obtained from Meteonorm7.

Solar envelope of east row



Solar envelope of West row

Figure 5.1: The algorithm of parametric solar envelope (Author, 2018).

The simulated envelopes are generated to comply with the following solar access conditions (see table (5.1) and figure (5.2)).

Table 5.1: Solar access conditions of generated parametric solar envelope in different latitudes (Author 2018).

Climatic zones according to the latitudes	**Generated solar envelopes**		
	Condition A	**Condition A+B**	**Condition A+B+C**
Latitude>35^0 Coastal zone (Oran)	The whole of the year (from sunrise to sunset) (See figure 5.2)	Condition A+ 21.2^{0}C<Dry Bulb Temperature<25.2^{0}C	ConditionA+ConditionB+ 536<Global Horizontal Radiation<660.78
Latitude>35^0 Highlands zone (Constantine)		Condition A+ 20^{0}C<Dry Bulb Temperature<24^{0}C	ConditionA+ConditionB+ 568<Global Horizontal Radiation<829
30^0<Latitude<35^0 Sahara zone A (Ouarguela)		Condition A+ 23.13^{0}C<Dry Bulb Temperature<27.13 ^{0}C	ConditionA+ConditionB+ 557<Global Horizontal Radiation<743.01
25^0<Latitude<30^0 Sahara zone B (ILLIZI)		Condition A+ 23.64^{0}C<Dry Bulb Temperature<27.64 ^{0}C	ConditionA+ConditionB+ 581<Global Horizontal Radiation<761.22
25^0<latitude<20^0 Sahara zone C (Tamanrasset)		Condition A+ 22.84^{0}C<Dry Bulb Temperature<26.84 ^{0}C	ConditionA+ConditionB+ 611<Global Horizontal Radiation<753.08
Latitude<20^0 Sahara zone D (Ain Guezzam)		Condition A+ 25.50^{0}C<Dry Bulb Temperature<29.50 ^{0}C	ConditionA+ConditionB+ 517<Global Horizontal Radiation<770.38
Explication of the range values	The period when solar access is required	These ranges are obtained by applying ASHRAE 55-2010 standard of adaptive comfort formula) on weather data of typical meteorological year (TYM.2017) (See appendices)	These ranges are determined, because the values of 536w/m^2, 568w/m^2, 557w/m^2, 581w/m^2 , 611w/m^2, 517w/m^2 are considered as a minimum requirement during winter period, where they represent the maximum value of global horizontal radiation during the design days of (Oran, Constantine, Ouarguela, ILLIZI, Tamanrasset, Ain Guezam) respectively. However, the values of 660.78w/m^2, 829w/m^2, 743.01w/m^2, 761.22w/m^2, 753.08w/m^2, 770.38w/m^2 are obtained by applying (ASHREA, 2009) formula on TYM.2017) (See Appendices)

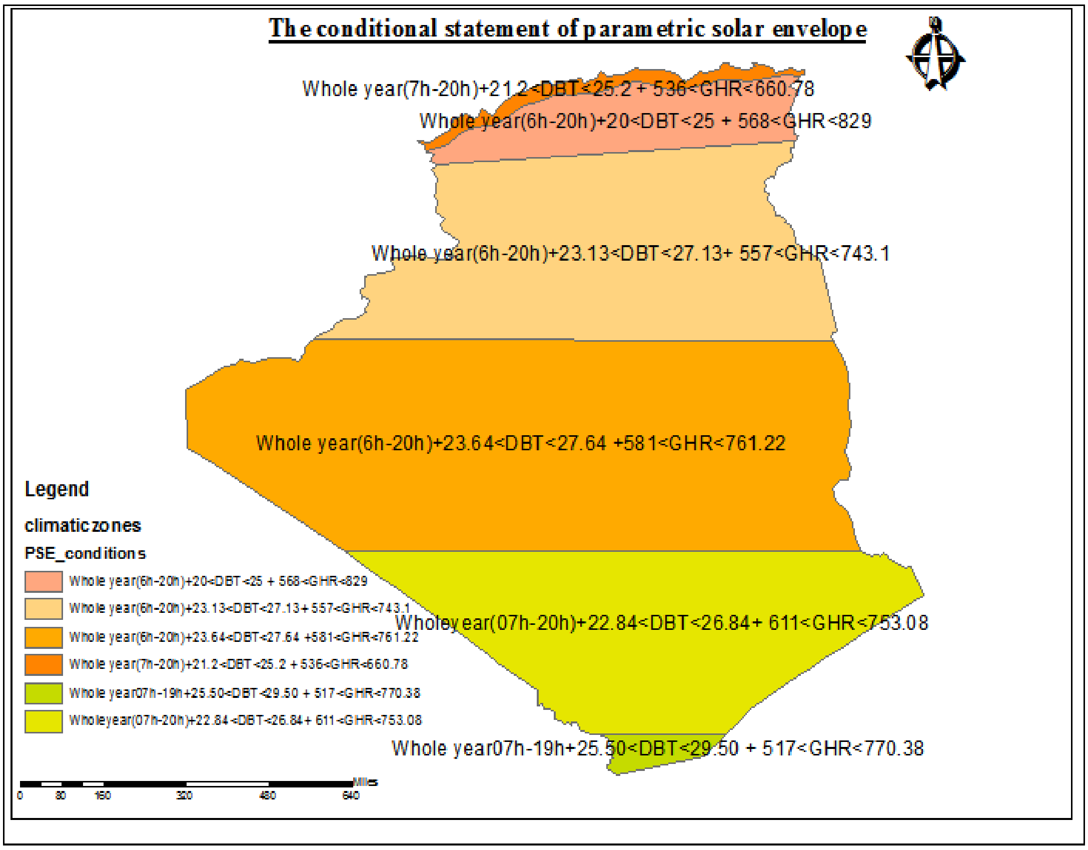


Figure5.2: The conditional statement of sun vectors in different latitudes (Author, 2018)

After determining the solar access conditions of the generated solar envelopes in different latitudes, a visualization of the SunPath with filtered suns using Ladybug is depicted in figures (5.3; 5.4; 5.5; 5.6; 5.7; 5.8). The previous figures (5.3 until 5.8) reveal that the more we precise the conditions range, the more the number of sun hours decreases in all the latitudes investigated. Therefore, the more we specify the initial requirements, the more sun hours can be omitted from the calculation of the parametric solar envelope.

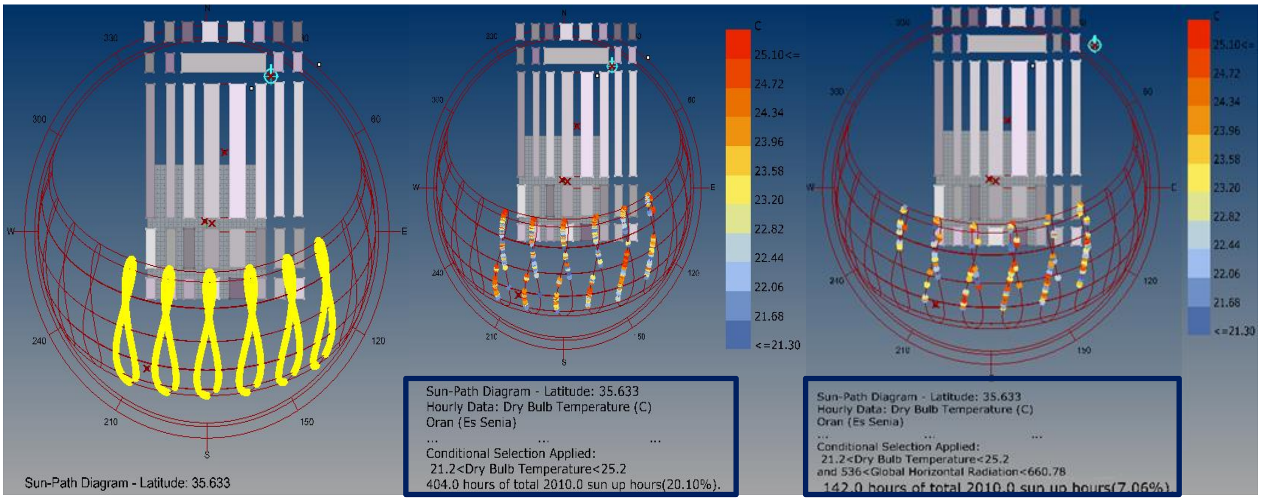


Figure5.3: Filtering process of sun vectors in Coastal zone (Latitude>35^0) (Author, 2019).

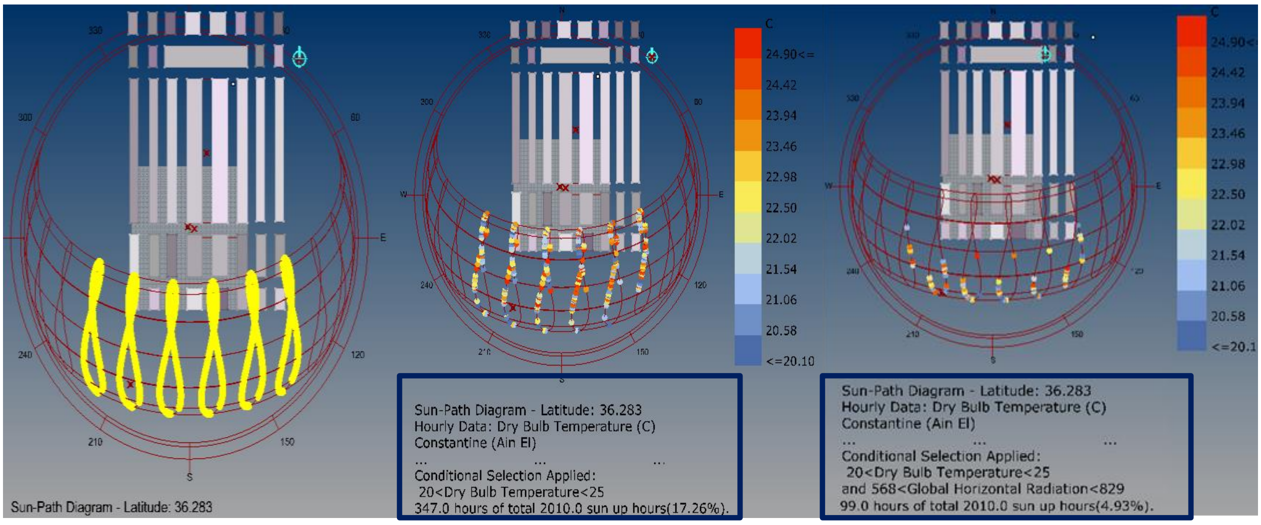


Figure 5.4: Filtering process of sun vectors in Highlands zone (Latitude>35^0) (Author, 2019).

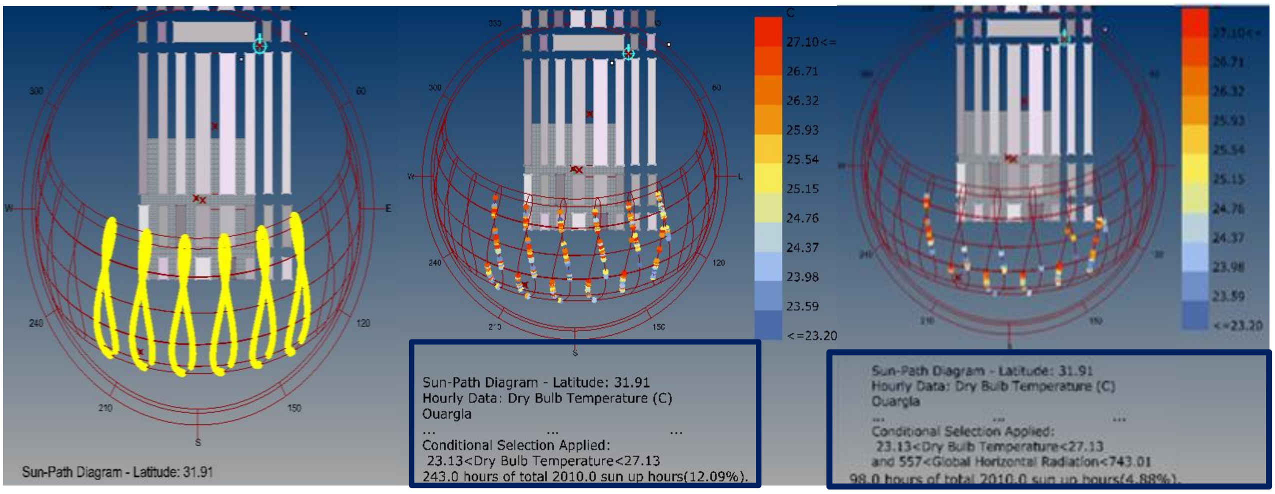
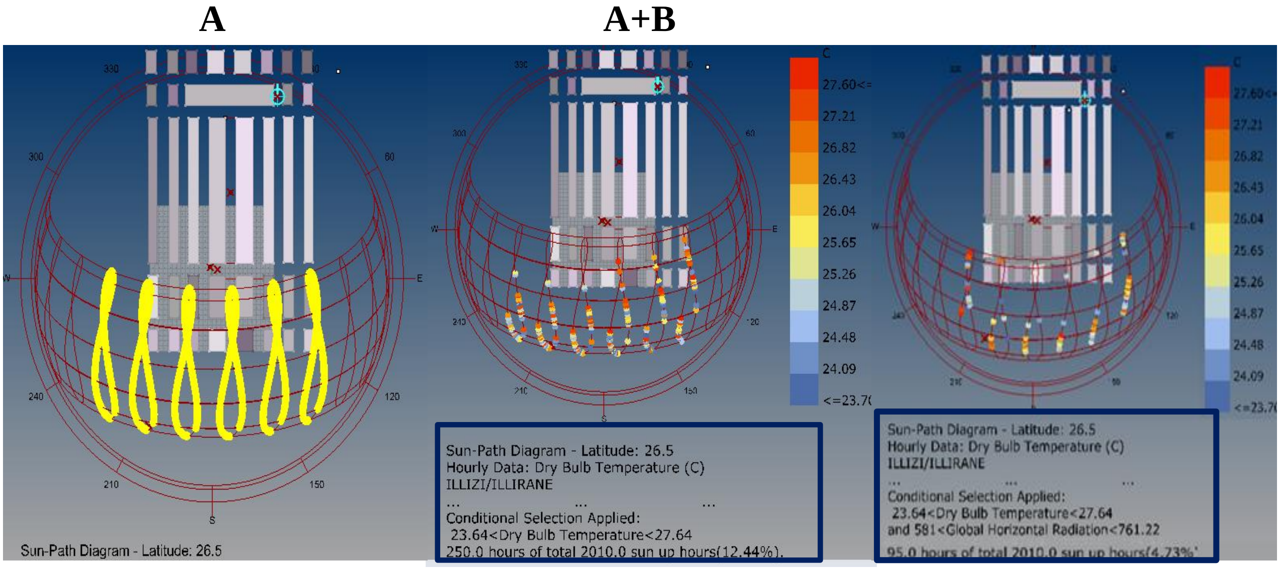


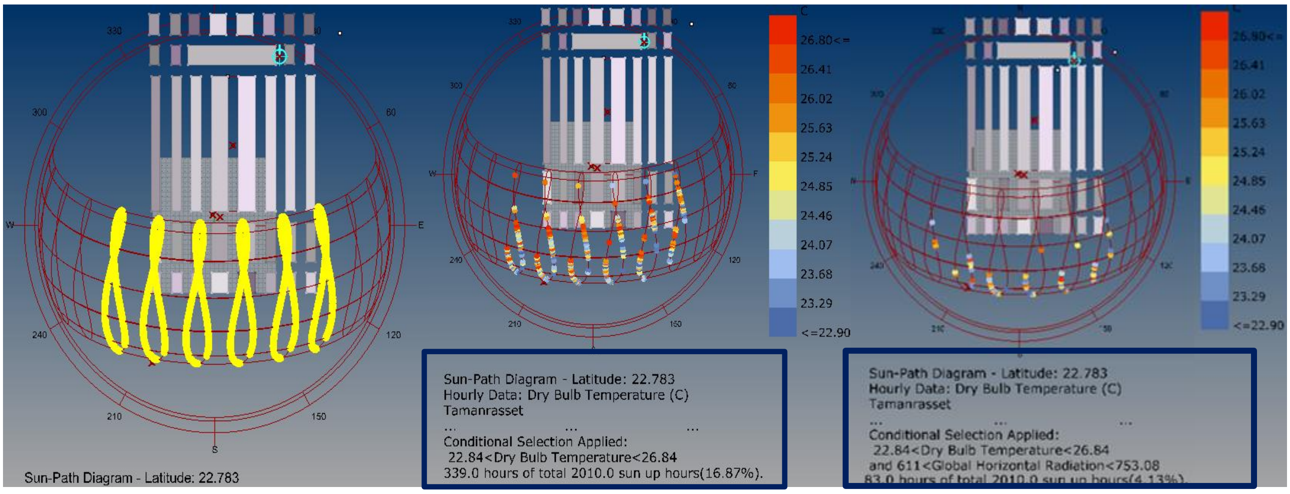
Figure 5.5: Filtering process of sun vectors in Sahara zone (A) (30^0<Latitude<35^0) Ouarguela (Author, 2019).



```
Sun-Path Diagram - Latitude: 26.5
Hourly Data: Dry Bulb Temperature (C)
ILLIZI/ILLIRANE
...                 ...                 ...
Conditional Selection Applied:
 23.64<Dry Bulb Temperature<27.64
250.0 hours of total 2010.0 sun up hours(12.44%).
```

```
Sun-Path Diagram - Latitude: 26.5
Hourly Data: Dry Bulb Temperature (C)
ILLIZI/ILLIRANE
...                 ...                 ...
Conditional Selection Applied:
 23.64<Dry Bulb Temperature<27.64
and 581<Global Horizontal Radiation<761.22
95.0 hours of total 2010.0 sun up hours(4.73%
```

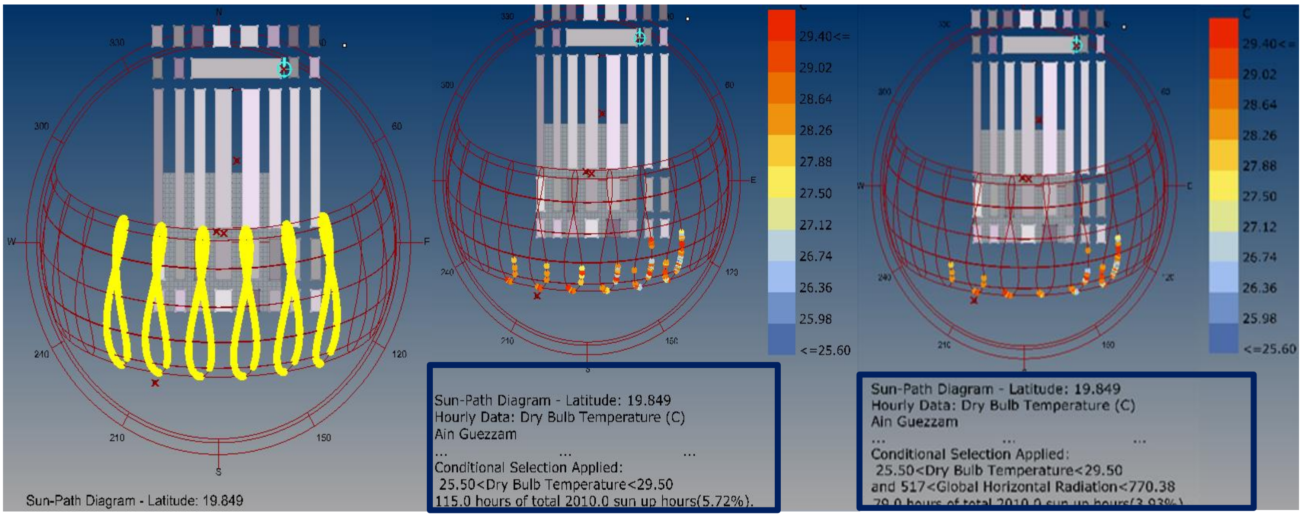
Figure 5.6: Filtering process of sun vectors in Sahara zone (B) (25^0<Latitude<30^0) ILLIZI (Author.2019).



```
Sun-Path Diagram - Latitude: 22.783
Hourly Data: Dry Bulb Temperature (C)
Tamanrasset
...                 ...                 ...
Conditional Selection Applied:
 22.84<Dry Bulb Temperature<26.84
339.0 hours of total 2010.0 sun up hours(16.87%).
```

```
Sun-Path Diagram - Latitude: 22.783
Hourly Data: Dry Bulb Temperature (C)
Tamanrasset
...                 ...                 ...
Conditional Selection Applied:
 22.84<Dry Bulb Temperature<26.84
and 611<Global Horizontal Radiation<753.08
83.0 hours of total 2010.0 sun up hours(4.13%).
```

Figure5.7: Filtering process of sun vectors in Sahara zone (C) (20^0<Latitude<25^0) Tamanrasset (Author, 2019)



```
Sun-Path Diagram - Latitude: 19.849
Hourly Data: Dry Bulb Temperature (C)
Ain Guezzam
...                 ...                 ...
Conditional Selection Applied:
 25.50<Dry Bulb Temperature<29.50
115.0 hours of total 2010.0 sun up hours(5.72%).
```

```
Sun-Path Diagram - Latitude: 19.849
Hourly Data: Dry Bulb Temperature (C)
Ain Guezzam
...                 ...                 ...
Conditional Selection Applied:
 25.50<Dry Bulb Temperature<29.50
and 517<Global Horizontal Radiation<770.38
79.0 hours of total 2010.0 sun up hours(3.93%).
```

Figure 5.8: Filtering process of sun vectors in Sahara zone (D) (Latitude< 20^0) Ain Guezzam (Author, 2019).

1-2-The effect of filtering process of sun hours on solar volume coefficient

The solar volume coefficient (Average height) is defined as the solar envelope's volume to its base area ratio (SEV/A) (Stasinopoulos, 2018, P.9).A numerical comparison on the effect of filtering process of sun hours on solar volume coefficient (V/S) in different latitudes can be evidenced by figures (5.9; and 5.10) and table (5.2). The results show that the solar volume coefficient of the generated solar envelopes of the aforementioned conditions of both east and west rows in different latitudes increases, when the initial requirement of sun vectors is more refined. Therefore the filtering process of sun vectors based on the conditional statement of SunPath diagram advocated by Capeluto and Boris (2017) leads to reconcile between maximizing solar access in spaces between buildings while achieving greater built density.

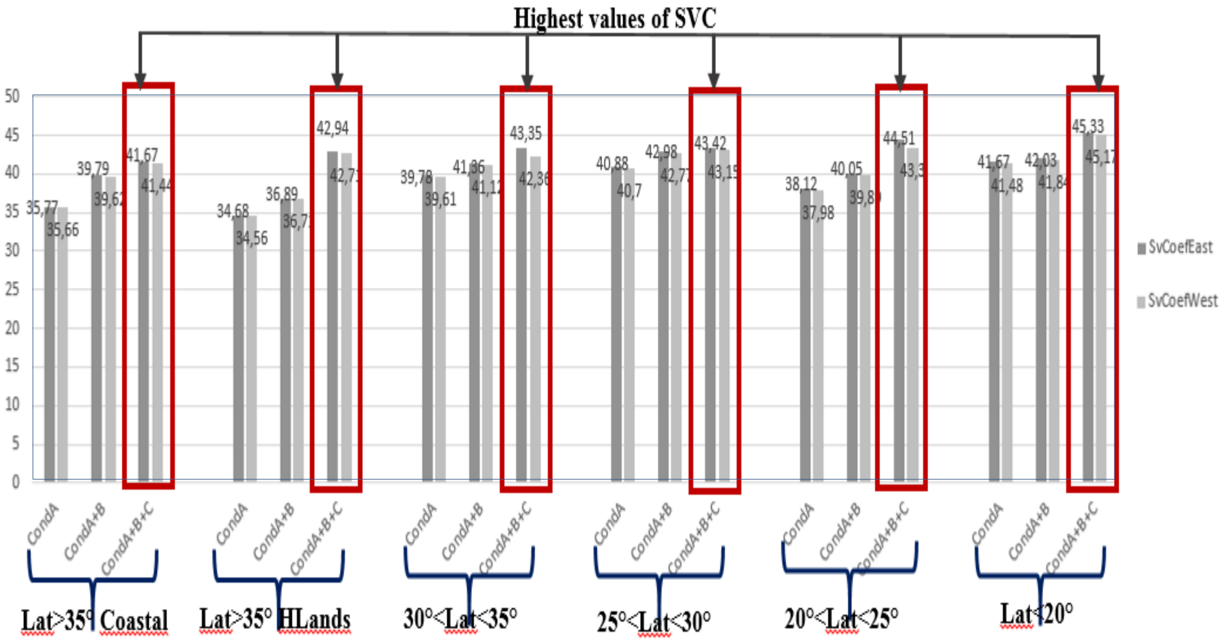


Figure 5.9: The effect of filtering process of sun hours on solar volume coefficient in different latitudes (Author, 2019)

Table 5.2: The effect of filtering process of sun hours on solar volume coefficient in different latitudes (Author, 2019)

Conditions	**Latitudes**			Lat>35^0 Coastal(Oran)	Lat>35$^0_{\text{High}}$ land (Constantine)	30^0<Lat<35^0 (Ouarguela)	25^0<Lat<30^0 (Illizi)	20^0<Lat<25^0 (Tamanrasset)	Lat<20^0 (Ain Guezzm)
Condition A	**Solar volume Coefficient (SVC$_{\text{condA}}$)**	East row		**34.68**	**35.77**	**38.12**	**39.78**	**40.88**	**41.67**
		West row		**34.56**	**35.63**	**37.98**	**39.61**	**40.70**	**41.48**
	Maximum height (Max$_{\text{height cond(A)}}$)	N	E$_{\text{row}}$	37.81m	37.54m	42.30m	43.73m	40.51m	43.48m
			W$_{\text{row}}$	37.52	37.54m	42.02m	43.41m	40.28m	43.16m
		E	E$_{\text{row}}$	37.81m	37.54m	42.30m	43.73m	40.52m	43.48m
			W$_{\text{row}}$	37.81m	37.54m	42.02m	43.41m	40.28m	43.16m
		S	E$_{\text{row}}$	37.81m	37.54m	42.30m	43.73m	40.52m	43.48m
			W$_{\text{row}}$	37.52m	37.54m	42.02m	43.41m	40.28m	43.16m
		W	E$_{\text{row}}$	37.52m	37.54m	42.30m	43.73m	40.52m	43.48m
			W$_{\text{row}}$	37.52m	37.54m	42.02m	43.41m	40.28m	43.16m
	Minimum height (Min$_{\text{height cond(A)}}$)	N	E$_{\text{row}}$	32.04m	30.57m	35.18m	36.02m	33.61m	36.45m
			W$_{\text{row}}$	32.04m	30.57m	35.18m	36.02m	33.61m	35.26m
		E	E$_{\text{row}}$	32.26m	30.57m	36m	36.02m	33.61m	36.45m
			W$_{\text{row}}$	32.04m	30.57m	35.18m	36.02m	33.61m	35.26m
		S	E$_{\text{row}}$	32.26m	32.30m	36m	36.6m	34.74m	36.48m
			W$_{\text{row}}$	32.04m	32.30m	35.18m	36.6m	34.74m	36.11m
		W	E$_{\text{row}}$	32.04m	30.57m	36m	36.02m	33.61m	36.45m
			W$_{\text{row}}$	32.26m	30.57m	35.18m	36.02m	33.61m	35.26m
Condition A+B	**Solar volume Coefficient (SVC$_{\text{condA+B}}$)**	East row		**36.89**	**39.79**	**40.05**	**41.36**	**42.03**	**42.98**
		West row		**36.72**	**39.62**	**39.98**	**41.12**	**41.84**	**42.77**
	Maximum height (Max$_{\text{height cond(A+B)}}$)	N	E$_{\text{row}}$	44.88m	42.35m	43.89m	45.83m	43.45m	45.72m
			W$_{\text{row}}$	44.59m	42.35m	43.59m	45.47m	43.16m	44.05m
		E	E$_{\text{row}}$	44.88	42.35m	43.89m	45.83m	43.45m	45.72
			W$_{\text{row}}$	44.59m	42.35m	43.59m	45.47m	43.16m	44.05m
		S	E$_{\text{row}}$	44.85m	42.35m	43.89m	45.83m	43.45m	45.72m
			W$_{\text{row}}$	44.59m	42.35m	43.59m	45.47m	43.16m	44.05m

		W	E	44.88m	42.35m	43.89m	45.83m	43.45m	45.72m
			W	44.59m	42.35m	43.59m	45.47m	43.16m	44.05m
	Minimum height (Min$_{height\ cond(A+B)}$)	N	E	34.23m	30.62m	35.18m	36.70m	33.89m	36.54m
			W	34.23m	30.62m	35.18m	36.70m	33.89m	36.54m
		E	E	34.23m	30.62m	35.18m	36.70m	33.89m	36.02m
			W	34.23m	30.62m	35.18m	36.70m	33.89m	36.02m
		S	E	37.59m	32.50m	36m	37.95m	35.89m	37.30m
			W	37.39m	32.50m	36m	37.95m	35.89m	37.30m
		W	E	34.23m	30.62m	35.18m	36.70m	33.89m	36.02m
			W	34.23m	30.62m	35.18m	36.70m	33.89m	36.02m
Condition A+B+C	**Solar volume coefficient (SVC$_{condA+B+C}$)**	E		**41.67**	**42.94**	**43.35**	**43.42**	**44.51**	**45.33**
		W		**41.44**	**42.36**	**42.71**	**43.15**	**43.30**	**45.17**
	Maximum height (Max$_{height\ cond(A+B+C)}$)	N	E	45.84m	46.68m	47.69m	47.64m	47. 48m	49.57m
			W	45.33m	46.27m	47.31m	47.21m	47.48m	48.42m
		E	E	45.84m	47.68m	47.69m	47.64m	48.16m	49.57m
			W	45.33m	47.68	47.31m	47.21m	48.16m	48.42m
		S	E	45.84m	47.68m	47.69m	47.64m	48.16m	49.57m
			W	45.33m	47.27m	47.31m	47.21m	48.16m	48.42m
		W	E	45.84m	47.27m	47.69m	47.64m	48.16m	49.57m
			W	45.33m	47.27m	47.31m	47.21m	48.16m	48.42m
	Minimum height (Min$_{height\ cond(A+B+C)}$)	N	E	35.44m	35.36m	36.57m	37.81m	35.25m	37.54m
			W	35.44m	35.36m	36.51m	37.81m	35.25m	37.54m
		E	E	36.18	35.36m	36.57m	37.81m	35.25m	37.3m
			W	36.18m	35.36m	38.2m	37.81m	35.25m	37.3m
		S	E	36.18m	37.1m	38.2m	37.81m	37.7m	37.3m
			W	36.18m	37.1m	38.2m	37.81m	37.7m	37.3m
		W	E	36.18m	35.36m	36.57m	37.81m	35.25m	37.54m
			W	36.18m	35.36m	38.2m	37.81m	35.25m	37.54m

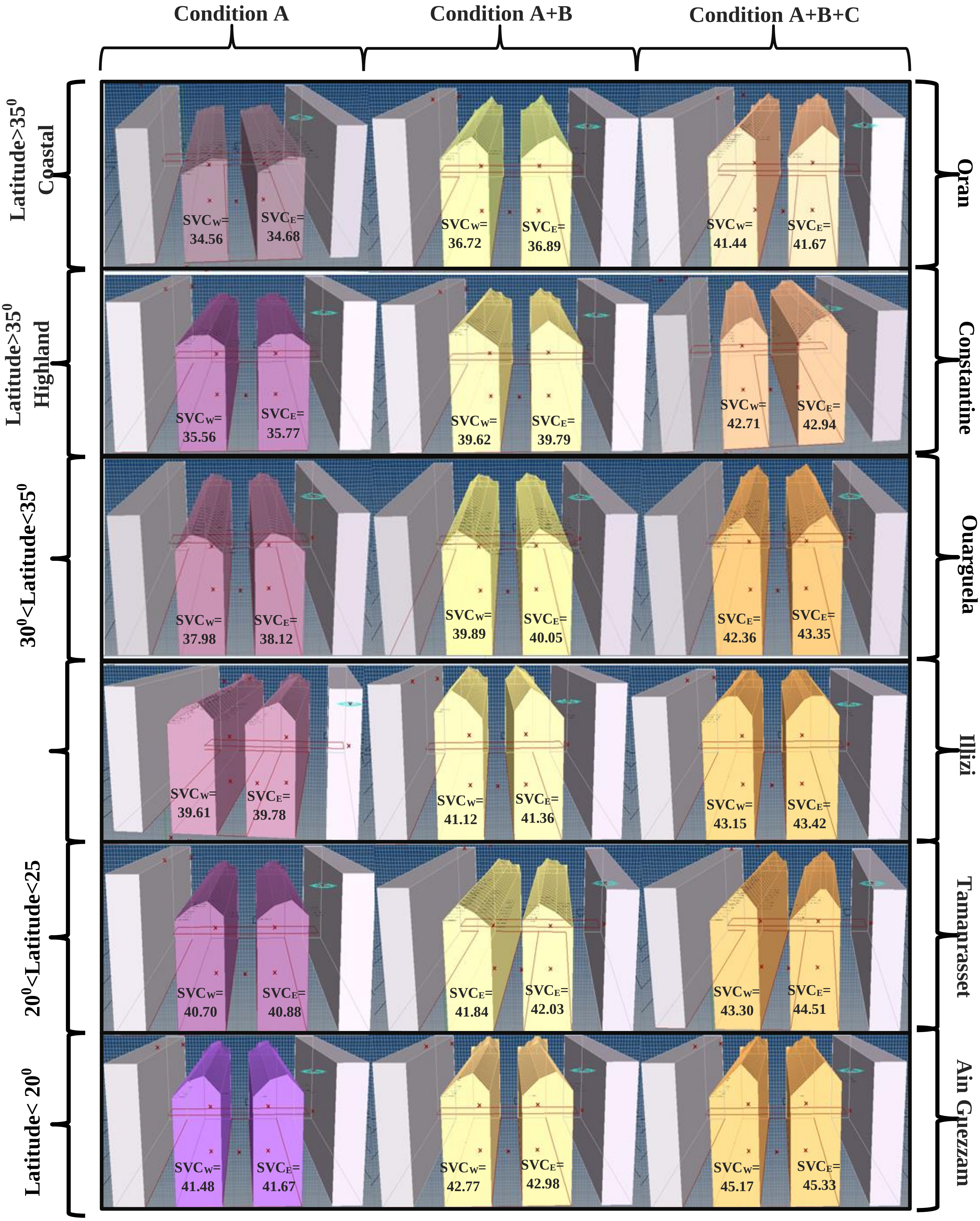


Figure 5.10: The generated solar envelopes according to the conditional requirement of each latitude (Author, 2019).

Table (5.2) shows that the minimum and maximum heights also the resulting solar volume coefficient of solar envelopes vary significantly according to the latitude of the climatic zones. As a general rule we see that the values of the solar volume coefficient in high latitudes (Coastal and Highlands zones) are small in comparison with the values of solar volume coefficient in low latitudes (Sahara zone A, B,C,D) which are characterized by hot and dry climate. The findings of this study also display that the minimum and maximum heights of the resulting solar envelope differ considerably to the orientation. While, the south east and west screens have higher values of heights (minimum and maximum) in comparison with north ones. This fact can be explained by that the north orientation revives less solar radiation in comparison with the other ones. Thus this later has to lower height in order to allow sun penetration to adjacent buildings as well as spaces surrounding them (See figures 5.11; 5.12; 5.13; 5.14; 5.15; 5.16).

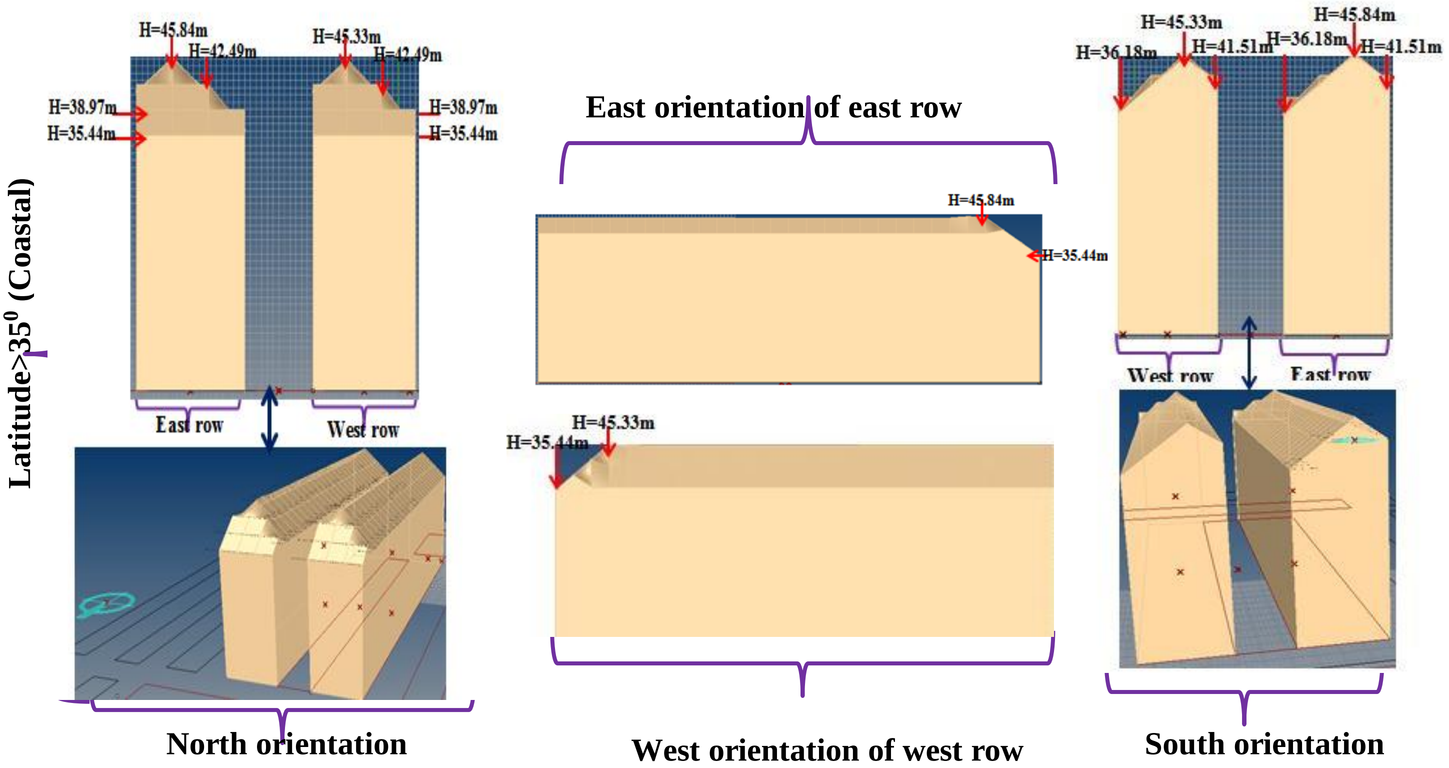


Figure 5.11: The maximum and minimum heights of solar envelope (A+B+C) in latitude>35^0(Coastal zone-Oran-) (Author, 2019)

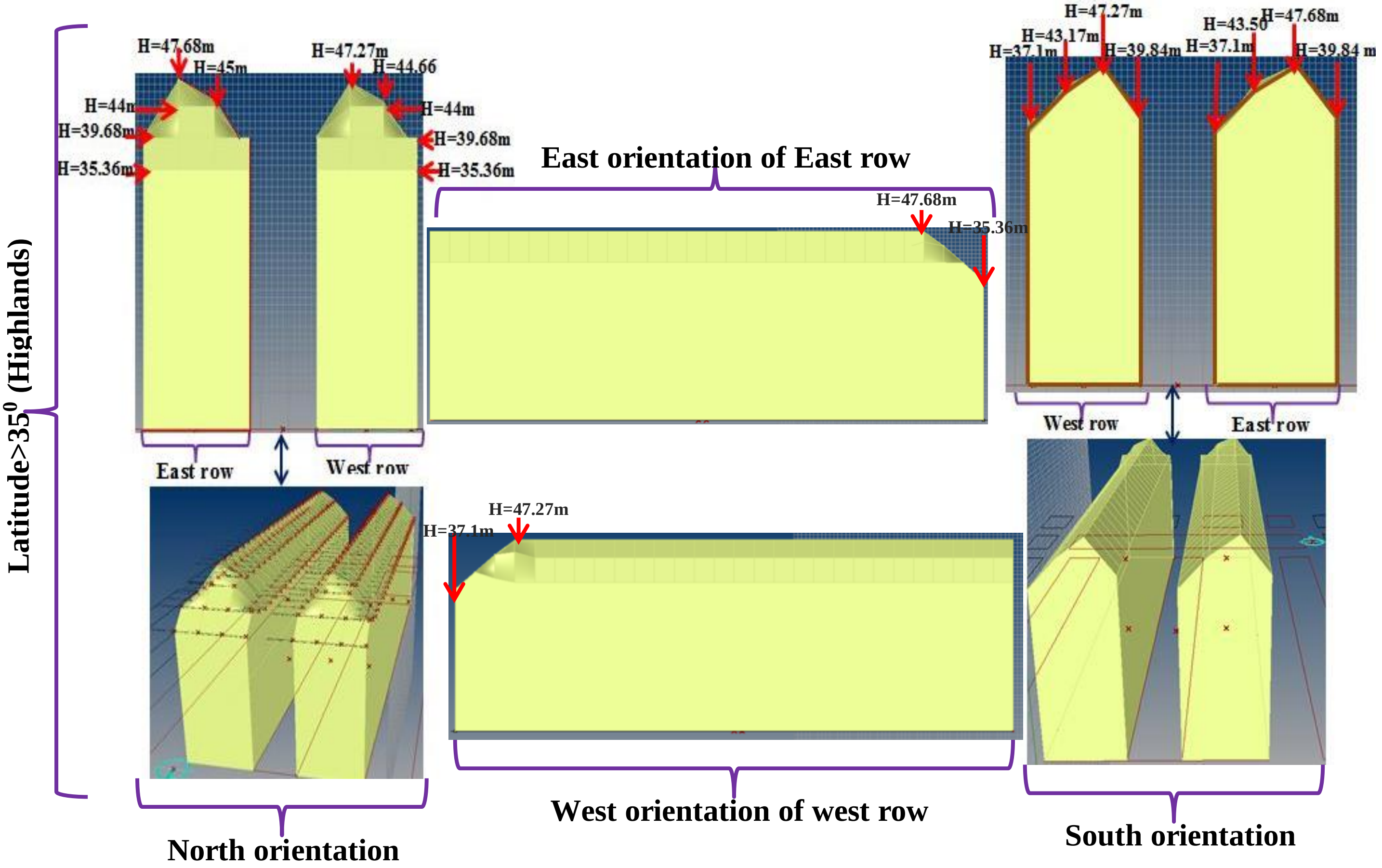


Figure 5.12: The maximum and minimum heights of solar envelope (A+B+C) in latitude>35^0(Highlands zone-Constantine-) (Author, 2019)

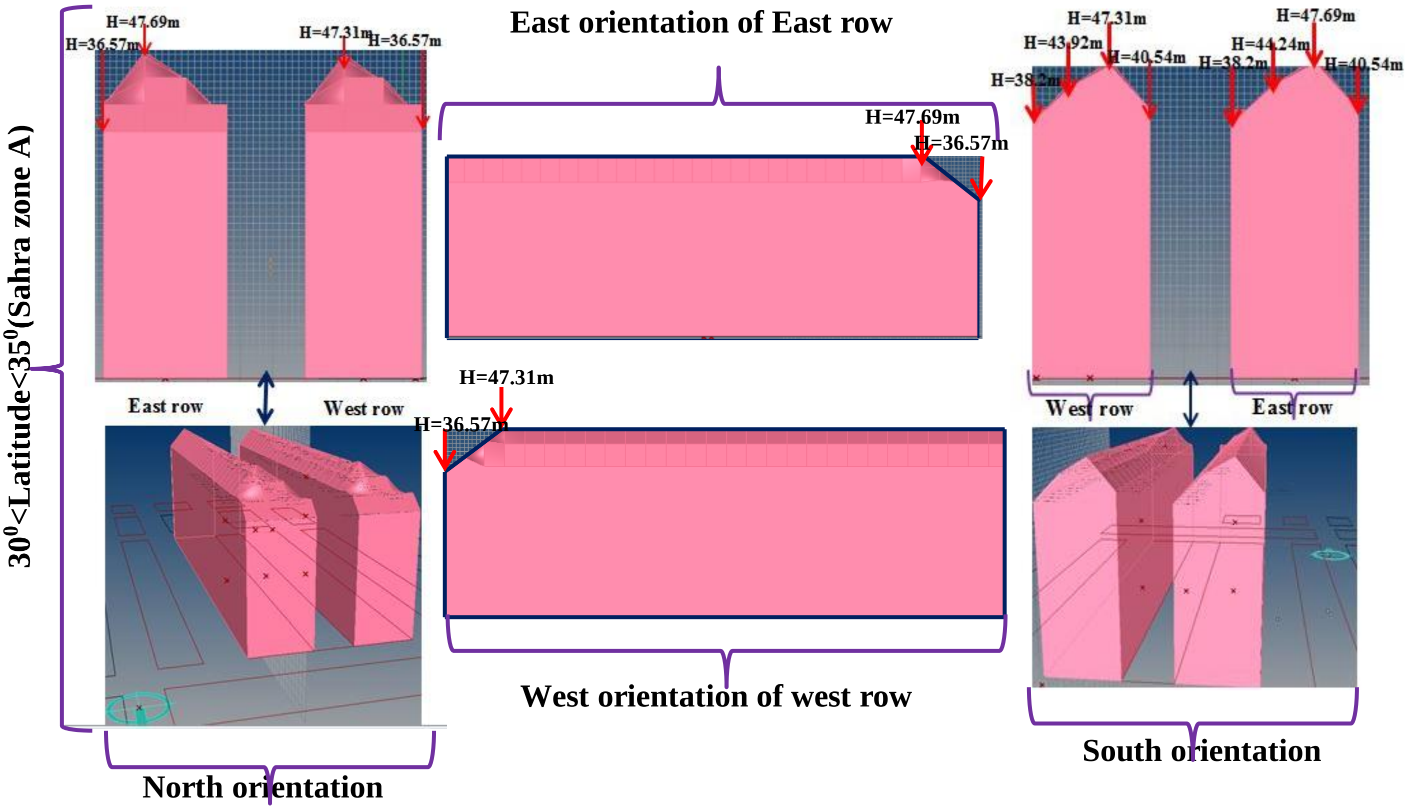


Figure 5.13: The maximum and minimum heights of solar envelope (A+B+C) in 30^0<Latitude <35^0 (Ouarguela) (Author, 2019)

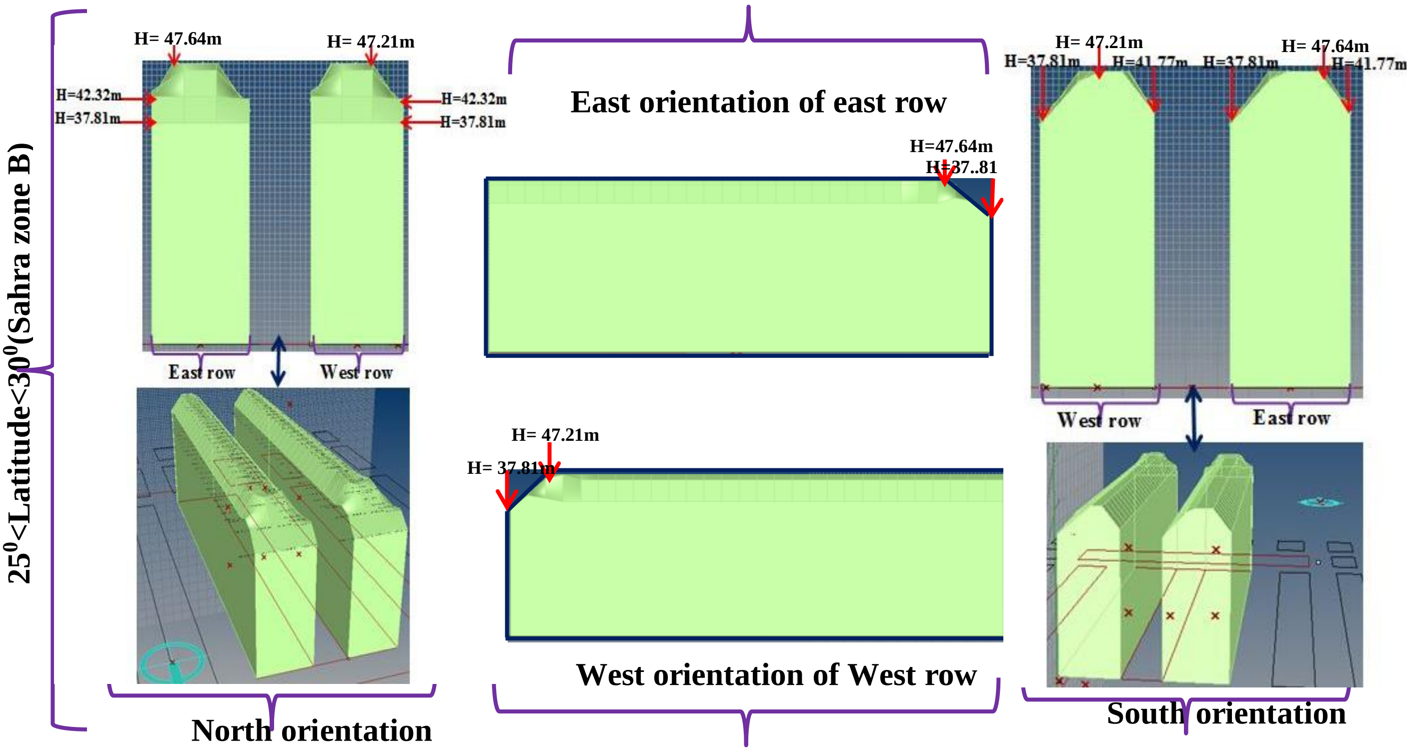


Figure 5.14: The maximum and minimum heights of solar envelope (A+B+C) in 25^0<Latitude <30^0 (Illizi) (Author, 2019)

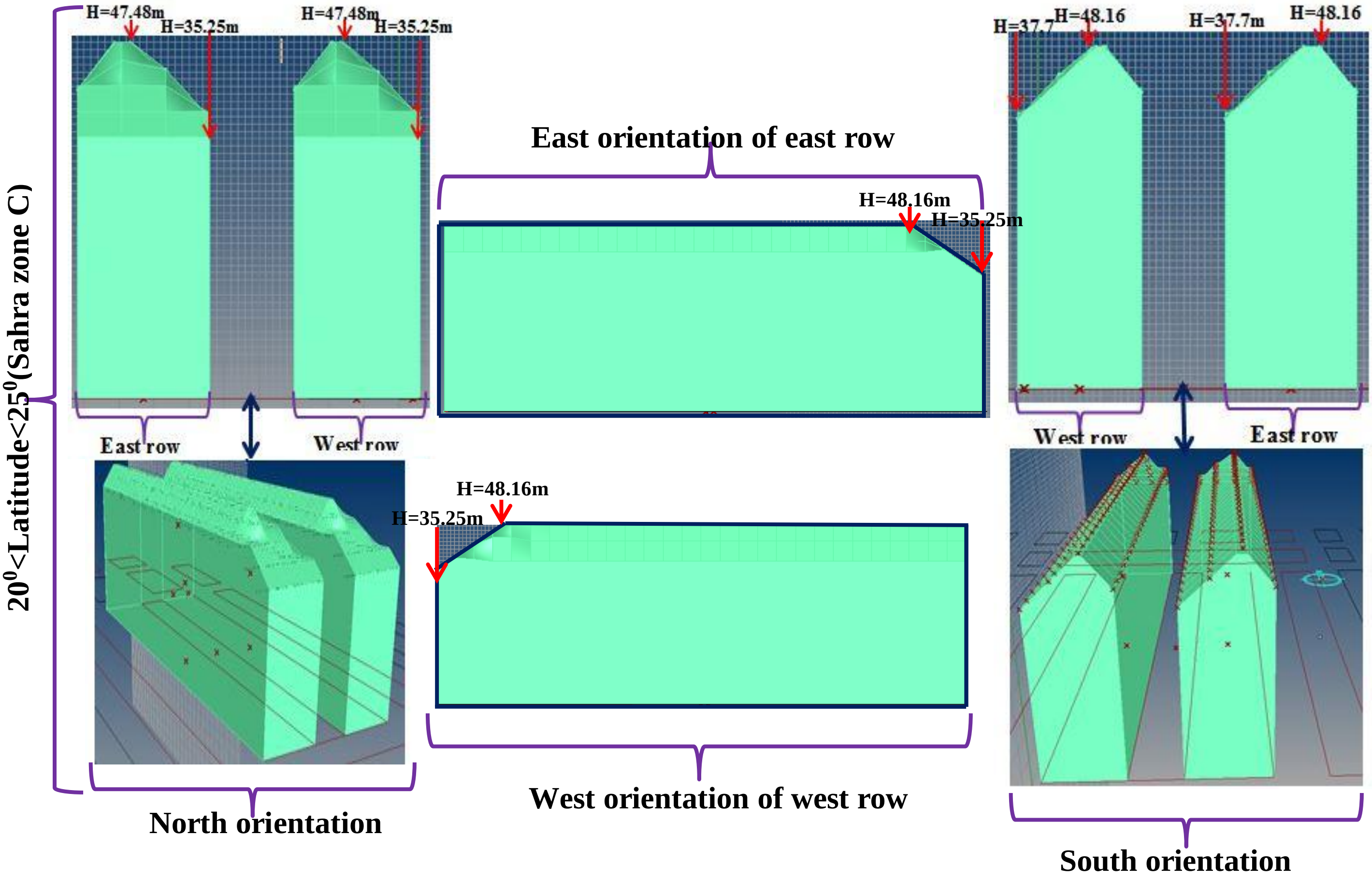


Figure 5.15: The maximum and minimum heights of solar envelope (A+B+C) in 20^0<Latitude <25^0 (Tamanrasset) (Author, 2019)

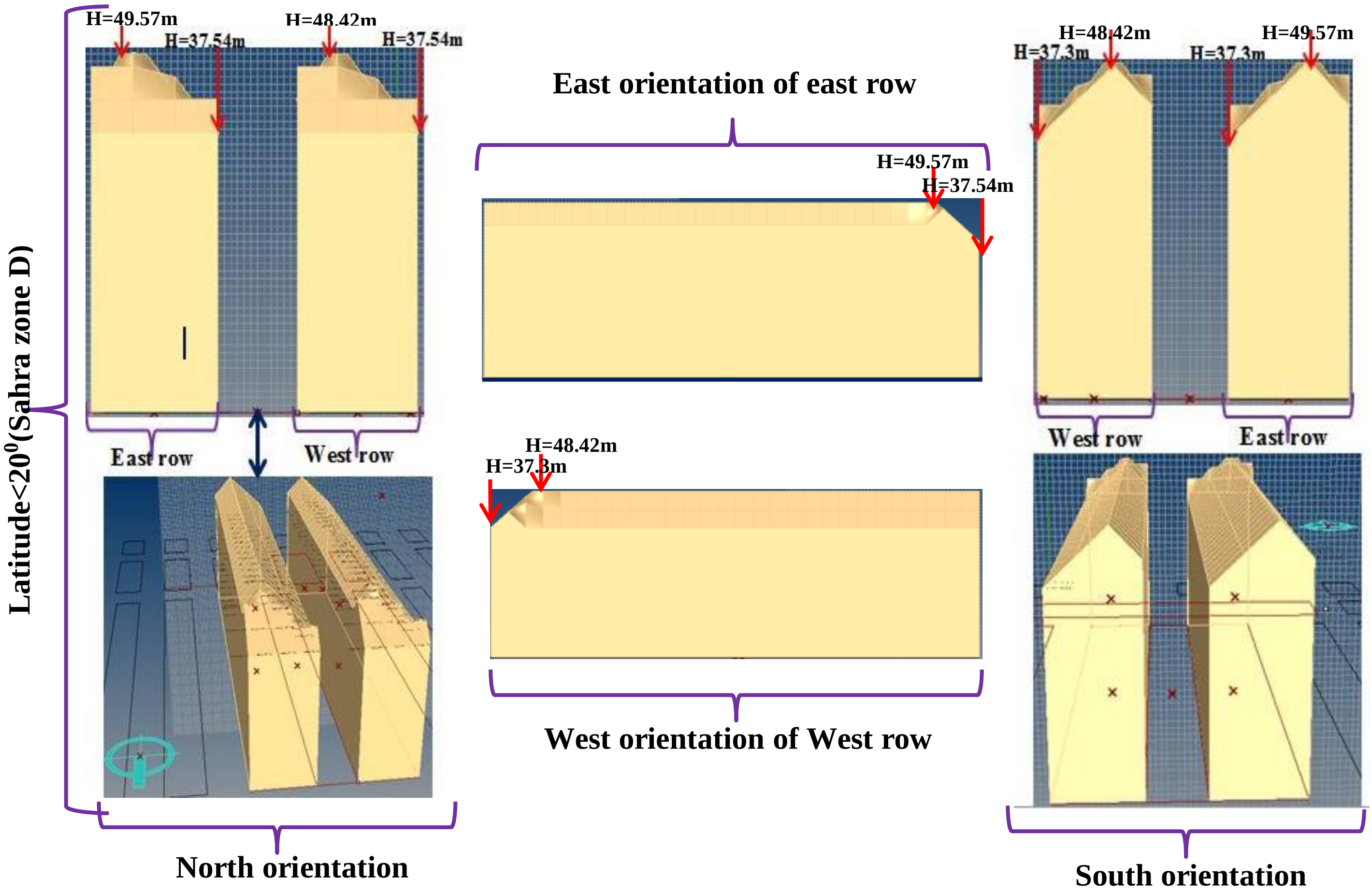


Figure 5.16: The maximum and minimum heights of solar envelope (A+B+C) in Latitude <20^0 (Ain Guezzam) (Author, 2019)

2- The effect of solar volume coefficient on solar radiation and outdoor thermal comfort

According to Arens et al. (2015) Solar access and shade have a crucial role in defining occupier thermal comfort both outdoors and indoors (Capeluto and Plotnikov,2017, P.397).Therefore, the design process has to appeal zoning regulations which consider the local climate and the specific context’s shading requirement into account. After assessing the effect of filtering process of sun vectors on solar volume coefficient in different latitudes according to climatic zones of Algerian territory, we attempt through this section to evaluate the effect of solar volume coefficient on solar radiation and outdoor thermal comfort at the level of urban street canyon in all the climatic zones of Algerian territory. This evaluation is mandatory to regulate the maximum acceptable height of a building that does not disrupt solar rights and shading requirement of neighboring buildings and spaces surroundings them. On one hand, the average values of solar radiation received at the level of ground surface of urban street canyon have been assessed by using ladybug radiation analysis (component in ladybug software). On the other hand, outdoor thermal sensation of the walker at the level of urban street canyon has been assessed by the calculation of the Universal Thermal Climate Index (UTCI). The calculation of this latter is done by applying the algorithm of UTCI calculation (See chapter 4, figure4.3, and page89). The investigation was conducted during both summer and winter periods. Weather data is obtained from Meteonorm 7.

2-1- The effect of solar volume coefficient on solar radiation:

Basically, the average values of solar radiation received at the level of ground surface of urban street canyon decrease with the increase of the height of the surrounding buildings. Figure (5.17) illustrates the effect of solar volume coefficient (Average height) of parametric solar envelopes (East and West rows) issued from the filtering process of sun vectors, on the average values of solar radiation received at the level of ground surface of urban street canyon, during both summer and winter periods. As we have demonstrated earlier in the previous section, the solar volume coefficient increases when the initial requirement of sun vectors is more refined. Also, the values of solar volume coefficient in high latitudes are smaller than the values of solar volume coefficient in low latitudes. On this basis we can say that the filtering process of sun vectors according to the initial requirement of sun access of the climatic zone has a significant effect on the values of solar volume coefficient, which influences directly the direct solar radiation impinged on ground surface of urban street canyon. Since the previous figure (5.17) shows that in high latitudes (Latitude>35^0 Coastal; Highlands) and low latitudes (30^0<Latitude<35^0; 25^0<Latitude<30^0; 20^0<Latitude<25^0; Latitude<20^0) the average values of solar radiation impinged on ground surface of urban street of solar volume coefficient of condition (A) during summer period are as following respectively to the latitude of their locations: 193.2 Kw/m^2, 196.94Kw/m^2, 242.01Kw/m^2, 386.62Kw/m^2, 395.9Kw/m^2, 275.9Kw/m^2. While, the average values of solar radiation received on ground surface of urban street of solar volume coefficient (SVC) of condition (A) during winter period are as following respectively to the latitude of their locations: 100.15Kw/m^2, 106.72Kw/m^2, 170.66 Kw/m^2 , 190Kw/m^2, 199.01 Kw/m^2, 200.37 Kw/m^2. However, on the other hand the average values of solar radiation impinged on ground surface of urban street canyon of (SVC) of condition (A+B+C) during winter period are as following respectively to the latitude of their locations: 70.14 Kw/m^2; 74.54 Kw/m^2; 108.94 Kw/m^2; 120.74 Kw/m^2; 166.75 Kw/m^2; 176.56 Kw/m^2 (See figures 5.18(a); 5.19(a); 5.20(a); 5.21(a); 5.22(a); 5.23(a)).While, during summer period the average values of solar radiation impinged on ground surface of urban street canyon of (SVC) of condition (A+B+C) are as following respectively to the latitude of their locations: 110.43 Kwh/m^2 ; 113.04 Kwh/m^2; 159.85 Kwh/m^2; 175.11 Kwh/m^2; 195.59 Kwh/m^2; 217.23 Kwh/m^2(See figures 5.18(b); 5.19(b); 5.20(b); 5.21(b); 5.22(b); 5.23(b)). These results indicate that in both high and low latitudes the ground surface of urban street canyon of small values of solar volume coefficient are the most exposed to direct solar radiation during summer and winter periods. These findings also show that refining condition of sun vectors leads to increase solar volume coefficient which leads to reduce the average values of solar radiation fallen on urban street canyon during summer and winter periods. In order to determine the optimum value of the solar volume coefficient, the effect of this latter on the universal thermal climate index (UTCI) will be examined in the next statement of this section.

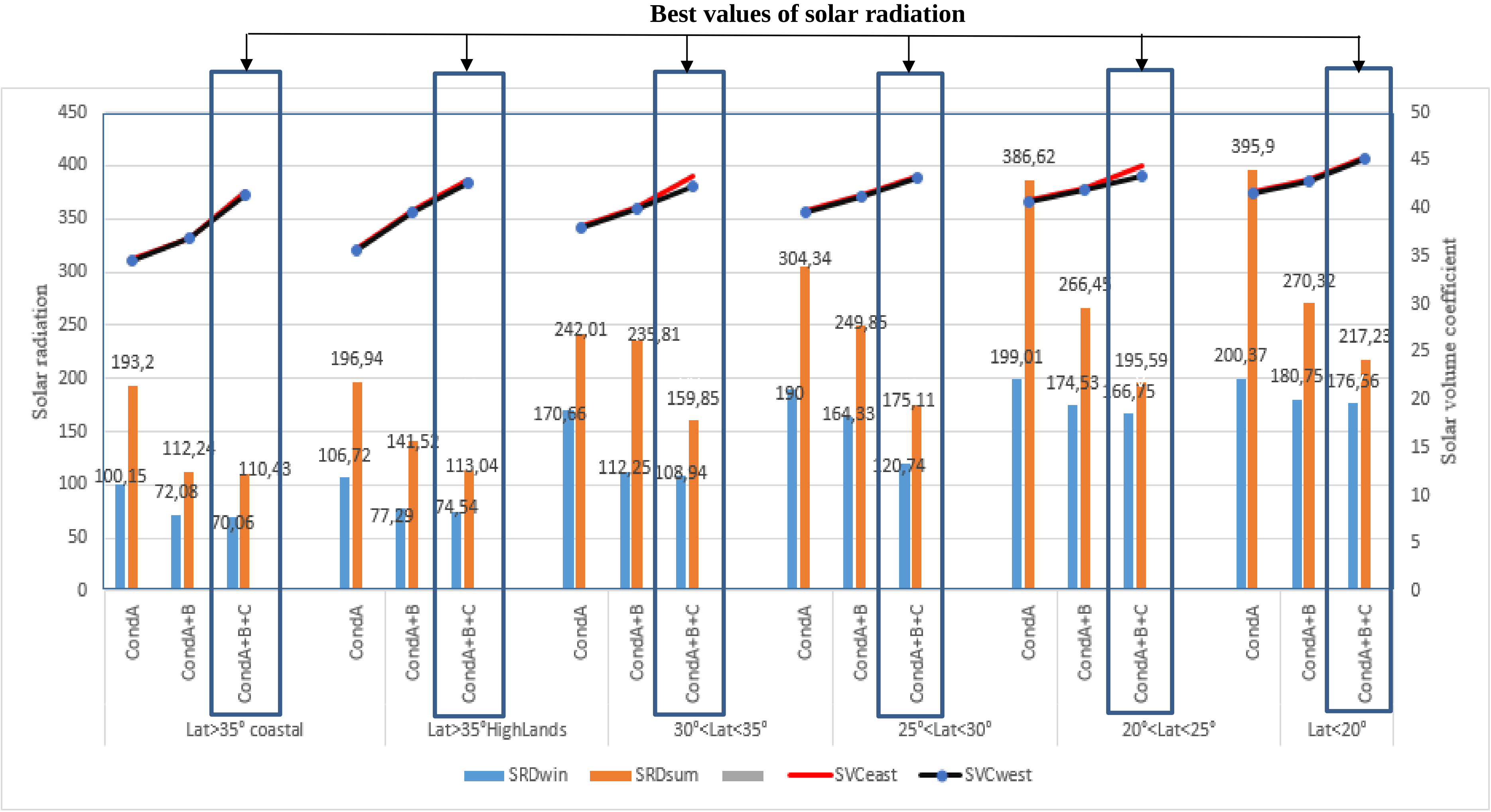


Figure 5.17: The effect of solar volume coefficient of parametric solar envelope of conditions (A; A+B; A+B+C) on solar radiation in different latitudes (Author, 2019)

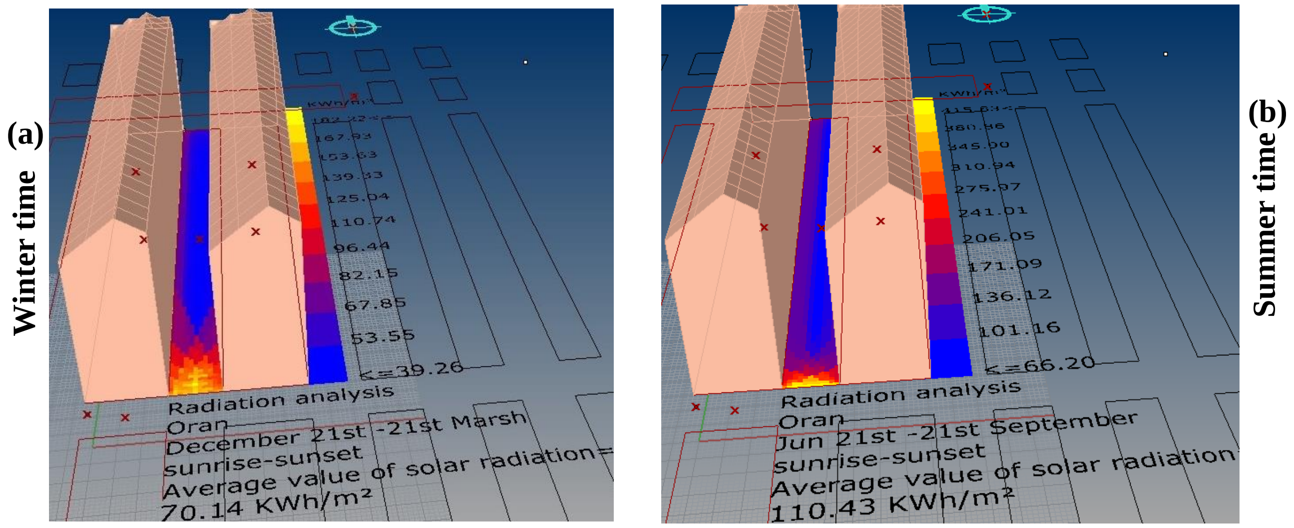


Figure 5.18(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Oran (Author, 2019).

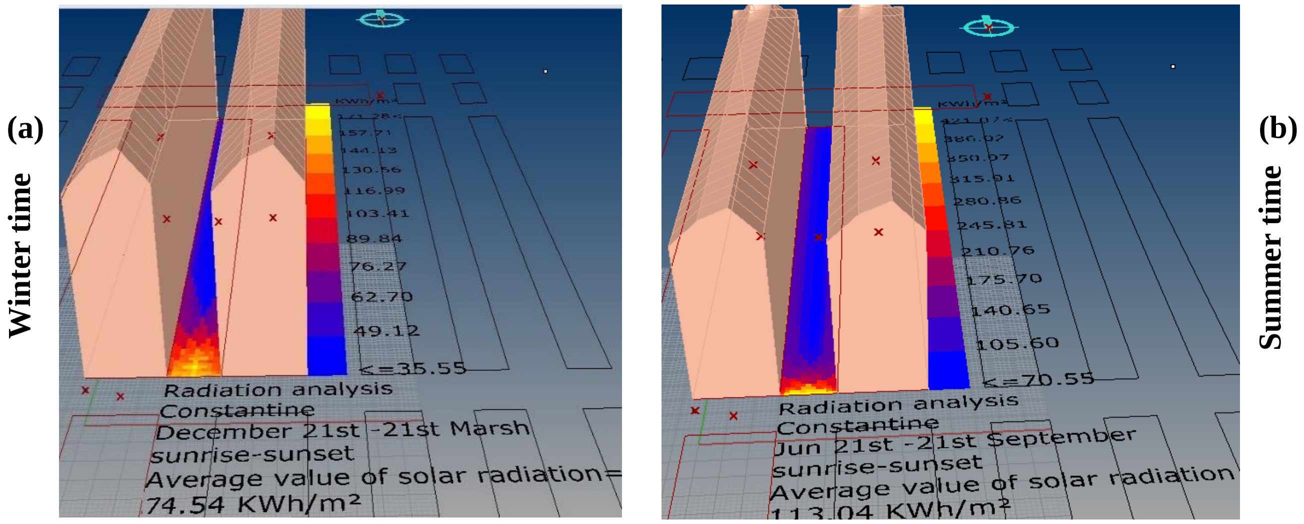


Figure 5.19(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Constantine (Author, 2019).

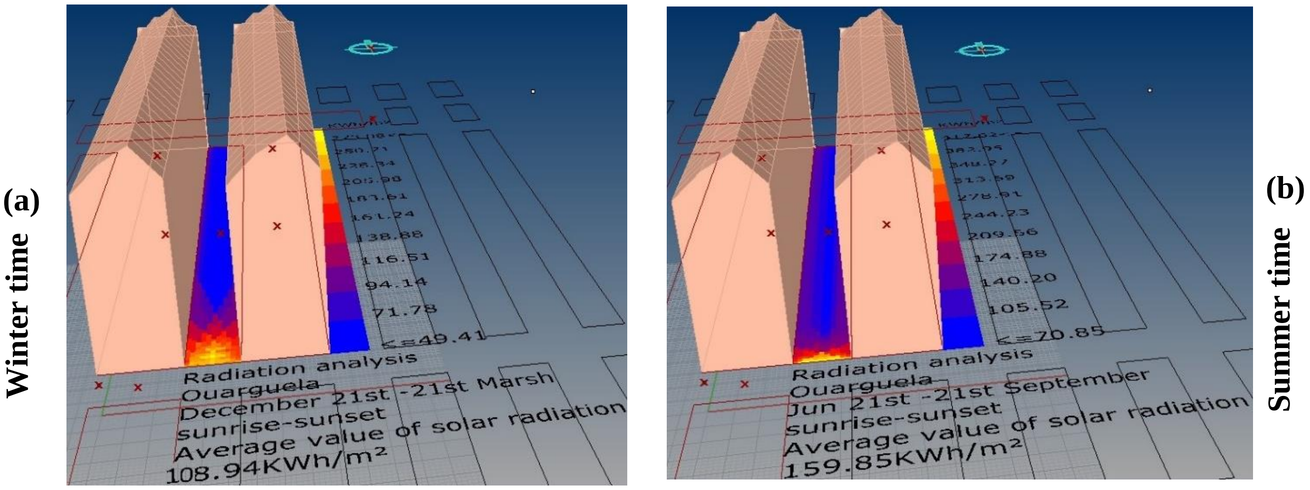


Figure 5.20(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Ouarguela (Author, 2019).

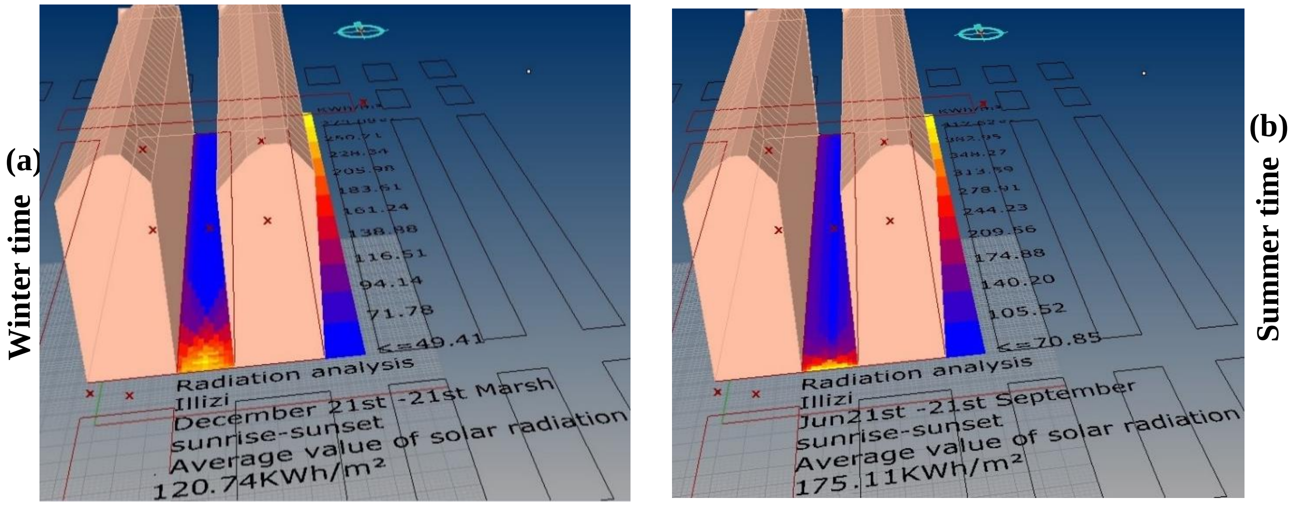


Figure 5.21(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Illizi. (Author, 2019).

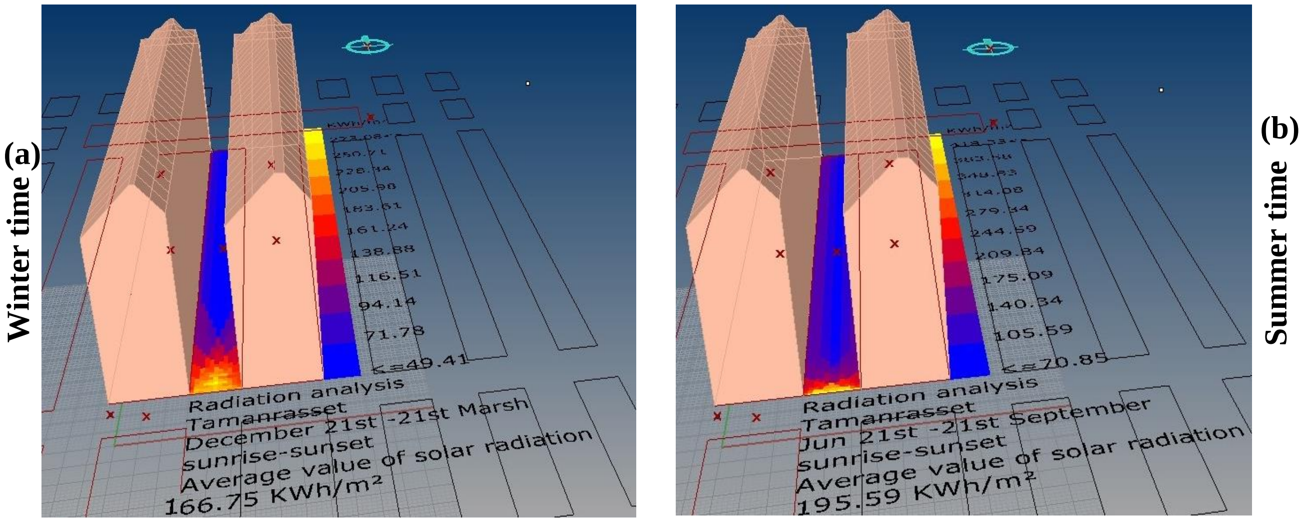


Figure 5.22(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Tamanrasset. (Author, 2019).

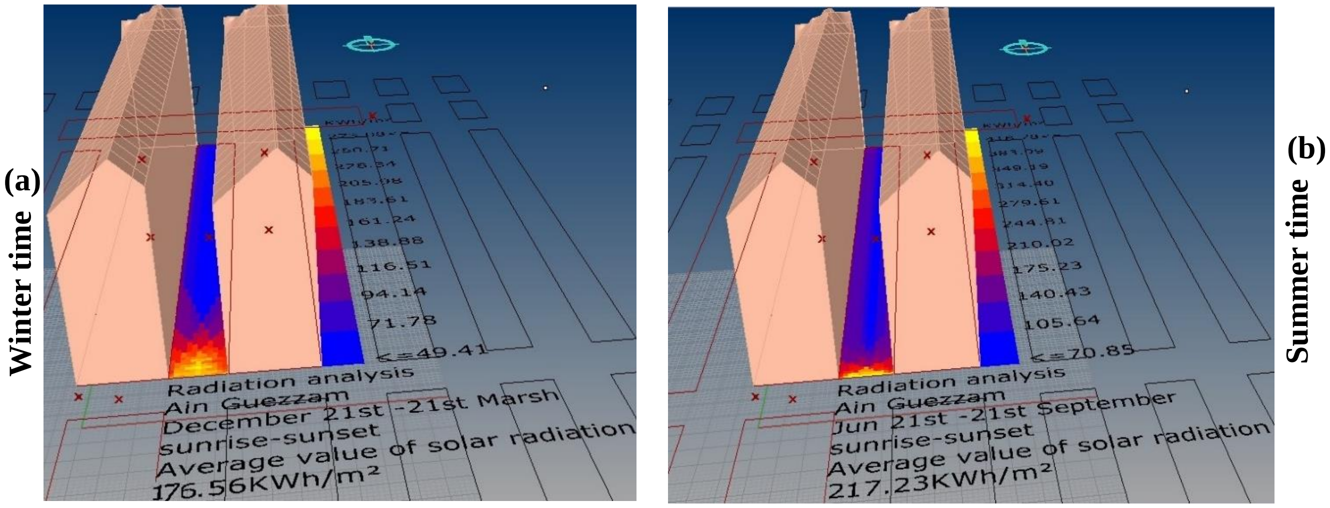


Figure 5.23(a, b): Solar radiation received on ground surface of urban street of solar envelope of condition (A+B+C) in Ain Guezzam. (Author, 2019).

2-2- The effect of solar volume coefficient on the universal thermal climate index (UTCI):

The effect of solar volume coefficient of the parametric solar envelopes of conditions (A; A+B; A+B+C) on the average values of (UTCI) has been assessed during summer and winter periods at different latitudes of the climatic zones in the national Algerian territory. Figure (5.24) reveals that when solar volume coefficient increases, the average values of UTCI decreases during both summer and winter periods, in all the investigated latitudes. From the summary of the simulation results shown in the previous figure (5.24) it can be concluded that the parametric solar envelope can mitigate the thermal sensation of the walker during winter period in high latitudes. However, the application of the parametric solar envelope drops summer outdoor thermal comfort in low latitudes. Since, after applying the parametric solar envelope of conditions (A; A+B; A+B+C), the average values of UTCI recorded during winter period in high latitude were as following respectively to the solar volume coefficient of conditions (A; A+B; A+B+C): 15.06^{0}C; 12.91^{0}C; 11.91^{0}C in the coastal zone; and 11.43^{0}C; 9.75^{0}C ; 9.36^{0}C in highlands zone. In comparison with the values of UTCI of the solar volume coefficient before applying the parametric solar envelope, these values were better for 7.47^{0}C; 5.32^{0}C; 4.32^{0}C, respectively to the solar volume coefficient of the conditions (A; A+B; A+B+C) in coastal zones, and were better for 5.26^{0}C; 3.58^{0}C; 3.19^{0}C, respectively to the solar volume coefficient of conditions (A; A+B; A+B+C) in highlands zone. Furthermore, these values indicate that winter outdoor thermal comfort is safeguarded because there is no thermal stress in such conditions (See Table2.4.page37). However, after applying the parametric solar envelope of conditions (A; A+B; A+B+C) in low latitudes, the average values of the UTCI during summer period were ranged between 40.54^{0}C and 43.85^{0}C in Sahara zone (A) (30^0<Latitude<35^0); 39.79^{0}C and 41.27^{0}C in Sahara zone (B) (25^0<Latitude<30^0); 32.62^{0}C and 34.22^{0}C in Sahara zone (C) (20^0<Latitude<25^0); 36.55^{0}C and 38.81^{0}C in Sahara zone (D) (Latitude<20^{0}C) . In comparison with the values of UTCI during summer period before applying the parametric solar envelope of conditions (A; A+B; A+B+C) in low latitudes, the results were worse of 1.7^{0}C to 5.01^{0}C in Sahara zone (A); 1.86^{0}C to 3.34^{0}C in Sahara zone (B); 2.6^{0}C to 4.2^{0}C in Sahara zone (C); 0.74^{0}C to 3^{0}C in Sahara zone (D). Since, these results indicate that the thermal sensation of the walker during summer period in such conditions is characterized by strong to extreme heat stress (See table2.4 page.37).

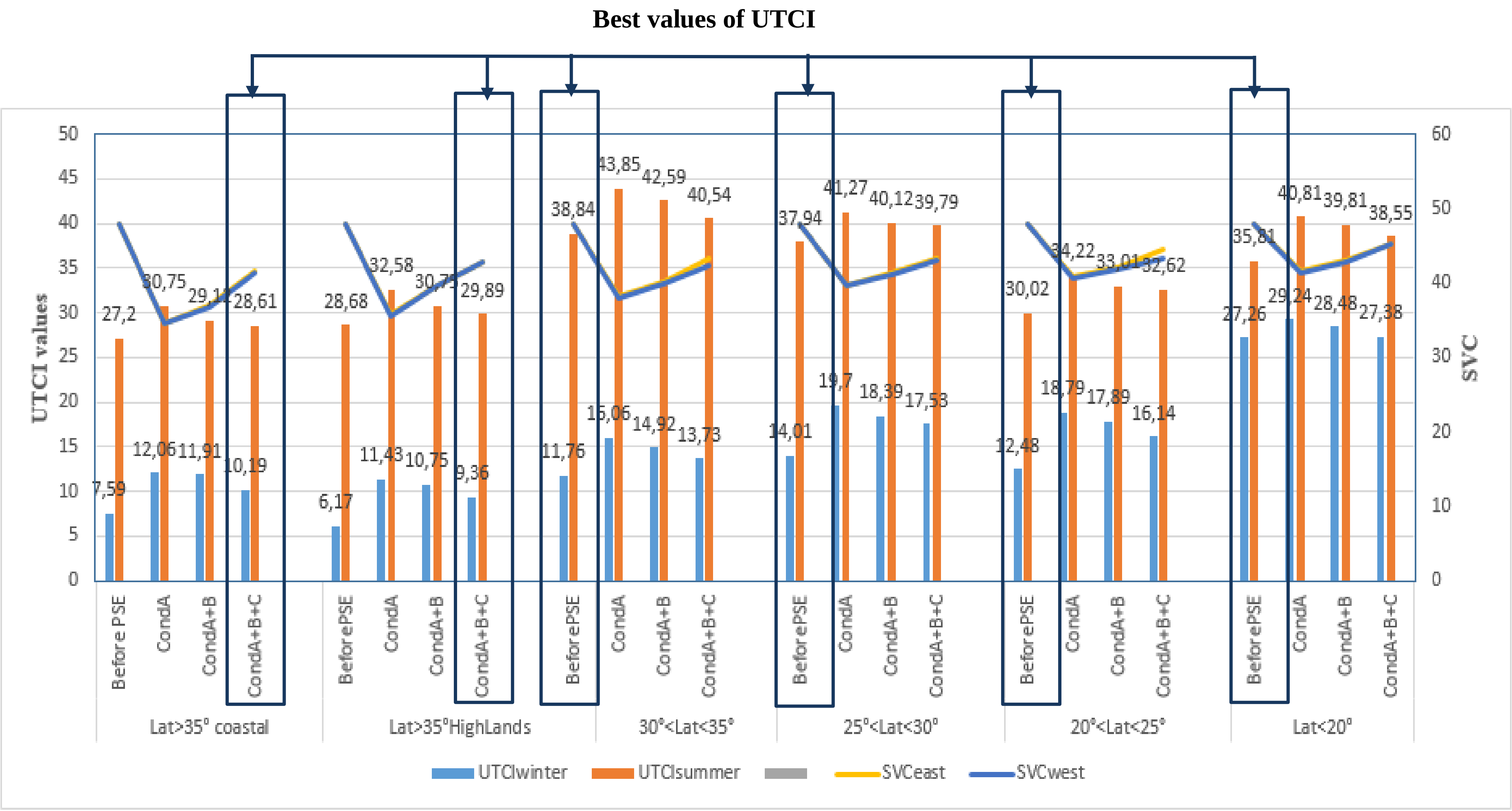


Figure5.24: The effect of solar volume coefficient of parametric solar envelope of conditions (A; A+B; A+B+C) on the UTCI in different latitudes (Author, 2019).

Therefore, the adoption of the solar volume coefficient issued from the application of parametric solar envelope of conditions (A; A+B; A+B+C) in low latitudes must be avoided to enhance summer outdoor thermal comfort. The findings of this study also demonstrate that in high latitude the solar volume coefficient of parametric solar envelopes of condition (A+B+C) is better than the solar volume coefficient of parametric solar envelope of conditions (A; A+B), because on one hand it can safeguard winter outdoor comfort, and on the other hand the average values of UTCI during summer time in both coastal and highlands zone are as following : 28.6^{0}C (Slights heat stress –comfortable for short periods of time) , 29.89^0 C (Moderate heat stress- hot but not dangerous) (See figures 5.25; 5.26). These values indicate that in high latitudes summer outdoor thermal sensation after implementing the solar volume coefficient of the parametric solar envelope of condition (A+B+C) is the same thermal sensation of the walker during summer time before applying the parametric solar envelope of condition (A+B+C). After this analysis, by the using of geographic information system (GIS) tool (ArcGIS 10.3), we have summarized the best values of the solar volume coefficient in the Algerian map according to the latitude of the climatic zones (See figure 5.27). This map will help urban planners and designers to draw future urban spaces in accordance with solar rights and shading requirement of the climatic zones. Despite this finding shows on one hand some improvement of outdoor thermal comfort, on the other hand, it presents some degree of lack, especially during summer period. Therefore, more studies about the effect of vegetation and biomimetic shading on pedestrian thermal comfort will be conducted in further studies.

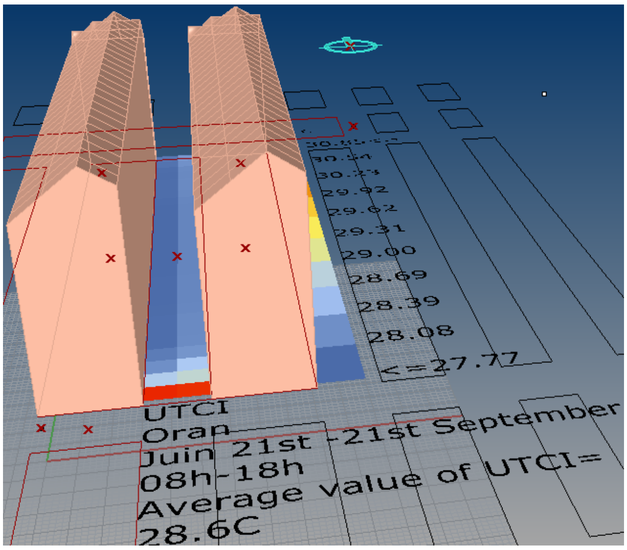


Figure 5.25: UTCI values during summer time in urban street of solar envelope of condition (A+B+C) in Oran (Author, 2019).

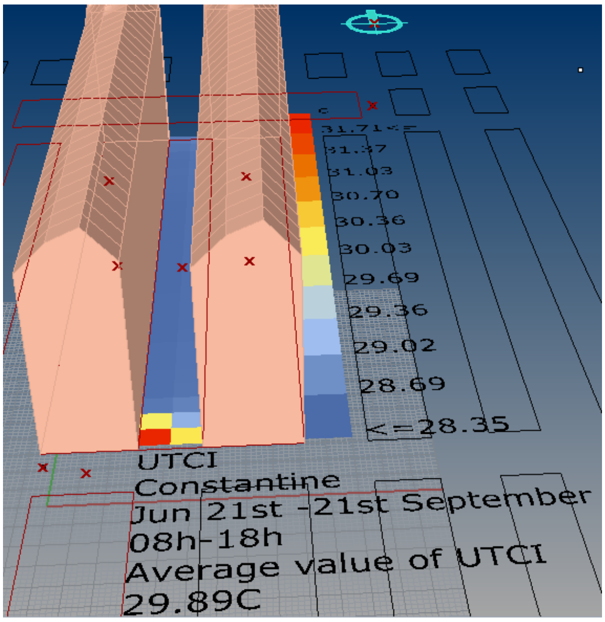


Figure 5.26: UTCI values during summer time in urban street of solar envelope of condition (A+B+C) in Constantine (Author, 2019).

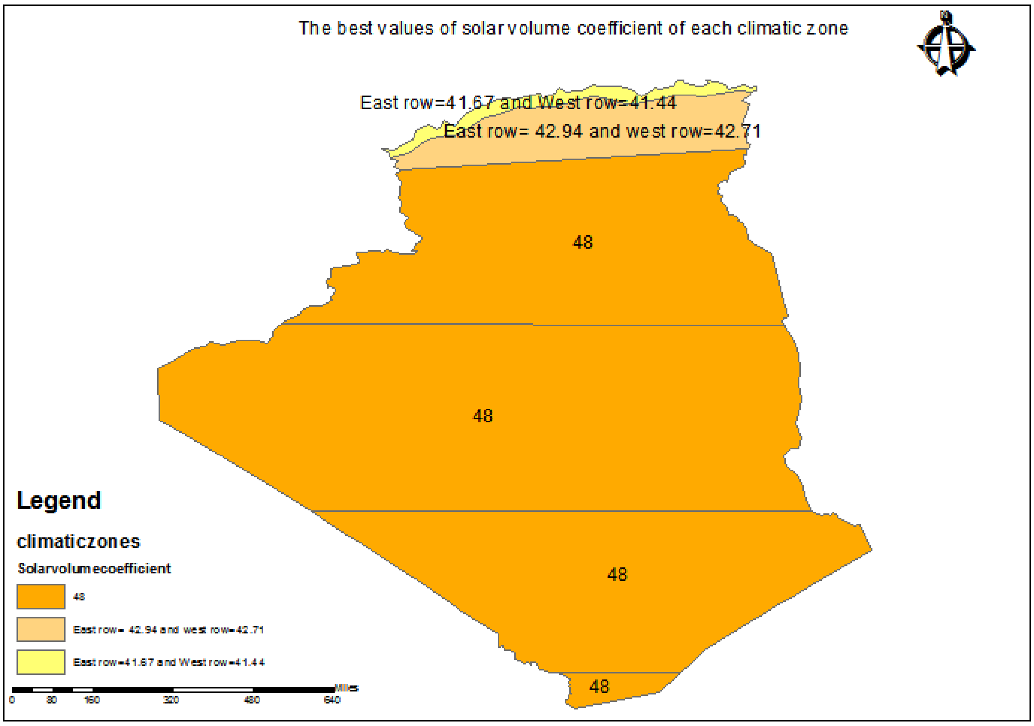


Figure 5.27: The best values of solar volume coefficient (Author, 2019)

Conclusion

Based on the filtering process of sun vectors, the parametric solar envelopes are generated to define the maximum acceptable height of a building that does not interrupt solar rights and shading requirement of adjacent buildings and spaces surroundings them. The findings of the present investigation reveal that the more we specify the primary requirements, the more sun hours can be omitted from the design of the parametric solar envelope resulting in a higher solar volume coefficient. The findings of this chapter also show that the resulting solar volume coefficient varies significantly according to the latitude of the climatic zones. As a general rule we see that the values of the solar volume coefficient in high latitudes (Coastal and Highlands zones) are small in comparison with the values of solar volume coefficient in low latitudes (Sahara zone A, B,C,D) which are characterized by hot and dry climate. It is noteworthy that in both high and low latitudes refining condition of sun vectors leads to decrease the average values of solar radiation impinged on urban street canyon during summer and winter periods. The findings of this study also demonstrate that in high latitude the solar volume coefficient of parametric solar envelopes of condition (A+B+C) is better than the solar volume coefficient of parametric solar envelope of conditions (A; A+B), because it can safeguard winter outdoor comfort, and summer outdoor thermal sensation after implementing the solar volume coefficient of the parametric solar envelope of condition (A+B+C) is the same thermal sensation of the walker during summer time before applying the parametric solar envelope of condition (A+B+C). Finally we can say that the application of the generative algorithm of parametric solar envelope allows urban planners to achieve greater built density and safeguard solar access in urban spaces as well as mitigate winter outdoor thermal comfort. Therefore, the third hypothesis of this thesis is confirmed over this chapter.

CHAPTER VI: SOLAR CONTROL OF URBAN SPACES OF FUTURE URBAN DENSIFICATION

Chapter 6: Solar control of urban spaces of future urban densification

Introduction

After analyzing over the previous chapters (3, and 4) the inadequacy of recent urban rules with solar rights, and outdoor thermal comfort in the context of the climatic zones of Algeria. Also, after assessing the parameters effect of urban street geometry and solar envelope on solar radiation and outdoor thermal comfort variation. It seems mandatory to analyze solar access and outdoor thermal comfort in the future urban densification. In this regard, the present chapter will determine the solar volume coefficient (SVC) for future urban densification. To achieve this goal, a combination between the inverted approach (ComfortCover model) and a generative algorithm of parametric solar envelope (PSE) will be applied. The present chapter is made of two main sections. The first section is focused on the ComfortCover model to determine the shape of future urban densification buildings. The second section is emphasized on the parametric solar envelope (PSE) to determine the solar volume coefficient (SVC) of the new building.

1- Workflow of Comfort Cover model & parametric solar envelope

Good sun design begins at the site layout proposal phase. Site microclimate and shading requirement of buildings is widely influenced by the overall proportions and detailed shape of the neighboring buildings. Hence, solar rights of urban spaces and building surrounding them have to be kept during the design process of implementing new building. Researchers and urban planners developped several methods to safeguard solar access and shading in the urban environment (Littelfair, 2000). The emphasis in this study is to apply new methods that allow urban designers and planners to determine the proper geometrical parameters of future urban densification in accordance with solar rights and shading requirement of each building and spaces surrounding them. As we have mentioned earlier in the previous chapter (chapter 3 page 81.) a process which deals between the inverted approach (ComfortCover) model (see page 78), and a generative algorithm of parametric solar envelope (PSE) (See page 72), has been applied in this study .Therefore, over the first part of this chapter, the ComfortCover model has been applied to determine the shape of the new buildings designed for future urban densification. Subsequently, an evolutionary algorithm (Octopus034) has been used for defining the adequate height of new buildings. Afterward, a generative algorithm of parametric solar volume has been added to the algorithm of the Comfort Cover model to determine the solar volume coefficient (SVC) of the new building.

1-1-Study area

In order to apply the suggested process, three urban sites have been chosen. As we have mentioned earlier in the previous chapters (3, and 4), despite the variety of the Algerian climate, the contemporary urban tissues are not conceived in accordance with climate conditions. Therefore, the selection of the cases study is explained by twofold criteria; location (climatic zone) and the era of creation (Contemporary). In this regard, three specimens of contemporary urban spaces have been investigated. The specimens of analysis are located in Coastal zone (presented by Oran), Highlands zone (presented by Constantine), and Sahara zone (presented by Ouraguela) (See table 6.1). The selected urban tissues are characterized by wide roads and large open spaces (See figures 6.1; 6.2; 6.3).

Table 6.1: Study area description (Author, 2018)

Climatic zones	**Specimens of analysis**		
	City	**Location**	**Climate**
Coastal zone	Oran (Hai El Yasmine)	35^{0}41$^{'}$27” Nord 0^{0}38$^{'}$30$^{''}$Ouest	Mediterranean climate, low rainfall (420mm) of rain, mean air temperature 25^{0}C
Highlands zone	New city(Ail Mendjeli)(UV.08) Constantine	36.17^{0} North and 07.23^{0} East, The altitude is about 687 m above sea level	Semi-arid, maximum temperature of 36^{0} C, The wind direction from the north, wind speed reaching 2.1 m/s
Sahara	Ouarguela (Hai Ennasr)	31°64′ N, 6° 14′ E	Hot and Dry, maximum temperature 400C , Humidity varies between 20% and23%; Solar radiation can reach 8039w/m2; wind speed 3m/s

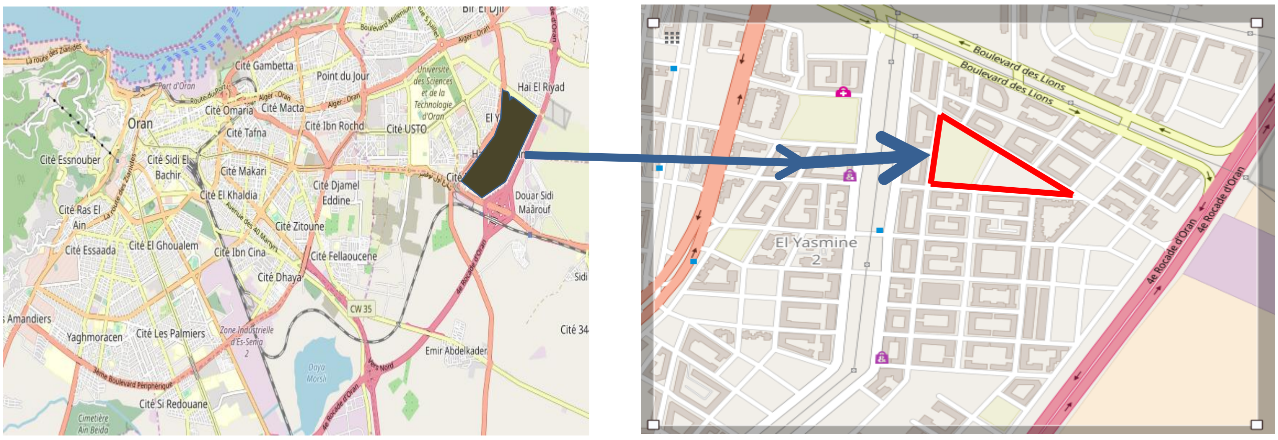


Figure6.1: View of the selected site of Oran from satellite imagery (OpenStreetMap),(2018) http://www.openstreetmap.org/ (accessed July 20, 2018)).

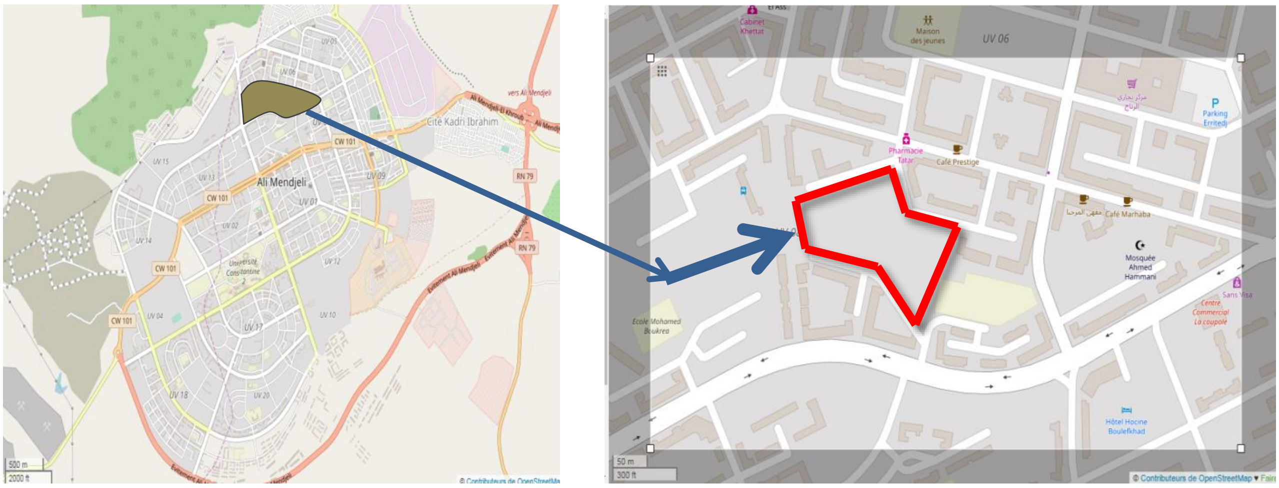


Figure6.2: View of the selected site of Constantine from satellite imagery (OpenStreetMap, (2018). http://www.openstreetmap.org/ (accessed July 20, 2018)).

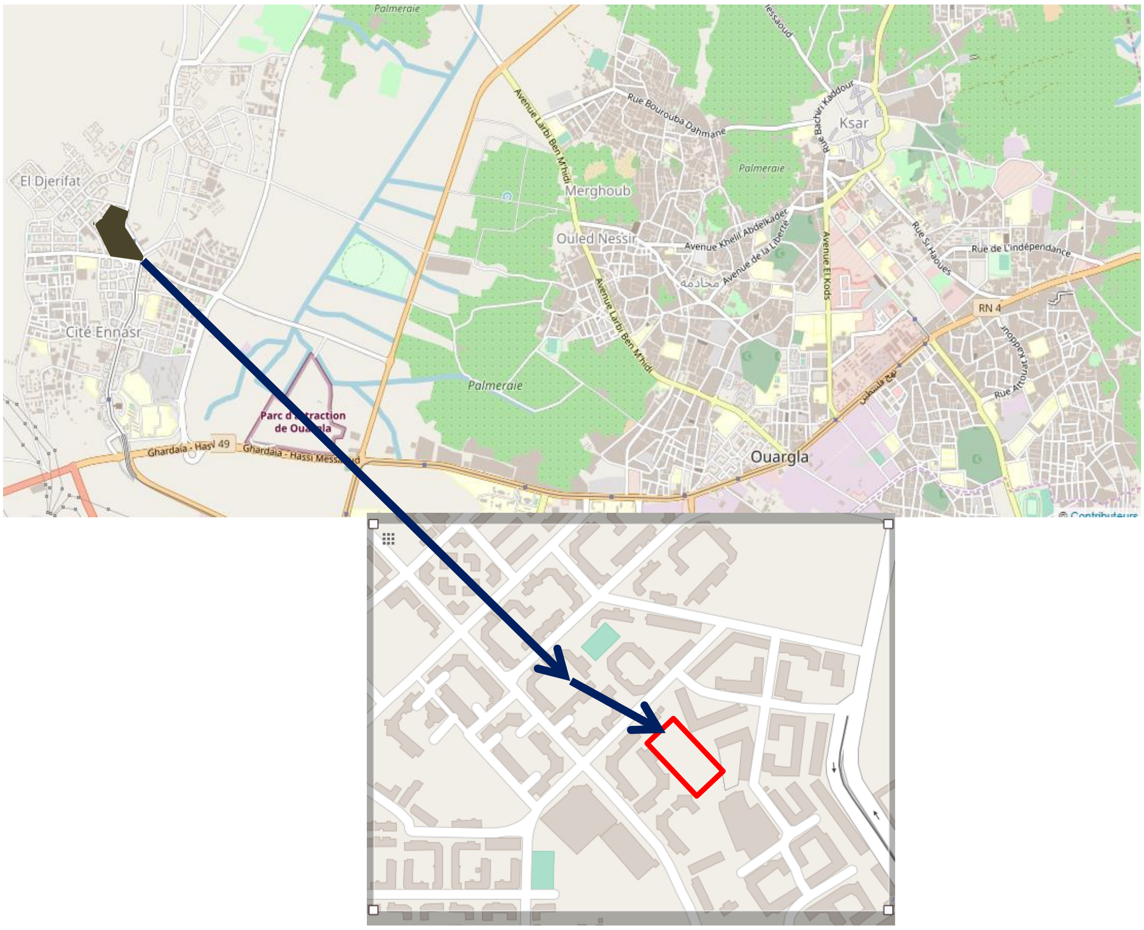


Figure6.3: View of the selected site of Ouargla from satellite imagery (OpenStreetMap, (2018). http://www.openstreetmap.org/ (accessed July 20, 2018)).

1-2- Study area selection :

The site selection has been done by using satellite image and Gismo Plugin. Gismo allows automatic creation of urban built and terrain geometry focused on situation's latitude-longitude coordinates/or address and radius (See figures6.4; 6.5; 6.6). Gismo includes connection with open street map website, and creation of constructions, trees, streets, rivers, and other map components. 3D buildings components can also be employed as a context for further analysis types: solar radiation, thermal/wind comfort, cfd analysis (https://github.com/stgeorges/gismo).

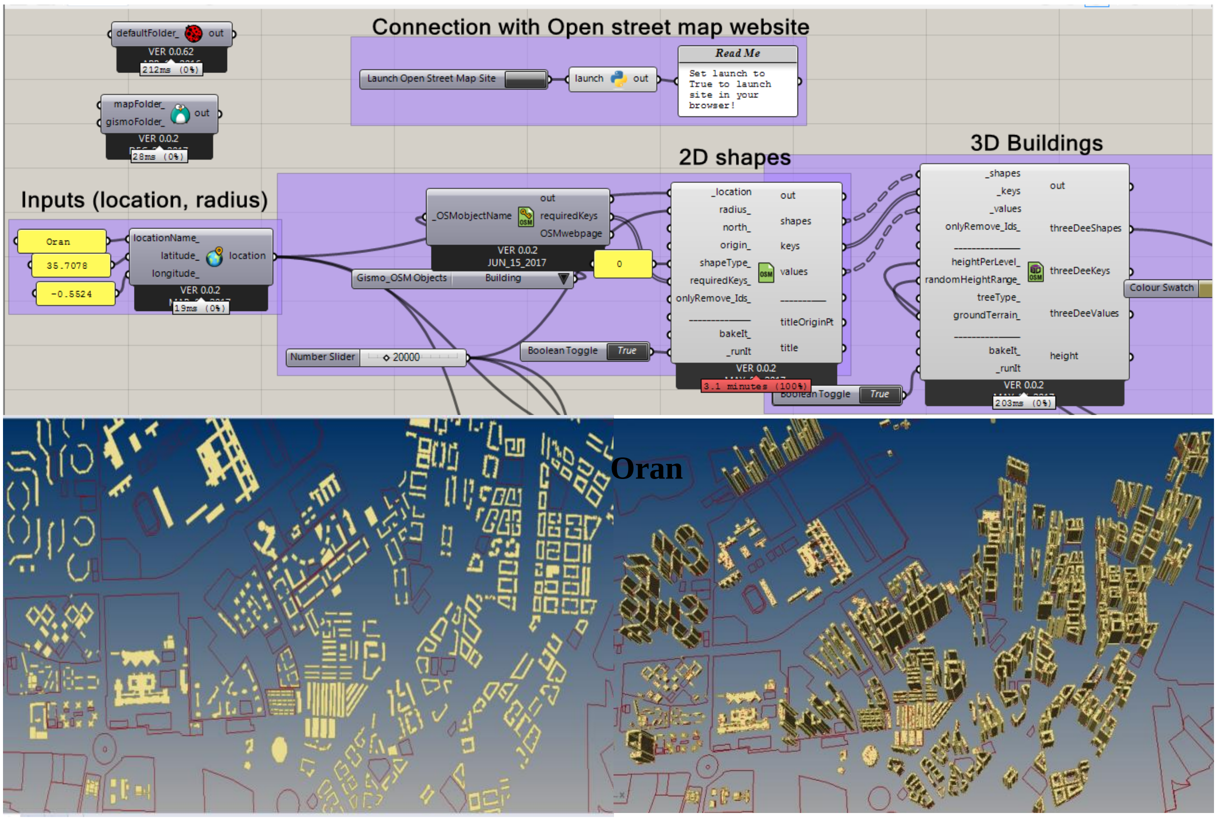


Figure6.4: Generation of urban environment and terrain geometry (Oran) on Rhinoceros/Grasshopper by using satellite imagery of open street Map and Gismo Plugin (Author, 2018).

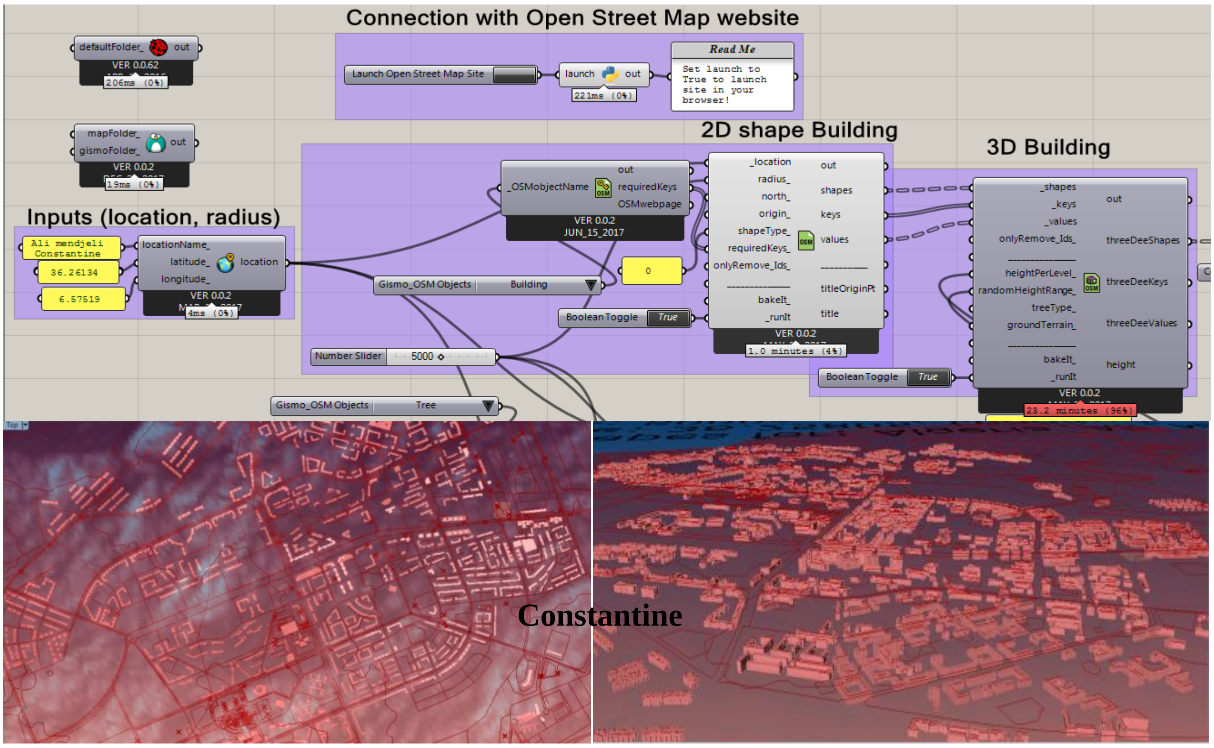


Figure6.5: Generation of urban environment and terrain geometry (Constantine) on Rhinoceros/Grasshopper by using satellite imagery of open street Map and Gismo Plugin (Author, 2018).

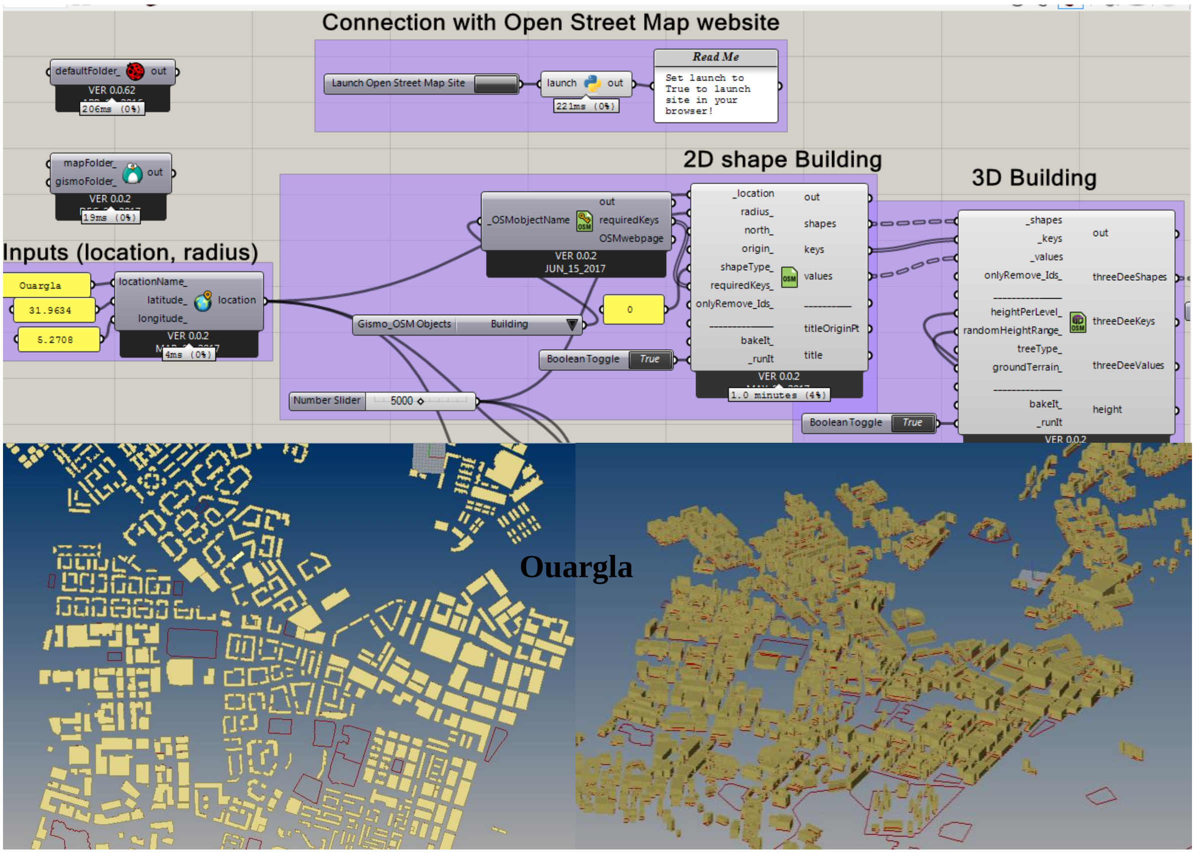


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Figure6.6: Visualization of the generation of urban environment and terrain geometry (Ouarguela) on Rhinoceros/Grasshopper by using satellite imagery of open street Map and Gismo Plugin (Author, 2018).

1-3-Using ComfortCover model for defining the geometrical parameters of future urban densification

Sun and shade are vital variables that must be considered for when planning comfortable outdoor spaces (Christopher Mackey 2015, P.111). In this way, the main aim of this part of chapter is to define the geometrical parameters (shape, obstruction angle (AOB), plot ratio (PR), Floor area ratio (FAR), surfaces) of the extension areas based on solar control and shadow conditions caused by existing built forms. The first step of the present process attempts to define the boundaries of ground-level geometry of the possible area of future urban densification according to the adequate obstruction angle (AOB). On one hand we have proved earlier in the previous chapter(3) that the obstruction angle (α) equal to 76^0 leads to improve outdoor thermal comfort during summer period in both high and low latitudes(Latitude<35^0). On the other hand, it drops outdoor thermal comfort during winter time mainly in high latitudes. However, we have demonstrated in chapter (4), that the parametric solar envelope (PSE) can upgrade the outdoor thermal sensation during winter period. In this way, the distance between the existing buildings and the new buildings of future urban densification has been determined according to the optimum obstruction angle (AOB=76^0) (7.65m for Oran, 9.24m for Constantine; 3.82m for Ouarguela) (See figures6.7).

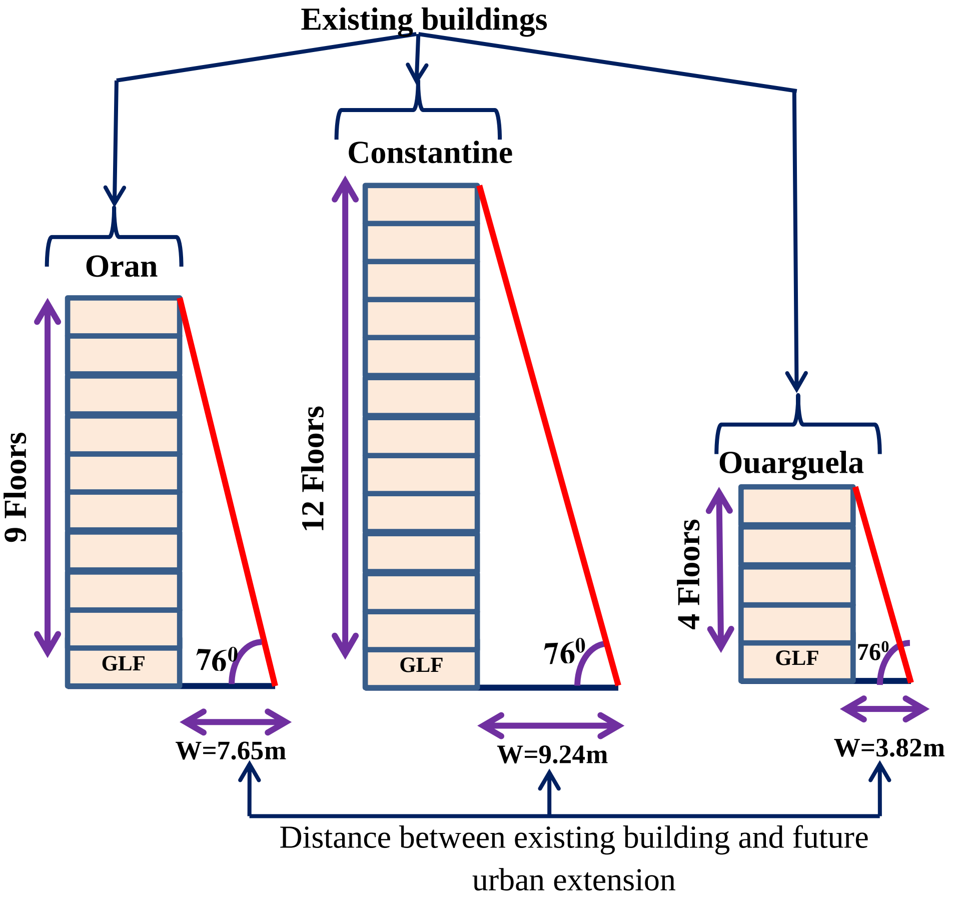

Figure 6.7: The distance between existing buildings and proposed buildings (Author, 2018)

The second step of the present process attempts to determine the form of the area of future urban densification. In order to decrease energy loads of buildings several methods for designing shades have appeared. As we have mentioned earlier in the chapter 3, the ComfortCover model used Ladybug Comfort Shade Benefit Evaluator to assess shading requirement in terms of comfort temperature (UTCI) by using sun vectors. The coloured mesh outputs display the desirability of shade, where a higher saturation of blue designates that shading is needed. A higher saturation of red designates that shading is unwanted. As depicted in figures (6.8; 6.9; 6.10) the areas of shade helpfulness (blue color) in coastal zone (Oran),Highlands zone (Constantine), Sahara (Ouarguela) are as following respectively to their locations 80.65% , 47.45%, 100% of the total areas which are reaching 24184.50 m^2 , 21116.59 m^2, 2734.15m^2. While the areas of shade harmfulness (red color) in coastal zone (Oran), Highlands zone (Constantine), Sahara (Ouarguela) are respectively as following

19.35% , 52.55% , 0% of the above total areas. These results confirm that the desirability of shade in Sahara (low latitude) is more required than high latitudes (coastal zone and highlands zone). From these results, we can determine the possible extension areas based on the desirability of shade for the whole year. In order to prevent future building shadowing during winter time, the area where shade is required (shade helpfulness-blue color-) is selected to be the surface of future urban densification. Therefore, the plot ratio (PR) of the final block surface for future urban densification is ranged on 0.80 in coastal zone (Oran), 0.47 in highlands zone (Constantine), 1 in Sahara zone (See figure6.11) .These values represent the areas of shade helpfulness in the aforementioned climatic zones.

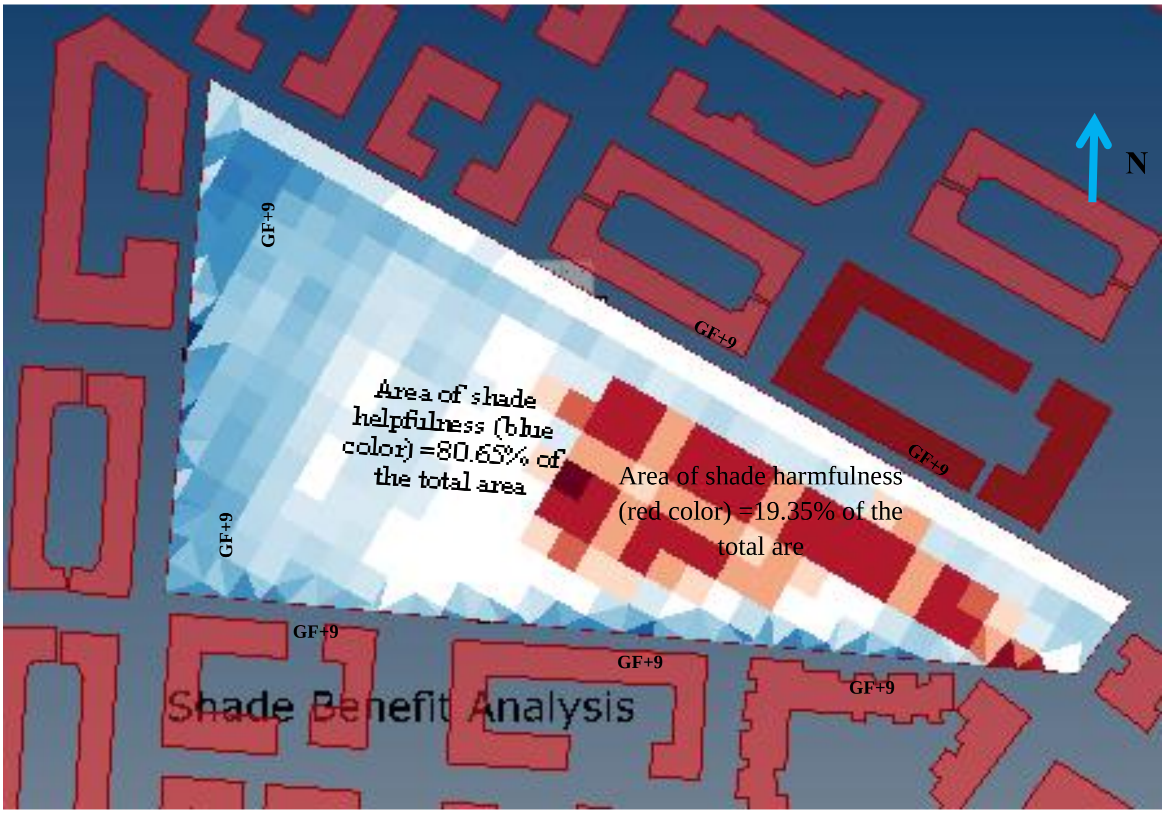

Figure 6.8: The area of shade harmfulness (red color) and the area of shade helpfulness (blue color) during the whole of the year in Oran case study (Author, 2018).

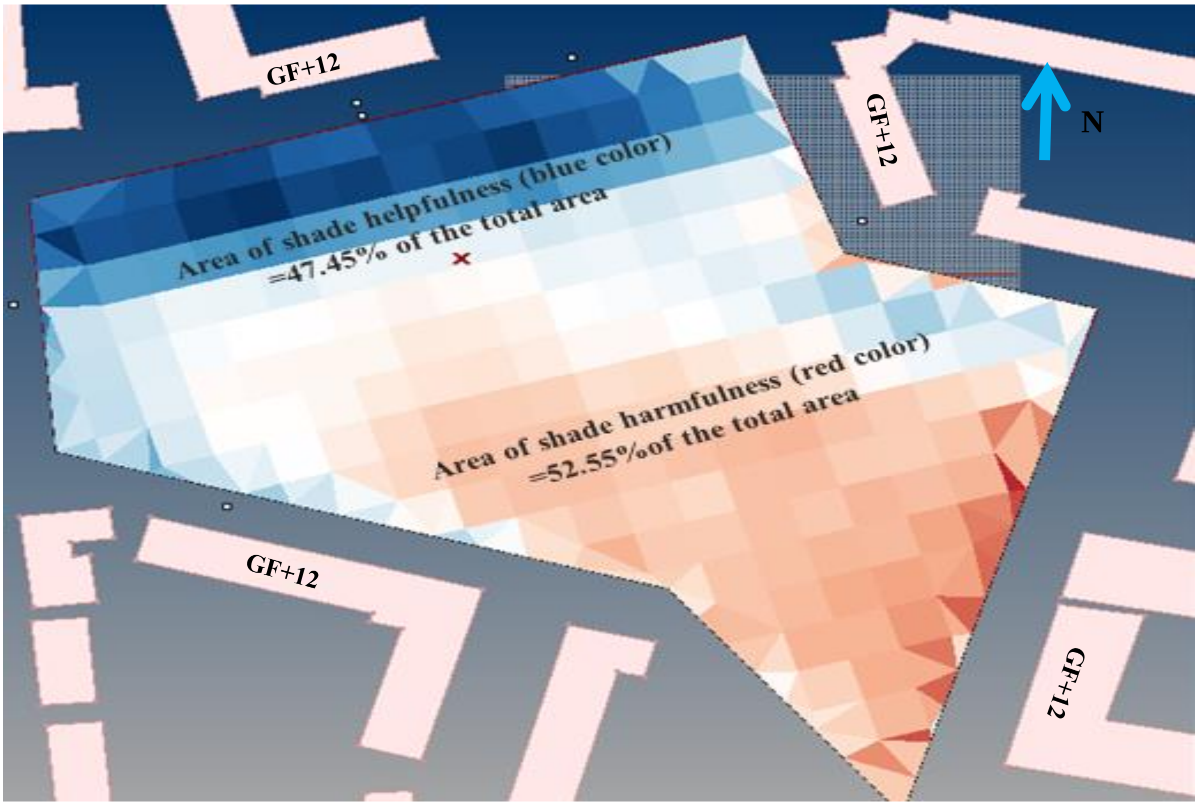

Figure 6.9: The area of shade harmfulness (red color) and the area of shade helpfulness (blue color) during the whole year in Constantine (Author, 2018).

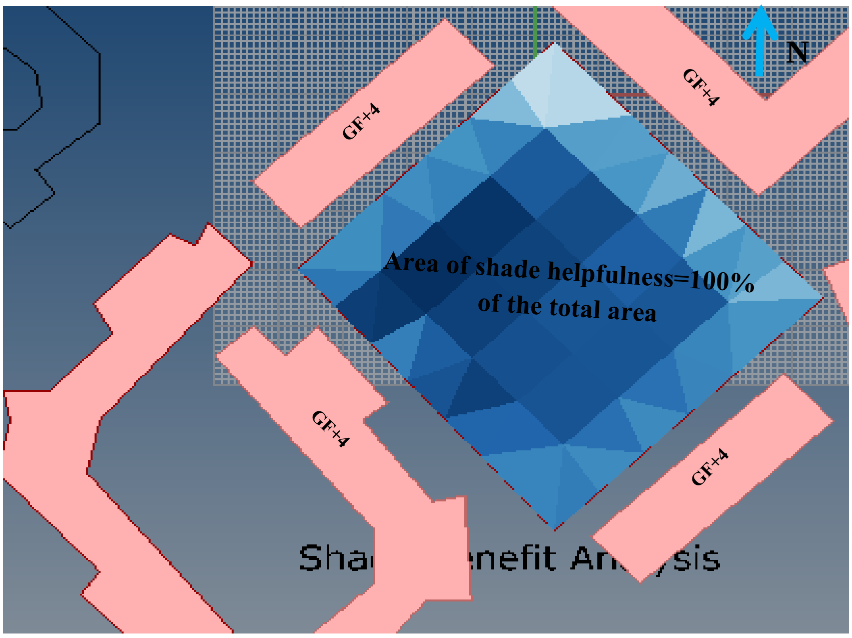

Figure6.10: The area of shade harmfulness (red color) and the area of shade helpfulness (blue color) during the whole year in Ouargla (Author,2018).

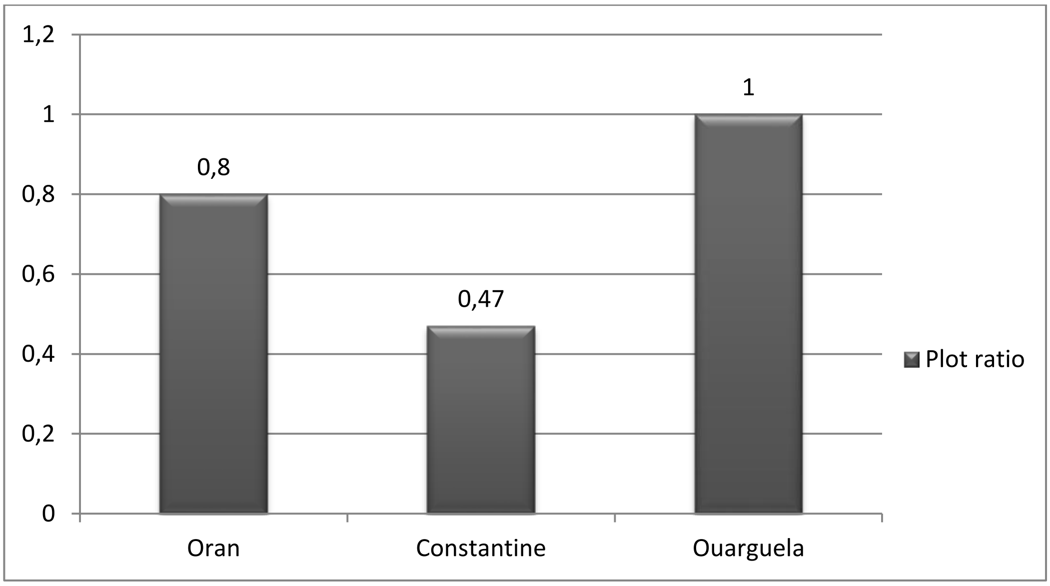

Figure 6.11: The plot ratio of the final block surface for future urban densification (Author, 2018)

1-4-The proper height of new building envelopes for future urban densification

After determining the final area for future urban densification in the previous step, in this stage a plug-in for applying evolutionary principles and problem solving (Octopus 034) has been used to determine the proper height that enhances pedestrian thermal comfort. In this way octopus is ran with twofold objectives; maximize **Universal Thermal Climate Index**

(UTCI) during winter time, and minimize it during summer time(1). The results presented in figures (6.12; 6.13; 6.14) show multiples fitness values to the optimization of building height by Octopus in the three examined climatic zones. Figures (6.15; 6.16; 6.17) reveal that there is a negative correlation between the height of building and (UTCI) values. This means that increasing height of building leads to decrease the UTCI in all the investigated climatic zones. Since, on one hand the average value of UTCI resulting of height of building (HBN18; height of building of fitness value number 18 outcomes from Octopus generation) equal 49.97m in the coastal zone presented by Oran city ranged between 8.12^0 C during winter (Slightly cold) and 26.01^0C during summer (Comfortable condition) (See table4.2 page73). However for the same climatic zone the average value of UTCI for height of building (HBN2) equal to 76.07m ranged between 5.21^0 during winter period (Slight cold stress) and 23.12^0C during summer period (Comfortable conditions) (See table4.2 page37). On the other hand, the UTCI results of building height (HBN24) equal to 5.16m in highlands zone presented by Constantine city is ranged between 12.22^0C during winter time (comfortable condition), and 36.95^0C during summer time (strong heat stress). Though, the UTCI for height of building (HNB7) equal to 43.56m is ranged between 6.08^0C during winter time (slight cold stress), and 28.03^0 C (moderate heat stress) during summer time. It is noteworthy, that the average value of UTCI recorded for height of building (HBN8) equal to 69.65m in Sahara zone presented by Ouarguela city is ranged between 9.01^0 C (Comfortable condition) during winter period and 31.96^0C during summer time (Moderate heat stress). However, the average value of UTCI noted for height of building (HBN13) equal to 9.32m in the same climatic zone is ranged between 18.37^0C (comfortable condition) during winter time, and 41.2^0C (Very strong to extreme heat stress- very dangerous) during summer time. The results depicted in figures (6.15; 6.16; 6.17) also reveal that 49.97 m, 43.56m, 69.65 are considered as the best fitness values of the optimization of the proper height of the new building for future urban densification in Coastal zone, Highlands zone, and Sahara zone respectively. From these results we can also deduce that in all the investigated climatic zones higher height of building can mitigate outdoor thermal comfort during summer time, however it drops it during winter time especially in high latitudes (Coastal and Highlands zones). After this

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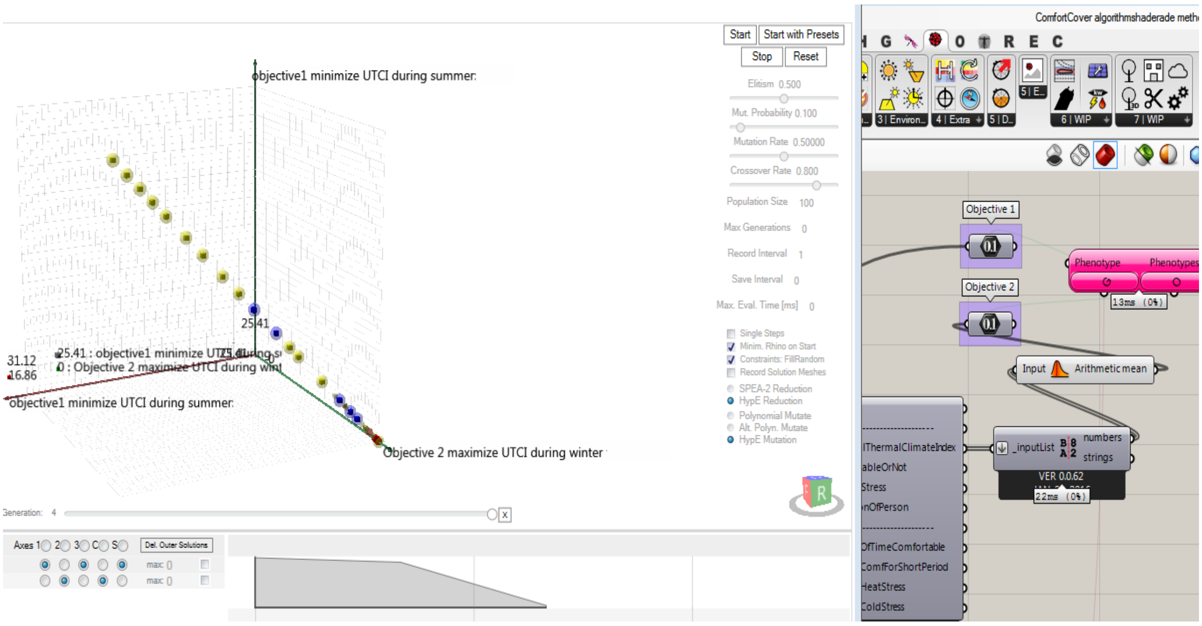
(1)As we have mentioned earlier in the previous chapter (1)page 37,the UTCI represents specific climates, weather and location much better than the other indices of outdoor thermal comfort, for this reason it has been chosen.

analysis, we have summarized the optimum geometrical parameters of the area of future urban densification (before applying the parametric solar envelope) in table (6.2).

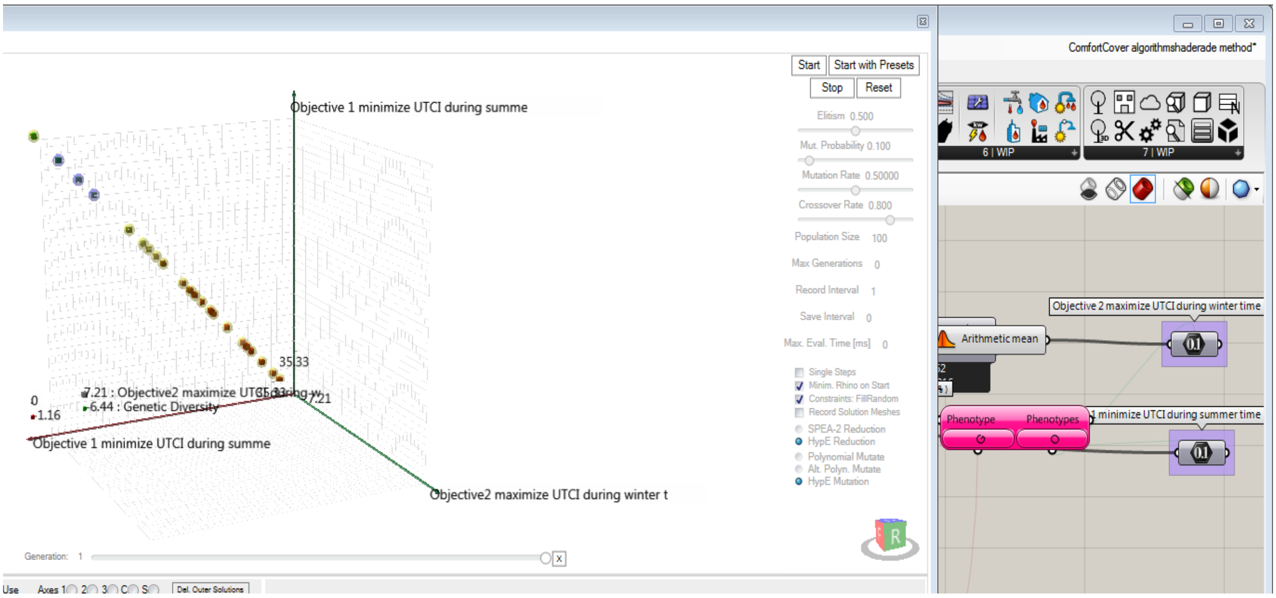
Elitism 0.500
Mut. Probability 0.100
Mutation Rate 0.50000
Crossover Rate 0.800
Population Size 100
Max Generations 0
Record Interval 1
Save Interval 0
Max. Eval. Time [ms] 0
☐ Single Steps
☑ Minim. Rhino on Start
☐ Constraints: FillRandom
☐ Record Solution Meshes
○ SPEA-2 Reduction
● HypE Reduction
○ Polynomial Mutate
○ Alt. Polyn. Mutate
● HypE Mutation

Figure 6.12: Fitness values by Octopus to determine the proper height of new building in Oran (Author, 2018).



Elitism 0.500
Mut. Probability 0.100
Mutation Rate 0.50000
Crossover Rate 0.800
Population Size 100
Max Generations 0
Record Interval 1
Save Interval 0
Max. Eval. Time [ms] 0
☐ Single Steps
☑ Minim. Rhino on Start
☑ Constraints: FillRandom
☐ Record Solution Meshes
○ SPEA-2 Reduction
● HypE Reduction
○ Polynomial Mutate
○ Alt. Polyn. Mutate
● HypE Mutation

Figure6.13: Fitness values of Octopus to determine new building height in Constantine (Author, 2018).



Elitism 0.500
Mut. Probability 0.100
Mutation Rate 0.50000
Crossover Rate 0.800
Population Size 100
Max Generations 0
Record Interval 1
Save Interval 0
Max. Eval. Time [ms] 0

☐ Single Steps
☑ Minim. Rhino on Start
☑ Constraints: FillRandom
☐ Record Solution Meshes

○ SPEA-2 Reduction
● HypE Reduction

○ Polynomial Mutate
○ Alt. Polyn. Mutate
● HypE Mutation

Figure6.14: Fitness values by Octopus to determine the proper new building height in Ouarguela (Author, 2018)

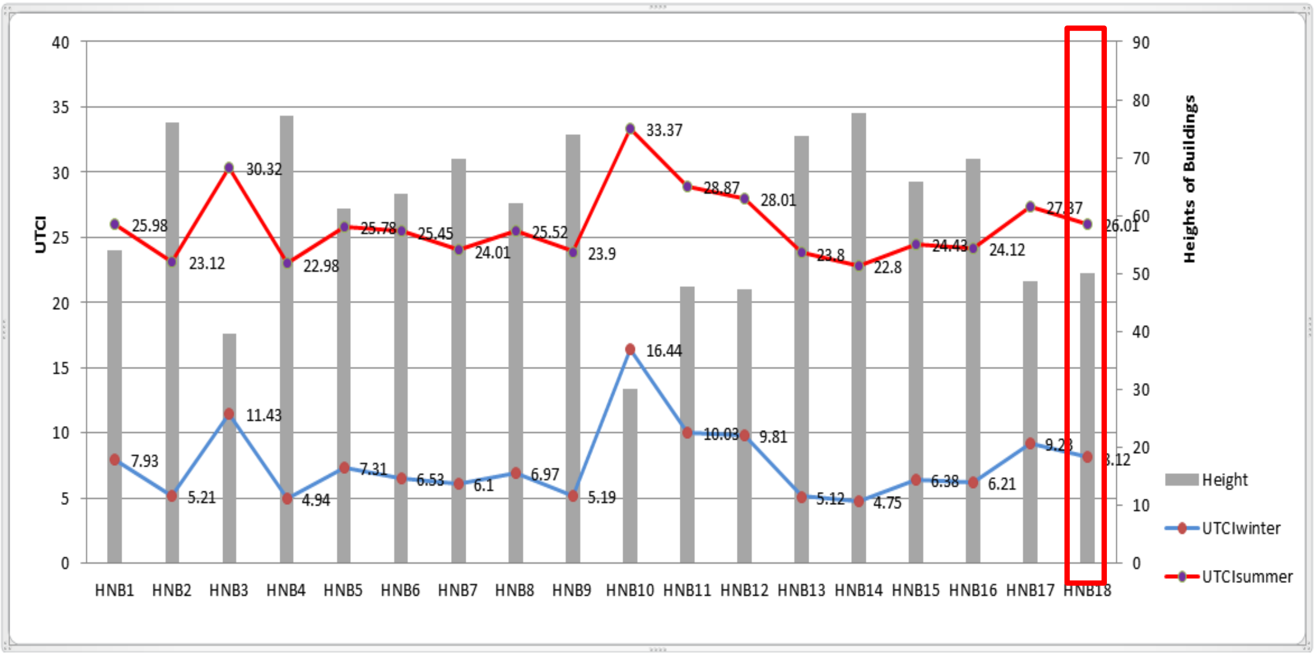


Figure6.15: The effect of building height on UTCI during summer and winter period in Oran (results of Octopus 034) (Author, 2018).

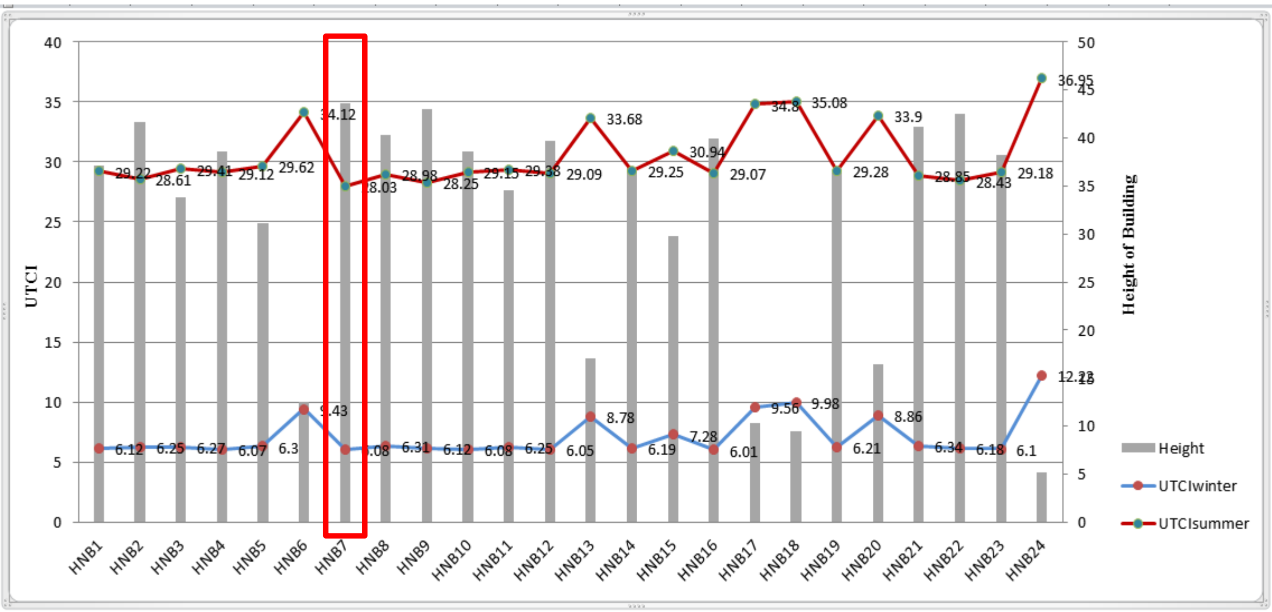


Figure 6.16: The effect of height of building on UTCI during summer and winter period in Constantine (results of Octopus 034) (Author, 2018).

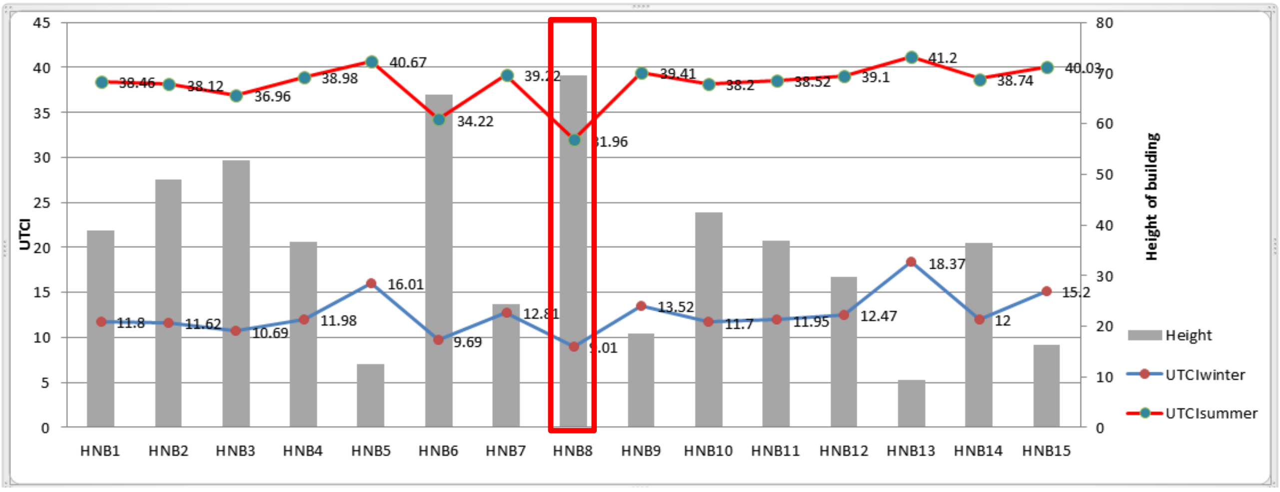
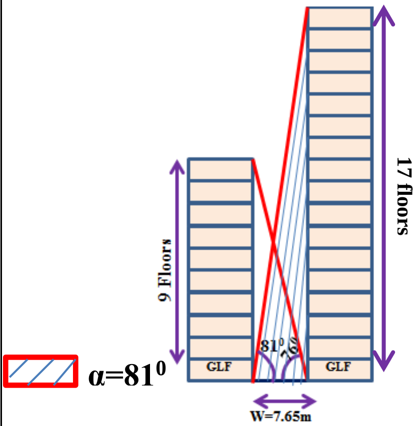
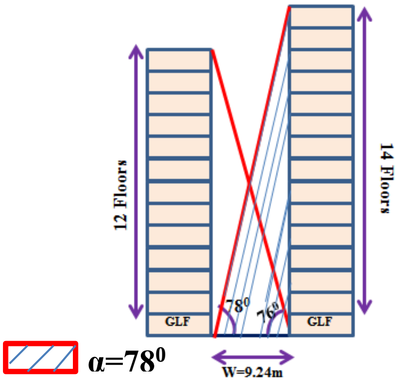
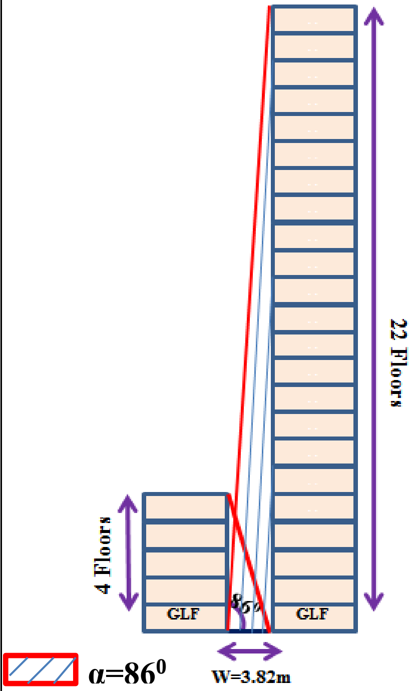


Figure 6.17: The effect of height of building on UTCI during summer and winter period in Ouarguela (results of Octopus 034) (Author, 2018).

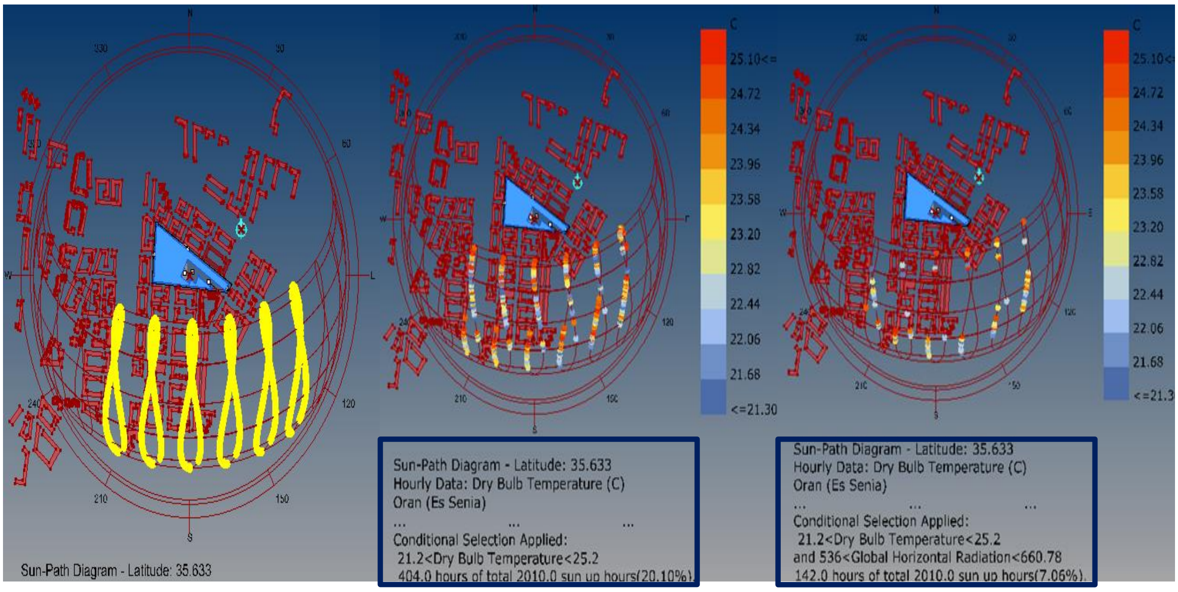
Table 6.2: Optimum geometrical parameters of building of future urban densification before applying PSE (Author, 2018).

Specimens of analysis	**Geometrical parameters of building of future urban densification before applying PSE**		
	Angle of obstruction	**Plot ratio**	**Floor Area ratio**
Latitude>35^0 Coastal zone Oran		**0.8**	**13.70**
Latitude>35^0 Highlands Constantine		**0.47**	**6.64**
Latitude<35^0 Sahara Ouarguela		**1**	**22**

In order to mitigate outdoor thermal comfort during summer and winter period, the parametric solar envelope (PSE) will be applied over the next step of this part of chapter. The PSE will be applied on the best fitness values of the optimization of the AOB of the new building for future urban densification of each climatic zone. However, according to the results of the previous chapter (4), the application of PSE in low latitudes (Sahara zone) must be avoided, because it gives dangerous conditions of thermal sensation during summer time in comparison with the results of UTCI before its application. Therefore, in the next step the parametric solar envelope will be applied only on the climatic zones of high latitudes (Coastal and highlands zones).

1-5-Parametric solar envelope application:

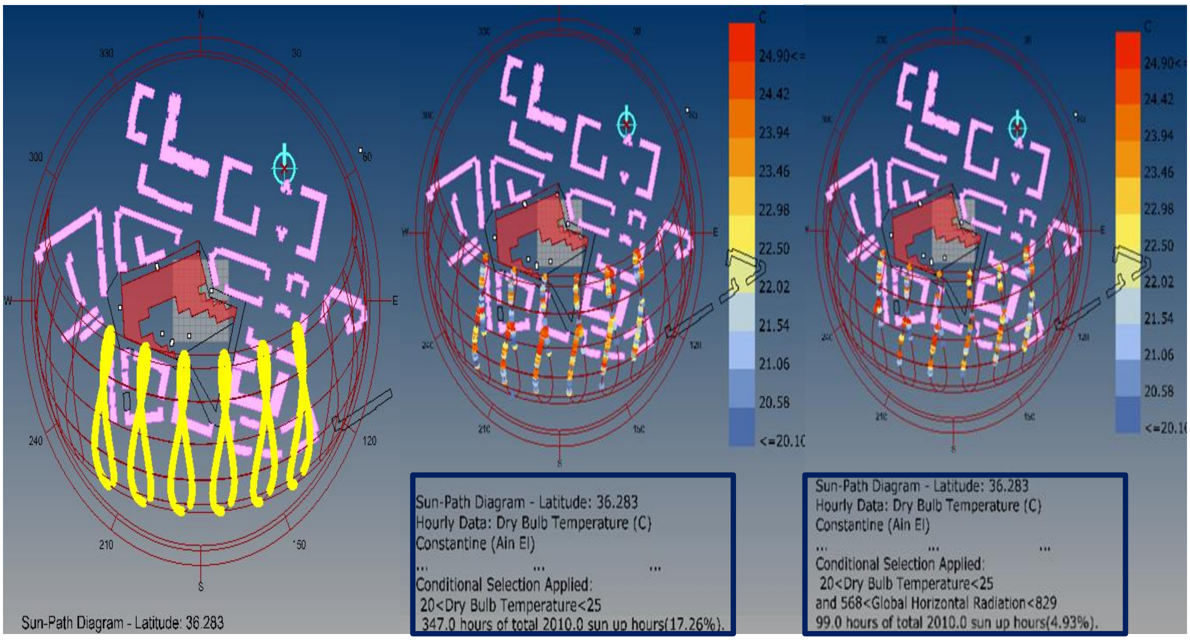
After determining the proper shape and height of the building of future urban densification in accordance with shading constraint and outdoor thermal comfort, we attempt over this step to enhance the results of outdoor thermal comfort, in the spaces surrounding the future building. To achieve the aforementioned goal the PSE has been applied on the height of buildings of the best fitness values in high latitudes (Coastal, Highlands's zones presented by Oran and Constantine respectively). As we have indicated earlier in the previous chapters (3, 5), the PSE is defined by a large collection of filter parameters created on specific appeals throughout the year. On this basis we have specified in the previous chapter 5 (See table5.1 page.118), the desirability of sun vectors in different latitudes of the climatic zones according to the following parameters: the period of when sun radiation is needed; Global horizontal radiation according to ASHREA, 2009 Formula and the design day; Dry bulb temperature according to ASHREA 55-2010 standard of adaptive comfort formula. Hence, by applying the parametric solar envelopes of the conditions (A; A+B; A+B+C) (See table5.1 page.118), on the building envelope of future urban densification in both Coastal and Highlands zones we obtain the following results (See figures 6.18; 6.19; 6.20; 6.21 and Tables 6.3; 6.4). As shown in figures (6.18; 6.19), a visualization of the SunPath with filtered suns, using Ladybug is depicted. These figures (6.18; 6.19) reveal that the more we refine the boundary conditions, the more the number of sun hours selected decreases. Likewise, a graphical and numerical comparison on the effect of filtering process of sun hours on solar volume coefficient (V/S) can be seen from Tables (6.3 and 6.4) and figures (6.20; 6.21) respectively. The results indicate that in coastal zone (Oran) the solar volume coefficient increases from 21.70 for the generated solar envelope of condition (A) to 34.03 for the generated solar envelope of condition (A+B+C). The results also display that in Highlands zone (Constantine) the solar volume coefficient of the generated solar envelopes of the aforementioned conditions increases from 18.31 for the condition (A) to 36.81 for the condition (A+B+C). From these results we can confirm that the more we refine the initial requirements, the more sun hours can be excluded from the calculation resulting in higher solar volume coefficient.



Sun-Path Diagram - Latitude: 35.633
Hourly Data: Dry Bulb Temperature (C)
Oran (Es Senia)
... ...
Conditional Selection Applied:
21.2<Dry Bulb Temperature<25.2
404.0 hours of total 2010.0 sun up hours(20.10%).

Sun-Path Diagram - Latitude: 35.633
Hourly Data: Dry Bulb Temperature (C)
Oran (Es Senia)
... ...
Conditional Selection Applied:
21.2<Dry Bulb Temperature<25.2
and 536<Global Horizontal Radiation<660.78
142.0 hours of total 2010.0 sun up hours(7.06%).

Figure6.18: A visualization of the SunPath with filtered suns of conditions (A; A+B; A+B+C) in Oran by using Ladybug (Author, 2018).



Sun-Path Diagram - Latitude: 36.283
Hourly Data: Dry Bulb Temperature (C)
Constantine (Ain El)
... ...
Conditional Selection Applied:
20<Dry Bulb Temperature<25
347.0 hours of total 2010.0 sun up hours(17.26%).

Sun-Path Diagram - Latitude: 36.283
Hourly Data: Dry Bulb Temperature (C)
Constantine (Ain El)
... ...
Conditional Selection Applied:
20<Dry Bulb Temperature<25
and 568<Global Horizontal Radiation<829
99.0 hours of total 2010.0 sun up hours(4.93%).

Figure 6.19: A visualization of the SunPath with filtered suns of conditions (A; A+B; A+B+C) in Constantine using Ladybug (Author, 2018).

Table 6.3: The effect of filtering process of sun hours on solar volume coefficient (V/S). (Oran).(Author,2019)

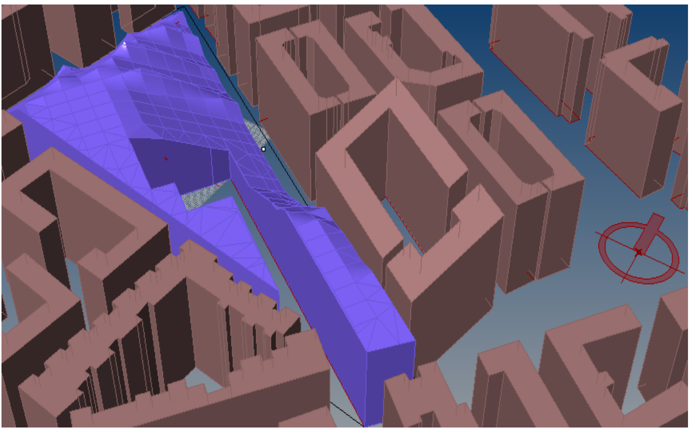
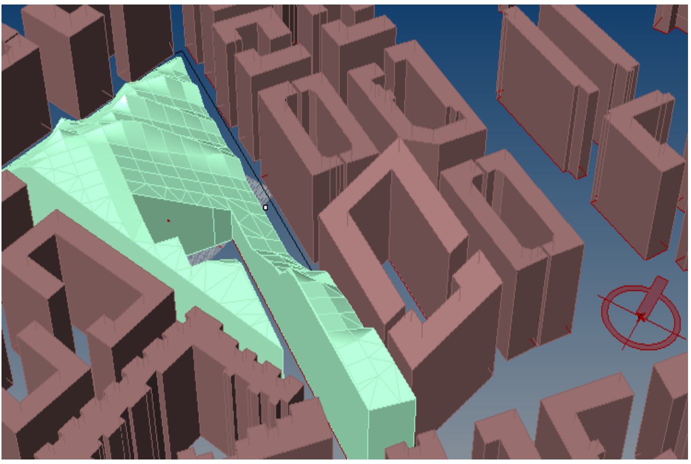
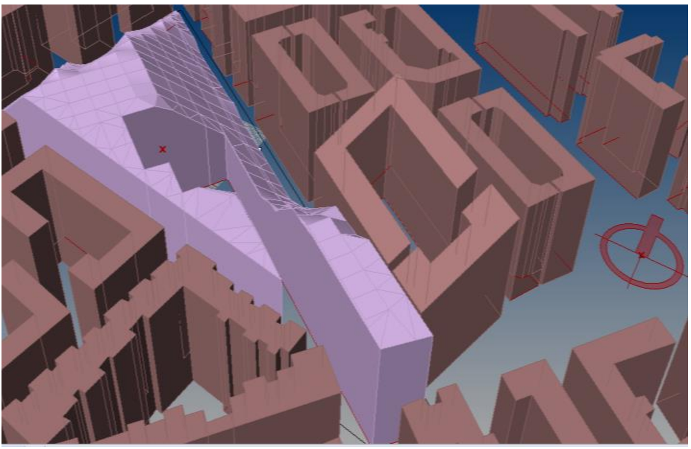
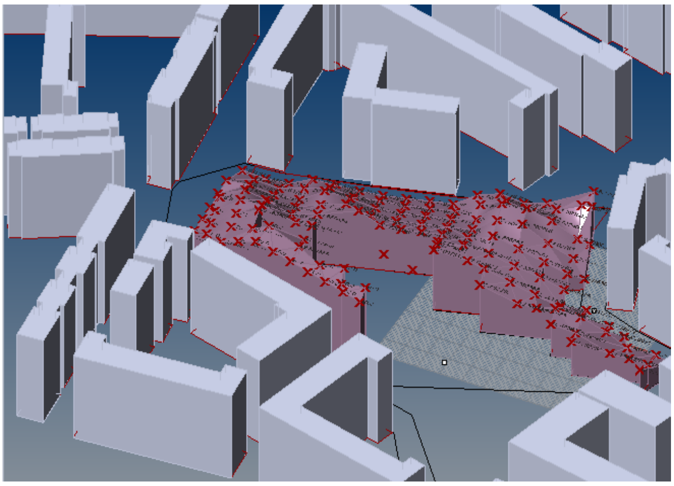
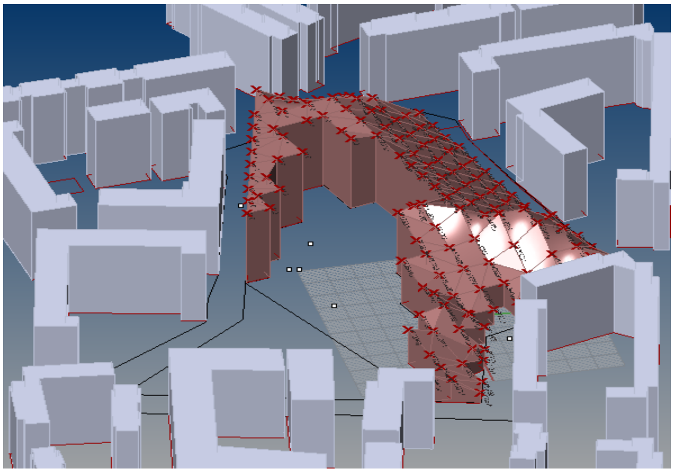
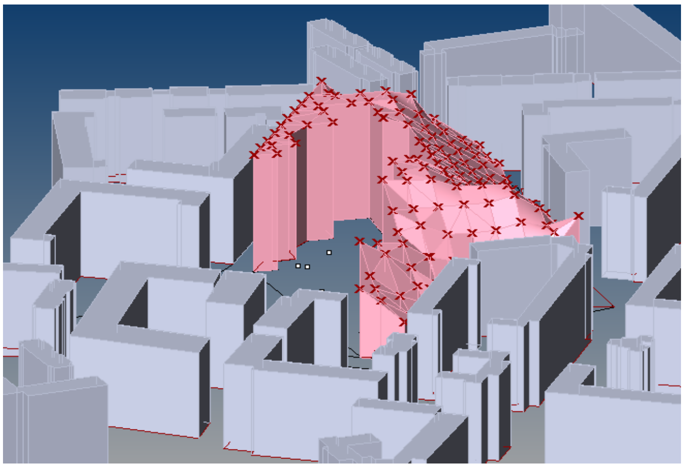
Conditions	Parametric solar envelopes	Max Height	Min Height	Solar volume coefficient
A The whole of the year (7h-20h)		42 m	5m	21.70
A+B ConditionA +21.2^{0}C<Dry Bulb Temperature<25.2^{0}C		45m	5m	28.90
A+B+C ConditionA +Condition B+ 536<Global Horizontal Radiation< 660.78		50m	8.66m	34.03

Table 6.4: The effect of filtering process of sun hours on solar volume coefficient (V/S). (Constantine). (Author, 2019).

Conditions	Parametric solar envelopes	Max Height	Min Height	Solar volume coefficient
A **The whole of the year** **(6h-20h)**		40 m	4.5m	18.21
A+B **Condition A+ 20^{0}C<Dry Bulb Temperature<25^{0}C**		41 m	5.70m	26.01
A+B+C **Condition A+ConditionB+ 568<Global Horizontal Radiation< 829**		44m	8.14m	36.81

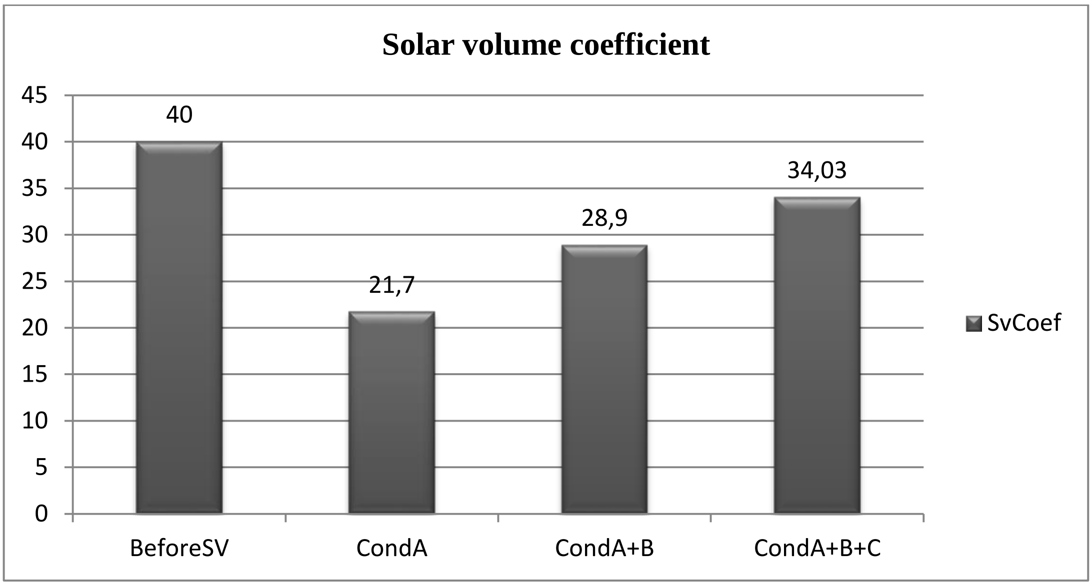


Figure 6.20: The effect of filtering process of sun hours on solar volume coefficient (V/S) in Oran (Author, 2019)

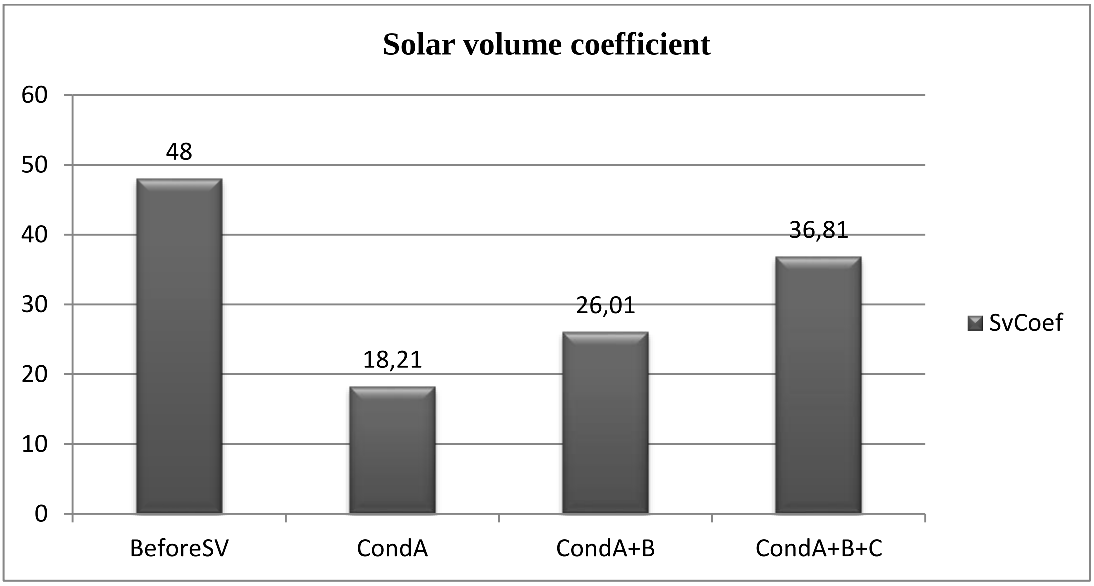


Figure6.21: The effect of filtering process of sun hours on solar volume coefficient (V/S) in Constantine (Author, 2019)

1-5-1-The effect of orientation

Good orientation and correct spacing between buildings, improve the outdoor thermal comfort and decrease energy consumption. According to Knowles (2000) :

> *“The designer is encouraged to differentiate building and urban form in graphic response to orientation.” (Knowles, 2000, P.649).*

Therefore,the direction of buildings has a decisive effect in determining the volume of solar envelope. The finding of this investigation also reveal that the orientation has a significant impact on the solar envelope’s height.Subsequently, the solar envelope’s elevation varies widely according to its direction. Since, the output of this analysis display that in all cases investigated the north elevations have the lowest ridge in comparison with the south, east and west facades height. Therefore, the AOB depends significantly to the orientation. Tables(6.5; 6.6), summarize the effect of orientation on the AOB (minimum and maximum) of all the investigated parametric solar envelopes in Oran and Constantine respectively.

Table 6.5: The effect of orientation on the obstruction angle (Oran). (Author, 2019).

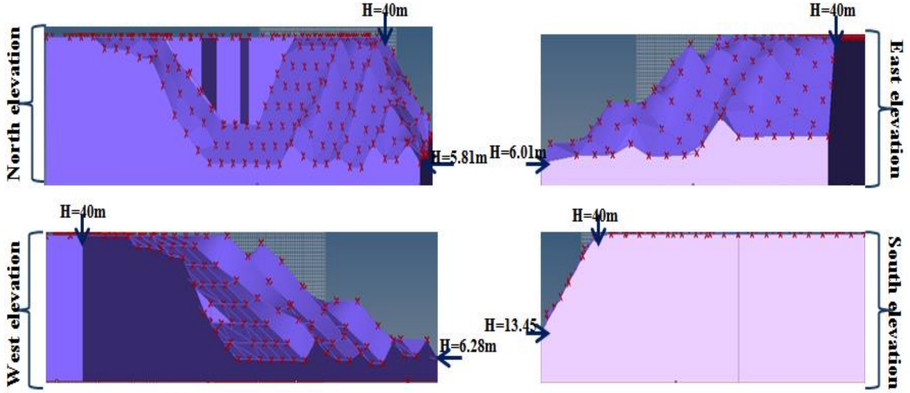
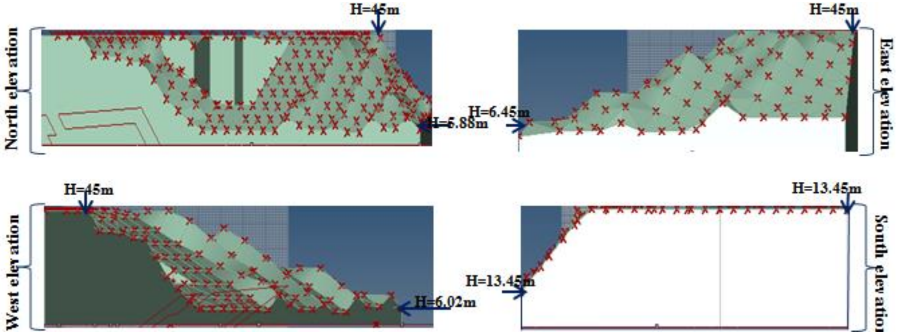
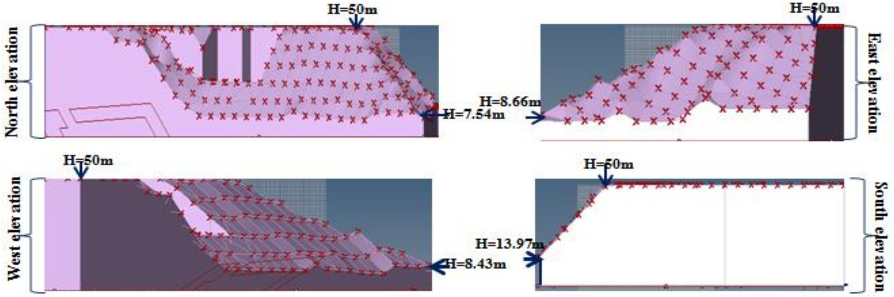
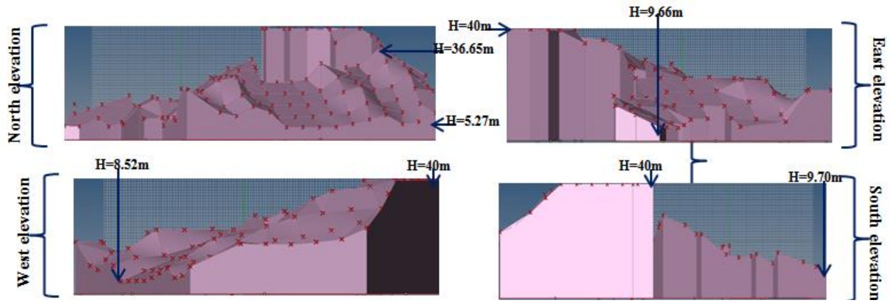
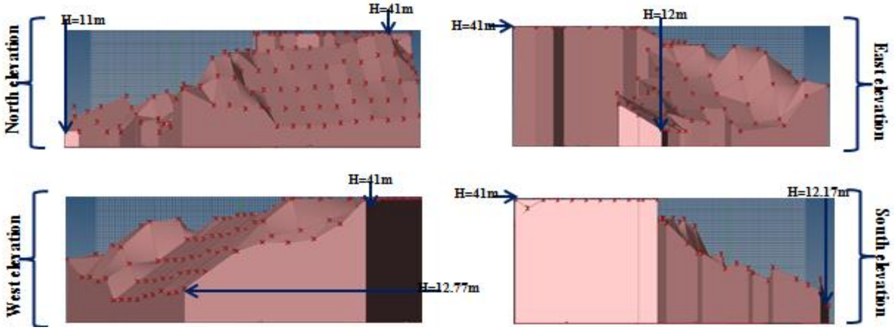
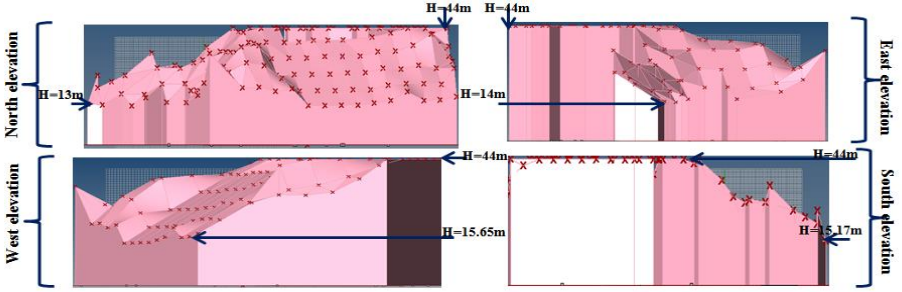
Condition	Solar envelope ‘s elevation according to the orientation	Maximum angle of obstruction				Minimum angle of obstruction			
		North	East	South	West	North	East	South	West
A **SVC=21.7**		78.90^0	78.90^0	78.90^0	78.90^0	36.50^0	37.43^0	59.73^0	38.65^0
A+B **SVC=28.9**		80.10^0	80.10^0	80.10^0	80.10^0	36.83^0	39.40^0	59.73^0	37.48^0
A+B+C **SVC=34.03**		$81^0.07$	81.07^0	81.07^0	81.07^0	43.84^0	47.80^0	60.66^0	47.04^0

Table 6.6: The effect of orientation on the obstruction angle (Constantine). (Author, 2019)

Condition	Solar envelope 's elevation according to the orientation	Maximum angle of obstruction				Minimum angle of obstruction			
		North	East	South	West	North	East	South	West
A **SVC=18.21**		75.84^0	77^0	77^0	77^0	29.70^0	46.36^0	46.4^0	42.67^0
A+B **SVC=26.01**		77.3^0	77.3^0	77.3^0	77.3^0	55.52^0	58.22^0	58.65^0	60.12^0
A+B+C **SVC=36.81**		78.14^0	78.14^0	78.14^0	78.14^0	60.66^0	62.86^0	65.17^0	66^0

2-The effect of the solar volume coefficient (SVC) on solar radiation and outdoor thermal comfort

After applying the proposed workflow of Comfort Cover model, and the parametric solar envelope on urban spaces, of future urban densification, and after testing its effect on the solar volume coefficient (Average height), of the solar volume in high latitudes (Coastal and Highlands zones), we attempt through this section by using Ladybug plugin to assess the effect of solar volume coefficient of conditions (A; A+B; A+B+C) on solar radiation and outdoor thermal comfort. This investigation has an amenity value, because it will be considered as a guideline in the design process of urban spaces of future urban densification. The simulation was conducted during summer and winter period in high latitudes (Coastal, and Highlands's zones).

2-1- The effect of solar volume coefficient on solar radiation

Figures (6.22; 6.23; 6.24; 6.25), reveal that in both climatic zones of high latitudes (Coastal, and Highlands) decreasing solar volume coefficient after applying the parametric solar volume (PSV) leads to rise solar radiation in the spaces surrounding buildings during both of times summer and winter in comparison with the average values of solar radiation before applying the (PSV). However, more we specify the condition of sun vectors, more the SVC of the PSV will be augmented which leads to reduce the average values of solar radiation in the space surrounding buildings during both of periods summer and winter. Since the average value of solar radiation fallen on the ground area surrounding the solar envelopes of condition (A+B+C) in Oran and Constantine reaching respectively 184,65 KWh/m^2, and 89.74 KWh/m^2 during winter period. While, the average values of solar radiation dropped on the ground area surrounding the solar envelopes of condition (A) during winter time reaching about 199.23 KWh/m^2,97.93 KWh/m^2 in Oran and Constantine respectively (See figures 6.24; 6.25). In order to determine the optimum value of the SVC, the effect of the PSV on the universal thermal climate index (UTCI) will be examined in the next phase of this part of chapter.

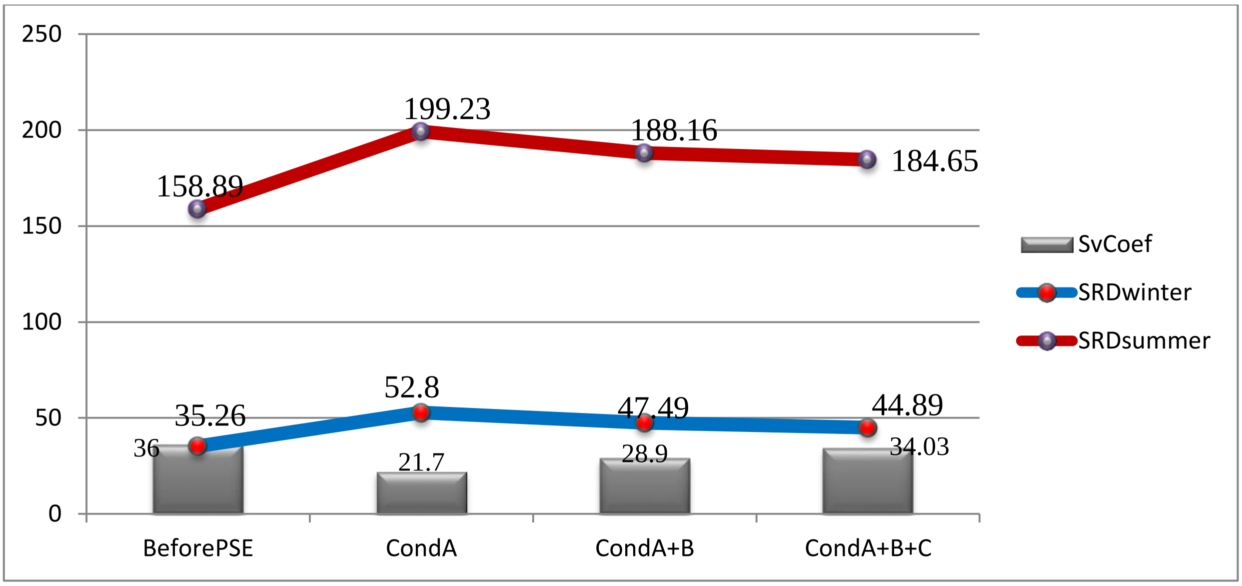


Figure 6.22: The effect of solar volume coefficient (V/S) on solar radiation in Oran (Author, 2019).

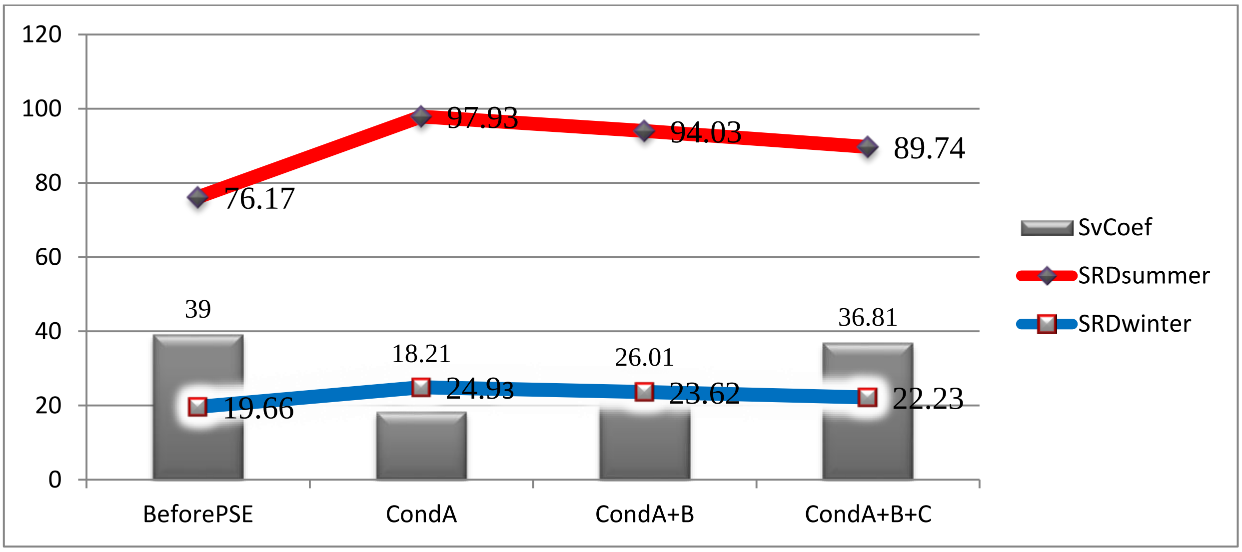


Figure6.23: The effect of solar volume coefficient (V/S) on solar radiation in Constantine (Author, 2019).

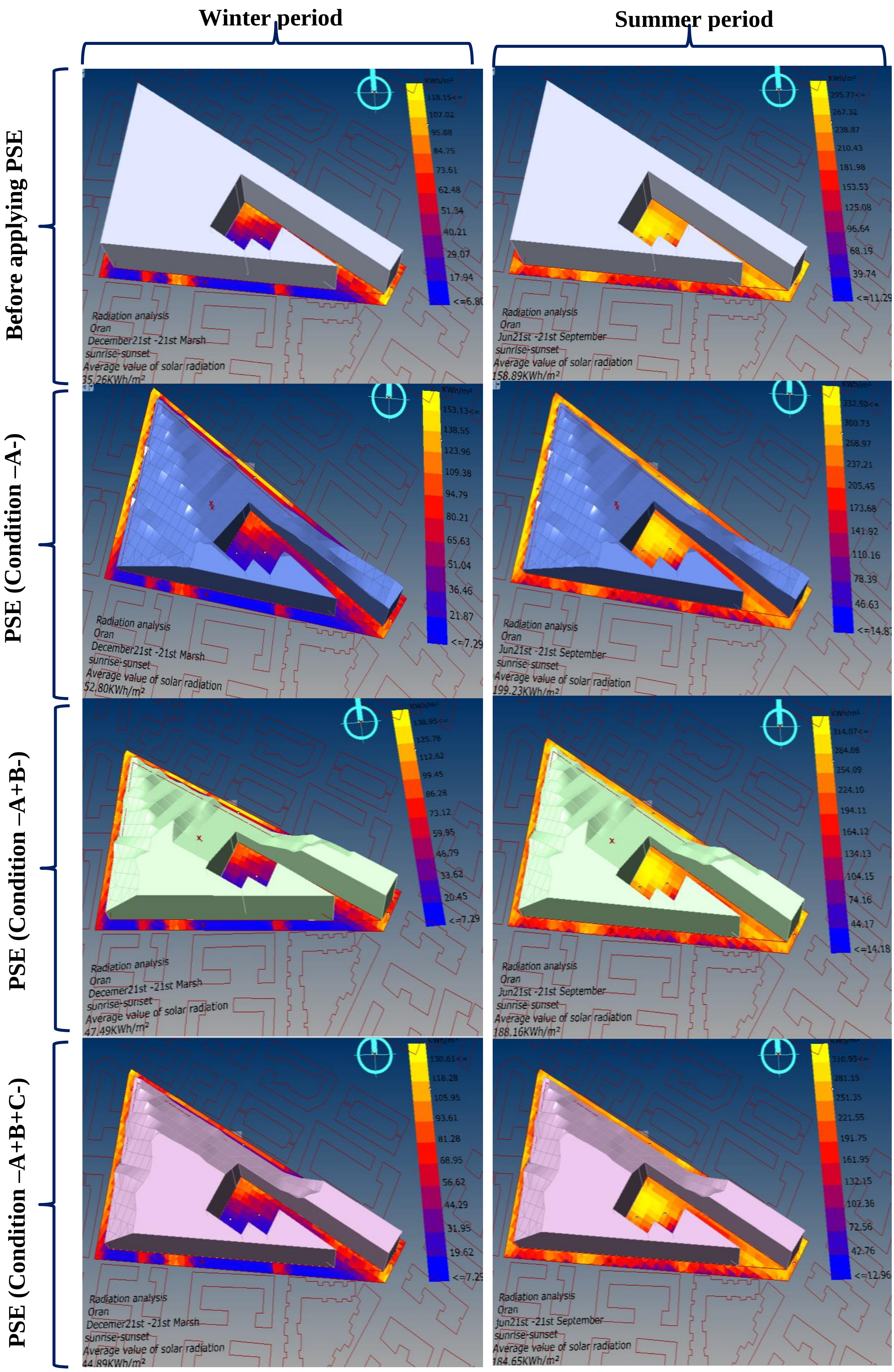


Figure 6.24: The effect of filtering process on solar radiation (Oran). (Author, 2019)

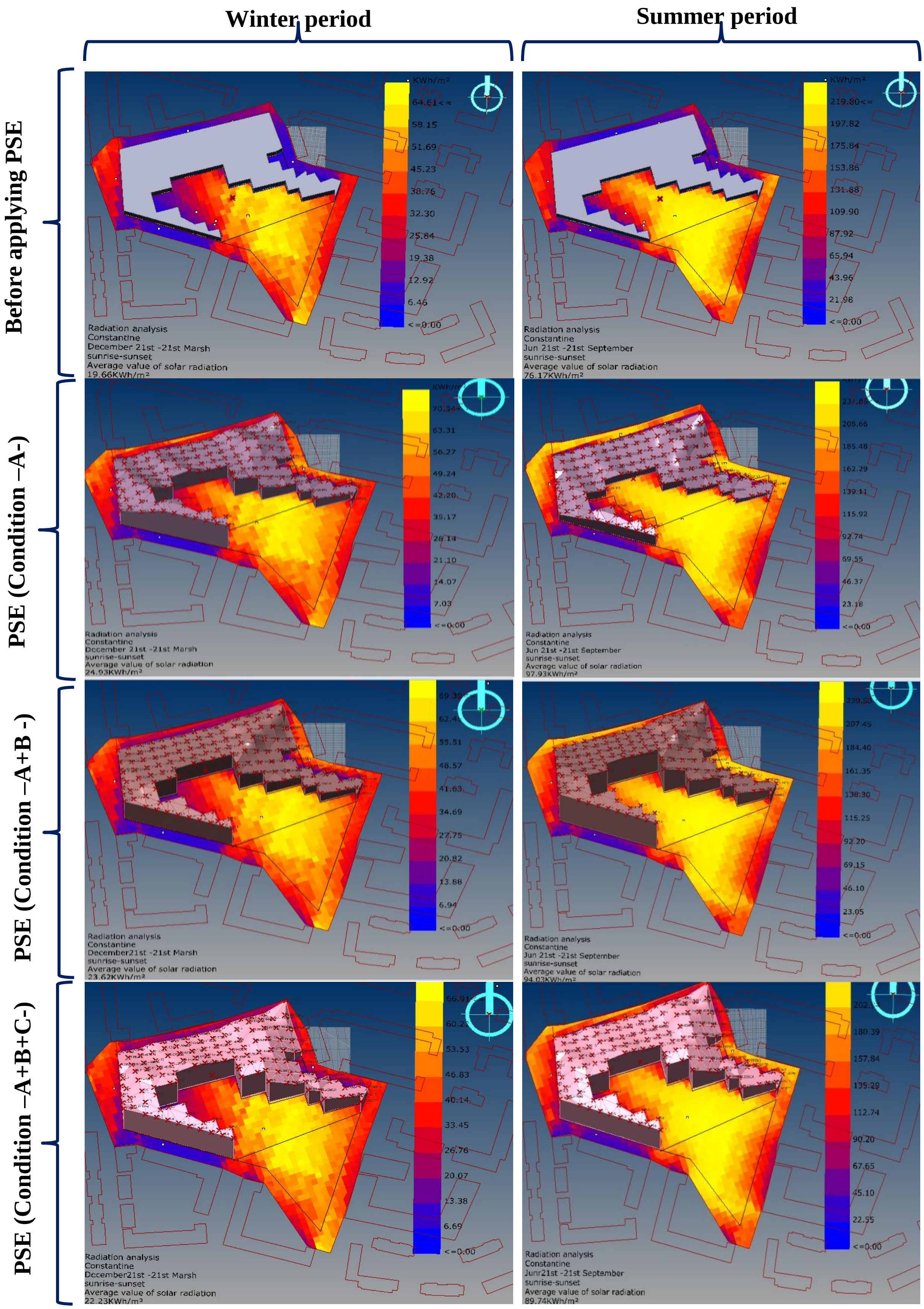


Figure 6.25: The effect of filtering process on solar radiation (Constantine). (Author, 2019)

2-2-The effect of solar volume coefficient on the Universal Thermal Climate Index (UTCI)

Geometrical parameters of the urban built have a crucial effect on thermal comfort. Hence, they have to be considered in the design process of the building environment (Dragan Milosevic et al -2016-).On this regard, another purpose of this study was to assess the effect of SVC before and after applying the PSE on outdoor thermal comfort during winter, and summer times. Likewise, the Universal Thermal Climate Index (UTCI) was chosen to assess the thermal sensation of walkers (See table2.4 page37). The selected locations of the Mankind for UTCI calculation were chosen according to the orientation (NS; NS-E; EW; and NS-W) of the spaces surrounding buildings. Therefore, six locations surrounding the new building were designated to calculate the UTCI in Coastal zone, and five locations abounding the new building were chosen to calculate the UTCI in Highland zone (See figures 6.26; 6.27).

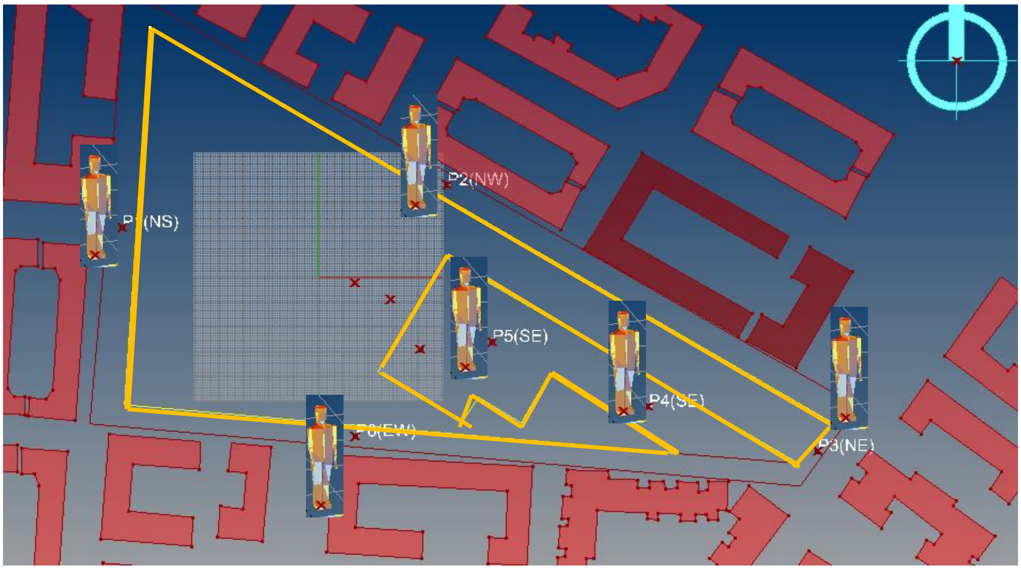


Figure 6.26: The selected locations of the Mankind for UTCI calculation in Oran (Author, 2019).

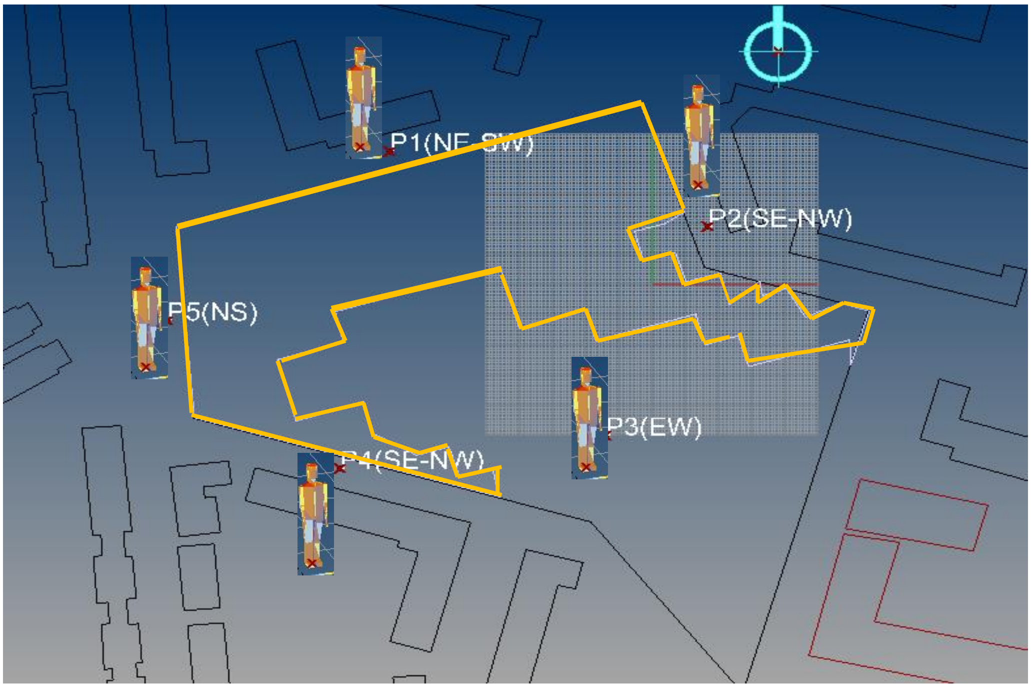


Figure6.27: The selected locations of the Mankind for UTCI calculation in Constantine (Author, 2019).

On one, hand the results reveal that during wintertime the average values of UTCI reaching about 10.77^{0}C, 8.47^{0}C, 10.28^{0}C, 8.53^{0}C, 7.24^{0}C, 7.74^{0}C in (P1, P2, P3, P4, P5, P6) respectively (See figure (6.28)). Therefore, the thermal sensation of the walker during winter period in coastal zone (Oran) before implementing the solar volume coefficient of the parametric solar envelope is characterized by slight cold stress in (P2, P4, P5, P6) locations. Whereas P1, P3 locations characterized by no thermal stress. On the other hand, figure (6.29) shows that the average values of UTCI before implementing the SVC of the PSE in highland zone (Constantine) during winter time in (P1NE-SW; P2SE-NW;P4SE-NW; P5NS) locations, were ranged from 4.320C to 4.420C, which indicates that the thermal sensation of the walker in these positions is characterized by slight cold stress (Comfortable for short periods of time), whereas P3EW location presents the maximum value of UTCI reaching 10.530C , indicating that there is no thermal stress in this setting (Comfortable conditions outdoors). However, figure (6.28) shows that for the same condition (before adopting the SVC of the PSE) the thermal sensation of the walker during summer time in all investigated settings in the coastal zone (Oran) is characterized by no thermal stress (Comfortable condition). Though, the maximum values of UTCI recorded in summer before applying the PSE in Highland zone were ranged from 27.67^{0}C to 28.85^{0}C in (P5NS; P3EW) respectively which indicates that there is a moderate heat stress (hot but not dangerous) in these locations, while the thermal sensation in (P1NE-SW; P2SE-NW; P4SE-NW) locations was comfortable (UTCI ranged from 25.080C to 25.820C). As explained before, we have defined the PSE according to sun vectors requirement of each zone by three conditions (A; A+B; A+B+C) (See table5.1 pages.118). Afterwards we displayed the effect of the filter parameters of solar envelope on the average values of UTCI. This is achieved by conducting a comparative analysis. As shown in figures (6.28;6.29), the results of the simulations indicate that strictly from the point of winter thermal comfort, the solar volume coefficient (SVC) of the parametric solar envelope (PSE) has an advantage while it leads to increase the average values of the UTCI for all locations investigated in both climatic zones. The results depicted in the previous figures (6.28; 6.29) also reveal that the application of the SVC of the parametric solar envelope of condition (A) alter the thermal sensation of the walker during summer period from comfortable to moderate heat stress (hot but not dangerous) in coastal zone, and from comfortable for short periods of time (before applying the solar envelope) to hot but not dangerous in Highland zone. However, more the initial condition is accurately defined, more the thermal comfort is upheld, whereas, for the condition (A+B+C), the UTCI in coastal zone can be ranged between 25.27^0C to 27.67^0C which means that thermal sensation of the walker in such condition is oscillated between comfortable for short periods of time to comfortable. Whereas in Highland zone (Constantine), the UTCI can reached 29.14^0C (hot but not dangerous) in P3EW location; 28.01^0C ; 27.820C (comfortable for short periods of time) in (P2SE-NW; P5NS) locations respectively, and 26.560C ; 25.830C (comfortable) in (P1NE-SW;P4SE-NW) locations respectively. It is noteworthy, that for the same condition (A+B+C) the thermal sensation of the walker during winter period in coastal zone (Oran) is characterized by no thermal stress (Comfortable). Although, in Highland zone the thermal sensation of the walker during winter period for the aformentioned condition (A+B+C) is considered comfortable for short period of time in (P4SE-NW) location and comfortable in (P1NE-SW;P2SE-NW; P3EW;P5NS) settings. Based on the findings, it is understood that in high latitudes (Lat >35^0), the adoption of solar volume coefficient (SVC) of the parametric solar envelope enhances thermal comfort in spaces surrounding building during winter time; however it offers some degree of lack during summer time where it drops the thermal sensation in some locations. The results of the comparative analysis also display that the solar volume coefficient of condition (A+B+C) is the best one. Because it safeguards sun penetration during winter time while achieving greater built density. Hence, the solar volume coefficient of condition (A+B+C) allows urban designers to reconcile between sun penetration and shade requirement. In order to assist urban planners in the design process, figures (5.30; 5.31) summarize the angles of obstructions of the resulting solar envelope (A+B+C) in both regions coastal and highlands.

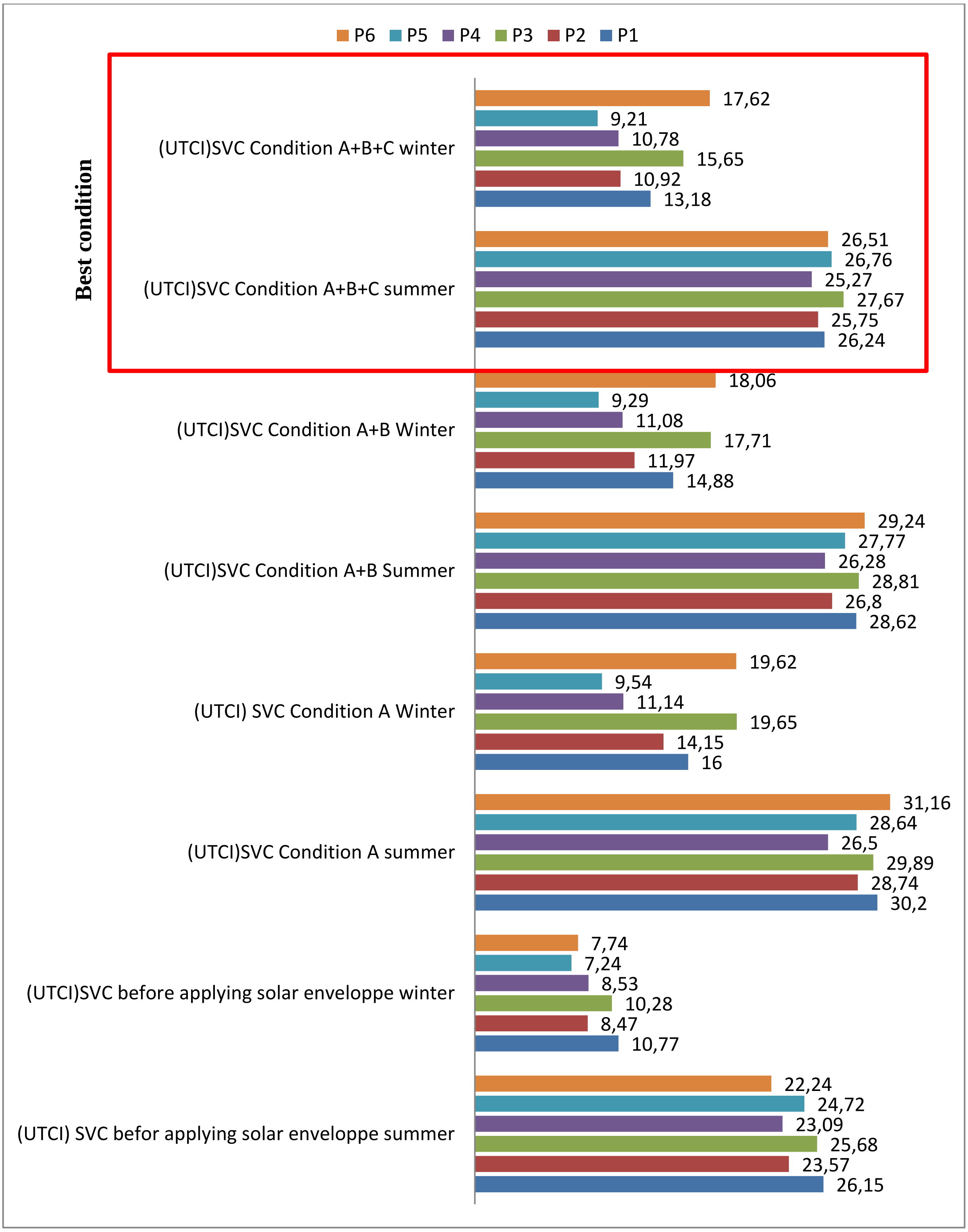


Figure 6.28: The effect of SVC on the UTCI during summer and winter periods in Oran (Author, 2019).

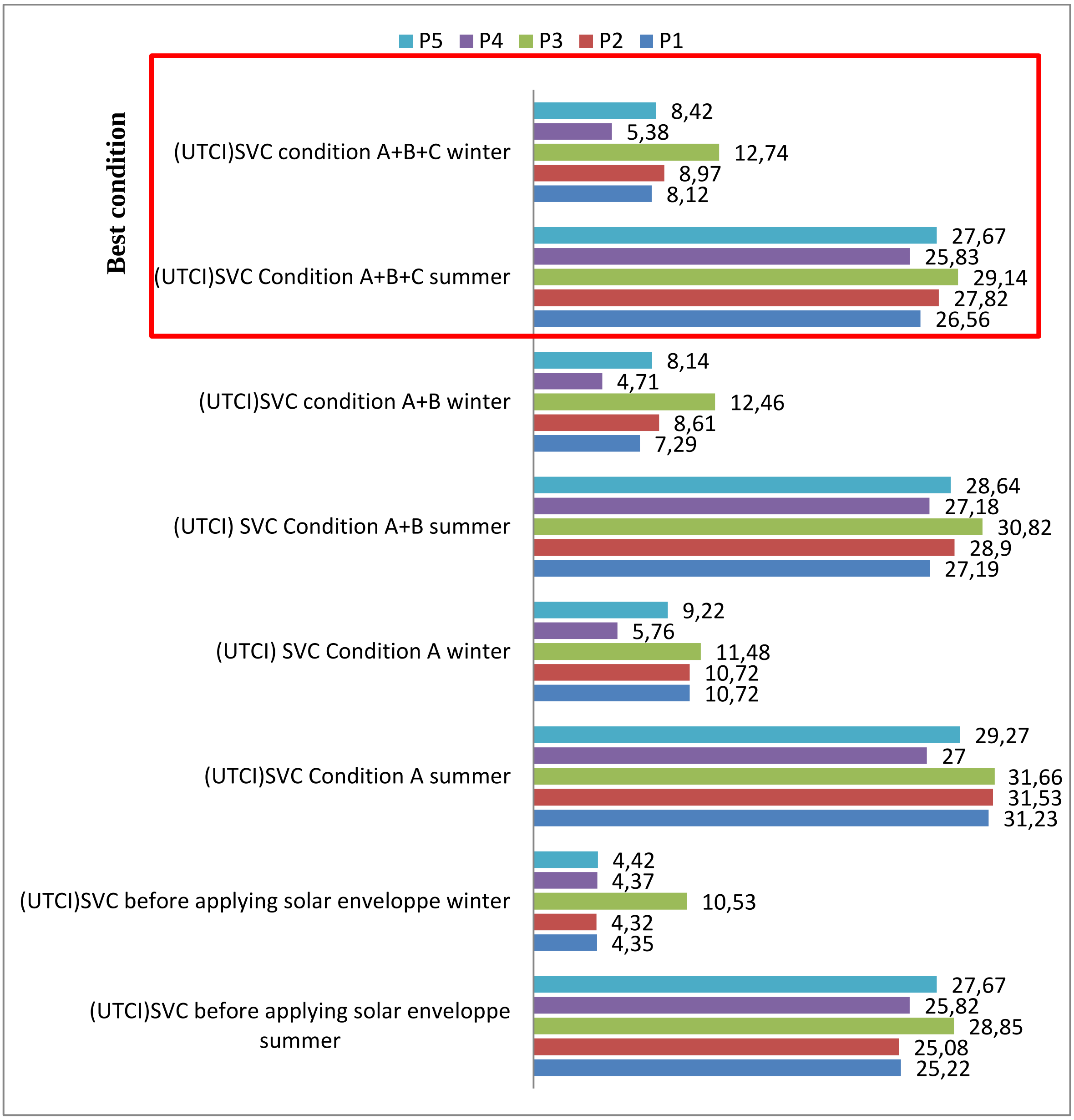


Figure 6.29: The effect of SVC on the UTCI during summer and winter periods in Constantine (Author, 2019).

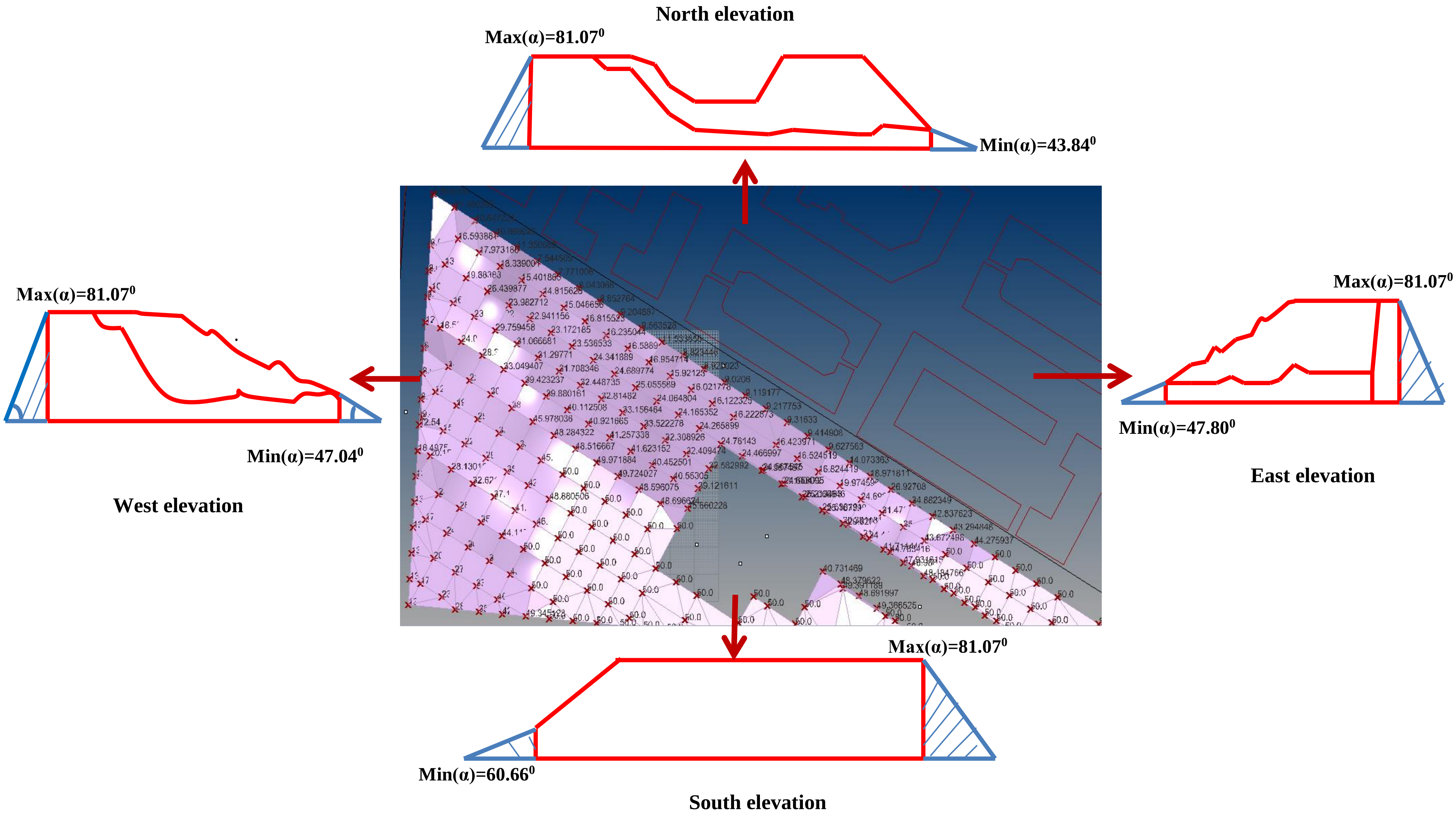


Figure 6.30: The optimum angle of obstruction according to the orientation-Oran- (Author, 2019)

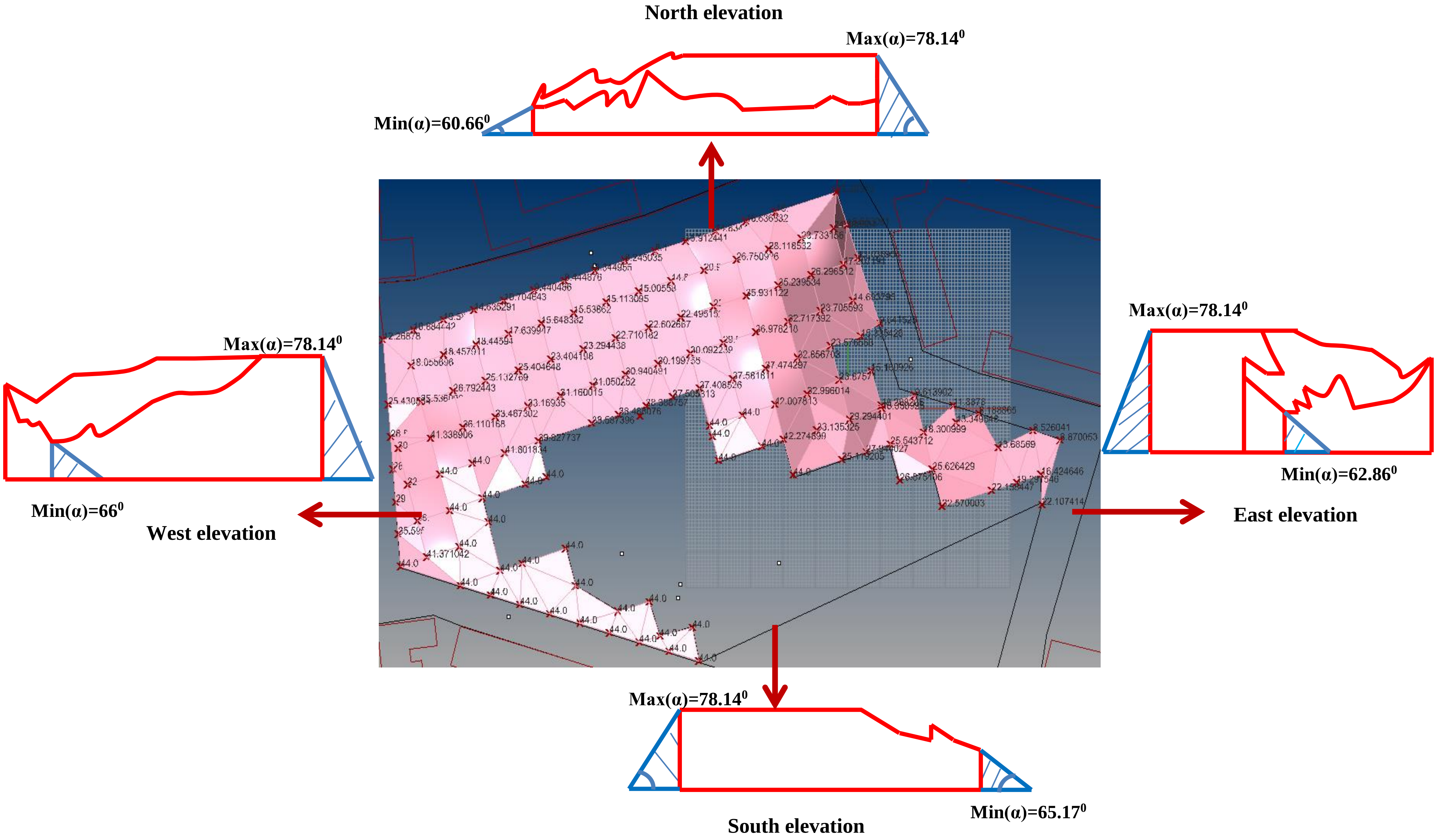


Figure 6.31: The optimum angle of obstruction according to the orientation-Constantine (Author, 2019)

Conclusion

The geometrical parameters of spaces between buildings have an important effect on solar rights, and shading requirement of the built environment. In this regard, a process which deals both, the ComfortCover model and a generative algorithm of parametric solar volume has been applied in this investigation to enhance pedestrian thermal comfort according to solar control, and shadow conditions caused by existing built forms. The study was carried out on three contemporary urban tissues located in three different climatic zones in Algeria (Coastal zone, Highlands zone, Sahara zone).

The findings of the first phase (ComfortCover model), determined the areas of where shade is required, and where it must be avoided. In order to ensure solar access during winter time, the area where shade is required (shade helpfulness-blue color-) is selected to be the surface of future urban densification. To determine the proper height of the new building which will be implanted in the surface of future urban densification, an evolutionary algorithm Octopus034 is run with twofold objectives; minimize UTCI during summer time, and maximize it during winter time. The results of Octopus034 generation show that in all the investigated climatic zones higher height of building can mitigate outdoor thermal comfort during summer time, however it drops it during winter time especially in high latitudes (Coastal and Highlands zones). In this way, in order to mitigate outdoor thermal comfort during summer and winter times, the parametric solar envelope has been applied on the best fitness values of the optimization of the proper height of the new building for future urban densification in high latitude. The application of the parametric solar envelope in low latitudes is omitted, because we have revealed earlier in the previous chapter that the application of the parametric solar envelope in Sahara climatic zones gives dangerous conditions of thermal sensation during summer time in comparison with the results of UTCI before its application. Based on the findings of the second stage of the applied workflow, it is approved that in both climatic zones of high latitudes (Coastal, and Highlands) decreasing solar volume coefficient after applying the parametric solar envelope leads to increase solar radiation in the space surrounding buildings during summer and winter times in comparison with the average values of solar radiation before applying the parametric solar envelope. Afterward, the effect of the parametric solar envelope on the universal thermal climate index (UTCI) has been assessed. The results indicate that the parametric solar envelope improves thermal comfort in spaces between buildings during winter time though it presents some degree of lack during summer time.

GENERAL CONCLUSION

General conclusion

The present research seeks primarily to tackle and identify the focal approaches of solar and shading control of urban spaces. Consequently, it has been organized in a way to apprehend the potential of solar access and shading in the design process of urban forms. This implied the assessment of urban planning rules in comparison with solar right and shading requirement rules. Moreover, a special focus was set on to develop a parametric investigation, which allows urban designers to determine the proper geometrical parameters of urban spaces in accordance with solar right, outdoor thermal comfort and latitudes.

We have highlighted through the literature review (1st, and 2nd chapters), the elements needed to understand the aspects of solar access, as well as the development of solar right. Also, the influence of geometrical parameters of urban spaces (Urban Density; Building form and orientation; Building outlines and street's orientation) on solar access has been clarified. It has been revealed through the literature overview that solar and shading control have a significant effect on the energy consumption for cooling, and heating, lighting, and human wellbeing.

The literature review shows two method classes of solar and shading control, such as evaluation and generative approaches. The evaluation methods attempt to assess the performance of a given design. This assessment serves to understand and identify the main geometrical parameters and urban rules that influence the human thermal comfort. The generative methods are classified in two types such as the descriptive and the performance methods. The descriptive methods are based on the search of the geometrical parameters of urban spaces, without taking into account the energy related with it. Whereas, the performance method is the method that outlines the requirements that have to be met such as the number of insolation required.

To overcome the uncomfortable conditions caused by the application of the recent urban rules, the present research pursues a process, which combines, between an evaluation method and a generative approach. The developed process begins with the assessment of the relationship between the geometrical parameters of urban spaces (Obstruction Angle, Orientation) and latitude on solar radiation impinged on the horizontal surfaces and outdoor thermal comfort. The investigation has been conducted during both of periods summer and winter.

However, the generative approach is based on two methods such as the application of the parametric solar envelope to determine the best values of obstruction angles as well as the application of a process, which deals between the ComfortCover model and the parametric solar envelope, to determine the solar volume coefficient of future urban densification. This workflow is established because it integrates the both constraints, solar access and shading. The modelling simulation has been done by using parametric tool (Rhinoceros/Grasshopper/Ladybug).

The results of the evaluative part of this thesis reveal that the application of prospect urban rule (obstruction angle α equal 45^0) preserves outdoor thermal comfort during winter time, but it cannot ensure it during summer period especially in low latitudes, where the thermal sensation is described by very strong to extreme heat stress. The results also show that during both period's summer and winter the average value of solar radiation decreased when latitude increased. Therefore, there is a relative dependence between latitude and the average value of solar radiation dropped in the ground surface of urban street canyons.

The results of the evaluative part also prove that low obstruction angle ensures solar right of urban spaces in both high and low latitudes. However, deep profiles of higher obstruction angle ($\alpha=76^0$) which are oriented to the north-south direction can mitigate outdoor thermal comfort during summer period in both high and low latitudes (Latitude$<35^0$), while during winter periods high obstruction angle leads to drop outdoor thermal comfort in high latitudes (Latitude$>35^0$). Hence, we can say that the obstruction angle (OBA) should be specified according to the site latitude. Based on the findings of this step, we can say that the first and the second hypothesis have been confirmed.

The results of the generative phase demonstrate that the application of the parametric solar envelope on deep profiles of urban street canyons allows urban planners to achieve greater built density while, maintaining solar access in urban spaces and improves outdoor thermal comfort during winter period. However, during summer time the application of PSE leads drop outdoor thermal comfort. The results of the generative phase also demonstrate that the application of PSE must be avoided in low latitudes (latitude$<35^0$). Therefore, through this investigation the third hypothesis is confirmed.

The application of ComfortCover model reveal that it can be considered as a good manner to determine the shape of the area of future urban densification. It determines the area of shade helpfulness (where shade is required), and the area of where shade must be avoided (shade harmfulness). Since, the findings of this analysis display that the plot ratio of the final block (areas of shade helpfulness) reaching about 0.80 in coastal zone (Oran), 0.47 in highlands zone (Constantine), 1 in Sahara zone .

The application of the parametric solar envelope on the area of future urban densification shows the same results of its application on urban street canyon. Since, the results indicated that the more the initial condition is specified, the more the number of sun hours selected decreases and the solar volume coefficient (SVC) would be increased, which leads to minimize the average values of solar radiation in spaces between buildings during both of periods summer and winter. The findings of this step also show that the solar volume coefficient (SVC) of the parametric solar envelope has a benefit effect while it leads to rise the average values of the UTCI for all the positions investigated in both climatic zones. Though, the (SVC) of condition (A+B+C) gives best values of UTCI in comparison with those of conditions (A; and A+B). Because the (SVC) of condition (A+B+C) maintain sun penetration during wintertime while fulfilling greater built density. Therefore, it permits urban planners to reconcile between shading requirement and sun penetration. Based on the findings of this step we can say that without any doubt the fourth hypothesis of this thesis is largely confirmed.

Research difficulties

We do not claim to present a perfect work or even to have clarified all the aspects that relate to this problematic because any research work has a part of insufficiencies whether in the collection of information, or in their processing, or even in the interpretation of the results. We would like to note the difficulties encountered in this study.

- The absence of people specializing in parametric tools (Rhinoceros/Grasshopper/Ladybug) in Algeria, so I found many learning difficulties.

- Ransom ware (virus)

- The unavailability of powerful instruments to perform high-performance simulations like that of Dragonfly.

Limitations of the study

Any research must be limited in its object. Our study meets two limits with regard to safeguarding sun penetration and relying to shading requirement.

- The developed process deals only with the effect of the geometric parameters of the urban space, and it does not take into account the effect of the other parameters such as vegetation, etc.

- The parametric solar envelope can mitigate outdoor thermal comfort during winter time , while it drops it during summer period.

Future lines of research

The treatment of this fascinating subject of research has opened up other perspectives for us, towards inexhaustible directions of which heaps of subjects and virgin lands remain to be discovered.

-Developing a process, which deals between the geometrical parameters of urban spaces, vegetation, smart material, and outdoor thermal comfort.

-Mitigating the lack of the PSE (during summer) by the dynamic shading and adaptive umbrella.

- Generating an urban layout by applying the idea of (Yn Kyu yi, 2014), the agent point

- Developing a study about indoor thermal comfort and urban forms.

REFERENCES LIST

References

Alcoforado, M.J., Andrade, H., Lopes, A., & Vasconcelos, J. (2009). Application of Climatic guidelines to urban planning. *Landscape and Urban Planning*, *90*(1-2), 56–65. doi:10.1016/j.landurbplan.2008.10.006.

Ali-Toudert, F. (2005). Dependence of Outdoor Thermal Comfort on Street Design in Hot and Dry Climate. [PhD Thesis - Meteorologisches Institut der Universität Freiburg]. https://www.researchgate.net/profile/Fazia_Ali-Toudert/publication/265983463_Dependence_of_outdoor_thermal_comfort_on_street_design_in_hot_and_dry_climate/links/5dd57cb7299bf11ec866c3f2/Dependence-of-outdoor-thermal-comfort-on-street-design-in-hot-and-dry-climate.pdf.

Amado, M., & Poggi, F. (2014). Solar Urban Planning: A Parametric Approach. *Energy Procedia*. *48*, 1539-1548. 10.1016/j.egypro.2014.02.174.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (2010). Ashrae standard. Thermal environmental conditions for human occupancy.http://arco-hvac.ir/wp-content/uploads/2015/11/ASHRAE-55-2010.pdf.

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (2009). Ashrae handbook fundamentals. file:///C:/Users/Dell/Downloads/Inch_Pound_Edition_2009_ASHRAE_HANDBOOK.pdf.

Arens, E., Hoyt, T., Zhou, X., Huang, L., Zhang, H., & Schiavon, S. (2015). Modeling the comfort effects of short-wave solar radiation indoors. *Building and Environment*, *88*, 3–9. doi:10.1016/j.buildenv.2014.09.004.

Ariane, M., Nancy, S., Bjorn, H., & Nalini, C.H. (2016). Impact of shade on outdoor thermal comfort—a seasonal field study in Tempe, Arizonax. *Int J Biometeorol*. *60,*1849–1861. Doi : 10.1007/s00484-016-1172-5.

Arnfield, A.J. (1989). Validation of an estimation model for urban surface albedo. *Phys Geogr*, 9,361–372.

ASHRAE. (1993). Physiological principles and thermal comfort. ASHRAE Handbook of Fundamentals. Atlanta, ASHRAE: 8.1-8.29.

Balint, H. (2015). *Density: Spatial patterns and perception*. [Master thesis. University of Vienna]. doi: 10.25365/thesis.39553. Urn:nbn:at:at-ubw:1-29622.88298.971362-0 .

Behsh, B. (2002). Building form as an option for enhancing the indoor thermal conditions. *Building Physics - 6th Nordic Symposium, Session 18: Indoor Environment*, *2*, 759- 766.

Belakehal, A., & Tabet Aoul, K. (1996). Shading and shadowing: Concepts for an interactive strategy between solar control and aesthetics in the design of the facade. Reference to arid zones. Renewable Energy, 8 (1-4), 323-326. https://doi.org/10.1016/0960-1481(96)88870-7.

Blazejczyk, K. (1994). New climatological-and-physiological model of the human heat balance outdoor (MENEX) and its applications in bioclimatological studies in different scales. [in:] BłaŜejczyk K., Krawczyk B. Bioclimatic research of the human heat balance. Zesz.IGiPZ PAN, 28, p. 27-58.

Blazejczyk, K., Epstein, Y., Jendritzky, Gerd. Staiger, H., & Tinz, B., (2012) Comparison of UTCI to selected thermal indices. International Journal of Biometeorol, 56, 515–535. https://doi.org/10.1007/s00484-011-0453-2.

Blazejczyk, K., Jendritzky, G., Bröde, P., & Dusan, B., Dusan, F., Bullet, G., Havenith, G., Yoram, B., Yoram, E., Psikuta, B., & Kampmann, B. (2013). An introduction to the

Universal Thermal Climate Index (UTCI). Geographia Polonica. 86, 5- https://doi.org/10. 10.7163/GPol.2013.1.

Boucheriba, F. (2017). Effet de la Densité Urbaine Exprimée Par le “CES” et le “COS” Sur le Microclimat Urbain. Recherche d’un Indicateur Morpho-Climatique de Densité « Cas de L’habitat Individuel à la Ville d’Ain Smara ». [Doctoral dissertation, University of Constantine 3, Departement of Architecture].

Bourbia, F, & Awbi, H.B. (2004). Building Cluster and Shading in Urban Canyon for Hot-Dry Climate. Part 2 Shading Simulations. Renewable Ennergy, 29:291–301. 10.1016/S0960-1481(03)00170-8.

Bourbia, F., & Boucheriba, F. (2010). Impact of street design on urban microclimate for semi-arid climate (Constantine). Renewable Energy, 35(2), 343-347. https://doi.org/10.1016/j.renene.2009.07.017.

Brown, M., & Grimmond, S. (2001). Sky View Factor Measurements in downtown Salt Lake City - Data Report for the DOE CBNP URBAN Field Experiment, Oct. 2000," LA-UR-01-1424.

Brown, M., Grimmond, C., & Ratti, C. (2001). Comparison of methodologies for computing sky view factor in urban environments. International Society of Environmental Hydraulics Conference, Tempe, AZ.

Capeluto, I. G., & Plotnikov, B. (2017). A Method for the generation of climate-based, context-dependent parametric solar envelopes. Architectural Science Review, 60(5), 395-407.doi: 10.1080/00038628.2017.1331334.

Capeluto I. G. & Shaviv E. (1997). Modeling the design of urban grids and fabric with solar rights consideration. In Proceedings of ISES, Taejon, Korea.

Capeluto, I. G. & Shaviv, E. (2000). Sust Arc: a Model for the design of urban fabric with solar rights considerations, in the 17th international conference on Passive and Low Energy Architecture, London.

Capeluto, I. G. (2003). Energy performance of the self-shading building envelope. Energy and Buildings, 35(3), 327–336. doi: 10.1016/s0378-7788(02)00105-6.

Capeluto, I. G., & Plotnikov, B. (2017). A method for the generation of climate-based, context-dependent parametric solar envelopes. Architectural Science Review, 60(5), 395–407. doi:10.1080/00038628.2017.1331334.

Capeluto, I. G., Yezioro, A., Bleiberg, T., & Shaviv, E. (2006). Solar rights in the design of urban spaces. In R. Compagnon, P. Haefeli, & W. Weber (Eds.), Clever design and affordable comfort - A Challenge for Low Energy Architecture and Urban Planning: Proceedings of the 23rd International Conference on Passive and Low Energy Architecture (PLEA 2006). Geneva.

Capeluto, I.G., & Shaviv, E. (2001). On the use of "Solar Volume" for determining the urban fabric, Sol. Energy. 70(2001), 275–280. Doi: 10.1016/S0038-092X(00)00088-8.

Carlo, R., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: archetypes, analysis and an arid climate. Energy and Buildings, 35(1), 49-59. https://doi.org/10.1016/S0378-7788(02)00079-8.

Cheng, V., Steemers, K. Montavon, M., & Compagnon, R. (2006). Urban Form, Density and Solar Potential. International Conference on Passive and Low Energy Architecture (PLEA 2006). Volume 23. https://www.researchgate.net/publication/37434409_Urban_Form_Density_and_Solar_Potential.

Cho, I. S., Heng, C. K., &Trivic, Z. (2015). Re-framing urban space urban design for emerging hybrid and high-density conditions. (1st Ed.). EBook ISBN9781315725147. Pub. Location New York. Imprint Routledge. https://doi.org/10.4324/9781315725147

Christopher, M., Sadeghipour, M., & Samaras, P. (2015).Comfort Cover: A Novel Method for the Design of Outdoor Shades. Proceedings of the symposium on simulation for architecture &urban design.

Clarke, K. (1986). Advances in geographic information systems. Computers, Environment and Urban Systems, 10(3.4), 175-184. 10. 175-184.

Cohen, P., Potchter, O., & Matzarakis, A. (2013). Human thermal perception of coastal Mediterranean outdoor urban environments. Applied Geography, 37, 1–10. https://doi.org/10.1016/j.apgeog.2012.11.001.

De Luca, F. (2016). Solar envelope optimization method for complex urban environments. Proceedings of CAADence in Architectrure Conference, Budapest University of Technology and Economics, Budapest, Hungary, 16-17 June 2016, 195-201.

DOI:10.1016/0198-9715(86)90006-2

Dovey, K., & Pafka, E. (2014). The urban density assemblage. Urban Design International, 19(1), 66–76. https://www.academia.edu/34596152/The_urban_density_assemblage_Modelling_multiple_measures.

Dra. L. A., Cárdenas. J., & Schulz, D. V. (2015). Thermal comfort in housing under solar obstruction derived from high building in urban renewal areas. ICUC9 - 9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment. July 2015.

Dulce Marques, D. A. (2014). The importance of street Shade for downtown traditional retail business. https://www.ictct.net/wp-content/uploads/23-Hague-2010/ictct_document_nr_683.pdf

Eirini, T. (2006). The Role of Courtyards in Relation to Air Temperature of Urban Dwellings in Athens. PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6-8 September 2006. Volume 2. Pages. 833-838.

Elaiab, F. M. (2014). Thermal Comfort Investigation of Multi-Storey Residential Buildings in Mediterranean Climate with Reference to Darnah, Libya. [PhD thesis, University of Nottingham]. http://eprints.nottingham.ac.uk/14201/1/phd_thesis_Fatima_Elaiab.pdf.

Elasfouri, A. S., Maraqa, R., & Tabbalat, R. (1991). Shading Control by neigh bouring buildings: application to buildings in Amman, Jordan. International Journal of Refrigeration, 14(2), 112–116. http://doi.org/10.1016/0140-7007(91)90083-S.

Elmira, J., & Priyadarsini, R. (2018).Effect of street design on pedestrian thermal comfort, Architectural Science Review, DOI: 10.1080/00038628.2018.1537236.

Emmanuel, R. (1993). A Hypothetical “Shadow Umbrella” for thermal comfort enhancement in the equatorial urban outdoors. Architectural Science Review, 36(4), 173–184. doi:10.1080/00038628.1993.9696759.

Emmanuel, R. (2005). An urban approach to climate sensitive design: strategies for the tropics. E & FN Spon Press, London.

Esch, M.M.E., Looman, R., & Hordijk, G. (2012). The effects of urban and building design parameters on solar access to the urban canyon and the potential for direct passive solar heating strategies. Energy and Buildings. 47,189–200. 10.1016/j.enbuild.2011.11.042.

Estefania, T., & Shubham, S. (2014). Building-up urban open spaces from shadow range analyses. Towards Smarter Cities - Volume 1 - eCAADe 32.

Eugenio, E., Baca, S., & Tsai, I. (2015). A model-based approach to measuring the effect of shading on outdoor thermal comfort. International journal of engineering and technology, 7, 116-121. 10.7763/IJET.2015.V7.777.

Farajzadehm, H., Saligheh, M., & Alijani, B. (2016). Application of universal thermal climate index in Iran from tourism perspective. Nat Eviron. Chang. 5, 117-138.

Fawcett, W. (1983). A note on the obstruction angle model for block spacing. Building and Environment, 18(3), 125–128. doi: 10.1016/0360-1323(83)90004-5.

Francesco, D. L., & Timur, D. (2019).A novel solar envelope method based on solar ordinances for urban planning. Build Simul, 12, 817–834. https://doi.org/10.1007/s12273-019-0561-1.

Fröhlich, D., & Matzarakis, A. (2015). Estimation of human bio meteorological conditions in south West Germany for the assessment of mitigation and adaptation potential. ICUC9 - 9th international conference on urban climate jointly with 12th symposium on the urban environment.

Givoni, B. (1969). Man, Climate, and Architecture. Elsevier Architectural Science Series.

Givoni, B. (1997). Climate considerations in buildings and urban design. Printed in the United States of America. ISBN 0-471-29177-3.

Goulding, J., Lewis, O., & Steemers, T. (1992). Energy in Architecture: The European passive solar handbook, B.T. Batsford for the Commission of the European Communities, Directorate General XII for Science, Research and Development, London.

Grunwalda, G., Hermeking, T., & Prang, T. (2016). Kinetic roof structure: Msheireb heart of Doha. International symposium on novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs. Procedia Engineering, 155(2016), 289 – 296. doi: 10.1016/j.proeng.2016.08.031

Güneralp, B., Zhou, Y., Ürge-Vorsatz, D., Gupta, M., Yu, S., Pralit, L., Fragkias, M., Xiaoma, L., & Karen, C. S. (2017). Global scenarios of urban density and its impacts on building energy use through 2050. Understanding and simulating global urban expansion in the context of climate change. Proceedings of the National Academy of Sciences, 114(34), 8945–8950. DOI: 10.1073/pnas.1606035114.

Gupta, V. K. (1984). Solar radiation and urban design for hot climates. Environment and planning B: Planning and Design, 11(04), 435-454. https://doi.org/10.1068/b110435.

Hachem, C., Athienitis, A., & Fazio, P. (2011). Investigation of solar potential of housing units in different neighborhood designs. Energy and Building. 43(9), 2262-2273. doi: https://doi.org/10.1016/j.enbuild.2011.05.008

Han, Y., Taylor, J. E., & Pisello, A. L. (2015). Toward mitigating urban heat island effects: Investigating the thermal-energy impact of bio-inspired retro-reflective building envelopes in dense urban settings. Energy and Buildings, 102, 380–389. doi:10.1016/j.enbuild.2015.05.040

Han, Y., Taylor, J. E., & Pisello, A. L. (2017). Exploring mutual shading and mutual reflection inter-building effects on building energy performance. Applied Energy, 185, 1556–1564. doi:10.1016/j.apenergy.2015.10.170

Heidt, V., & Neef, M. (n.d.). Benefits of urban green space for improving urban climate. Ecology, Planning, and Management of Urban Forests, 84–96. Doi: 10.1007/978-0-387-71425-7_6.

Höppe, P. (1999).The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. Int J Biometeorol, 43, 71–75. https://doi.org/10.1007/s004840050118.

http://designlike.com/high-tech-giant-umbrellas-improve-al-masjid-al-nabawi-mosques-natural-micro-climate/

http://www.achimmenges.net/?p=5922

http://www.openstreetmap.org.

https://carloratti.com/project/sunshade/

https://github.com/stgeorges/gismo.

https://www.cder.dz/spip.php?article40.

https://www.metropolismag.com/sustainability/ralph-knowles-pioneer-solar-design/.

Hyde, R. (2000). Climate responsive design: a study of buildings in moderate and hot humid climates. E, FN Spon_ Chapman & Hall. UK.

Jendritzky, G., De Dear, R., & Havenith, G. (2012). UTCI--why another thermal index? Int J Biometeorol, 56(3), 421-428. doi:10.1007/s00484-011-0513-7.

Johansson, E. (2006). Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. Building and Environment, 41(10), 1326–1338. doi:10.1016/j.buildenv.2005.05.022.

Johansson, E., Thorsson, S., Emmanuel, R., & Krüger, E. (2014) Instruments and methods in outdoor thermal comfort studies—the need for standardization. Urban Climate, 10,346–366. https://doi.org/10.1016/j.uclim.2013.12.002.

José, B., Pedro, A., & José, D. (2012). Parametric Urban Design. City Modelling - Volume 1 - eCAADe 30.P.167-175.

Kampf, H. J., & Robinson, D. (2010).Optimisation of building form for solar energy utilisation using constrained evolutionary algorithms. Journal Energy and buildings Elsevier, 42(6), 807-814. doi:10.1016/j.enbuild.2009.11.019.

Kanters, J., & Horvat, M. (2012). Solar energy as a design parameter in urban planning. Energy Procedia. 30, 1143-1152. 10.1016/j.egypro.2012.11.127.

Kapnoullas, A. (2010). The ideal model for solar access rights, Monash University Honours Program on 1st October 2010.

Kapnoullas, A. (2011). The ideal model for solar access rights. Environmental and Planning Law Journal. 416, 438 n 227.

Khoukhi, M., & Fezzioui, N. (2012). Thermal comfort design of traditional houses in hot dry region of Algeria. Int J Energy Environ Eng. 3(5). https://doi.org/10.1186/2251-6832-3-5.

Knowles, R. (2003).The solar envelope: It's meaning for energy and buildings. Energy and Buildings. 35(1). 15-25. DOI: 10.1016/S0378-7788(02)00076-2.

Knowles, R.L., & Berry R.D. (1980). Solar envelope concepts: Moderate density building applications, Solar Energy Research Institute, Golden Co.

Koenigsberger, O.H., Ingersoll,T.G., Mayhew,A., & Szokolay,S.V.(1973). Housing and building. Part one: Climatic design. Published in the United States of America by Longman Inc., New York. ISBN 0582 44546 9.

Littlefair, J., Santamouris, M., Alvarez, S., Dupagne, A., Hall, D., Teller, J., Coronel, J. F., & Papanikolaou, N. (2000). Environmental site layout planning: Solar access, microclimate and passive cooling in urban areas.

Littlefair, P. (2001). Daylight, sunlight and solar gain in the urban environment. Solar Energy, 70, 177-185. 10.1016/S0038-092X(00)00099-2.

Lorenzo, V., & Danil, N. (2020). Retrieved from https://www.autodesk.com/autodesk-university/article/Generative-Design-Architectural-Space-Planning-2020

Makaremi, N., Salleh, E., Jaafar, M.F., & Ghaffarianhoseini, A. (2012). Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia. Building and Environment, 48, 7-14. doi:10.1016/J.BUILDENV.2011.07.024.

Mansour, N., Mohd, Z. k., Ghomeshi, M., Moeinzadeh, N., & Ghasemi, M. (2011). Investigating the effectiveness of self-shading strategy on overall thermal transfer value and window size in high rise buildings .World Academy of Science, Engineering and Technology

International Journal of Civil and Environmental Engineering , 5(2), 103-108. doi.org/10.5281/zenodo.1335096.

Marko, J. (2016) Genetic algorithm application as a sustainable urban planning optimization tool. 4th International Regional eCAADe Workshop, Novi Sad, May 2016. ISBN - 978-86-7892-807-9. P.31-38.

Martinelli, L., Tzu-Ping, L., & Matzarakis, A. (2015).Journal of Building and Environment, 92, 30-38. https://doi.org/10.1016/j.buildenv.2015.04.013 .

Matzarakis, A. (2001) .Assessing climate for tourism purposes: Existing methods and tools for the thermal complex. Proceedings of the first international workshop on climate, tourism and recreation, ed. by A. Matzarakis and C. R. de Freitas. International Society of Biometeorology, Commission on Climate Tourism and Recreation. 101-112.

Matzarakis, A., Mayer, H., & Iziomon, M. (1999). Applications of a universal thermal index: physiological equivalent temperature. Int J Biometeorol, 43, 76–84 https://doi.org/10.1007/s004840050119.

Mazouz, S. (2007). Elements de conception architecturale. éditions OPU, 2007.

Mazouz, S., & Zerouala, M. S. (1999). The Derivation and Re-Use of Vernacular Urban Space Concepts, Architectural Science Review, 42:1, 3-13, DOI: 10.1080/00038628.1999.9696843.

Megahed, N. A. (2018). An exploration of the control strategies for responsive umbrella-like structures. Indoor and Built Environment, 27(1), 7-18. https://doi.org/10.1177/1420326X16669750

Meir, I.A. (2000). Courtyard microclimate: A hot arid region case study. In: Steemers, K. and Yannas, S. (eds), Architecture–City–Environment, pp. 218–223. London: James & James.

Mills, G. (2006). The climate of London by Luke Howard (1883). https://docs.ufpr.br/~feltrim/LIVROS/LukeHoward_Climate-of-London-V1.pdf.

Milosevic, D., Bajsanski. I., Savic, S., & Ziberna, I. (2016). Benefits of the environmental simulations for the urban planning process. In 4th International Regional eCAADe Workshop, Novi Sad, May 2016 ISBN - 978-86-7892-807-9.

Mirkovic, M., & Alawadi, K. (2017). The effect of urban density on energy consumption and solar gains: the study of Abu Dhabi’s neighborhood. Energy Procedia, 143,277-282. doi:10.1016/j.egypro.2017.12.684.

Montavon, M. (2010). Optimisation of urban form by the evaluation of the solar potential. [Doctoral dissertation, Federal institute of technology in Lausanne, Suisse]. file:///C:/Users/Dell/Downloads/EPFL_TH4657.pdf.

Morello, E., & Carlo, R. (2009). “Sunscapes: ‘Solar Envelopes’ and the analysis of urban DEMs.” Computers, Environment and Urban Systems 33: 26–34.

Morello, E., & Ratti, C. (2005). Sun scapes: Extending the ‘Solar Envelopes’ concept through ‘Iso solar Surfaces’. Proceedings of the 22nd International Conference on Passive and Low Energy Architecture, Beirut.

Naidja, A., Khammar .Z. & Bourbia. F. (2017). The effect of geometrical parameters of urban street on shading requirement in hot arid climate- contemporary urban street of Biskra- PLEA 2017 Edinburgh – 33rd International Conference on Passive and Low Energy Architecture. Cities, Buildings, People: Towards Regenerative Environments.

Nicola, D. (2008). Quality of the built environment in urban neighborhoods. Journal Planning Practice and Research. 23(2), 249-264. https://doi.org/10.1080/02697450802327198.

Okeil, A. (2004). In search for energy efficient urban forms: The residential solar block, In: CIB World Build. Congr. Futur. 5th Int. Conf. Indoor Air Qual. Vent. Energy Conserv. Build. Proc.

Okeil, A. (2010). A holistic approach to energy efficient building forms. Energy and Buildings, 42(9), 1437–1444. doi:10.1016/j.enbuild.2010.03.013.

Open Street Map. (2018). http://www.openstreetmap.org/ (accessed July 20, 2018).

Ould Henia, A. (2003). Choix climatique et construction. zone aride et semi arides. La maison à cour de Bou Saada. [Doctoral dissertation Polytechnic School of Lausanne, 'EPFL', Lausanne, 181].

Pesenti, M., Masera, G., Fiorito, F., & Sauchelli, M. (2015). Kinetic solar skin: A responsive folding technique. Energy Procedia, 70, 661–672. https://doi.org/10.1016/j.egypro.2015.02.174.

Pisello, A.L., Taylor, J. E., Xiaoqi, X., & Cotana, F. (2012). Inter-building effect: Simulating the impact of a network of buildings on the accuracy of building energy performance predictions. Building and Environment, 58, 37-45. 10.1016/j.buildenv.2012.06.017

Plotnikov, B. (2015). New solar envelope component now available. http://www.grasshopper3d.com/group/ladybug/forum/topics/new-solar-envelope-component-now-available. Accessed April 2017.

Raboudi, K. (2013). A morphological generator of urban rules of solar control. Proceedings of the 29th International PLEA Conference: Sustainable Architecture for a renewable future. PLEA 2013 Munich, 2013. Dans W. Lang.

Raboudi, K. (2017). Générateur morphologique de règles urbaines de contrôle solaire. [Doctoral dissertation, University of Carthage, Tunis]. file:///C:/Users/Dell/Downloads/thesepdfapublier.pdf.

Raboudi, K., & Ben Saci, A. (2013). A morphological generator of urban rules of solar control. In sustainable architecture for a renewable future: Proceedings of the 29th International Conference on Passive and Low Energy Architecture. Munich.

Raven, J. (2011). Cooling the public realm: Climate-Resilient urban design. 10.1007/978-94-007-0785-6_45. Manchester Architecture Research Centre (MARC) Centre for the History of Science Technology and Medicine (CHSTM). - Chancellor's Hall, The University of Manchester. https://www.usgbc.org/sites/default/files/CoolingthePublicRealm.pdf.

Richard, D. D., & Pickup, J. (2000). An outdoor thermal comfort index (Out_SET*)–Part 1–The model and its assumptions. https://www.researchgate.net/publication/268983057_An_outdoor_thermal_comfort_index_Out_SET-Part_1-The_model_and_its_assumptions.

Riiber, J. (2013). Generative processes in architectural design. [PhD thesis. The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, Philip de Langes Allé 10 DK-1435 Copenhagen K]. https://issuu.com/cita_copenhagen/docs/cita-phd-thesis_jacob_riiber-2013/270.

Rosenlund, H. (2000). Climatic design of buildings using passive techniques. Building Issues, 10(1), 3-26.

Sanaieian, H., Tenpierik, M., Linden, K.V. D., Seraj, F. M., & Shemrani, S.M.M. (2014). Review of the impact of urban block form on thermal performance, solar access and ventilation. Renewable and Sustainable Energy Reviews, 38,551–560. doi: 10.1016/j.rser.2014.06.007

Shinichi, W., Kazuo, N., Jin, I., &Tetsumi, H. (2014). Evaluation of outdoor thermal comfort in sunlight, building shade, and pergola shade during summer in a humid subtropical region.

Journal of Building and Environment, 82, 556-565. https://doi.org/10.1016/j.buildenv.2014.10.002.

Shishegar, N. (2015). Street design and urban microclimate: analyzing the effects of street geometry and orientation on airflow and solar access in urban canyons. Journal of Clean Energy Technologies, 1(1), 52-56. https://doi.org/10.6084/m9.figshare.1480457.v1

Siret, D. (1996). A generative computer tool to model shadings and openings that achieve sun lighting properties in architectural design. ENVIROSOFT'96, Sep 1996, Como, Italy. p. 695-704. ⟨halshs-02472137⟩.

Siret, D. (Juin 1997). Propositions pour une approche déclarative des ambiances dans le projet architectural et urbain, application a l'ensoleillement. Financement bdi cnrs – [Doctorat en Sciences de l'Ingénieur spécialité Architecture, Université de Nantes].

Spronken-Smith, R.A., & Oke, T.R. (1999).Scale modelling of Nocturnal Cooling in Urban Parks. Boundary-Layer Meteorology, 93, 287–312. https://doi.org/10.1023/A:1002001408973.

Stasinopoulos, T. N. (2018). A survey of solar envelopes properties using solid modelling. In Journal of green building. doi: 10.3992/1943-4618.13.1.3.

Steemers, K., Baker, N., Crowther, D., Nikolopoulou, M., & Clocquet, R. (1996). 'Project ZED: Modelling environmental characteristics of urban forms', solar energy in architecture and urban planning, H. S. Stephens, Bedford, 4- 7.

Strømann-Andersen, J. & Sattrup, P.A. (2011). The urban canyon and building energy use: Urban density versus daylight and passive solar gains. Lancet. 43(8), 2011-2020. 10.1016/j.enbuild.2011.04.007.

Suyoto, W., Indraprastha, A., & Purbo, H. (2015). Parametric approach as a tool for decision-making in planning and design process. Case study: Office tower in Kebayoran Lama. Procedia - Social and Behavioral Sciences. 184. 10.1016/j.sbspro.2015.05.098.

Tahbaz, M. (2011). Psychrometric chart as a basis for outdoor thermal analysis. International Journal of Architectural Engineering and Urban Planning.21, 59-109. Corpus ID: 56268474.

Taleghani, M., Kleerekoper, L., Tenpierik, M., & Dobbelsteen, A. V.D. (2015).Outdoor thermal comfort within five different urban forms in the Netherlands. Building and Environment, 83, 65-78. https://doi.org/10.1016/j.buildenv.2014.03.014

Tapias, E., & Soni, S. (2014). Building-up urban open spaces from shadow range analyses. Thompson, Emine Mine (ed.), Fusion - Proceedings of the 32nd eCAADe Conference - Volume 1, Department of Architecture and Built Environment, Faculty of Engineering and Environment, Newcastle upon Tyne, England, UK, 10-12 September. 129-135.

Taylor Buck, N. (2017). The art of imitating life: The potential contribution of biomimicry in shaping the future of our cities. Environment and Planning B: Urban Analytics and City Science, 44(1), 120–140. https://doi.org/10.1177/0265813515611417.

Topaloglu, B. (2003). Solar Envelope and Form Generation in Architecture. [Master Theisis, The middle east technical university].

Turki Koubaa, L., Raboudi, K., &Ben Saci, A. (2018). Stratégies de prospect du droit solaire par l'immersion. SHS Web Conf. 47(2018). SCAN'18 – 8e Séminaire de Conception Architecturale Numérique.

Twarowski, M. (1967). Soleil et architecture (édition originale : Slonce w architekturze). Paris: Dunod.

Tzu-Ping, L., & Matzarakis, A. (2008). Tourism climate and thermal comfort in Sun Moon Lake, Taiwan. Int J Biometeorol .52, 281–290. DOI 10.1007/s00484-007-0122-7.

Van Esch, M.M.E., Looman, R.H.J., & De Bruin-Hordijk, G.J. (2012) The effects of urban and building design parameters on solar access to the urban canyon and the potential for direct passive solar heating strategies. Energy and Buildings . 47, 189-200. https://doi.org/10.1016/j.enbuild.2011.11.042.

Vartholomaios, A. (2015). The Residential Solar Block envelope: A method for enabling the development of compact urban blocks with high passive solar potential. Energy and Buildings, 99, 302-312. 10.1016/j.enbuild.2015.04.046.

Vergauwen, A., Mira, L. A., Roovers, K., & De Temmerman, N. (2013). Parametric design of adaptive shading elements based on Curved-line Folding. Proceedings of the first conference transformable. In the honor of Emilio Perez Piñero 18th -20th September 2013, School of Architecture Seville, Spain EDITORIAL STARBOOKS. Felix Escrig and Jose Sanchez (eds).

Vermeulen, T. (2014). Optimisation de formes urbaines soumises au rayonnement solaire. [Thèse de doctorat. Spécialité Physique urbaine] .Université de Technologie De Compiègne. https://tel.archives-ouvertes.fr/tel-01095637/document

Walls, W., Parker, N., & Walliss, J. (2015). Designing with thermal comfort indices in outdoor sites. Living and Learning: Research for a Better Built Environment: 49th International Conference of the Architectural Science Association, 1117-1128. http://anzasca.net/wpcontent/uploads/2015/12/107_Walls_Parker_Walliss_ASA2015.pdf.

Wang, Y., & Akbari, H. (2014). Effect of sky view factor on outdoor temperature and comfort in Montreal. Environmental Engineering Science. 31, 272-287. 10.1089/ees.2013.0430.

Ye Kang, K. (2012). The energy impact of urban form: An approach to morphologically evaluating the energy performance of neighborhoods. [Ph D. Dissertation. University of California, Berkeley]. https://escholarship.org/uc/item/6zd36454.

Yezioro, A., & Shaviv, E. (1994). A design tool for analyzing mutual shading between buildings. Solar Energy. 52(1), 27-37. Pergamon Press Ltd., USA.

Yun, K. Y., & Hyoungsub, K. (2015). Agent-based geometry optimization with Genetic Algorithm (GA) for tall apartment's solar right. Solar Energy, 113(2015), 236-250.doi: https://doi.org/10.1016/j.solener.2014.11.007

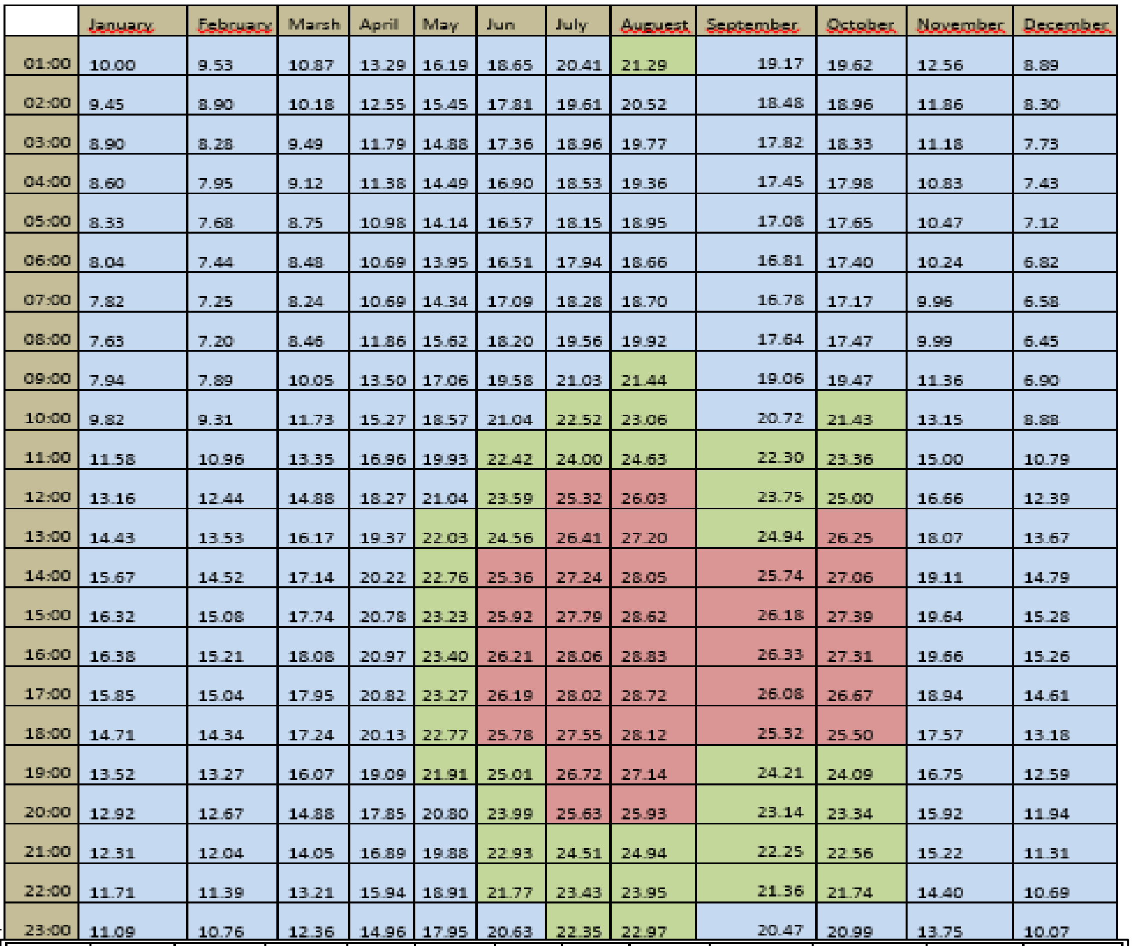
Zare, S., Hasheminejad, N., Bateni, M., Baneshi, M., Shirvan, H., & Hemmatjo, R. (2018). The association between wet-bulb globe temperature and other thermal indices (DI, MDI, PMV, PPD, PHS, PSI and PSI hr): A field study. International Journal of Occupational Safety and Ergonomics. 26, 1-9. DOI:10.1080/10803548.2018.1475957.

APPENDICES

Appendice

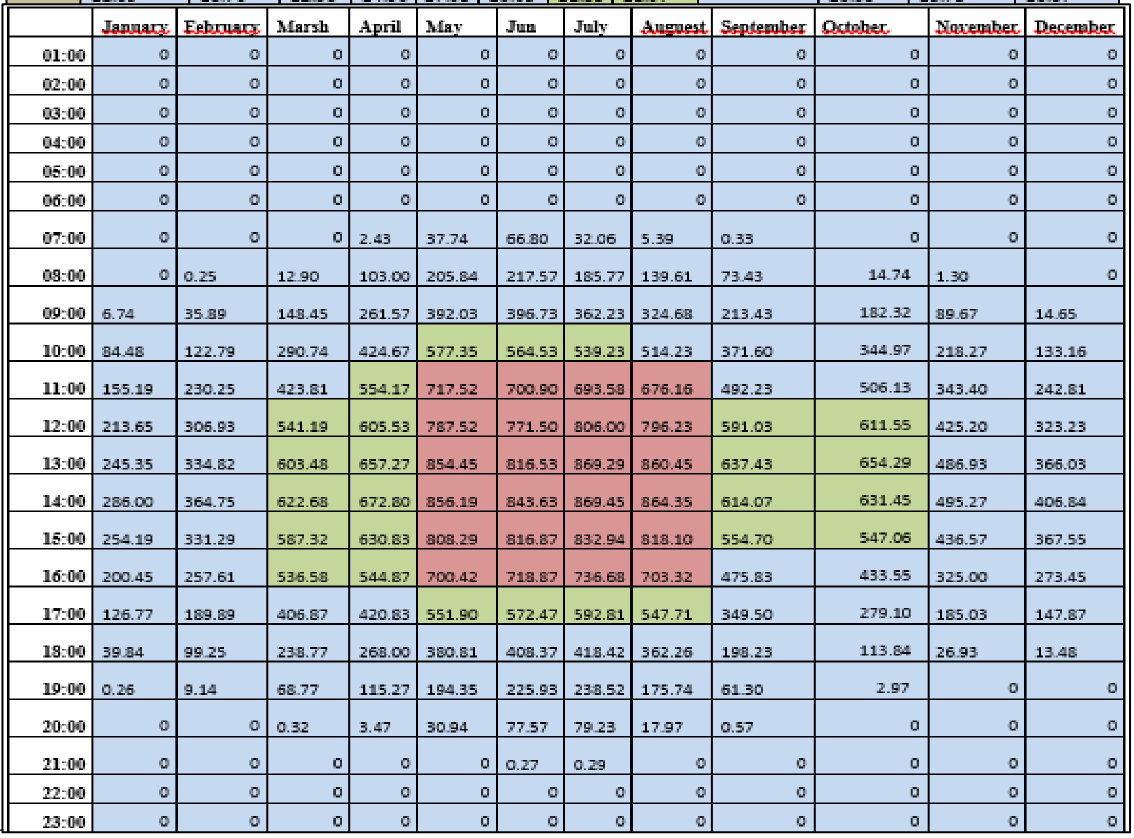
Appendix A (Oran)

Dry bulb temperature values



	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	10.00	9.53	10.87	13.29	16.19	18.65	20.41	21.29	19.17	19.62	12.56	8.89
02:00	9.45	8.90	10.18	12.55	15.45	17.81	19.61	20.52	18.48	18.96	11.86	8.30
03:00	8.90	8.28	9.49	11.79	14.88	17.36	18.96	19.77	17.82	18.33	11.18	7.73
04:00	8.60	7.95	9.12	11.38	14.49	16.90	18.53	19.36	17.45	17.98	10.83	7.43
05:00	8.33	7.68	8.75	10.98	14.14	16.57	18.15	18.95	17.08	17.65	10.47	7.12
06:00	8.04	7.44	8.48	10.69	13.95	16.51	17.94	18.66	16.81	17.40	10.24	6.82
07:00	7.82	7.25	8.24	10.69	14.34	17.09	18.28	18.70	16.78	17.17	9.96	6.58
08:00	7.63	7.20	8.46	11.86	15.62	18.20	19.56	19.92	17.64	17.47	9.99	6.45
09:00	7.94	7.89	10.05	13.50	17.06	19.58	21.03	21.44	19.06	19.47	11.36	6.90
10:00	9.82	9.31	11.73	15.27	18.57	21.04	22.52	23.06	20.72	21.43	13.15	8.88
11:00	11.58	10.96	13.35	16.96	19.93	22.42	24.00	24.63	22.30	23.36	15.00	10.79
12:00	13.16	12.44	14.88	18.27	21.04	23.59	25.32	26.03	23.75	25.00	16.66	12.39
13:00	14.43	13.53	16.17	19.37	22.03	24.56	26.41	27.20	24.94	26.25	18.07	13.67
14:00	15.67	14.52	17.14	20.22	22.76	25.36	27.24	28.05	25.74	27.06	19.11	14.79
15:00	16.32	15.08	17.74	20.78	23.23	25.92	27.79	28.62	26.18	27.39	19.64	15.28
16:00	16.38	15.21	18.08	20.97	23.40	26.21	28.06	28.83	26.33	27.31	19.66	15.26
17:00	15.85	15.04	17.95	20.82	23.27	26.19	28.02	28.72	26.08	26.67	18.94	14.61
18:00	14.71	14.34	17.24	20.13	22.77	25.78	27.55	28.12	25.32	25.50	17.57	13.18
19:00	13.52	13.27	16.07	19.09	21.91	25.01	26.72	27.14	24.21	24.09	16.75	12.59
20:00	12.92	12.67	14.88	17.85	20.80	23.99	25.63	25.93	23.14	23.34	15.92	11.94
21:00	12.31	12.04	14.05	16.89	19.88	22.93	24.51	24.94	22.25	22.56	15.22	11.31
22:00	11.71	11.39	13.21	15.94	18.91	21.77	23.43	23.95	21.36	21.74	14.40	10.69
23:00	11.09	10.76	12.36	14.96	17.95	20.63	22.35	22.97	20.47	20.99	13.75	10.07

Solar radiation values

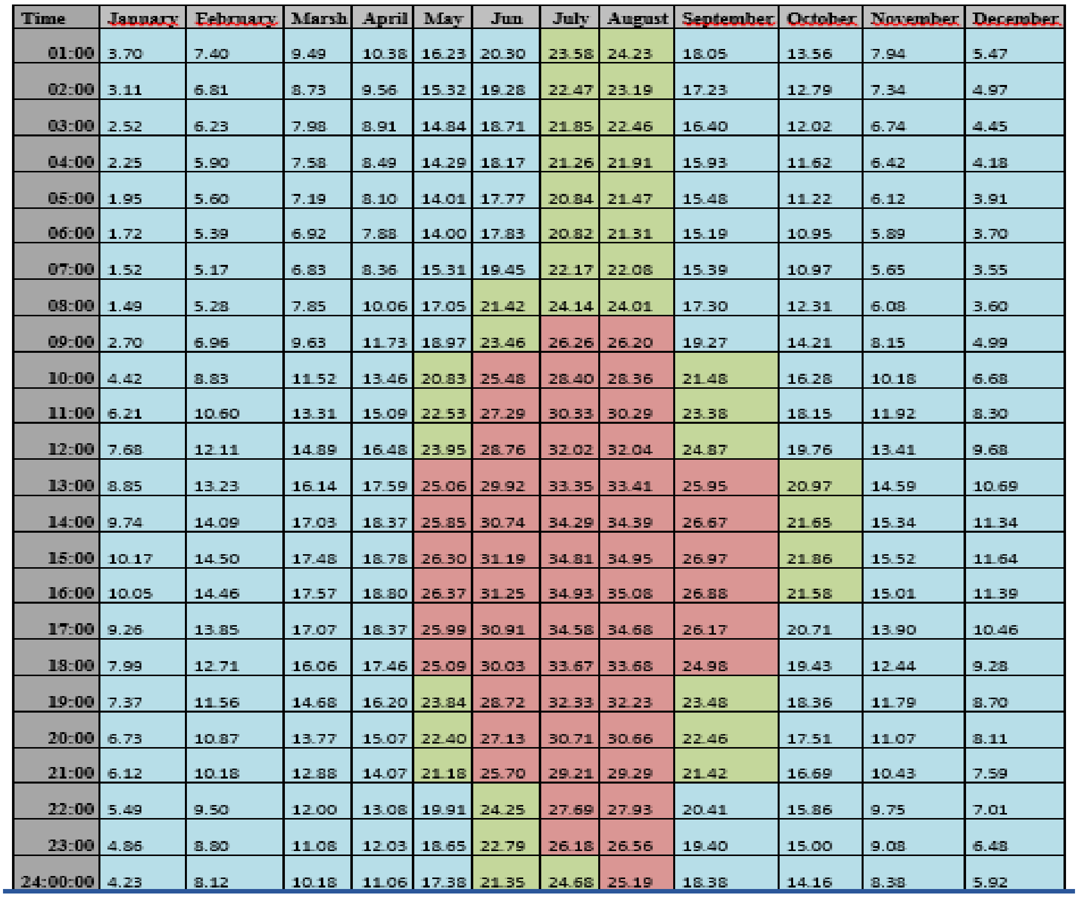


	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0	0	0	0	0	0	0	0
07:00	0	0	0	2.43	37.74	66.80	32.06	5.39	0.33	0	0	0
08:00	0	0.25	12.90	103.00	205.84	217.57	185.77	139.61	73.43	14.74	1.30	0
09:00	6.74	35.89	148.45	261.57	392.03	396.73	362.23	324.68	213.43	182.32	89.67	14.65
10:00	84.48	122.79	290.74	424.67	577.35	564.53	539.23	514.23	371.60	344.97	218.27	133.16
11:00	155.19	230.25	423.81	554.17	717.52	700.90	693.58	676.16	492.23	506.13	343.40	242.81
12:00	213.65	306.93	541.19	605.53	787.52	771.50	806.00	796.23	591.03	611.55	425.20	323.23
13:00	245.35	334.82	603.48	657.27	854.45	816.53	869.29	860.45	637.43	654.29	486.93	366.03
14:00	286.00	364.75	622.68	672.80	856.19	843.63	869.45	864.35	614.07	631.45	495.27	406.84
15:00	254.19	331.29	587.32	630.83	808.29	816.87	832.94	818.10	554.70	547.06	436.57	367.55
16:00	200.45	257.61	536.58	544.87	700.42	718.87	736.68	703.32	475.83	433.55	325.00	273.45
17:00	126.77	189.89	406.87	420.83	551.90	572.47	592.81	547.71	349.50	279.10	185.03	147.87
18:00	39.84	99.25	238.77	268.00	380.81	408.37	418.42	362.26	198.23	113.84	26.93	13.48
19:00	0.26	9.14	68.77	115.27	194.35	225.93	238.52	175.74	61.30	2.97	0	0
20:00	0	0	0.32	3.47	30.94	77.57	79.23	17.97	0.57	0	0	0
21:00	0	0	0	0	0	0.27	0.29	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendice

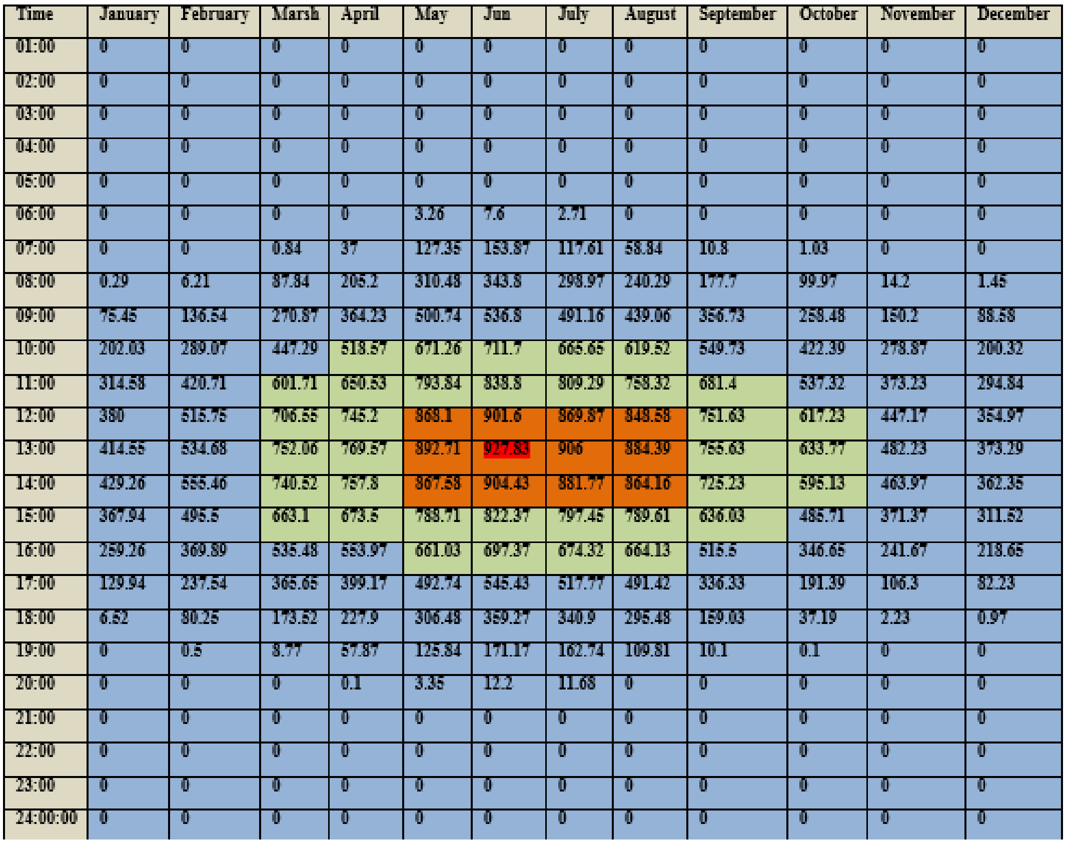
Appendix B (Constantine)

Dry bulb temperature values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
01:00	3.70	7.40	9.49	10.38	16.23	20.30	23.58	24.23	18.05	13.56	7.94	5.47
02:00	3.11	6.81	8.73	9.56	15.32	19.28	22.47	23.19	17.23	12.79	7.34	4.97
03:00	2.52	6.23	7.98	8.91	14.84	18.71	21.85	22.46	16.40	12.02	6.74	4.45
04:00	2.25	5.90	7.58	8.49	14.29	18.17	21.26	21.91	15.93	11.62	6.42	4.18
05:00	1.95	5.60	7.19	8.10	14.01	17.77	20.84	21.47	15.48	11.22	6.12	3.91
06:00	1.72	5.39	6.92	7.88	14.00	17.83	20.82	21.31	15.19	10.95	5.89	3.70
07:00	1.52	5.17	6.83	8.36	15.31	19.45	22.17	22.08	15.39	10.97	5.65	3.55
08:00	1.49	5.28	7.85	10.06	17.05	21.42	24.14	24.01	17.30	12.31	6.08	3.60
09:00	2.70	6.96	9.63	11.73	18.97	23.46	26.26	26.20	19.27	14.21	8.15	4.99
10:00	4.42	8.83	11.52	13.46	20.83	25.48	28.40	28.36	21.48	16.28	10.18	6.68
11:00	6.21	10.60	13.31	15.09	22.53	27.29	30.33	30.29	23.38	18.15	11.92	8.30
12:00	7.68	12.11	14.89	16.48	23.95	28.76	32.02	32.04	24.87	19.76	13.41	9.68
13:00	8.85	13.23	16.14	17.59	25.06	29.92	33.35	33.41	25.95	20.97	14.59	10.69
14:00	9.74	14.09	17.03	18.37	25.85	30.74	34.29	34.39	26.67	21.65	15.34	11.34
15:00	10.17	14.50	17.48	18.78	26.30	31.19	34.81	34.95	26.97	21.86	15.52	11.64
16:00	10.05	14.46	17.57	18.80	26.37	31.25	34.93	35.08	26.88	21.58	15.01	11.39
17:00	9.26	13.85	17.07	18.37	25.99	30.91	34.58	34.68	26.17	20.71	13.90	10.46
18:00	7.99	12.71	16.06	17.46	25.09	30.03	33.67	33.68	24.98	19.43	12.44	9.28
19:00	7.37	11.56	14.68	16.20	23.84	28.72	32.33	32.23	23.48	18.36	11.79	8.70
20:00	6.73	10.87	13.77	15.07	22.40	27.13	30.71	30.66	22.46	17.51	11.07	8.11
21:00	6.12	10.18	12.88	14.07	21.18	25.70	29.21	29.29	21.42	16.69	10.43	7.59
22:00	5.49	9.50	12.00	13.08	19.91	24.25	27.69	27.93	20.41	15.86	9.75	7.01
23:00	4.86	8.80	11.08	12.03	18.65	22.79	26.18	26.56	19.40	15.00	9.08	6.48
24:00:00	4.23	8.12	10.18	11.06	17.38	21.35	24.68	25.19	18.38	14.16	8.38	5.92

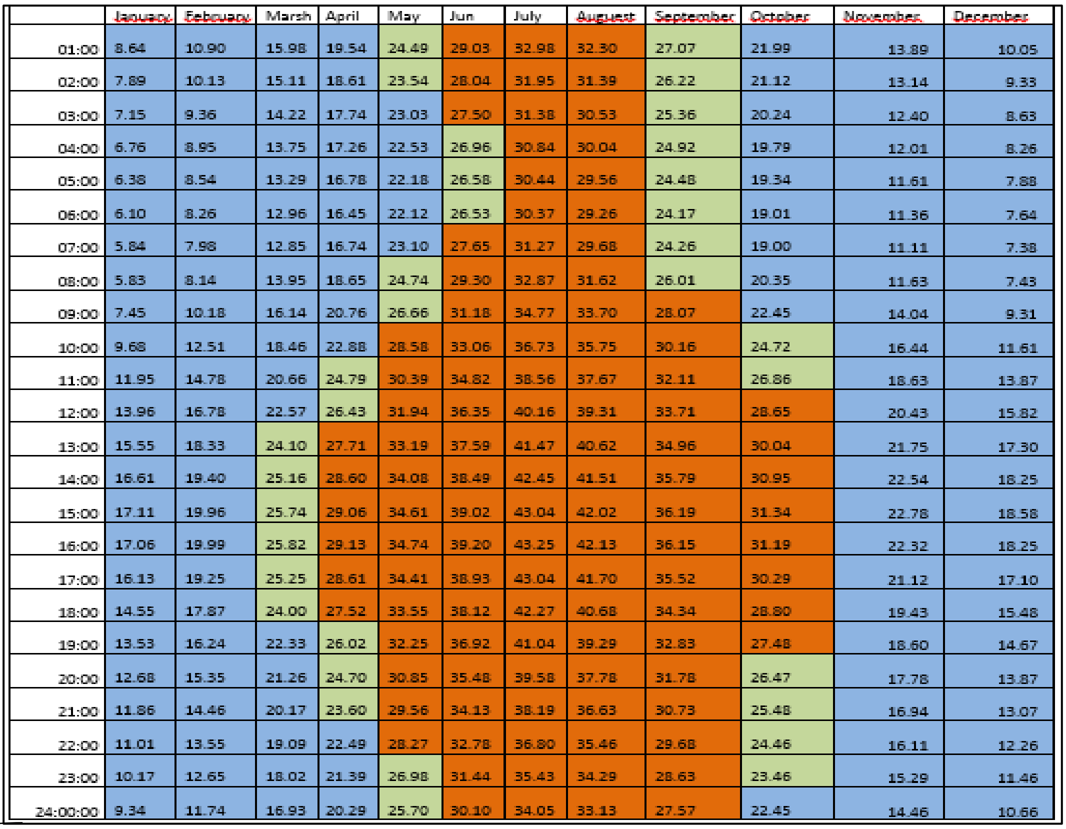
Solar radiation values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	3.26	7.6	2.71	0	0	0	0	0
07:00	0	0	0.84	37	127.35	153.87	117.61	58.84	10.8	1.03	0	0
08:00	0.29	6.21	87.84	205.2	310.48	343.8	298.97	240.29	177.7	99.97	14.2	1.45
09:00	75.45	136.54	270.87	364.23	500.74	536.8	491.16	439.06	356.73	258.48	150.2	88.58
10:00	202.03	289.07	447.29	518.57	671.26	711.7	665.65	619.52	549.73	422.39	278.87	200.32
11:00	314.58	420.71	601.71	650.53	793.84	838.8	809.29	758.32	681.4	537.32	373.23	294.84
12:00	380	515.75	706.55	745.2	868.1	901.6	869.87	848.58	751.63	617.23	447.17	354.97
13:00	414.55	534.68	752.06	769.57	892.71	927.83	906	884.39	755.63	633.77	482.23	373.29
14:00	429.26	555.46	740.52	757.8	867.58	904.43	881.77	864.16	725.23	595.13	463.97	362.35
15:00	367.94	495.5	663.1	673.5	788.71	822.37	797.45	789.61	636.03	485.71	371.37	311.52
16:00	259.26	369.89	535.48	553.97	661.03	697.37	674.32	664.13	515.5	346.65	241.67	218.65
17:00	129.94	237.54	365.65	399.17	492.74	545.43	517.77	491.42	336.33	191.39	106.3	82.23
18:00	6.52	80.25	173.52	227.9	306.48	359.27	340.9	295.48	159.03	37.19	2.23	0.97
19:00	0	0.5	8.77	57.87	125.84	171.17	162.74	109.81	10.1	0.1	0	0
20:00	0	0	0	0.1	3.35	12.2	11.68	0	0	0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00:00	0	0	0	0	0	0	0	0	0	0	0	0

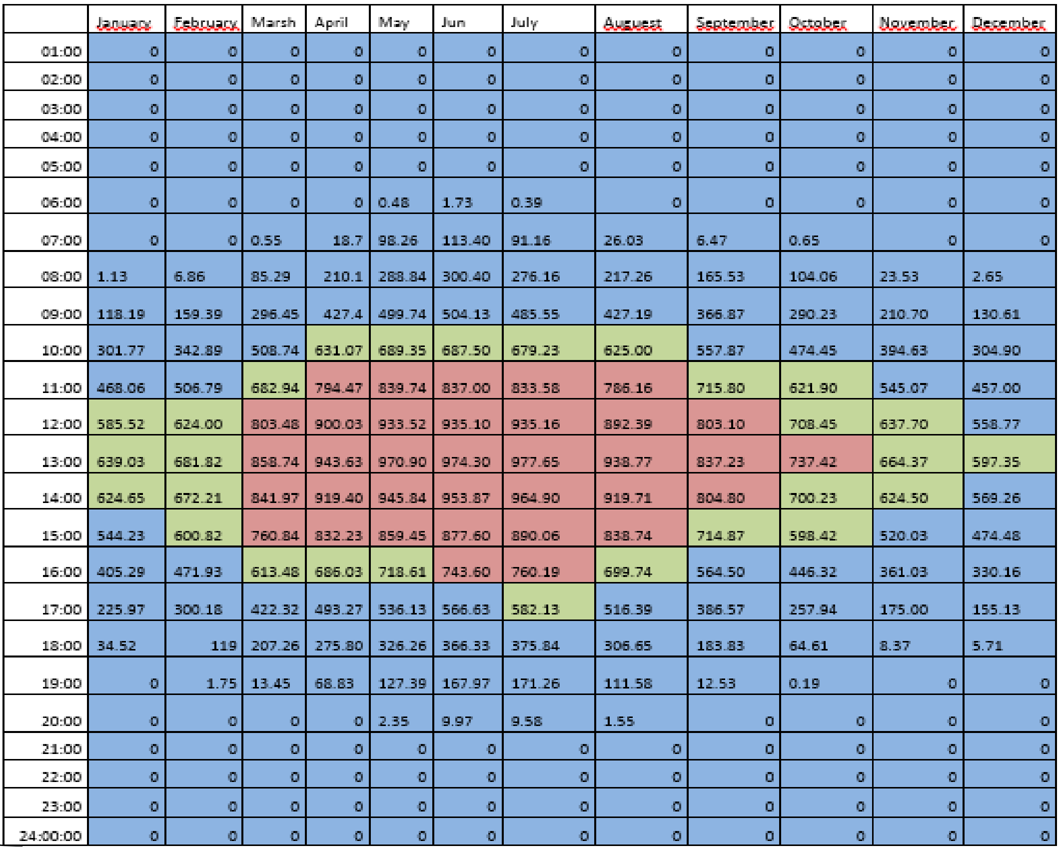
Appendix C (Ouargla)

Dry bulb temperature values



	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	8.64	10.90	15.98	19.54	24.49	29.03	32.98	32.30	27.07	21.99	13.89	10.05
02:00	7.89	10.13	15.11	18.61	23.54	28.04	31.95	31.39	26.22	21.12	13.14	9.33
03:00	7.15	9.36	14.22	17.74	23.03	27.50	31.38	30.53	25.36	20.24	12.40	8.63
04:00	6.76	8.95	13.75	17.26	22.53	26.96	30.84	30.04	24.92	19.79	12.01	8.26
05:00	6.38	8.54	13.29	16.78	22.18	26.58	30.44	29.56	24.48	19.34	11.61	7.88
06:00	6.10	8.26	12.96	16.45	22.12	26.53	30.37	29.26	24.17	19.01	11.36	7.64
07:00	5.84	7.98	12.85	16.74	23.10	27.65	31.27	29.68	24.26	19.00	11.11	7.38
08:00	5.83	8.14	13.95	18.65	24.74	29.30	32.87	31.62	26.01	20.35	11.63	7.43
09:00	7.45	10.18	16.14	20.76	26.66	31.18	34.77	33.70	28.07	22.45	14.04	9.31
10:00	9.68	12.51	18.46	22.88	28.58	33.06	36.73	35.75	30.16	24.72	16.44	11.61
11:00	11.95	14.78	20.66	24.79	30.39	34.82	38.56	37.67	32.11	26.86	18.63	13.87
12:00	13.96	16.78	22.57	26.43	31.94	36.35	40.16	39.31	33.71	28.65	20.43	15.82
13:00	15.55	18.33	24.10	27.71	33.19	37.59	41.47	40.62	34.96	30.04	21.75	17.30
14:00	16.61	19.40	25.16	28.60	34.08	38.49	42.45	41.51	35.79	30.95	22.54	18.25
15:00	17.11	19.96	25.74	29.06	34.61	39.02	43.04	42.02	36.19	31.34	22.78	18.58
16:00	17.06	19.99	25.82	29.13	34.74	39.20	43.25	42.13	36.15	31.19	22.32	18.25
17:00	16.13	19.25	25.25	28.61	34.41	38.93	43.04	41.70	35.52	30.29	21.12	17.10
18:00	14.55	17.87	24.00	27.52	33.55	38.12	42.27	40.68	34.34	28.80	19.43	15.48
19:00	13.53	16.24	22.33	26.02	32.25	36.92	41.04	39.29	32.83	27.48	18.60	14.67
20:00	12.68	15.35	21.26	24.70	30.85	35.48	39.58	37.78	31.78	26.47	17.78	13.87
21:00	11.86	14.46	20.17	23.60	29.56	34.13	38.19	36.63	30.73	25.48	16.94	13.07
22:00	11.01	13.55	19.09	22.49	28.27	32.78	36.80	35.46	29.68	24.46	16.11	12.26
23:00	10.17	12.65	18.02	21.39	26.98	31.44	35.43	34.29	28.63	23.46	15.29	11.46
24:00:00	9.34	11.74	16.93	20.29	25.70	30.10	34.05	33.13	27.57	22.45	14.46	10.66

Solar radiation values

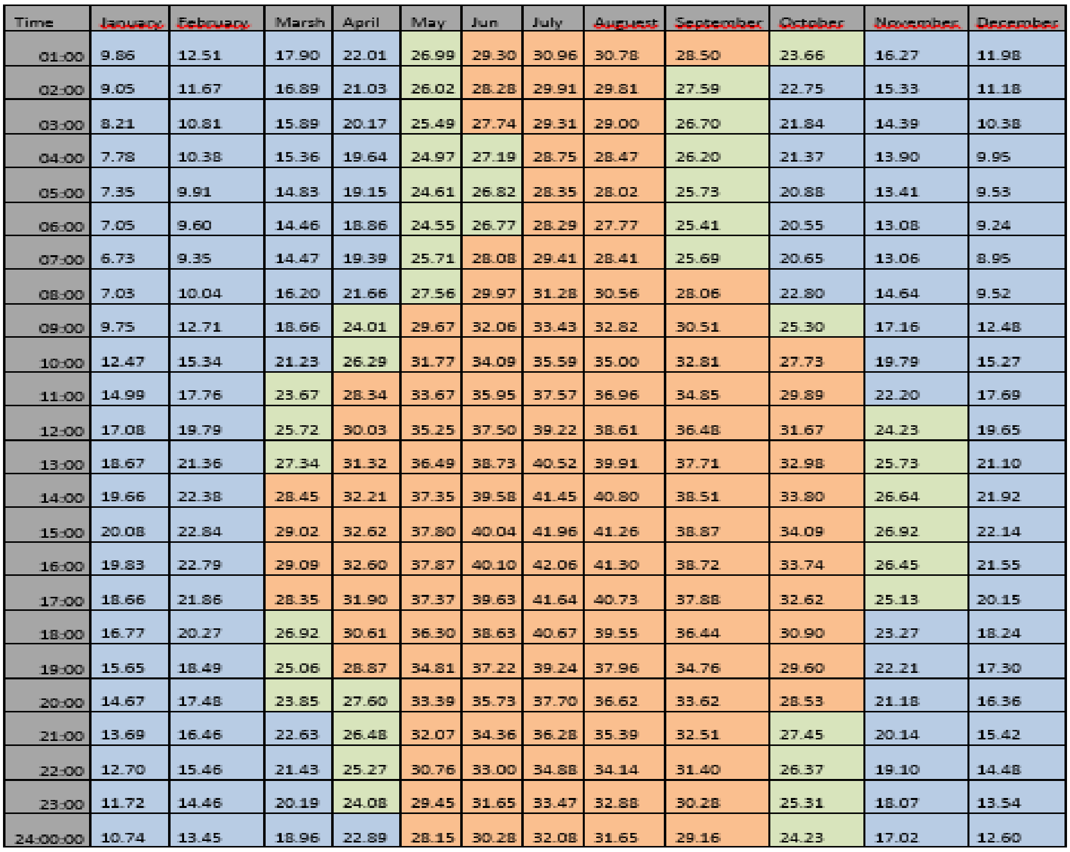


	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0.48	1.73	0.39	0	0	0	0	0
07:00	0	0	0.55	18.7	98.26	113.40	91.16	26.03	6.47	0.65	0	0
08:00	1.13	6.86	85.29	210.1	288.84	300.40	276.16	217.26	165.53	104.06	23.53	2.65
09:00	118.19	159.39	296.45	427.4	499.74	504.13	485.55	427.19	366.87	290.23	210.70	130.61
10:00	301.77	342.89	508.74	631.07	689.35	687.50	679.23	625.00	557.87	474.45	394.63	304.90
11:00	468.06	506.79	682.94	794.47	839.74	837.00	833.58	786.16	715.80	621.90	545.07	457.00
12:00	585.52	624.00	803.48	900.03	933.52	935.10	935.16	892.39	803.10	708.45	637.70	558.77
13:00	639.03	681.82	858.74	943.63	970.90	974.30	977.65	938.77	837.23	737.42	664.37	597.35
14:00	624.65	672.21	841.97	919.40	945.84	953.87	964.90	919.71	804.80	700.23	624.50	569.26
15:00	544.23	600.82	760.84	832.23	859.45	877.60	890.06	838.74	714.87	598.42	520.03	474.48
16:00	405.29	471.93	613.48	686.03	718.61	743.60	760.19	699.74	564.50	446.32	361.03	330.16
17:00	225.97	300.18	422.32	493.27	536.13	566.63	582.13	516.39	386.57	257.94	175.00	155.13
18:00	34.52	119	207.26	275.80	326.26	366.33	375.84	306.65	183.83	64.61	8.37	5.71
19:00	0	1.75	13.45	68.83	127.39	167.97	171.26	111.58	12.53	0.19	0	0
20:00	0	0	0	0	2.35	9.97	9.58	1.55	0	0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendice

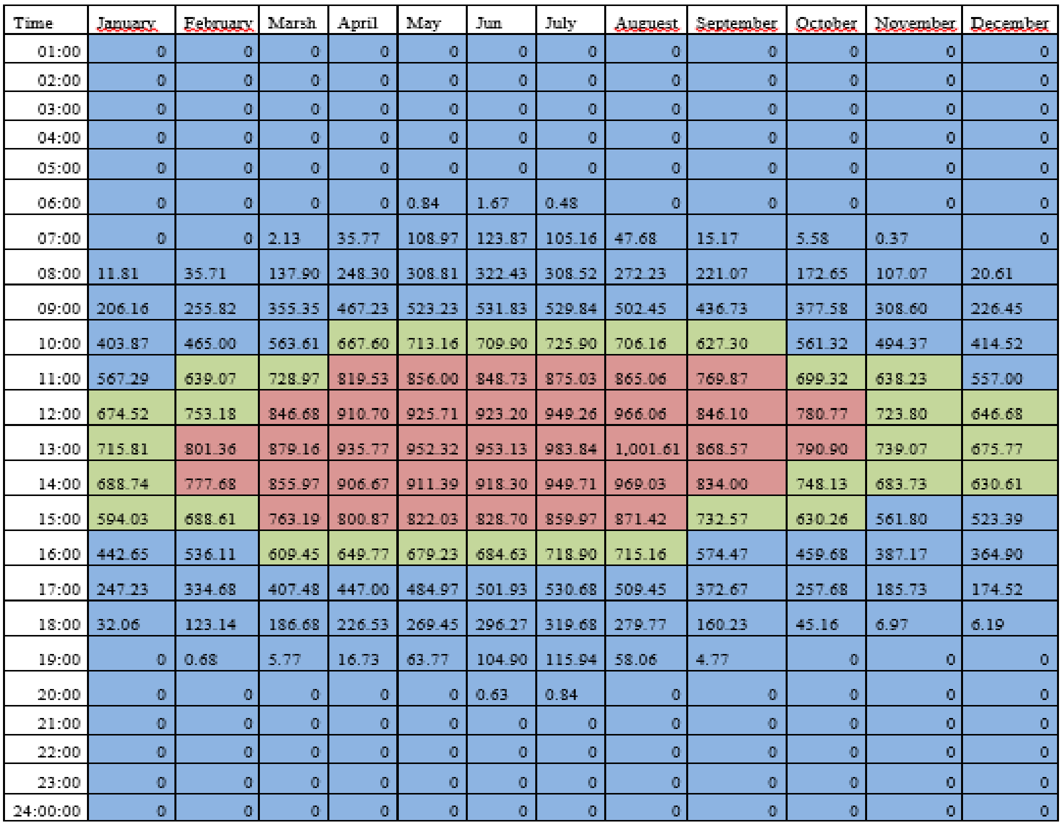
Appendix D(ILLIZI)

Dry bulb temperature values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
01:00	9.86	12.51	17.90	22.01	26.99	29.30	30.96	30.78	28.50	23.66	16.27	11.98
02:00	9.05	11.67	16.89	21.03	26.02	28.28	29.91	29.81	27.59	22.75	15.33	11.18
03:00	8.21	10.81	15.89	20.17	25.49	27.74	29.31	29.00	26.70	21.84	14.39	10.38
04:00	7.78	10.38	15.36	19.64	24.97	27.19	28.75	28.47	26.20	21.37	13.90	9.95
05:00	7.35	9.91	14.83	19.15	24.61	26.82	28.35	28.02	25.73	20.88	13.41	9.53
06:00	7.05	9.60	14.46	18.86	24.55	26.77	28.29	27.77	25.41	20.55	13.08	9.24
07:00	6.73	9.35	14.47	19.39	25.71	28.08	29.41	28.41	25.69	20.65	13.06	8.95
08:00	7.03	10.04	16.20	21.66	27.56	29.97	31.28	30.56	28.06	22.80	14.64	9.52
09:00	9.75	12.71	18.66	24.01	29.67	32.06	33.43	32.82	30.51	25.30	17.16	12.48
10:00	12.47	15.34	21.23	26.29	31.77	34.09	35.59	35.00	32.81	27.73	19.79	15.27
11:00	14.99	17.76	23.67	28.34	33.67	35.95	37.57	36.96	34.85	29.89	22.20	17.69
12:00	17.08	19.79	25.72	30.03	35.25	37.50	39.22	38.61	36.48	31.67	24.23	19.65
13:00	18.67	21.36	27.34	31.32	36.49	38.73	40.52	39.91	37.71	32.98	25.73	21.10
14:00	19.66	22.38	28.45	32.21	37.35	39.58	41.45	40.80	38.51	33.80	26.64	21.92
15:00	20.08	22.84	29.02	32.62	37.80	40.04	41.96	41.26	38.87	34.09	26.92	22.14
16:00	19.83	22.79	29.09	32.60	37.87	40.10	42.06	41.30	38.72	33.74	26.45	21.55
17:00	18.66	21.86	28.35	31.90	37.37	39.63	41.64	40.73	37.88	32.62	25.13	20.15
18:00	16.77	20.27	26.92	30.61	36.30	38.63	40.67	39.55	36.44	30.90	23.27	18.24
19:00	15.65	18.49	25.06	28.87	34.81	37.22	39.24	37.96	34.76	29.60	22.21	17.30
20:00	14.67	17.48	23.85	27.60	33.39	35.73	37.70	36.62	33.62	28.53	21.18	16.36
21:00	13.69	16.46	22.63	26.48	32.07	34.36	36.28	35.39	32.51	27.45	20.14	15.42
22:00	12.70	15.46	21.43	25.27	30.76	33.00	34.88	34.14	31.40	26.37	19.10	14.48
23:00	11.72	14.46	20.19	24.08	29.45	31.65	33.47	32.88	30.28	25.31	18.07	13.54
24:00:00	10.74	13.45	18.96	22.89	28.15	30.28	32.08	31.65	29.16	24.23	17.02	12.60

Solar radiation values

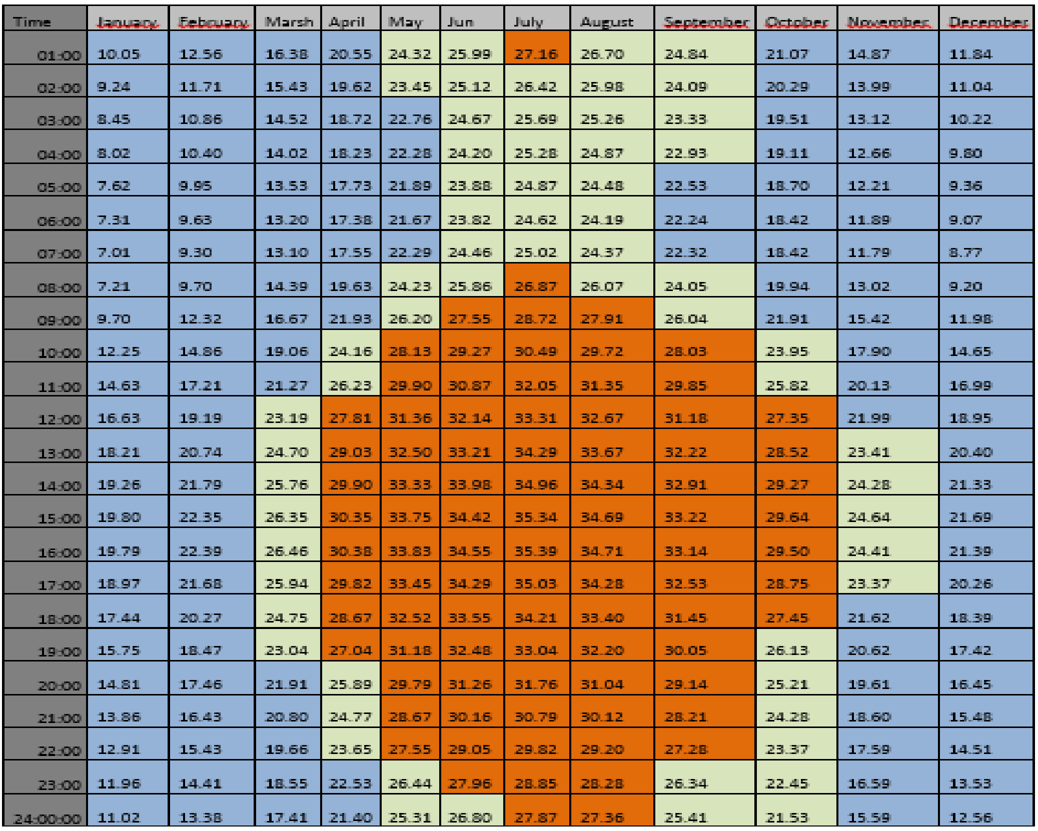


Time	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0.84	1.67	0.48	0	0	0	0	0
07:00	0	0	2.13	35.77	108.97	123.87	105.16	47.68	15.17	5.58	0.37	0
08:00	11.81	35.71	137.90	248.30	308.81	322.43	308.52	272.23	221.07	172.65	107.07	20.61
09:00	206.16	255.82	355.35	467.23	523.23	531.83	529.84	502.45	436.73	377.58	308.60	226.45
10:00	403.87	465.00	563.61	667.60	713.16	709.90	725.90	706.16	627.30	561.32	494.37	414.52
11:00	567.29	639.07	728.97	819.53	856.00	848.73	875.03	865.06	769.87	699.32	638.23	557.00
12:00	674.52	753.18	846.68	910.70	925.71	923.20	949.26	966.06	846.10	780.77	723.80	646.68
13:00	715.81	801.36	879.16	935.77	952.32	953.13	983.84	1,001.61	868.57	790.90	739.07	675.77
14:00	688.74	777.68	855.97	906.67	911.39	918.30	949.71	969.03	834.00	748.13	683.73	630.61
15:00	594.03	688.61	763.19	800.87	822.03	828.70	859.97	871.42	732.57	630.26	561.80	523.39
16:00	442.65	536.11	609.45	649.77	679.23	684.63	718.90	715.16	574.47	459.68	387.17	364.90
17:00	247.23	334.68	407.48	447.00	484.97	501.93	530.68	509.45	372.67	257.68	185.73	174.52
18:00	32.06	123.14	186.68	226.53	269.45	296.27	319.68	279.77	160.23	45.16	6.97	6.19
19:00	0	0.68	5.77	16.73	63.77	104.90	115.94	58.06	4.77	0	0	0
20:00	0	0	0	0	0	0.63	0.84	0	0	0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendice

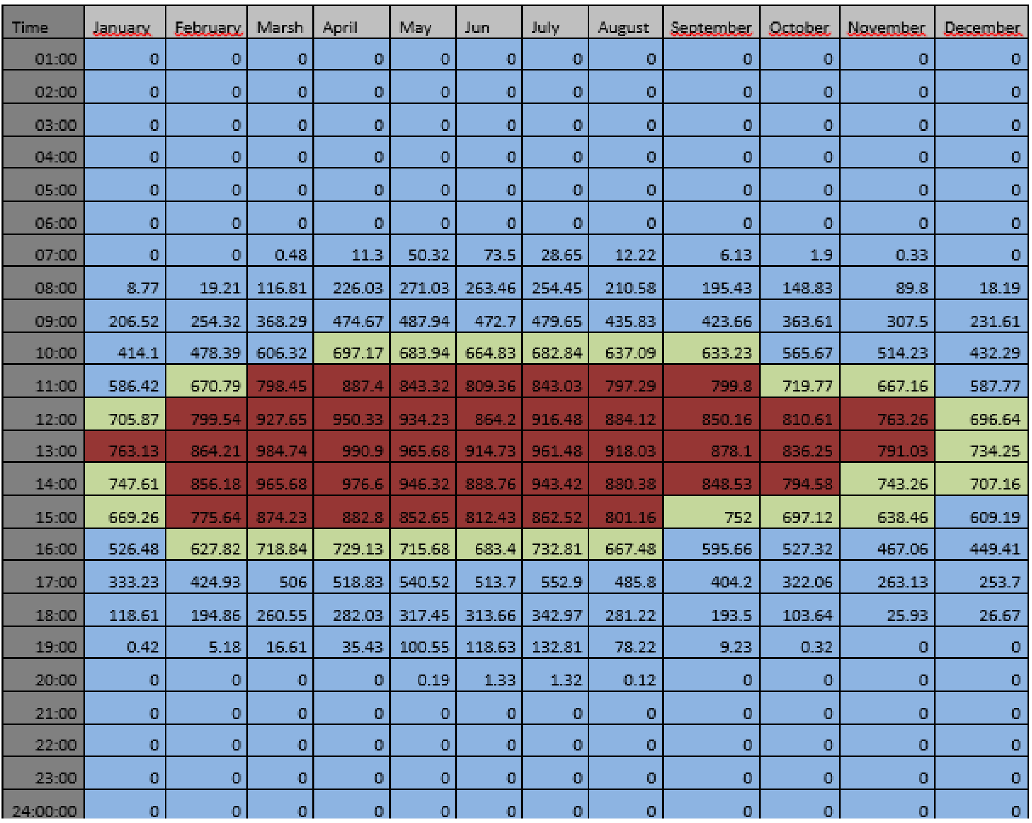
Appendix E (Tamanrasset)

Dry bulb temperature values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
01:00	10.05	12.56	16.38	20.55	24.32	25.99	27.16	26.70	24.84	21.07	14.87	11.84
02:00	9.24	11.71	15.43	19.62	23.45	25.12	26.42	25.98	24.09	20.29	13.99	11.04
03:00	8.45	10.86	14.52	18.72	22.76	24.67	25.69	25.26	23.33	19.51	13.12	10.22
04:00	8.02	10.40	14.02	18.23	22.28	24.20	25.28	24.87	22.93	19.11	12.66	9.80
05:00	7.62	9.95	13.53	17.73	21.89	23.88	24.87	24.48	22.53	18.70	12.21	9.36
06:00	7.31	9.63	13.20	17.38	21.67	23.82	24.62	24.19	22.24	18.42	11.89	9.07
07:00	7.01	9.30	13.10	17.55	22.29	24.46	25.02	24.37	22.32	18.42	11.79	8.77
08:00	7.21	9.70	14.39	19.63	24.23	25.86	26.87	26.07	24.05	19.94	13.02	9.20
09:00	9.70	12.32	16.67	21.93	26.20	27.55	28.72	27.91	26.04	21.91	15.42	11.98
10:00	12.25	14.86	19.06	24.16	28.13	29.27	30.49	29.72	28.03	23.95	17.90	14.65
11:00	14.63	17.21	21.27	26.23	29.90	30.87	32.05	31.35	29.85	25.82	20.13	16.99
12:00	16.63	19.19	23.19	27.81	31.36	32.14	33.31	32.67	31.18	27.35	21.99	18.95
13:00	18.21	20.74	24.70	29.03	32.50	33.21	34.29	33.67	32.22	28.52	23.41	20.40
14:00	19.26	21.79	25.76	29.90	33.33	33.98	34.96	34.34	32.91	29.27	24.28	21.33
15:00	19.80	22.35	26.35	30.35	33.75	34.42	35.34	34.69	33.22	29.64	24.64	21.69
16:00	19.79	22.39	26.46	30.38	33.83	34.55	35.39	34.71	33.14	29.50	24.41	21.39
17:00	18.97	21.68	25.94	29.82	33.45	34.29	35.03	34.28	32.53	28.75	23.37	20.26
18:00	17.44	20.27	24.75	28.67	32.52	33.55	34.21	33.40	31.45	27.45	21.62	18.39
19:00	15.75	18.47	23.04	27.04	31.18	32.48	33.04	32.20	30.05	26.13	20.62	17.42
20:00	14.81	17.46	21.91	25.89	29.79	31.26	31.76	31.04	29.14	25.21	19.61	16.45
21:00	13.86	16.43	20.80	24.77	28.67	30.16	30.79	30.12	28.21	24.28	18.60	15.48
22:00	12.91	15.43	19.66	23.65	27.55	29.05	29.82	29.20	27.28	23.37	17.59	14.51
23:00	11.96	14.41	18.55	22.53	26.44	27.96	28.85	28.28	26.34	22.45	16.59	13.53
24:00:00	11.02	13.38	17.41	21.40	25.31	26.80	27.87	27.36	25.41	21.53	15.59	12.56

Solar radiation values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
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02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0	0	0	0	0	0	0	0
07:00	0	0	0.48	11.3	50.32	73.5	28.65	12.22	6.13	1.9	0.33	0
08:00	8.77	19.21	116.81	226.03	271.03	263.46	254.45	210.58	195.43	148.83	89.8	18.19
09:00	206.52	254.32	368.29	474.67	487.94	472.7	479.65	435.83	423.66	363.61	307.5	231.61
10:00	414.1	478.39	606.32	697.17	683.94	664.83	682.84	637.09	633.23	565.67	514.23	432.29
11:00	586.42	670.79	798.45	887.4	843.32	809.36	843.03	797.29	799.8	719.77	667.16	587.77
12:00	705.87	799.54	927.65	950.33	934.23	864.2	916.48	884.12	850.16	810.61	763.26	696.64
13:00	763.13	864.21	984.74	990.9	965.68	914.73	961.48	918.03	878.1	836.25	791.03	734.25
14:00	747.61	856.18	965.68	976.6	946.32	888.76	943.42	880.38	848.53	794.58	743.26	707.16
15:00	669.26	775.64	874.23	882.8	852.65	812.43	862.52	801.16	752	697.12	638.46	609.19
16:00	526.48	627.82	718.84	729.13	715.68	683.4	732.81	667.48	595.66	527.32	467.06	449.41
17:00	333.23	424.93	506	518.83	540.52	513.7	552.9	485.8	404.2	322.06	263.13	253.7
18:00	118.61	194.86	260.55	282.03	317.45	313.66	342.97	281.22	193.5	103.64	25.93	26.67
19:00	0.42	5.18	16.61	35.43	100.55	118.63	132.81	78.22	9.23	0.32	0	0
20:00	0	0	0	0	0.19	1.33	1.32	0.12	0	0	0	0
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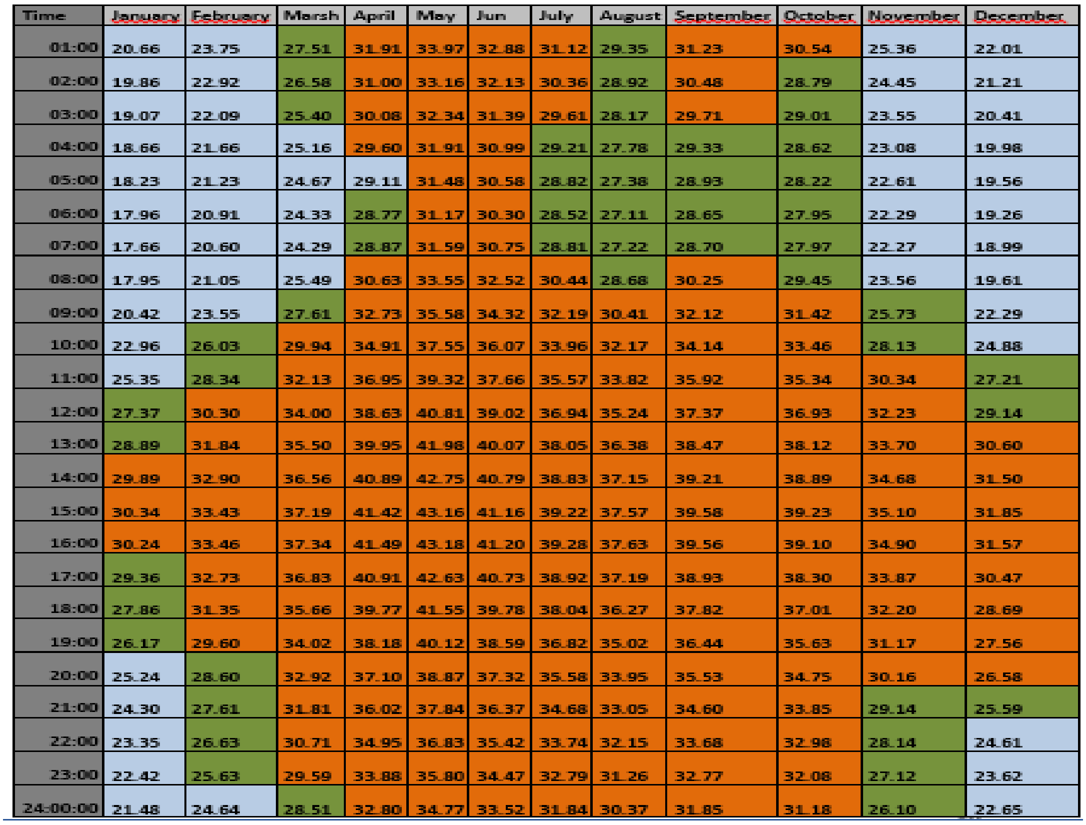
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendice

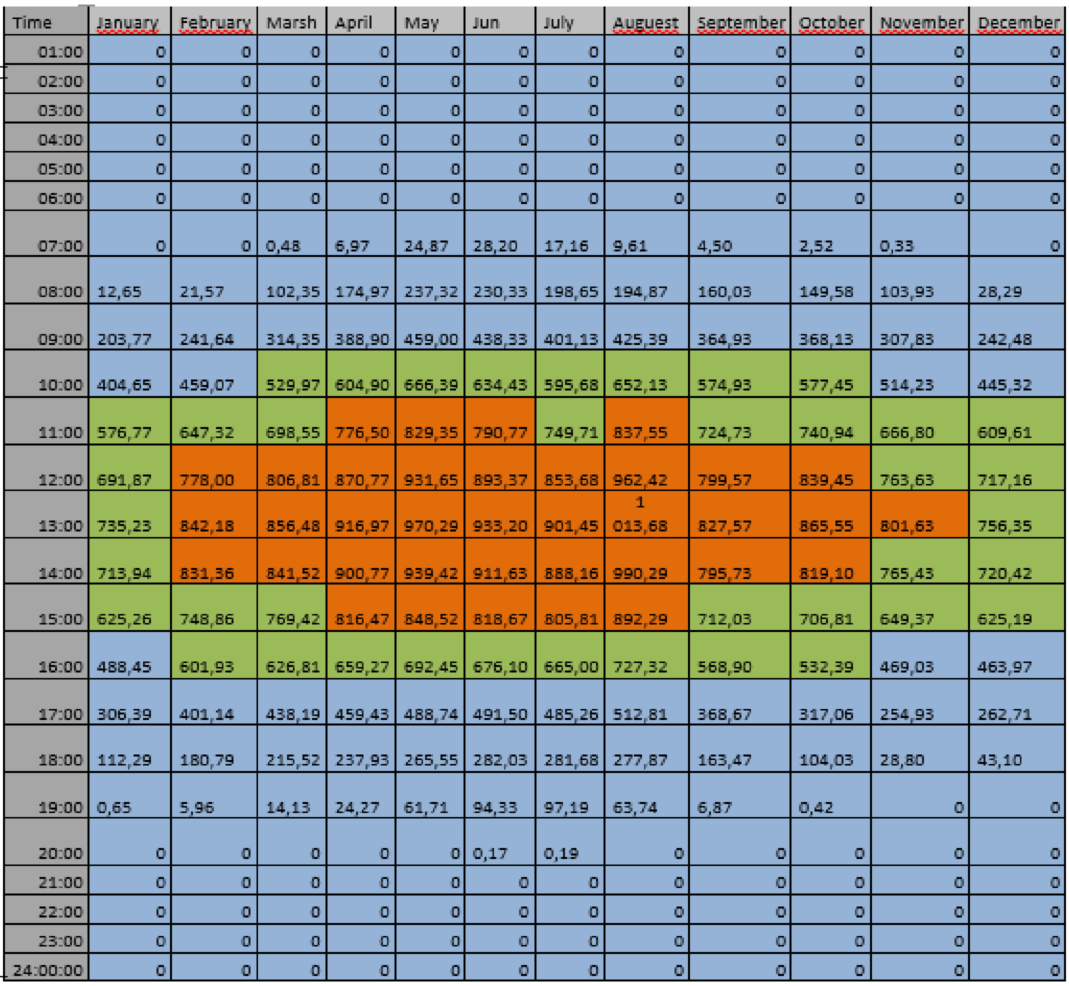
Appendix F (Ain Guezzam)

Dry bulb temperature values



Time	January	February	Marsh	April	May	Jun	July	August	September	October	November	December
01:00	20.66	23.75	27.51	31.91	33.97	32.88	31.12	29.35	31.23	30.54	25.36	22.01
02:00	19.86	22.92	26.58	31.00	33.16	32.13	30.36	28.92	30.48	28.79	24.45	21.21
03:00	19.07	22.09	25.40	30.08	32.34	31.39	29.61	28.17	29.71	29.01	23.55	20.41
04:00	18.66	21.66	25.16	29.60	31.91	30.99	29.21	27.78	29.33	28.62	23.08	19.98
05:00	18.23	21.23	24.67	29.11	31.48	30.58	28.82	27.38	28.93	28.22	22.61	19.56
06:00	17.96	20.91	24.33	28.77	31.17	30.30	28.52	27.11	28.65	27.95	22.29	19.26
07:00	17.66	20.60	24.29	28.87	31.59	30.75	28.81	27.22	28.70	27.97	22.27	18.99
08:00	17.95	21.05	25.49	30.63	33.55	32.52	30.44	28.68	30.25	29.45	23.56	19.61
09:00	20.42	23.55	27.61	32.73	35.58	34.32	32.19	30.41	32.12	31.42	25.73	22.29
10:00	22.96	26.03	29.94	34.91	37.55	36.07	33.96	32.17	34.14	33.46	28.13	24.88
11:00	25.35	28.34	32.13	36.95	39.32	37.66	35.57	33.82	35.92	35.34	30.34	27.21
12:00	27.37	30.30	34.00	38.63	40.81	39.02	36.94	35.24	37.37	36.93	32.23	29.14
13:00	28.89	31.84	35.50	39.95	41.98	40.07	38.05	36.38	38.47	38.12	33.70	30.60
14:00	29.89	32.90	36.56	40.89	42.75	40.79	38.83	37.15	39.21	38.89	34.68	31.50
15:00	30.34	33.43	37.19	41.42	43.16	41.16	39.22	37.57	39.58	39.23	35.10	31.85
16:00	30.24	33.46	37.34	41.49	43.18	41.20	39.28	37.63	39.56	39.10	34.90	31.57
17:00	29.36	32.73	36.83	40.91	42.63	40.73	38.92	37.19	38.93	38.30	33.87	30.47
18:00	27.86	31.35	35.66	39.77	41.55	39.78	38.04	36.27	37.82	37.01	32.20	28.69
19:00	26.17	29.60	34.02	38.18	40.12	38.59	36.82	35.02	36.44	35.63	31.17	27.56
20:00	25.24	28.60	32.92	37.10	38.87	37.32	35.58	33.95	35.53	34.75	30.16	26.58
21:00	24.30	27.61	31.81	36.02	37.84	36.37	34.68	33.05	34.60	33.85	29.14	25.59
22:00	23.35	26.63	30.71	34.95	36.83	35.42	33.74	32.15	33.68	32.98	28.14	24.61
23:00	22.42	25.63	29.59	33.88	35.80	34.47	32.79	31.26	32.77	32.08	27.12	23.62
24:00:00	21.48	24.64	28.51	32.80	34.77	33.52	31.84	30.37	31.85	31.18	26.10	22.65

Solar radiation values



Time	January	February	Marsh	April	May	Jun	July	Auguest	September	October	November	December
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0	0	0	0	0	0	0	0
07:00	0	0	0,48	6,97	24,87	28,20	17,16	9,61	4,50	2,52	0,33	0
08:00	12,65	21,57	102,35	174,97	237,32	230,33	198,65	194,87	160,03	149,58	103,93	28,29
09:00	203,77	241,64	314,35	388,90	459,00	438,33	401,13	425,39	364,93	368,13	307,83	242,48
10:00	404,65	459,07	529,97	604,90	666,39	634,43	595,68	652,13	574,93	577,45	514,23	445,32
11:00	576,77	647,32	698,55	776,50	829,35	790,77	749,71	837,55	724,73	740,94	666,80	609,61
12:00	691,87	778,00	806,81	870,77	931,65	893,37	853,68	962,42	799,57	839,45	763,63	717,16
13:00	735,23	842,18	856,48	916,97	970,29	933,20	901,45	1 013,68	827,57	865,55	801,63	756,35
14:00	713,94	831,36	841,52	900,77	939,42	911,63	888,16	990,29	795,73	819,10	765,43	720,42
15:00	625,26	748,86	769,42	816,47	848,52	818,67	805,81	892,29	712,03	706,81	649,37	625,19
16:00	488,45	601,93	626,81	659,27	692,45	676,10	665,00	727,32	568,90	532,39	469,03	463,97
17:00	306,39	401,14	438,19	459,43	488,74	491,50	485,26	512,81	368,67	317,06	254,93	262,71
18:00	112,29	180,79	215,52	237,93	265,55	282,03	281,68	277,87	163,47	104,03	28,80	43,10
19:00	0,65	5,96	14,13	24,27	61,71	94,33	97,19	63,74	6,87	0,42	0	0
20:00	0	0	0	0	0	0,17	0,19	0	0	0	0	0
21:00	0	0	0	0	0	0	0	0	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00:00	0	0	0	0	0	0	0	0	0	0	0	0

Appendix G (Solar radiation's range values) :

Oran

-A value of 536 w/m2 was chosen as a minimum requirement as it represents the radiation on 23rd of January (Coldest month-design month) at 15.00.

-After calculation, the defined threshold of the amount of incident solar radiation is 660.782 W / m², obtained by the following formula: 869.45x0.76=660.782

Constantine

-A value of 568 w/m2 was chosen as a minimum requirement as it represents the radiation on 15th of December (Coldest month-design month) at 16.00.

-After calculation, the defined threshold of the amount of incident solar radiation is 829 W / m², obtained by the following formula: 1090.78x0.76=829

Ouargla

-575 Kw/m2 as a minimum requirement (The maximum value during the coldest day 16December at 13h)

-The maximum requirement is 743.01 obtained by this formula (977.65*0.76)

ILLIZI

-581 Kw/m2 as a minimum requirement (the maximum value during the coldest day 31st December at 13h)

-The maximum requirement is 761.22 obtained by this formula (1001.61 x 0.76)

Tamanrasset

-611 Kw/m2 as a minimum requirement (the maximum value during the coldest day 27th December at 13h)

-The maximum requirement is 753.08 obtained by this formula (990.9 x 0.76)

Ain Guezzam

-517 Kw/m2 as a minimum requirement (the maximum value during the coldest day 16th January at 13h)

-The maximum requirement is 770.38 obtained by this formula (1013.67 x 0.76)

Appendix H (Dry Bulb Temperature's range values):

Oran:

According to the climate data of the city of Oran, the annual average of air temperatures is as following Tm = Σ tm/12 = 17.2 °C.

So: Tn = 17.8 + (0.31× 17.2) = 23.13 +2/-2 (Comfort limit 21.2-25.2)

After calculation, the comfort limit temperatures are set between **21.2 ° -25.2 °.** Once this threshold is determined, the comfort zone and the zones of overheating

Constantine:

According to the climate data of the city of Constantine, the annual average of air temperatures is as following : Tm = Σ tm/12 = 16.25°C

So: Tn = 17.8 + (0.31× 16.25) = 22.84 +2/-2 (Comfort limit 20.84-24.84)

After calculation, the comfort limit temperatures are set between 20.84 ° -24.84 °. Once this threshold is determined, the comfort zone and the zones of overheating

Ouargla :

According to the climate data of the city of T Ouarguela, the annual average of air temperatures is as following : Tm = Σ tm/12 = 23.64°C

So: Tn = 17.8 + (0.31× 23.64) = 25.13 +2/-2 (Comfort limit 23.13-27.13)

After calculation, the comfort limit temperatures are set between 23.13 ° -27.13 °. Once this threshold is determined, the comfort zone and the zones of overheating

Illizi:

According to the climate data of the city of Tamanrasset, the annual average of air temperatures is as following : Tm = Σ tm/12 = 25.32°C

So: Tn = 17.8 + (0.31× 25.32)= 25.64 +2/-2 (Comfort limit 23.64-27.64)

After calculation, the comfort limit temperatures are set between 23.64 ° -27.64 °. Once this threshold is determined, the comfort zone and the zones of overheating .

Tamanrasset:

According to the climate data of the city of Tamanrasset, the annual average of air temperatures is as following Tm = Σ tm/12 = 22.71 °C

So: Tn = 17.8 + (0.31× 22.71)= 24.84 +2/-2 (Comfort limit 22.84-26.84)

After calculation, the comfort limit temperatures are set between 22.84 ° -26.84 °. Once this threshold is determined, the comfort zone and the zones of overheating.

Ain Guezzam

According to the climate data of the city of Tamanrasset, the annual average of air temperatures is as following Tm = Σ tm/12 = 31.30°C

So: Tn = 17.8 + (0.31× 31.30) = 27.50+2/-2 (Comfort limit 25.50-29.50)

After calculation, the comfort limit temperatures are set between 25.50° -29.50 °. Once this threshold is determined, the comfort zone and the zones of overheating.

Name and Familly name : Amina Naidja
Title: Parametric study on solar control of urban spaces-Spaces between buildings-
Thesis submitted in order to obtain the degree of
Doctor of science in Bioclimatic Architecture and Environment

Abstract

Spaces between buildings constitute the crucial module of the city fabric and have a great influence on the performance of the buildings abutting them. The geometrical parameters of urban spaces influence widely sun penetration, shading requirement, and outdoor thermal comfort. However, these spaces are given a little importance in the design process and urban planning. Moreover, in developing countries, urban regulations frequently are founded on imported rules and they are poorly adapted to their local climate. In this regard, the present research work attempt to assess the Algerian urban planning rules, in accordance to solar movement and outdoor thermal comfort in the main climatic zones of Algeria. The present study attempt to develop a parametric solution, which allows urban designers to determine the proper geometrical parameters of urban spaces in accordance with solar right, outdoor thermal comfort. In addition, we pursue through this research to assist urban designers in linking between fulfilling greater built density and guaranteeing solar rights of spaces between buildings. To achieve the goal of this study, an evaluation and generative method has been used. The first phase of the process, focused on the evaluation effect of obstruction angle, orientation and geographical latitudes on solar radiation dropped on ground surface of urban spaces and outdoor thermal comfort during summer and winter times. Whereas, in the second phase, the generative approach based on twofold steps; the application of parametric solar envelope to optimize the results of the first phase, and the application of the Comfort Cover model to determine the urban areas for future urban densification in accordance with the desirability of shade and outdoor thermal comfort (UTCI). Afterward, the parametric solar envelope is applied on the blocks reserved for future urban densification. The findings of this research reveal some guidelines; low obstruction angle safeguard solar right of urban spaces in both high and low latitudes. However, high angle of obstruction mitigate outdoor thermal comfort during summer period in both high and low latitudes, while during winter periods high obstruction angle leads to drop outdoor thermal comfort in high latitudes. In addition, the generative algorithm of parametric solar envelope permits urban planners to fulfill greater built density and safeguard solar access in urban spaces and mitigate winter outdoor thermal comfort. Moreover, the generative algorithm of Comfort Cover model permits urban designers to define the area of future urban densification in accordance with shading requirement and outdoor thermal comfort.

Key words: Urban Spaces, shadings, solar rights, outdoor thermal comfort, parametric solar envelope, Comfort Cover model.

Director of thesis : Professor Bourbia Fatiha –University of Conastantine 3-

University year : 2020-2021