Achieving thermal comfort by applying passive cooling strategies to courtyard houses in Dubai (UAE).

By

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Dissertation submitted in partial fulfillment of
MSc. in Sustainable Design of the Built Environment
Faculty of Engineering & IT

Dissertation Supervisor
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May-2014

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ABSTRACT

A passive design approach is centered upon integrating the microclimatic requests into the design to accomplish advanced comfort levels with lower energy depletion. The purpose of this research was to examine the cooling effect of designated passive parameters on the outdoor air temperature, wind speed , shading, indoor and outdoor daylight of an open courtyard. Numerous variables that demonstrated formerly to improve the outdoor environments were assessed conjointly to achieve the effect that passive design has over outdoor air temperature.

The computer simulation was discovered to be the utmost appropriate tool for analysis affording to the resources accessible. Three variables were examined originally, orientation, geometry and vegetation among these the coolest parameter were combined into one scenario titled the enhanced scenario. Two scenarios entitled the existing scenario presents a specific site circumstances and the enhanced scenario conjoining the coolest parameters, were equated and assessed.

The NW orientation, the highest geometry of a height to width (H:W) ratio of 1.35, groups of trees and continuous grass were discovered to be the coolest parameters included in the enhanced scenario. The enhanced scenario was then equated to the existing case scenario constructed with NNE orientation, 0.85 H:W ratio and no vegetation which had the higher temperature ranks. The outcomes discovered had a small increase in improvement of the outdoor air temperature owing to the passive principles pertained. The proportional outcomes performance cased a smaller progress among the enhanced scenario and the existing scenario presenting the site conditions of Dubai the villa owed to the assimilation of a these principles only. The outcomes of temperature and wind patterns verified and helped in accepting numerous outdoor performances which are helpful for directing an ecological design for courtyard spaces.

One of the foremost conclusions was the reality of a limit to the amount of passive applications to accomplish a substantial enhancement still, an increase in it was achievable. Nevertheless, the performance of the outdoor parameters remains somewhat complicated and impulsive that involves additional exploration.

الملخص

وتتركز نهج التصميم السلبي على دمج طلبات المناخية الصغرى في تصميم لتحقيق مستويات متقدمة من الراحة مع انخفاض استنزاف الطاقة. كان الغرض من هذا البحث لدراسة تأثير التبريد السلبي من المعلمات المعينين على درجة الحرارة في الهواء الطلق الهواء ، وسرعة الرياح، و التظليل، و ضوء النهار داخلية وخارجية من فناء مفتوح . تم تقييم المتغيرات العديدة التي أثبتت سابقا لتحسين البيئات في الهواء الطلق سوية لتحقيق التأثير السلبي أن تصميم ما يزيد على درجة حرارة الهواء في الهواء الطلق.

تم اكتشاف المحاكاة الحاسوبية أن تكون الأداة المناسبة لتحليل قصوى تكفل للموارد للوصول. تم فحص ثلاثة متغيرات في الأصل ، والتوجه ، والهندسة والغطاء النباتي بين هذه تم الجمع بين أروع معلمة في سيناريو واحد بعنوان السيناريو المحسنة. سيناريو هين بعنوان السيناريو الحالي يمثل الظروف موقع معين و السيناريو تعزيز تضافر أروع المعلمات ، و مساواته وتقييمها.

التوجه NW ، وهو أعلى الهندسة من الطول و العرض (H : W) نسبة 1.35 ، تم اكتشاف مجموعات من الأشجار و العشب مستمرة ل تكون أروع المعلمات المدرجة في السيناريو المحسنة. ثم ساوى بين السيناريو معززة ل سيناريو الحالة القائمة التي شيدت مع NNE التوجه ، H 0.85 : نسبة W وليس الغطاء النباتي الذي كان في صفوف ارتفاع درجة الحرارة . وكان نتائج اكتشفت زيادة طفيفة في تحسين درجة حرارة الهواء الخارجي نظرا ل مبادئ تتعلق السلبي . فتش أداء نتائج متناسبة تقدما أصغر بين السيناريو تعزيز و السيناريو القائم تقديم ظروف الموقع من دبي الفيلا المستحقة لل استيعاب من هذه المبادئ فقط. نتائج درجة الحرارة و أنماط الرياح التحقق و ساعدت في قبول العديد من العروض في الهواء الطلق والتي هي مفيدة ل توجيه تصميم البيئي للمساحات الفناء.

كان واحدا من الاستنتاجات قبل كل شيء واقع حد لكمية من التطبيقات السلبي لإنجاز كبير لا يزال تعزيز ، وزيادة في أنه كان يمكن تحقيقه. ومع ذلك، فإن أداء المعلمات في الهواء الطلق لا تزال معقدة إلى حد ما والتسرع الذي ينطوي على استكشاف إضافية.

ACKNOWLEDGEMENT

I would like to extend my deep thanks to my professor and supervisor Dr. hanan taleb who has encouraged me passionately all through my thesis stage. She contributed her knowledge and effort to upgrade my understanding in which is guaranteed by now. The other thanks go to all my professors who added a lot to my knowledge through the entire program that indirectly helped me accomplish this work.

This thesis would have never been possible without the love and support of my mom dad and my brother whom have always inspired me and strengthened my will. Mostly, I'm grateful to my loving friend mu for bearing me through all stressful moments and providing me with the warmest love and support ever. I would like to acknowledge the financial, academic and technical support of the British university of Dubai and mainly the basis of my study Cardiff University in UK for spreading their knowledge to the entire world.

Last but not least, I would like to thank all my other friends and fellows who helped me in any respect and made me commence this work which I am really proud of and grateful to have them all in my life.

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Glossary

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AIA Florida	American Institute of Architects where its purpose is to highlight the architect's leading role in creating energy efficient environments and in leading the nation to a sustainable future.
CO2	Carbon dioxide
Altitude	A solar angle indicates the sun height in the sky
Latitude	Location of a place on Earth north or south of the equator
Longitude	Geographic coordinate of a place for east-west measurements
PMV	Physical Mean Vote
SVF	Sky View Factor
M/S	Meter per Second
K	Kelvin
Standard Deviation	It shows how much variation or there is from the average value
U Value	Coefficient of heat transfer; expressed as [W/mÇ K]
LEED	An internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies intended to improve performance in metrics such as energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.
Estidama	Abu Dhabi's Plan 2030 establishes a clear vision for sustainability as the foundation of any new development occurring in the Emirate and capital city of Abu Dhabi
Ecological foot print	A standard measurement of a unit's influence on its habitat based on consumption and pollution
BREEAM	The world's foremost environmental assessment method and rating system for buildings
GLA	Great London's Authority that aims to continuously improve its environmental performance, as far as resources allow through conserving energy, renewable energy techniques …etc.

CHAPTER 1: INTRODUCTION

1.1 The Sustainable Ecosystem

A system which has an ability to maintain its sequence of inputs and outputs and strike a balance for itself can be regarded as a successful system. Every successful system tries not to reach the exhaustible limits of its own which can lead to its fall off. Besides economy everything in this world comprises of a system within itself. Entire world is based upon a complex natural system which is quite difficult to sustain. Balance of earth's natural ecosystem is very much similar to the system to economy based upon demand and supply. The natural resources being the supply to the ecosystem and consuming of these resources for various reasons by the humans and animals can be attributed to the demand of this ecosystem. (Wright and Boorse , 2011). If the demand is more than the supply it can lead to a disastrous situation resulting in the depletion of natural resources at a very rapid pace. The formation of natural resources is a very slow mechanism and hence takes centuries to augment hence it is very critical to conserve these natural resources and take initiatives in enhancing them for future.

The environmental conservation has become a routine part of daily headlines and given utmost importance. The concern for environment is not confined to only headlines but it has become essential for all the commerce to put couple of environmental laws into implementation in their factories. It is the most important development in this span of ten years. The concern is not only to care about immediate future but to sustain the environment for long term future so that the future generations doesn't have to face adverse effects at their time. In order to reduce the amount of carbon foot print in this world our living standard has to be in accordance with sustainability of environment. It is very essential to take initiatives at both individual and governmental level to bring in the concept of sustainability into our way of living. (Wright and Boorse ,2011).

The use of energy efficiently has become one of the most important concern over the past one decade. It is quite evident that the temperature of the globe has increased over the years and one of the prime reasons for this development has been the emission of large amount of carbon dioxide in the atmosphere. Series of irresponsible actions that have happened during the past industrial revolution and capitalism era have led to this drastic change in the global climate. Almost 40 percent of the energy related to emissions of carbon dioxide comes from electricity generated from fossil fuels. (IEA , 2009). The role of construction has a major part to play in degradation of environment. Several construction works by the humans have certainly degraded the environment due to things like deforestation, waste disposal etc.

1.2 Carbon Dioxide Emission and Global climate change

Major developments that have taken place in the past were done with a less thought towards environmental conservation; hence they have depleted most of the natural resources and resulted in high carbon dioxide emission. According to global footprint Network (2010) the smouldering of fossil fuels results in emissions of carbon footprint which is equal to 54% of the total ecological foot print. According to international agency (2010) the major players who contribute almost two third of the ecological foot print are construction industry, electricity and heating and transportation. The main culprits being the electricity and residential buildings having the severe impact among all on the environment as per the figure 1.1 below

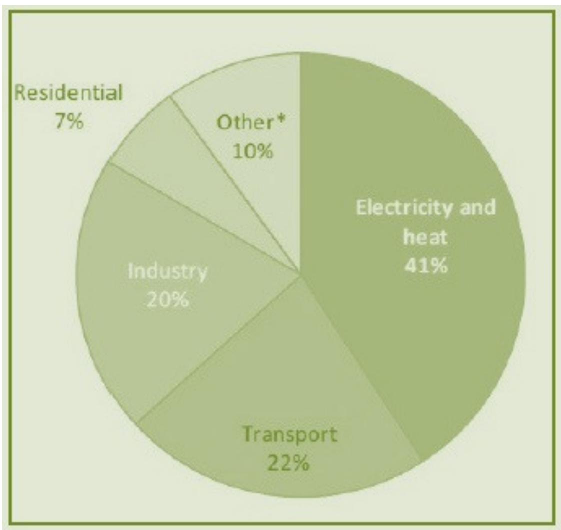


Fig 1.1 World CO2 emissions by sector in 2008 (Source: IEA 2010).

One of the major contributing regions for carbon dioxide emissions is Middle East. Figure 1.2 below shows the emissions of CO2 from various sectors and countries. The growth rate of developing countries is so fast that they will soon surpass the developed countries. As a result of relentless economic increase and development of urban infrastructure the region has been the major contributor towards emissions of CO2.

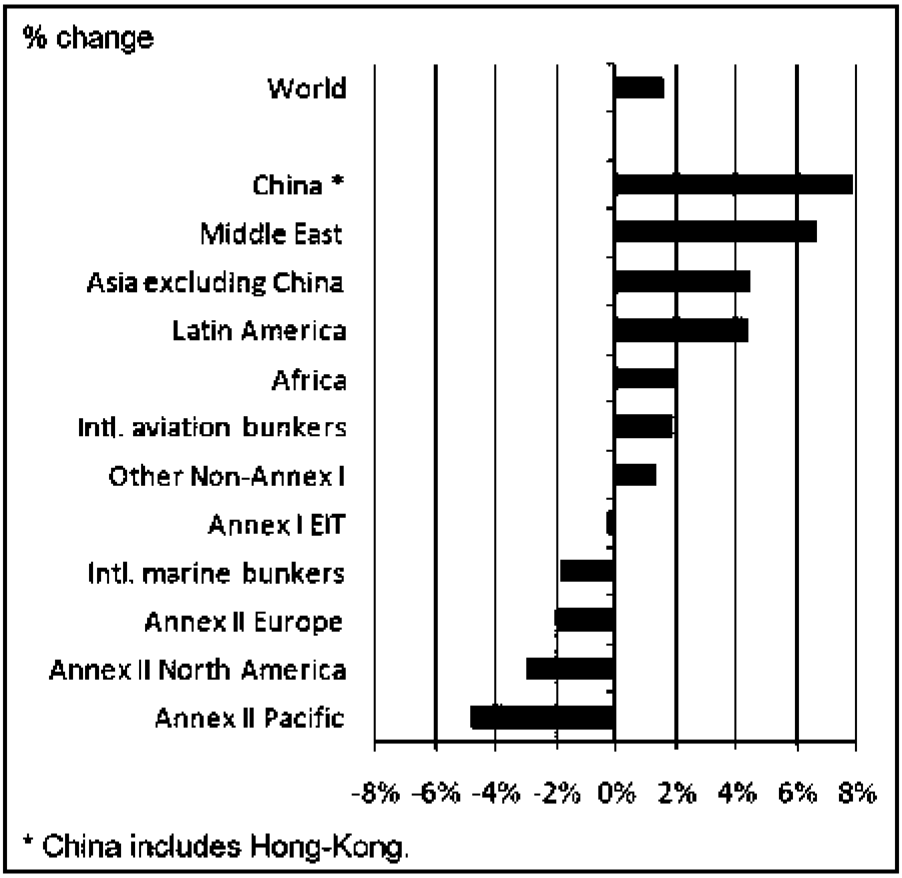


Figure 1.2 Variance of CO2 emissions by region (2007-2008) (Source: IEA 2010).

According to United Nation Environment Programme (UNEP) the construction industry is the cause for more than 40 percent of the energy usage mainly due to electricity usage in the residential buildings causing huge amount of green house gas emissions and CO2 emissions. Emission of these gases due to electricity is at increasing rate of 1.7 percent per year for residential buildings. (Levine et al , 2007 , cited in UNEP 2007). 23 percent of the electricity generated is being consumed in house hold buildings. Sustainable construction is unswervingly connected to environment conservation. Other developments in different sectors are also playing their part to save environment from further deterioration such as sustainable urban development, more vegetation, pollution free transportation, building regulations, waste management etc. The various sectors which contribute towards the green house gas emissions are somehow related to various architectural designs of our current infrastructure throughout the globe. Unfriendly building designs towards the environment coupled with enhancement in the usage of electricity, heating and cooling, smouldering of fossil fuels and excavation of various minerals have all been the main culprits for environment deterioration.

Construction sector is the prime contributor towards environmental degradation. Not only the misuse and usage of energy but also the overall distress to mankind in regards to microclimatic fall is an issue to look at the broader view. Some of the microclimatic factors of urban form which affect the people in their day to day activities are like urban concentration, typology arrangement, choice of building material etc.

Development in the architecture filed does not only mean change in the urban structure or boost in construction sector it means a lot more than that as in development and change in typology and arrangement of building forms which can be environment friendly. Various aspects of building typology like active and passive design measures, human comfort, micro climatic conditions and environmental degradation should taken into consideration. All these aspects should be improvised in order to make construction sector environment friendly which can be associated to the development of architecture. Various factors of micro climatic conditions such day light infiltration, flow of air , thermal comfort, normal ventilation and shading measures have to be looked while making the building design. There are two forms built form typology. One is called introverted form which can be associated with the building having main part towards inward courtyard direction. The second form is called extroverted form having its main towards the exterior side.

The courtyard built form which is a part of vernacular typology is to be taken into consideration while making the building as it plays a vital role in affecting the micro climatic conditions. It is very effective to change the built form typology and configuration as it helps in changing the micro climatic conditions inside and around the building. Better built typology and configuration always help to reduce energy consumption thus affecting environment in a positive way. Such passive design methods always have an impact on the micro climatic conditions.

As of now such passive design measures play a significant role in reducing carbon foot print by holding on to climatic, cultural and environment distinctiveness without conceding the living standard. Similarly it happened in the past before the modern era of construction came into place, the built form was sustainable and responded to various factors of environment in a positive way.

1.3 Research potential and limitations

In the present era Dubai which is one of the emirates of UAE has become the most advanced city of not only the Middle East but in the entire world. The city has grown rapidly in the last two decades and has become a financial hub for various multinational companies making the country more strong financially. Dubai has a quest to be among the world's top cities .The city wants to place its name on top in the list of countries trying to conserve environment.. hence it has become very essential to put in ecological rules and regulations in many major projects not in Dubai only but all across UAE. The country has made its own rating system to gain achievements in sustainable design constructions like Estidma. These play a pivotal role in regularising the drive for urban construction across the country.

The key challenge that the government of Dubai faces is to control and regularise the urbanization process. One aspect which needs further examining is the area to be allocated for liveable spaces. There is a disproportion percentage between built form and open spaces in the infrastructure of this city as per the climate. One of the most important defect in their plans of the buildings is that there are very less social spaces. They have designed open spaces but they can't be used for social gathering or we can say human factor has not been considered. More ecological spaces are required to be formed across the cities in order to cater to the psychological needs of the humans besides the physiological ones. One needs to make such open spaces which could pull the people towards thus influencing the surroundings of that place as well.. the open spaces in Dubai are not that well designed in its infrastructure thus one can always have a better feeling looking at the buildings while going in a car rather than walking through its streets. The open spaces ought to be made with a set of design principals in order to achieve the desired results from them or else the open spaces which aren't designed well can neither satisfy psychological needs nor physiological needs of humans.

Due to the hot and humid weather in UAE it is very difficult to utilise outdoor spaces. Almost half of the year is hot in Dubai and thus it is quite difficult to provide solutions for outdoor spaces. However it is better to have one extreme rather than two where the place has extreme high temperature during summer s and extreme cold during the winters. Cities like Dubai which have extreme hot climate require profound solution during the summers where as during winters the temperature is naturally within the thermal comfort zone. Hence no specific measures need to be taken during the winters to influence the temperature. Several measures need to be taken to design the outdoor spaces in an ecological way

Various Investigations and researches have been conducted on built environment of a place. In this research we have studied the effects of outdoor micro climate. The major focus of this research is the effect on the microclimate due to courtyards inside the Dubai villas. There is a lack of proper orientation, geometry, openings and vegetation in most of the buildings present in Dubai due to which the desired cooling effect is not attained. Hence this needed attention to in order to improve the effect from the same. In this we have studied the consequence of proper geometry space, orientation, opening and vegetation on the microclimate in order to reduce the discomfort felt during the summer months. By just altering the geometry the microclimate of a courtyard changes to a large extent. Vegetation coupled with different geometrical cases also plays a role in effecting the micro climate of a courtyard as it is a function of height and width ratio. Thus implementing these passive heats reducing strategies can always be very beneficial in hot and humid areas such as UAE where the solar heat penetration is high and consumption of energy is huge for cooling.

The concern for environment is still very new concept for many architects and designers. There are a lot of difficulties and limitations faced by architects and designers when designing projects which are ecological compared to that of there own targets which they have to fulfil. Tools which measure existing values, social surveys, experiments and computer simulations are very different from the ones that are used. Every tool has its own pros and cons in different cases. Studies which are based on restricted time and financial resources use the computer simulation very effectively. For this research as well we have used the same. A computer simulation is very effective in emulating the actual situation thus helping the person who s conducting the study to manoeuvre the environment to attain the desired results. The reason behind controlling the various variables of a project is to examine them before the actual construction period in order to see the quality of final product. However the software available to examine many of the parameters of the outdoor environment are very limited.

Outdoor environments are more complicated than the indoor environments as there are many uncontrollable factors that always have an impact on the accuracy of the results. If the simulation of the imitation procedure is more close to the original one then there are more chances that the outcomes will be more authentic. We have used Envi-MET and IES soft wares in this project as our simulation tools to quantify the variance in air temperature according to the used principals and design procedures. According to Kevin (2002) one of the prime benefits of using these tools is that they are able to comprehend many parameters of the outdoor environment and its multifaceted behaviour. In this project a courtyard house located in The Villa Dubai has been chosen as a case study and the reason for the same has been explained completely in chapter (3).

1.4 Future Benefits and Purpose of the Study

The aim of this project is to provide an elaborate view of some of the parameters of outdoor environment which can cause a change in the surrounding microclimate. It would be beneficial for people related to this industry such architects and designers to have such an investigation as they can apply to their own projects and make difference in the micro climate. The study includes various variables such geometry, orientation and vegetation which have been tested in different situations to check if the temperature of the place gets reduced. A review of the parameters which were examined provided us with an insight of their relationship with the outdoor environment and the reasons for that. Environmental researchers hugely benefits from such ideas and solutions for altering the micro climate towards a positive direction.

If the recommendations and guidelines provided will be used by Dubai design authorities it would be very beneficial and would contribute a lot towards suatinable architecture of the new projects. This would certainly help in making the city more ecological and reduce the discomfort levels for its habitants. The applications of these principals would not only make a difference to authorities but it would be beneficial for the developers of the city as well. The energy which is consumed for the cooling effect can be reduced to a large extent. This study focuses on the hot arid climate regions where implementations can be expanded over a large area. Most of the gulf countries have hot arid climate and the urban construction is rapidly increasing. The findings and observation of this study about the parameters' related to outdoor environment, and their effects can be very useful to researchers etc.

Different scenarios have been taken and compared to each other and the outcome of those comparisons has been presented. One of the site selected in this study is The Villa Dubai and then second case is based on passive design parameters which will be useful to achieve the goal of effecting the micro climate. These comparisons should be helpful in showing the difference in temperature that passive design strategies make to a house or villa when applied to its courtyard. A test conducted is completely explained in chapter 3 which signifies the investigated variables of the space such as geometry, allotment and compactness of vegetation and space orientation. The benefits of the ecological courtyard spaces in for the short run as well as long run will be explained thoroughly in the last chapter which will give confidence to builders and landlords to embody these ideas in their projects.

1.5 Research Framework

1.5.1 Hypotheses

i. Use of passive cooling strategies in courtyard houses enhances the ambient air temperature in the climate of Dubai.

ii. Application of the passive design principles such as geometry, orientation, and vegetation increases the cooling effect significantly within the spaces.

1.5.2 Aim and Objectives

The aim of this study is to calculate the effect of proper geometry, vegetation and space orientation on the temperature and comfort due to it in courtyard houses in Dubai. The study will be composed of simulations to see the effect of passive design strategies and its cooling effect on temperature, wind speed and performance of day light inside the villa and in the outdoor courtyards in the hot arid climate through investigation in order:

- To understand the working principle of courtyard effect for cooling from previous time to the latest developments.
- To examine the effects of the variation in courtyard geometries on the thermal comfort.
- To examine different orientation for courtyards to study their effect on thermal comfort.

- To examine different densities of vegetation in courtyards to study their effect on thermal comfort.
- To predict the energy benefits of passive cooling strategies.

1.5 Research outline

- Chapter one is composed of introducing the consequence of altering the introverted built form and set up into extroverted form in Dubai in order to change the micro climatic condition which in turn will reduce the load on energy consumption and preserve environment.

- The second chapter will be comprised of scientific literature review of the built form, environment and design parameters which make a difference to micro climatic performance of the courtyard.

- Chapter 3 describes the proposal of the study with regards to its parameters and assessments comparing different types methods and software to perform same studies and there advantages and limitations. It also explains the method selected and software used for research assessment.

- The 4th chapter explains the steps of simulation method with regards to Dubai climate analysis, set up of computer model and validation of process decisions.

- Chapter 5 will help to give complete insight of the simulation results. An extensive discussion will be provided to find the advantages and disadvantages of the built form performance.

- Chapter 6 will be conclusion and summary of the findings and will provide with recommendations for the future research

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In this section a descriptive literature review about the key concepts of this study will be presented. Some typical key words such a s passive cooling design, thermal comfort in courtyards and the outcome of various variables such geometry , vegetation and orientation on the courtyard climate will be discussed. Some of the words that were used in used search engines for the investigation process were like hot outdoor spaces and passive cooling for outdoor spaces. The main concepts that were used for study were mainly for the hot regions as there was very less information available for research in the hot climate areas. Difference in hot humid and hot dry climate was also studied in order to check the outcome achieved from those papers. All the parameters will be carefully analysed and then possible limitations and advantages will be stated for same type of studies. Earlier researchers used electronic scientific resources for evaluation of projects which were based on main concepts.

The articles that were found have gone through a selection process of including and excluding criterion in order to choose the most relevant one to the study. Articles which had better ideas and design objective which would help in reducing the outdoor temperature were considered for deep review. The variables that are to be used for simulations of passive design parameters in chapter are discussed in this literature review. The variables which have undergone analysis and had the ability to reduce the heat strees are dependant on various factors such as social, environmental and technical. This becomes very evident that the shape, size, design of a courtyard has always an impact on the comfort level in a positive way and also helps to reduce the load of energy consumption. (Smith and More, 2002).

The concern of global warming and the constraints of natural renewable sources have made this vernacular architecture very important for the designers and builders. It has the ability to modify the indoor and outdoor environment of a house or building. Vernacular architecture means architecture which is environmental friendly and makes optimum use of natural resources for the benefit of the inhabitants of those buildings. Where as the on the other hand modern architecture tries to heat up the building interiors with the limitations in the passive design.. However the focus on artificial ventilation has reduced the importance of natural ventilation in the design of modern infrastructure.

Indoor air temperature of the building is always affected by the pattern of airflow within it or surrounding it. The main idea of passive design strategies in the vernacular architecture is to enhance the natural ventilation, optimum air movement and very less solar radiation in the built form. One of the vernacular architecture designs comprises of having a courtyard inside the house. It helps to influence the micro climatic condition of the house. Various variables get influenced such as reduction in solar radiation, adequate air movement and proper shading due to geometrical factors resulting in the cooling affect.

The main aim of this research is to mitigate the problems faced by the inhabitants of hot and humid areas. Certain strategies were required which would help in reducing the temperature around the built form in a more natural way rather than heavy dependence on energy consumption. Courtyard houses were one way to influence the micro climate how ever due to extremely hot weather people could afford the luxury of using these courtyards for few months. In this research it will be discussed how proper design of courtyards can be very effective in reducing the temperature and also can help to use it through out the year. These days the technology has made things very human friendly. People have the luxury to control the indoor temperature according to their comfort level. However the comfort level varies from person to person as in one temperature range might be comfortable for a person where as it wont be for the second person sitting in the same room. Same is the case for lighting as people now a day can adjust the lighting of their indoor spaces according to the sunlight coming in through the windows. Similarly sound insulations can be fit in the built form according to the comfort level.

All these measures taken can cater to the indoor comfort needs of inhabitants; the big question mark has always been the comfort level in outdoor spaces. Out door spaces which could be used more often than just having limited use needs proper designing. Designers are yet to develop a set manual or design principals that would make out door spaces more usable. The amount of literature present and research done on this topic is very limited compared to research done for indoor spaces. Outdoor parameters have been investigated and explained in various ways by different designers and climatologists in order to find a link between investigations and comfort. (Toudert and Mayer, 2005).

It is not possible to use the same design principles to achieve the outdoor comfort level that have been used to achieve the indoor comfort levels. The outdoor environment has a complete set of uncontrollable variables such wind, sunlight, air movement etc. All these have a huge role to play in influencing the thermal comfort levels of outdoor spaces. Complete detailed information is needed when dealing with the outdoor environment. Indoor and outdoor spaces are interrelated and compliment each other always. It is essential to strike the right balance between indoor and outdoor spaces in order to influence the micro climatic conditions in a positive way and achieve proper design.

2.2 Passive Design

In the ancient days people used more natural ways to subdue the harsh temperature effect on them. People generally used techniques like evaporation of water from springs, windows designed towards the breeze flowing side of the house and absorption of heat from sunlight during the day. These types of strategies which make use of natural resources are called passive design strategies. However lately all these techniques were considered futile as people had the option of mechanical cooling and heating their houses with electricity, thus consuming huge amount of energy. Passive design strategies are dependant on the surrounding temperature and have a potential to reduce the dependence on equipments used in the buildings for influencing the temperature. The energy cost also come down drastically making passive design more important in recent times. Techniques such as heat sinks, evaporation, and convection are used to influence the temperature. Temperature changes and relative humidity in the surroundings play a major role in passive cooling technique.

The main aim of passive design is to achieve the bioclimatic design. A passive design of a building involves the micro climate factors of the surroundings to influence the building temperature thus reducing the use of energy as much as possible. Its also strives for attaining different comfort levels such as visual, thermal etc for an individual within that space coupled with economic, social and environmental benefits for the society at large. Adhering to these principals would help in achieving the sustainable nourished future.

In order to achieve the passive design for outdoor spaces one needs to have complete information about the various parameters of the environment around. Two main factors which have a major role to play in achieving the passivep design are the microclimate of the space around which is natural and the other is man made factor that is urban built form design within that space. The interrelation among these two factors will help in achieving the passive design (Gaitani et al , 2005).

2.3 Thermal comfort

According to ASHRAE a state of mind that articulates the contentment with the surrounding environment can be defined as thermal comfort (ANSI/ASHRAE 55). The surrounding environment is comprised of built form structures and spaces for the basic human needs of shelter. Many efforts have been done to control the environment in order to create a comfort level for humans in natural way, however still that much success has not been achieved in the same field. In this study deep analysis have been done to control the natural environment and make optimum use of it for human comfort. This would certainly help in reducing the consumption energy in rigid built form structures and also will be beneficial for the environment in the long run.

Thermal comfort zone is a point where a human feels comfortable with the temperature surrounding him or her. The various physical parameters that help to achieve the a thermal comfort zone for an individual are as relative humidity, air speed, air temperature and mean temperature due to sunlight. A graphical representation called psychometric chart can be very helpful to illustrate the comfort range depending on the climate zone. A psychometric chart is always a baseline against which the thermal comfort levels are measured using the various tools. Other factors which are external such as clothing and activity done by a human also affects the thermal comfort level. It is the combination of psychological and physiological factors that help to attain the desired thermal comfort level. Many other factors determine the comfort level on an individual such as the life style of a person, expectations of weather before going out in the external environment, clothing etc.

According to Nikolopoulou et al (2001) the expectations of comfort zone for the citizens of Dubai are very high as most of the activities done here are based on non natural cooling methods. A perfect balance between all the various parameters has to be there in order to attain the maximum results for thermal comfort. This study is conducted in order to reduce the ambient air temperature which adds to the entire thermal sensation of the area.

2.4 Residential building form in relation to Micro Climatic Efficiency

The climate of a place is always an influencing factor for typology of the house. Architectural design of built form is always responsive to a specific climate and alterations are done in design based on the surrounding climate of that place. Various environmental factors have an influence on the internal micro climatic condition of a built form thus determining the amount of energy to be consumed. Some of the environmental factors are existing wind, humidity, radiation from sun and climatic temperature. Other factors which influence the internal micro climate are orientation, building form, opening ratio and materials used for the construction. Passive design helps to make the architectural design better in order to attain efficient micro climatic conditions within the building.

In places like Dubai the external environment is very harsh as there is extreme solar radiation and very high temperature which makes it pretty difficult to provide comfort within the internal environment. These conditions require very high demand of thermal comfort and huge amount of energy is consumed for the cooling effect. The shape of the building and material used for building plays an effective role between the exterior and interior conditions. It is up to the balance between the two which helps to determine the amount of sunlight penetration, thermal comfort, lighting and cooling required for the interiors.

There is lot of variety in the scale and design of the Dubai buildings. However the general type of design for most of the buildings is enclosed extroverted block structure. The structure comprises of having an extroverted type courtyard. Most of the design regulations such as external obstruction, span of leas, opening ratio and material type are standard, however still many regulations are not as per the green design regulations. Regulations should be modified after a deep analysis of the environmental conditions of the region. The present infrastructure and building form is very inappropriate and less effective towards the harsh climate of Dubai. The internal comfort is only attained by consuming huge amount of energy for cooling. The rapid economic growth of the place has lead to enormous expansion of urban infrastructure. The passive design strategy which uses the natural factors for the comfort of inhabitants has been given very less consideration as compared to artificial methods.

One of the most frequent designs which have been used in the gulf region is the passive design having courtyard typology. These courtyards were integrated in the design as a responsive measure to social, climatic and cultural conditions. The main concept behind the employment of courtyard in the built form is mitigate the effect of heat due to high solar radiation and also it helps in the air movement. When these tow effects couple up hence they result in a pleasant outdoor and indoor climate. Passive design has a lot of scope for improvement and development and everyday new strategies are being analysed to increase the comfortable conditions for the inhabitants. Improvement in terms of geometry, orientation, openings and vegetation has a key role to play in influencing the micro climatic conditions.

The courtyard built form has the ability to reduce the consumption of energy thus helping in conserving the environment. Lately it has been found that most of degradation to environment is done by consuming various forms of energy for the artificial cooling or heating and various other purposes. Thus passive design is the best alternative in attaining the comfortable conditions at a very less cost and energy. It helps in developing a sustainable future. this study will help in determining the benefits of passive design with courtyards in influencing the micro climatic conditions. Passive design has the ability to control the penetration of solar radiation through various variables such as opening orientation, opening ratio, geometry, shading and material used for built form. The control of daylight in turn helps in lowering the internal temperature thus reducing the dependence on air conditioners at low temperatures. Passive design structure helps in air movement within and around the building thus helping in maintaining low temperature. Thus integrating a courtyard in modern built form typology helps in achieving a very good passive design typology.

All the factors that are being considered have to be environment friendly in the building developments. The environment can be preserved by using green building standards through design optimization and systematic methods.

2.5 History of courtyard Houses

The presence of a courtyard in the architecture dates back to many urban civilizations in the history. According to Edawards etl al (2006) the integration of courtyards in the design is been there since 3000 BC. The houses having courtyards have been located from bronze period of Greece to Hellenistic and roman period. It has continued to be present through the Americas, Europe, Middle East, Far East and Africa. It has continues to evolve through various civilizations from bronze age Mesopotamian, Egyptian Sumerian. Indus valley, Mediterranean (Mier I .A et al , 1995).

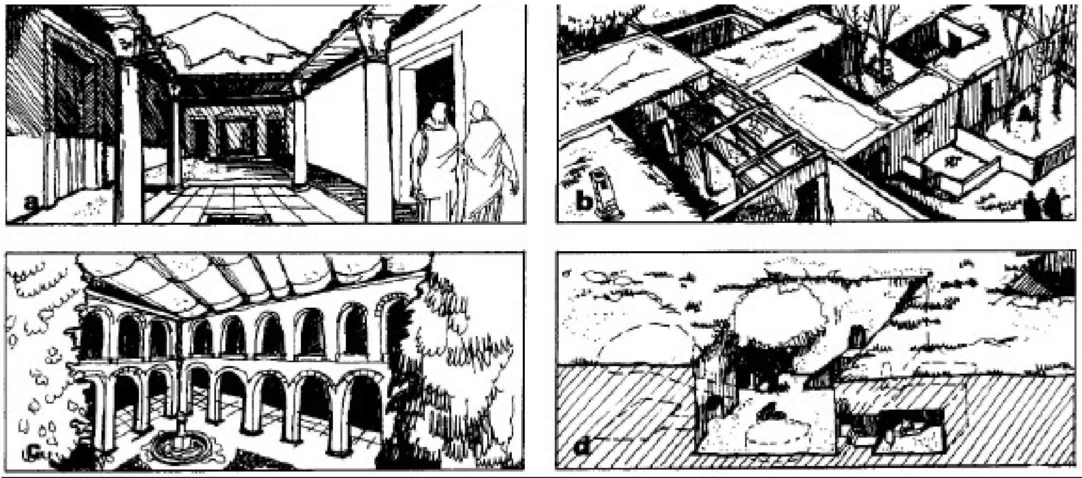


Fig 2.1 shows the proliferation of the courtyard housing.Courtyard dwellings: (a) Greece, (b) Mongolia, (c) Spain, (d) North Africa (Source: Meir I. A. et al., 1995).

The nomads from Arab used the concept of courtyard in the centre surrounded by the tents in order to protect their cattle and provide them with shelter. In the Middle East society, courtyard housing dates back to Islamic and pre Islamic period. A courtyard house is completely covered on all sides with a piece of land in centre. Some of the examples of such houses in Middle East are like chogha zanbil from1250 BC in Iran, Jmai fahraj mosque from 8th AD, Susa palace of dairo which dates back to Achaemenid dynasty from 550 BCin Iran, Mosque of Uqba in Tunisia dating back to 670 AD and Bayt Al badr in Kuwait from 1840 (Edwarrds et al, 2006).

The shape of the courtyard may differ from place to place but the universal design within enclosed walls remains same everywhere.Figure2.1. Countries like Tunisia, Algeria, morocco etc got inspired by the courtyard housing of the early Egyptian civilization of 8th and 9th century AD. Hence they started making the courtyard houses with a rectangular courtyard shape which was surrounded by symmetric rooms and a T shaped reception. Courtyard implementation has various socio cultural and environment benefits and same is acknowledged throughout the world. however in middle east they implemented this typology in the design for various reasons like mitigating the effect of harsh temperature, more air movement within the interiors, safety and shelter and private gatherings. Many outdoor activities were performed within the enclosed walls such as playing, gathering, cooking and sleeping in open during high temperature weather; hence it became an essential feature for the Arab houses to have a courtyard.

During the early days courtyard houses used to be a single storey and then it transformed into double storey houses. Over the years it has evolved from residential blocks to commercialization of residential places to apartments. All this is a consequence of economic crisis, growth in population, high demand for oil. The contemporary apartment designed buildings have been the major reason for decrease of courtyard houses in the region.

During the colonization period courtyard houses were used more for social gatherings rather than being the climate pacifier. Over the period time these adapted standard European design and transformed the courtyard house into a villa having enclosed space in centre. Due to rapid economic growth and huge population growth these houses were being curtailed and the modern architecture of apartments came into play. Need of accommodating more people within a less area have contributed allot in decrease of courtyard houses. The artificial cooling and lighting have further dented the progress of courtyard houses as people don't rely on natural sources to effect the micro climate around them.

In European and American region courtyard development has an ancient origin. Some of the examples are like Imperial Rome and renaissance. Courtyard shapes were formalized in the 19^{th} century in Europe. In the medieval cities courtyards wre used to be in random shape. These cities lacked the infrastructure which would help in allowing the adequate solar penetration and air movement within and around the buildings. This unplanned dense architecture which allowed less solar penetration and air movement coupled with ineffective sanitary disposal system had worse consequence on the health of people. Courtyards played an effective role in better solar radiation penetration and air movement inside the house and also played an effective in providing a proper sanitary order. Courtyard orientation varies from place to place according to the need of the region. Scotland had priority for better air movement and urban ventilation where as in Germany solar penetration was more important (Edwards et al, 2006). The 19th and the 20th century witnessed exchange of ideas between Europe and America for the betterment of architectural designs and courtyard development.

2.6 Types of Courtyards

There are various forms of courtyards. Some courtyards are fully enclosed while others are semi closed. One form of courtyard which is completely enclosed on all sides represents the traditional form of courtyard and is generally used in residential built forms. On the other hand semi closed courtyard is very rare and has few openings. It is used in various built forms but not used for residential buildings. one of the examples of semi closed courtyard is a plaza having two buildings surrounding a piece of land with an opening between them. Positioning of the courtyard is different in different buildings some buildings have it in centre where as others have it at the side of built form.

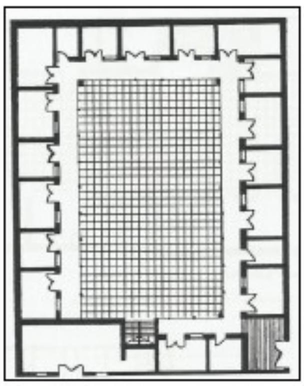


Fig.2.2 A plan of a single-courtyard (Source: Edwards et al 2006)

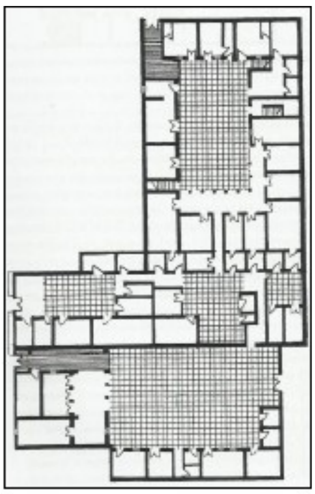


Fig.2.3 Bayt al-Badr floor plan (Source: Edwards et al. 2006).

Historical courtyards have demonstrated the integration of more than one courtyard in its dwelling. Manifold courtyards are better for security and privacy purpose. In rural areas houses have multiple courtyards. One is allocated for private gatherings of the family, others are allocated for stable called annexes, while others are for keeping farming equipments, tools etc. .In the urban society there are also multiple courtyards one which is the inner most is for private gatherings and for females where they remain unseen by strangers, where as the outermost is for reception where generally male guests sit called the Majlis.

2.7 Social and cultural dimensions

Architectural design depicts the culture and society of a region or area. The behaviour of the people always has an influence on the culture and thus on the architecture as well. Architecture is influenced by the interaction of various factors such as different thinking and ideas, change of a period and the concern about privacy in the society. Throughout the history the architecture has been built which suited the needs of the region. Courtyards were developed for social and climatic needs. Courtyards had many other functional values as well. There are various shapes and designs for courtyards depending on the environment around and other factors. In the middle east region and other Islamic countries the social, cultural and privacy factors are evident in the architectural design.

Privacy in this region is one of the fundamental soci cultural factors that influences the shape and design of the built form. Women need segregation from men and thus require their own private space limiting their exposure to strangers and social stress thus affecting the design of a courtyard. The shape and design of European courtyards have been very similar to the ones in Middle East. Both the societies developed a typology which articulated the gender division in domestic household. According to Edwards at al (2006) the courtyard for women and children are separate from men. The introvert side of the design comprised of having a kitchen bath room and bedrooms where women would generally work where as the extroverted side used to have social space for men. The rear side of the courtyard facing street was being utilised by men. The concern for privacy is one of the major factors influencing the design, spatial organization, facade, openings and entrance for an introverted enclosed courtyard. An introverted courtyard helps the spatial organisation of rooms to open towards the central courtyard thus helping them to maintain their privacy. Fig 2.4.

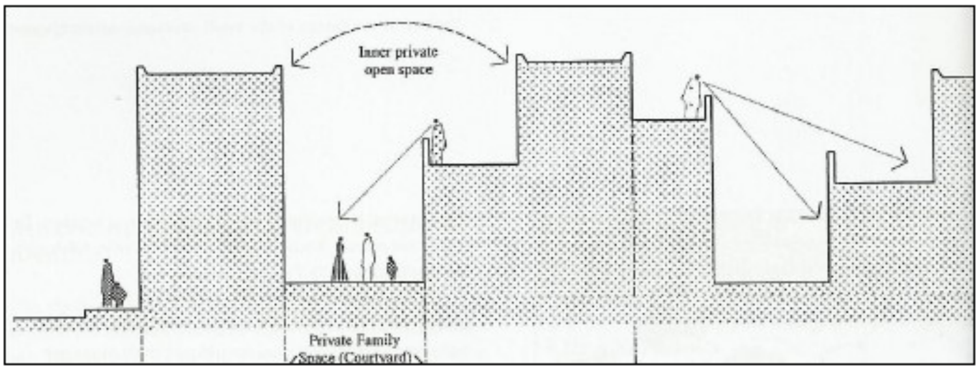


Fig.2.4. A section through adjoining houses showing how setbacks maintain privacy between them (Source: Edwards et al. 2006).

Increase in the space configuration of the courtyard allocated for the entrance area called Majlis and separating the courtyards between family area and guest area controls the privacy without any compromise on comfort for the guests. As shown in Fig 2.5 the application of "bent entrance" principle at the entrance and the opening points protect the housing sections from direct sight. The bent entrance principle shifts the entry from courtyard axis and places a wall parallel to the entry which helps to design the passage from the entrance to courtyard and spaces.

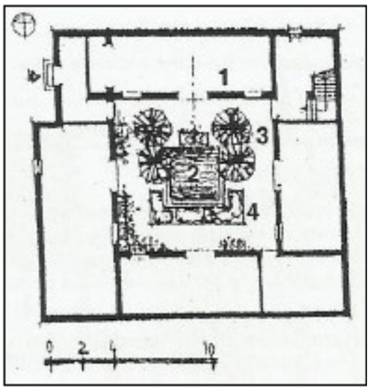


Fig.2.5. Bent entrance in Beit-Radwan, Marrakesh (Source: Edwards et al. 2006).

Since the inception of using the courtyards the need for privacy according to social norms has been an influencing factor in shaping the architectural design and the dressing of the inhabitants. Fig 2.6 shows the use of layers in which the outer part is completely covered to highlight the importance of protection.

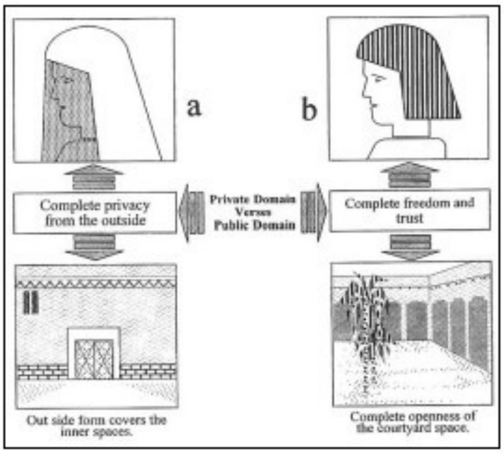


Fig.2.6 (a) Private domain (b) Public Domain (Source: Edwards et al. 2006).

In the ancient era the shape and design of courtyards was like an enclosed courtyard covered on all sides. The reason for this was women being limited to do only house hold activities and not much of the work outside the house. The protective and conservative feeling was major reason for enclosed courtyards. However over a period of time the mentality of the people has changed, the amount of exposure has increased and also more liberty and freedom for women. This is quite evident in modern architecture and built forms as it is more open, height of the fences has reduced, design of envelope and interior spatial organization has also changed. This shows the change of social mindsets and development and exposure in terms of advancement of civilizations which is reflecting in the modern architecture and built forms. These comprehensive changes are necessary to suit the needs of present age and proper environmental function. Hence it becomes quite clear that people's belief values, way of living developed a set up which helps to shape the built form linking social and spatial orders.

2.8 Climate

2.8.1 The Microclimate

There is certain pattern of weather called climate which is a part of environment. Climate can be addressed by various names such micro climate and macro climate depending on the radius of area which is influenced. It is the average weather over a period of time which has been divided into zones having similar characteristics. Changes in the weather can be experienced within an area of few kilometres from one place to another. This form of small scale pattern over a small over small area of few kilometres is called micro climate (Santamouris and asimapoulos ,1996). Climatologists have worked very hard to determine and segregate the climate of certain regions which have similar characteristics that would help people to follow a set norm of living in that particular region. The main motto behind all these researches was to attain the bioclimatic comfort for the inhabitants. Bioclimatic comfort is a condition where an inhabitant acclimatizes to the surrounding environment at the cost of minimum energy usage. According to Mahmoud (2011) four main climate patterns which are cool, temperate, hot and humid and hot and arid were formed as a result of an organised approach and bioclimatic building design by olgyay in the starting 1960s. Each of these categories has different needs and requires different building design strategy in response to wind, sun and rain.

The thermal comfort levels for humans in different climatic zones can be indicated by using psychometric charts. Psychometric charts have been a very useful tool over the period time for designers to determine the information about the temperature and moisture levels within the climate. When the comfort zone is shown in a visual presentation it helps to make bioclimatic classification simple for many people. The consumption of energy is increasing day by day and the need to preserve the environment for future generations has been a major concern for present generation researchers. Hence the architectural design of the built form has also undergone many researches in order to form environment friendly buildings making maximum use of natural energy rather than artificial energy. The process of conserving environment starts with understanding the surrounding environment around us. The ecological foot print has to be reduced. The use and application of the principals of bio climatic zones can be very useful for fields like landscape and solar energy. Mahmoud (2011) states that the aim in classifying the bio climatic zones is to develop responsive strategies for such climates in particular regions. This would be helpful for governments to act on those strategies.

2.8.2 Parameters affecting the Climate

According to spagnolo and dear (2003), the outdoor environment is a very vast and complex field of study. There are a lot of uncontrolled parameters in outdoor environment which outnumber the indoor parameters. In the indoor environment there are a limited number of surfaces and average temperature of the surface can be calculated easily. Where as in the outdoor environment the numbers of surfaces are countless, especially when vegetation is also present making it difficult to calculate the surface temperature (Mahmoud , 2011). The studies and researches done for outdoor spaces are very close to reality when certain assumptions are taken. Some of the major parameters have been found out which affect the outdoor spaces and thermal comfort, the four principal factors which influence the thermal feeling of an individual in an open space are:

Air velocity: it majorly influences convection and evaporation. It can increase near a clothed body due to body motion. Due to permanent natural air movement a minimum speed of 0.1m/s is always present.

Ambient air Temperature: Heat transfer quotient and dry and humid exchanges are always affected by this.

Relative Humidity: Humidity in air greatly influences the sweat evaporation and thus is the cause for wet skin. However if no sweat is coming out of body then the respiratory exchange and abnormal skin perspiration are the only two transfers affiliated with humidity.

Mean Radiant temperature: Mean radiant temperature is the average temperature of the surface in an enclosure within which a person exchanges the heat by radiation as the real environment considered. In case of outdoor spaces the average temperature of an imaginary surface is considered among all surfaces of imaginary enclosure at the same temperature (matazarakis and mayer, 2000).

According to Mahmoud (2011) one of the most important parameters which affect the thermal comfort level is the air temperature within the environment. This parameter can be indicated with ease and can be rated easily by people. Many other investigations which were conducted to attain nice outdoor environments also indicated air temperature as the most influential parameter for thermal micro climate. It has been observed and analysed by various researchers that the little bit of change in other parameters such wind speed and humidity cannot be very affective for the users if the temperature levels are within the comfort zone (Nikolopoulou and Lykoudis, 2006). All parameters play essential roles depending upon the region where one becomes more important and other becomes less, however air temperature is essential in all climate zones.

Understanding the climatic characteristic of a region is one of the basic guidelines for environmental design works for the standard levels of comfort. Only after understanding of climate one can focus on the other parameters of outdoor environment. In Dubai the use of bio climatic approach for outdoor urban spaces should start with understanding of conditions around the site which has been selected for investigation. Then it should be followed by differentiating the existing design that interprets the functional requirements of the site.

2.8.3 Climate of Dubai

Dubai is positioned on the coordinates of 25 degree north and 55 degree east and is known to be high temperate climate zone with very less precipitation levels as compared to other cities in subtropical zone. The temperature reaches maximum between June and September where it reaches its lowest during the winter months between December and march with very less precipitation (Dubai metrological office , 2010). High humidity is a concern and the main reason for thermal discomfort for everyone. People stay inside the artificially cooled buildings for most of the year. The humidity and high temperature doesn't allow people to enjoy the outings and are major barriers for people to stay in outdoor spaces for long. Only during the months between November and March people have the luxury to use their outdoor spaces and they use them as much as possible without bothering about discomfort factors such as dust and wind.

A psychological approach was being used by Fabrous (2009) to check the thermal comfort level in Dubai. A survey was being conducted for four months out of which three months of summer and one month of winter. In accordance with the previous studies conducted on outdoor spaces in Dubai, the air temperature has been the most influential factor causing discomfort for people due to very high solar radiation. However when the shading was provided the number of users for using outdoor spaces were more satisfied and were willing to use the space for short periods of the day. Therefore the author has recommended high levels of shading especially in transit areas where thermal discomfort is the highest. The highest level of relative humidity is in summer months between May and September which adds to the heating effect of the air temperature.

On the other hand the humidity levels are high in the month of January. During January and February there is an increase in winds resulting in discomfort during the winters. A balance is needed which would help to reduce the wind during the winters while increase it in summers in order to lessen the thermal sensation due to high temperature. The project helps us to understand various weather patterns of Dubai and its influence on the citizens for using outdoor spaces. it is challenge for various researchers to design in such a way which would help to attain thermal comfort in outdoor spaces in Dubai. Using of natural resources and reducing dependence on artificial cooling will play a major role in the usage of outdoor spaces throughout the year. Maximum thermal discomfort due to high temperature is during the months of June, July and august and where as during the month of January thermal discomfort is due to cold (Fabrous , 2009).

2.8.4 Design Guidelines for Hot Humid Regions

Dubai is in a region with hot and humid climate. The city has high temperature levels during summer due to its exposure to extreme solar radiation. Vegetation plays an important role in influencing the climate of a region or area. Givoni (1991) has set the standards for design of urban spaces which would be suitable according to the surrounding climatic conditions. Wind and shading have an important role to play in influencing the climate especially in this region which is prone to high humidity levels. The use of plants has been stressed in this study for increasing the thermal comfort of outdoor spaces. The author has suggested thick vegetation in groups which would enable shading; however they should not be placed in such a way that they become an obstruction for air movement and winds. Use of grass is suggested as it has the ability of to absorb less solar radiation. Planting of shrubs help to avoid direct breeze to enter spaces. The basic idea to create maximum shading spots in the outdoor spaces with nice air movement that would help to attain thermal comfort sensation. The role of wind is different in two different climate types. In hot and dry climates wind is not preferred where as in hot and humid climate the wind is preferred hence the design which would allow maximum wind to enter is highly recommended in such regions.

2.9 Design Guidelines and Principles

2.9.1 Form, Geometry and Configuration

Due to high temperature levels and hot winds it was essential for Arabs to develop courtyards in order to get some relief from desert climate. Hence it is quite natural to narrow the street in order o get more shade and restrict the hot winds of desert (Ratti et al , 2003). The environmental performance of a courtyard is always affected by its form, geometry and configuration. There are various shapes and sizes of courtyards which are integrated in the built form such as square, rectangular, circular and polygonal. In the past the rectangular and square shape was mostly applied for courtyards. However the plot size and topography influences to use the different shapes. An example of a circular shape courtyard in the samba village in Africa , Fig 2.7.

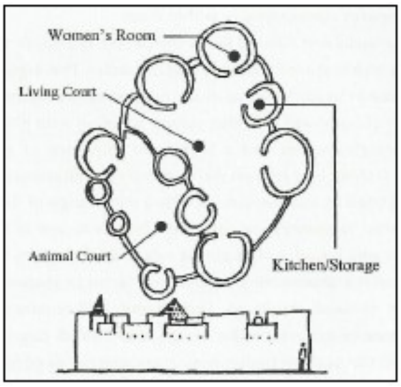


Fig.2.7 Samba Village (Source: Edwards et al. 2006).

The micro climatic properties of courtyard and its influence on the temperature of the surrounding environment varies with different geometrical proportions such as width, length, height, solar shadow index and aspect ratio etc. Study performed in 60,s by Leslie martin and Lionel march about the effect of built form archetypal on environment was reviewed by Ratti, Raydan and Steemers in 2003. A series of urban arrays of two archetypical buildings represented the built form. Old form was represented by courtyard and the modern form was represented by pavilion with the help of finding of the previous study martin and march compared courtyard and pavilion arrays having the same site coverage of 50 percent. 49 pavilions and 25 courtyard forms were analysed having the same height and total floor area, figure 28. Analysis helped us to make understand that both forms can add up to same floor area and interior room depth, however courtyard have similar floor space in the analogous building depth on contrary requiring one third of pavilion height. Figure 29. Fresnel diagram illustrates the notion of square geometry of each point having same area (Ratti et al 2003).

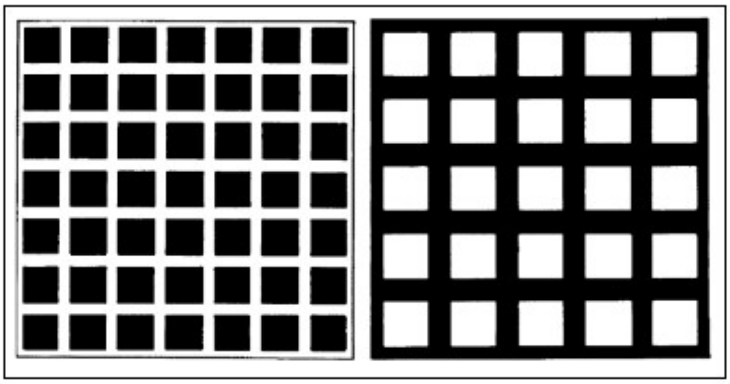


Fig.2.8 Two archetypal urban patterns, based on pavilions and courts (black represents buildings) with the same site coverage, building height, and total floor space (Source: Ratti et al. 2003).

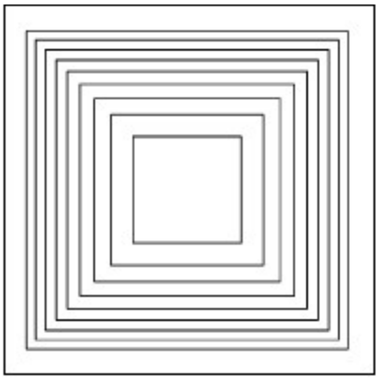


Fig.2.9 Two archetypal urban patterns, based on pavilions and courts (black represents buildings) with the same site coverage, building height, and total floor space (Source: Ratti et al. 2003).

A study was carried out by Muhaisen (2006) to check the effect of different geometrical proportion of a courtyard on courtyard thermal performance, exposure and shading. The study was carried in four different cities Kaula Lumpur, Cairo, Rome and Stockholm. The different climatic conditions of each place show the need for different courtyards geometrical forms in terms of height and width ratio. The proportion parameters are inspected by a ratio of floor perimeter to height which is represented by R1 and width to length corresponding to R2 (2006). The ratio of courtyard floor perimeter (P) to height

(H) which is (P/H) is represented by R1 ratio. This ratio ranges from 1 to 10. On the other hand R2 represents width to length ratio which ranges from 0.1 to 1. The regular wall surface is the interior wall surface area of the courtyard. It has been given very high importance due to its effect on thermal performance compared to ground and external wall surface. In this section of study Muhaisen will measure the best geometric courtyard ratio in hot arid climate of Cairo. It will also explain the amount of solar radiation exposure and shading that would be most preferred to best geometric effect of courtyard performance. As the area of all walls is same the area which receives sunlight and the shade on walls can be taken as percentage of total unit area of walls. When R1 gets to 1 which is the shallowest form the shaded area lessens. The best values of R1for hot dry climate range in summer and winter ranges from four to eight. 4 correspond to deep form where as 8 represent the shallow form. Range from 0.3 to 0.8 represents the best values of R2, figure 2.10.

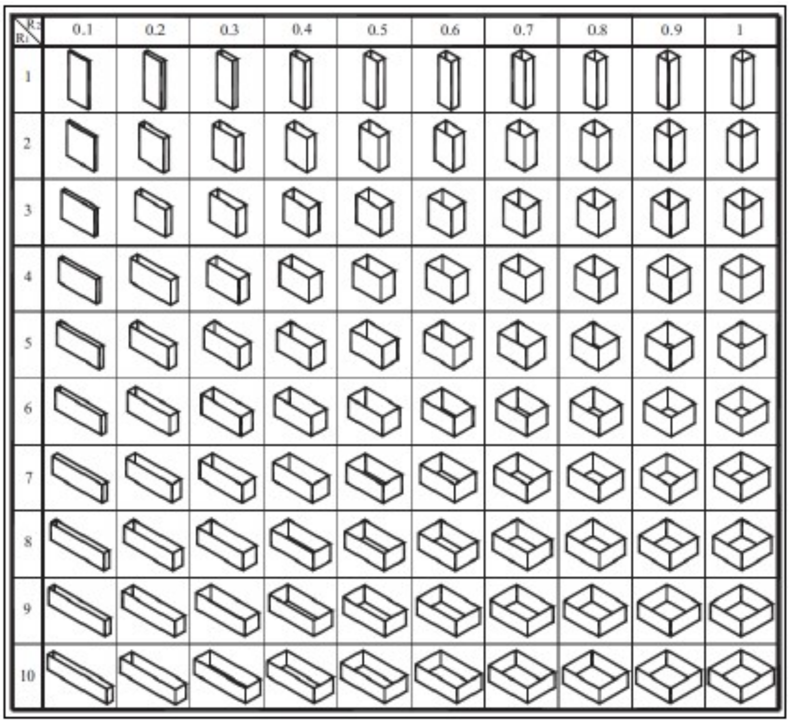


Fig.2.10 Rectangular courtyard forms relation between R1 and R2 ratio (Source: Edwards et al. 2006).

Koch Nielsen has made a figure which shows the preferred width of courtyard which ranges from x to 3x with x as the courtyard height. Figure 2.11 (2002, p57). On the other hand Laffah states that common ratio of width to length are 1:1:8 and 1:3:6 (cited in edwards et al 2006,p.149). According to Reynold (2002) the courtyard should be 25 to 30 % of the built area.

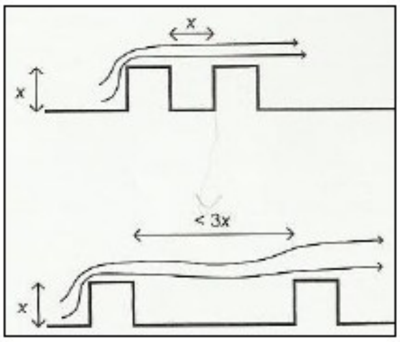


Fig.2.11 Width to height relationship (Source: Koch-Nielsen 2002).

Courtyard exposure has two parametric factors, one is aspect ratio(AR) and the other is Solar Shadow Index (SSI) (Reynolds , 2002, p.16&17). The degree to whcih the surface is exposed to sky is called the aspect ratio. Hence more aspect ratio means more exposure to sky absorbing more solar radiation. The aspect ratio is calculated as shown below (Reynold, 2002):

Aspect Ratio = area of the courtyard floor (m^2)
(Average height of surrounding walls) ^{2}(2.1)

The exposure to sun in winter is called is called solar shadow index. This means that if the SSI is more it will lead to less solar radiation reaching the south wall and floor perimeter. SSI is calculated as shown below (Reynold, 2002):

Solar Shadow Index = South wall height (m)
North-South floor width (m)(2.2)

The series of heat gain throughout the day as a cause of high temperatures and loss of heat at the night time is to be managed by crucial height to width space ratio of the adjacent buildings within a space. According to Johansson (2006) the detachment between buildings which is an open space plays an important role in the inward and outward heat radiation between these buildings. It also influences the wind speed. Inefficient space geometry will have the negative consequences resulting in excessive heat gain and preventing proper air movement within the site.

Thermal comfort level in outdoor spaces is always influenced positively due to more shading. Shading in outdoor spaces has always had a cooling effect in outdoor spaces. Adjacent buildings and tress provide natural shading on surrounding or integrated open space. The height and closeness of the buildings determine the amount of shading in a space helping to minimise the incoming solar radiation. Spaces which aren't covered on all sides attract more solar radiation than the ones which are covered on all sides by tall buildings. Researches which have been done in the past on urban canyons H/W ratios have been very useful for this study as they helped in finding out a proper ratio for outdoor spaces.

According to Toudert and Mayer (2006) close fit narrow canyons with less height to width ratio is more effective for cooling during the peak hours of the day. On the other hand wider canyons with more height to width ratio have less cooling effect due to less shading. It has been proved in many studies that shading has a cooling effect in outdoor spaces. A simulation was conducted for four different ratios to certify the effect of H/W ratio in accordance with the sky view factor SVF as shown in fig 2.12. SVF is the openness of the buildings to the sky. There is an inverse relationship between H/W ratio and the air temperature. Less H/W ratio (0.5 and a SVF of 0.87) results in higher air temperature levels than that of H/W ratio of 4 and SVF of 0.37 with difference of 3 degrees Kelvin. However the most suitable balance in accordance with SVF of 0.54 is the H/W ratio of 2. on the other hand the more the shading provided to a space the dimmer it becomes. Hence it becomes necessary to illuminate that space by consuming more energy for lighting. This is the reason Toudert and Mayer (2006) showed the SVF with the analysis of H/W ratio.

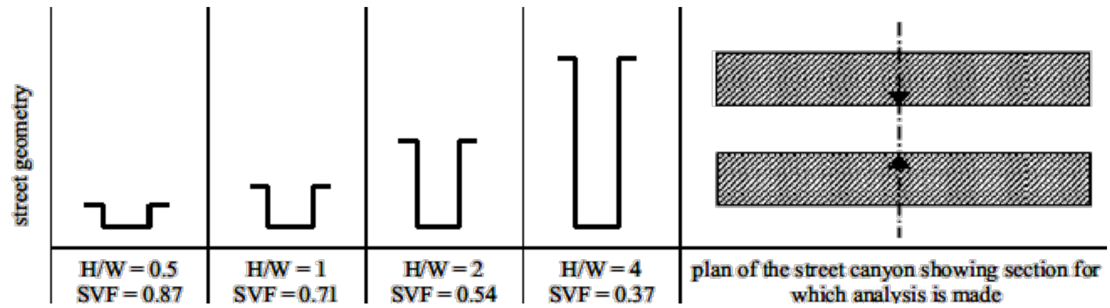


Figure 2.12 Schemes of simulated street canyons.Source: Toudert and Mayer, 2006

Oke (1988) in his research recomended that the ratio between 0.4<H/W> 6.0 can be a good balance between the thermal needs (high ratios) and the pollution needs (low ratios). Arnfeild (1990) said the ratio is appropriate only in cities with maximum cloud coverage. Study conducted by Ahmed revealed that the maximum temperature declined by 4.5K in Dhaka Bangladesh, when the H/W ratio increased from 0.3 to 2.8 .this decline was enough to attain the thermal comfort levels (Etzion et al, 2004). Hoffman and Bar (2003) said adjacent building geometry is a part of space geometry and the plays an important role in influencing the micro climate. Making use of cluster thermal time constant CTTC model they analysed the cooling effect of colonnades in the base of the building. For example in the Mediterranean coastal region the highest cooling effect of collonnades was like 3-5K for H/W ratio of 0.5 and 2 to 3 K for narrower streets having H/W ratio of 3 in day time during the summer.

H/W ratios which have been suggested for summer design cannot be a complete solution for making the environment comfortable in outdoor spaces. These summer designs can be a barrier for solar radiation which would result in extra cooling of those areas during winters. The solar path keeps on changing according to different areas, cities, locations. One should figure the out the problematic areas where excessive solar radiation falls during the day, that part needs to covered by different methods of shading.

Aim of this study is to attain a balanced ratio that will reduce the penetration of solar radiation resulting in less heat gain and would encourage heat loss during the night during the complete year. If a proper design ratio is followed it will help to attain the thermal comfort level in the courtyard spaces and surroundings as well.

2.9.2 Orientation

Orientation of outdoor spaces can be done in such a way which would help to maintain a good air flow thus resulting in cooling effect during the hot summer days. It is important to keep the wind factor in mind before doing the orientation as the excessive wind can cause discomfort in an outdoor space. It is one of most important factors influencing the air temperature in an outdoor space, hence needs further studies along with temperature studies. The exposure to solar radiation is another important factor which is affected by space orientation. Thermal comfort levels can be achieved by shading however solar exposure levels decline on the other side. Orientation of space is much more useful for the distribution of temperature on surfaces and the total solar energy absorbed in a particular time frame and space than on the absorbed quantities. According to Toudert and Mayer (2006) the stress of temperature was high in E-W canyon as compared to N-S orientation resulting in better thermal comfort. In NE-SW and NW-SE orientations the shading coefficient increases thus resulting in achieving better comfort levels with a minimal difference between the two. According to the investigation by Haggag and Elmasry (2011) the SE-NW axis has the ability to catch the cooling breeze and provide shading thus resulting in reduction of thermal loads in buildings.

Two different seasons of the year winter and summer have different temperature levels; hence it becomes necessary to have that kind of orientation which would suit the needs for both seasons. The orientation factor is not that effective when it comes to air temperature deviation as compared to W/H ratio of the space. Orientations which have high solar exposure need deeper spaces (Large H/W ratio) on the other hand orientations which experience very less exposure to solar radiation can have wider spaces (smaller H/W ratios). Figure 2.13 below shows the different orientations examined with same H/W ratio.

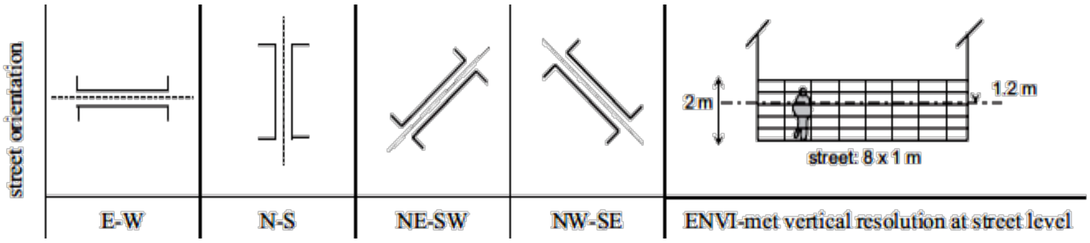


Figure 2.13. Various orientations tested through simulation by standardizing the H/W ratio.Source: Toudert and Mayer, 2006.

Bar and Hoffman submitted the geometry orientation and greenery factors in the CTTC model to improve the thermal comfort level. As per the results of orientation from CTTC model the E-W and N-S orientations have very minimal difference. 83 percent of shading was provided by N-S orientation where as E-W orientation provided less shaded area of 74 percent. Figure 2.14 shows the less difference between the two orientations in accordance with average solar radiation energy on the ground (Bar and Hoffman, 2003).

One of the studies done recently illustrated the influence of orientation on wind flow and air quality rather than shading percentages. It helped to validate the relationship between air quality and wind flow as movement of air helps in preventing air stagnation and reduces pollution blockage. Obviously the quality of air is not good due to presence of pollution which in return results in high temperature. The recommendations of the study are to keep the orientations of the canyon in parallel to wind flow as it would increase the inflow of air in outdoor spaces. Preventing site orientations which cause wind blockage is highly suggested (Minella et al, 2010).

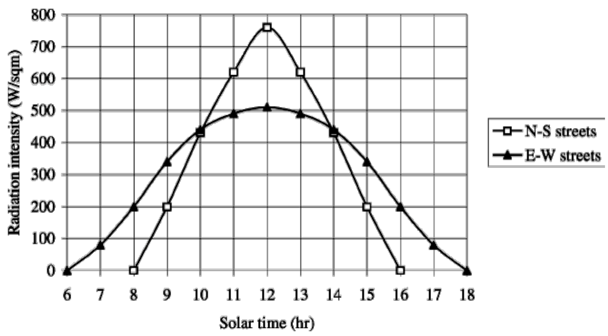


Figure 2.14. Daily variation of the mean solar radiation intensity on the ground in Jerusalem streets on the 21 September. Source: Bar and Hoffman, 2003

Wind factor and shading co efficient are the two factors which should be considered while making the orientation for outdoor spaces in a master plan. Certain criteria should be followed based on difference in seasonal requirements and difference of day and night requirements. Studies in the past have reached a conclusion that the influence of orientation on the air temperature is minimal between 1 to 2 degrees on average. This paper aims to create small effects from different parameters which would add up to make a noticeable change and improvement in the outdoor air temperature.

2.9.3 Vegetation

Vegetation has been one of the most influential parameter for making the micro climate due its many benefits. According to Wilmer's (1988) vegetation has the ability to reduce the air temperature up to 20K. Not only will it reduce the air temperature at that spot but also in the surrounding built environment which is known as background effect (Hoffman and Bar 2000). As per Win et al, (2007) the change in the temperature in the background can be up to 1.3 degree Celsius. This is the reason why the temperature of an area which is nearby to an urban park is cooler than the one which is surrounded by urban buildings. The radius of the cooling effect is different ranging from 100 meters for a small green park to 2kms of an area if the nearby park is really big and area is full of greenery. Thus vegetation cannot be only beneficial for small level but it can used for a wider scale of things.

Vegetation can reduce the temperature in various ways such as planting trees, shrubs, grass etc. All these help in shading which results in less heat absorption by the surface which is shaded. According to Hoffman and Bar (2003) eleven sites of Tel-Aviv urban complex experienced almost 80% of the thermal comfort effect due to the shading provided by trees. During the day time the penetrating solar radiation is stopped by tress and help in shading. In order to test the effects a CTTC model was used which helped in passive cooling of the surroundings.

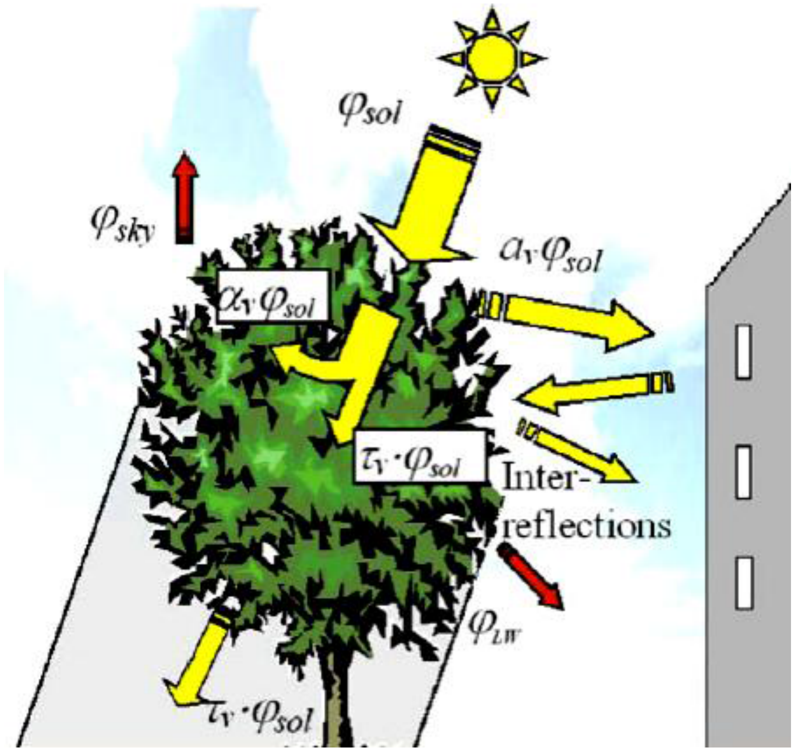


Figure 2.15 Schematic representations of radiative exchanges of a tree.
Source: Hoffman and Bar, 2003

Oke (1989) illustrated the mechanisms of air exchange of lengthy and small wave radiation among the trees and its nearby area which contributes to cooling effect as explained in figure 2.15. The effect of heat gets less due to transpiration and convective heat exchange with the air.

In addition to a water pond effect vegetation also plays a critical role in influencing the micro climate. Both the parameters were tested and the results proved to be beneficial for attaining the thermal comfort. During the test the geometry was kept very simple. Layout orientation was very important for augmenting the cooling effect. Wind was useful in spreading the cooled air within the layout as shown in figure.2.16 (Robitu et al, 2005). Another major factor which plays an important role in influencing the micro climate is the soil characteristics. Green sites are generally cooler due to the inability of its soil to absorb heat as vegetation surfaces absorb very less amount of heat due to many reasons.

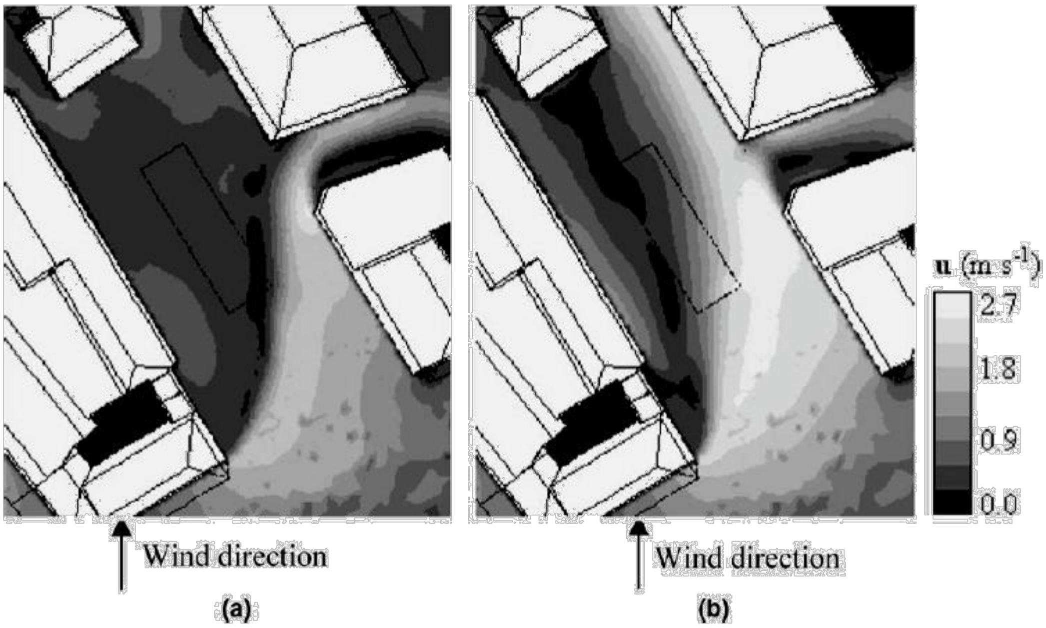


Figure 2.16 Wind speed in an open space in Fleuriot Square where case (a) shows an empty situation and case (b) is with the application of vegetation and water pond.Source: Robitu et al., 2005

The natural composition of trees minimizes their performance to accumulate heat due to evapo-transpiration process (Robitu et al , 2006). Colour and surface of the plants also play crucial role in neutralizing the thermal effect.

Givoni (1991) had conducted a study in the past which illustrated various studies which helped to show the thermal effects of plants in urban areas. The findings of the study were that greenery helps in reducing the energy consumption for artificial cooling as it helps reduce the temperature of the surroundings. According to parker (1989) vegetation and landscaping helped in reducing the cooling loads of buildings by almost 50 percent savings. The electricity loads for cooling came down from 5.56kw to 2.28kw and during the peak time of loading it came down from 8.65kw to 3.67kw. Besides reducing the cooling loads vegetation also helps in reducing pollution, noise pollution, and promotes social gatherings.

Opposite of heat island affect a simple cooling effect due to planting of trees, shrubs and grass in parks and outdoor spaces is known as park cooling island. Almost upto 4K temperature comes down in areas with greenery (Bernatzkey, 1982; oke1989; Hoffman and Bar 2000; Dimoudi and Nikoloupoulou, 2003; Chen and wong, 2006). It has been a great implication depending on various types and distribution of vegetation, micro climate and topographical factors of the site. Vegetation being a passive cooling strategy is dependant on various other elements for influencing the micro climate. Some of the elements are controllable while others are uncontrollable. For instance cooling effect of a group of trees depends on various factors in a space such as amount of grass, stones used, geometry of the space, the orientations and composition of the nearby buildings. All these elements interact with each other and determine the amount of heat gain and loss.

Bar et al (2009) concentrated on water utilization of various mixtures of shades and vegetation in accordance with cooling effect they generate in an urban area. Six different types of combinations of trees, grass and shade were examined which would help in setting up a beneficial guideline of passive design (Table 2.1).

Shading provided through a canopy mesh proved to be inefficient for temperate arid climate regions as compared to shading provided by trees. Also it caused a little surge in heating effect up to 0.9 k.

The air temperature was reduced by grass however it utilized more water unless proper shading was provided. The preferred shading would be from trees.

Grass under the shade of a canopy or trees produce more cooling effect than the shaded area without grass.

Most useful form of vegetation in terms of reducing the cooling loads and less water consumption is planting of trees.

Table 2.1. Six landscape strategies followed.Source: Bar et el. 2009

Overhead treatment	Ground surface	
	Bare soil and concrete pavers	Irrigated Durban grass
Exposed	"Exposed-Bare"	"Exposed-Grass"
Trees	"Trees-Bare"	"Trees-Grass"
Shade mesh	"Mesh-Bare"	"Mesh-Grass"

Combination and proper balance of trees and grass has been the most effective form of vegetation among all in influencing the micro climate by shading and respiration. Figure 2.17 shows various landscape techniques and their efficiency and ability for cooling down the surroundings (Bar et al , 2009).

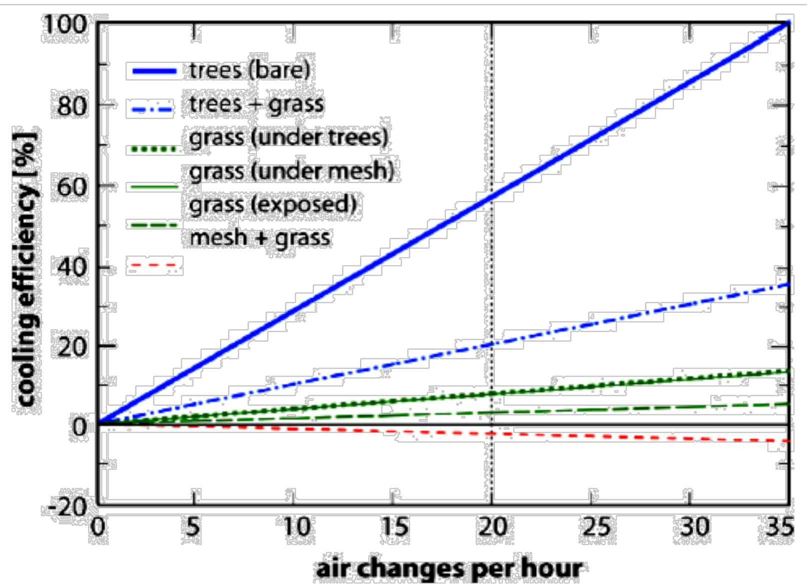


Figure 2.17. The effect of calculated cooling efficiency of various assumed air change rates in the courtyards.Source: Bar et el. 2009

Masmoudi and mazouz (2004) conducted a study which showed the relationship between vegetation and its influence on the micro climate. Almost about 5 degree Celsius change was found on the ground level in various plan forms (Square and rectangular). It is the type of presence of vegetation which influences the micro climate rather than the quantity. Implanting of trees are much more effective in high temperate areas. NE/ SW were found out to be the best orientation of tree lines as it helped to reduce the solar energy absorbed on the ground surface.

The application of greenery needs much more attention as it is not only useful for reducing the thermal effect but it also has other bio climatic advantages. Outsized vegetated areas may influence the thermal climate more than the small green areas however it requires a lot ground area and becomes a costly affair. On the other hand large vegetation lands during the night become much cooler than expected thus affecting the surrounding areas as well. According to wong et al (2007) it is difficult for heavily vegetated areas to dissipate heat at night time due to huge vegetable masses. Another factor which needs to be investigated is the space interval between green parts as it influences the desired air movement and temperature in an outdoor space if distributed properly (Hoffman and Bar, 2000). According to Goergi and dimitriou (2010) in an area of 100 meter square it would be good to have 8 trees with a 5 meter gap between them to attain the desired thermal comfort level all through the year.

Micro climates is influenced by various out comes of vegetation such as shading, reducing surface temperature, cooling due to evaporation (Mc Pherson et al , 1994). The use of urban canopy along with trees can be very significant for influencing the temperature. High shading increases the thermal comfort at day time on the other hand results in decline of long wave radiation loss at the surface causing high temperature at night time. Hwang et al (2010) state that a fine balance is required to be achieved between less solar radiation during the hot summer and maximising it in winter that would help in heat gain during cold days. Grass surfaces help in cooling effect but a proper design ratio between trees and grass surface to be used will be recommended.

2.10 Summary of variables

The various parameters which have been studied have been successful in improving the air temperature. The findings have showed that vegetation has the most profound effect on temperature and then followed by geometry of space and orientation of the design. Trees have proved to more effective than grass in influencing the micro climate of a place. The composition of plants and shading provided by them enhances the cooling effect on a large scale as compared to just having grass on surface. The South East and North West orientations have proved to be mores influential orientations in terms of reducing the thermal effect in UAE. Shading and allowance of air movement in these orientations are much more effective for cooling effect than other orientations. The geometry with higher ratios has proved to be more effective than the low ratios. Not many studies have revealed the combined effect of these three variables (vegetation, geometry and orientation) together. However separately they have been studied and all have proved to be beneficial for reducing the thermal stress.

Passive design strategies need further studies to make it a complete success. The specifications of the design need to be figured properly. Tight spaces can help in increasing the thermal comfort during summers however the same thing results in extreme cooling during the winters. Similarly very concentrated vegetation helps in cooling but at the same time act as barrier to wind. H/W ratio is inversely proportional to SVF thus resulting in less solar exposure and more use of energy for artificial lighting of that place. Hence it is important to strike a right balance in passive design strategies for both summer and winter season. This would help in reducing heat stress and at the same time allows desired sunlight and winds to enter the space.

2.11 Environmental dimensions

2.11.1 Solar radiation, Daylight and Shading analysis.

Proportions of courtyard and its exposure to solar radiation, natural daylight, vegetation within it play a crucial role in micro climate. Various factors such as latitude, altitude of the sun, presence of clouds, orientation of the structure towards the sun and aspect ratio play a major role in determining the amount of solar radiation falling on the exposed surface of courtyard. Higher the altitude of the sun , more is the intensity of solar radiation. The amount of heat transmitted depends on the coverage of clouds. As there aren't clouds in Dubai so the heat is in long wave radiation form. The amount of heat transmitted in the buildings is dependant on various forms of solar radiation such as direct solar radiation, diffused solar radiation and reflected solar radiation. The thermal comfort of the building is directly affected by the type of solar radiation. In accordance with the study of Muhaisen he has found out different effects of solar radiation and shade on circular, polygonal and rectangle shaped courtyard geometrical forms with the help of IES computer simulation program. Muhaisen (2006) has mainly focused on traditional forms of courtyards which are rectangular in shape with the help of two ratios he tested exposure and shading in 4 different climatic conditions which would help to show the maximum sunlit area during winters and the shading on walls during summers. The ratios are R1 which ranges from 1 to 10 and R2 which ranges from 0.1 to 1 as shown below (Muhaisen,2006).

R1 = floor area (m_2)
height (m) (2.3)
R2 = width (m)
length (m) (2.4)

The study helped in showing the effect of height on the performance of shading. To examine the effect of height a reference model was chosen with R2 of0.5 and the height of building as 3meters. The test was conducted using various heights ranging from one storey to fifth storey in summer and winter respectively figures 2.18.

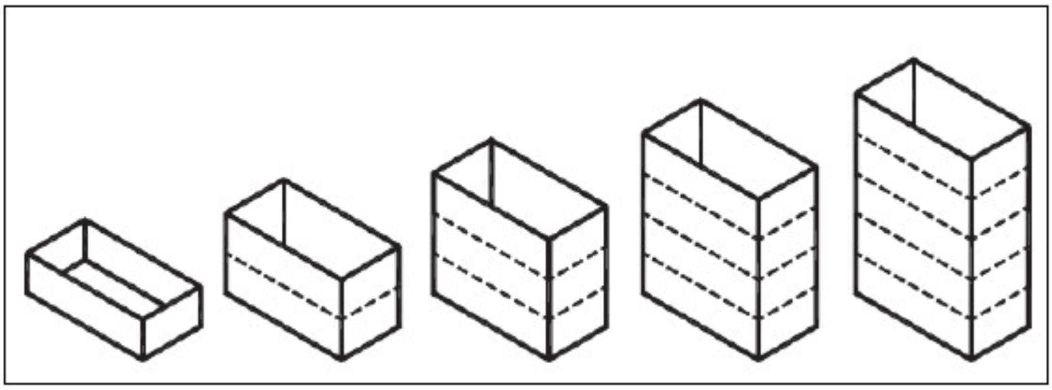


Fig.2.18. Investigated heights of the courtyards building (Source: Muhaisen 2006).

Results have showed that as the number of stories increase the shaded area also increases. As there is an increase in sun altitude the shaded area decreases. As shown in table 2.2 in Cairo the average rate at which the shadow increases with increase in height in summer is 2.5 percent and inn winter -7.5 percent. He also explainns the best the desired performance of a courtyard with regards to shade and exposure both in summer and winter season can be attained by having two storey height, table 2.3. the surface areas of walls being equal, sunlit and shaded area on the walls are considered as percentage of the total area of the walls. There is a decline in the percentage of shading when R1 increases from 1 to5. The most preferred range for the ratio of R1 is between 4 and 8 for the entire year whereas R2 ratio ranges between 0.3 and 0.8. The transformation of a higher courtyard to a deeper courtyard provides more shade. This is the reason deep courtyard forms have very less solar gain and provide more shadow in summer resulting in efficient cooling effect.

According to Muhaisen (2006) courtyards can play a major role in influencing the climate if it is proportioned properly so that there is adequate shading during the summer for the cooling effect and solar radiation during the winters to increase the heating effect.

Table 2.2 Average rate of increasing the shaded area and decreasing the exposed area due toincreasing height by one storey (Source: Muhaisen 2006)

Kuala Lumpur		Cairo		Rome		Stockholm	
Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
4.3%	−6%	2.5%	−7.5%	3.4%	−6.6%	6.3%	−1.3%

Table 2.3 Reduction percentage in the maximum achievable shaded and sunlit area(Source:Muhaisen 2006)

Building height	Kuala Lumpur		Cairo		Rome		Stockholm	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
One storey	17	0	10	0	14	0	25	0
Two-storey	14	5	8	14	11	16	19	3
Three-storey	10	11	6	23	7	22	13	4
Four-storey	6	18	3	27	4	25	6	5
Five-storey	0	24	0	30	0	26	0	5

One more study was reviewed by Meir et al (1995) which analysed the internal shading in summer for two courtyards in hot arid climate. The shape of the courtyards is same and other factors were also kept similar for both of them except the orientation. The two orientations were south and west figure 2.19. 3.8 was taken as the ratio for length to width, where as height to width ratio was kept in between 0.47 to 0.56.

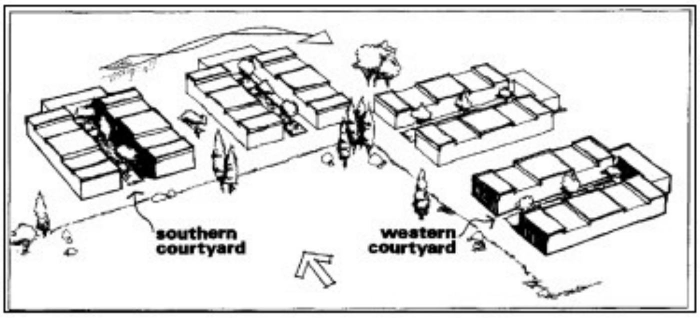


Fig.2.19. General layout of the monitored courtyards' area (Source: Meir et al. 1995).

It was found out that the courtyard facing towards the south direction received less solar radiation during mornings and afternoons as compared to the one facing towards the west. Figure 2.21 and 2.22. Trapping the solar radiation and inefficient air movement in the courtyards resulted in increasing the thermal effect irrespective of the orientation.

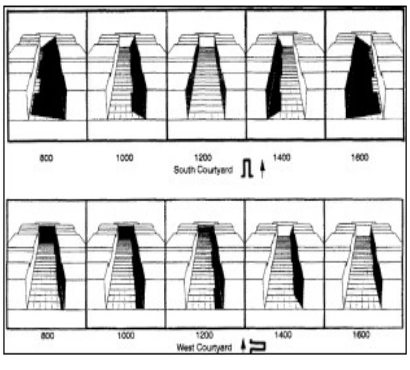


Fig.2.21Internal shading of surfaces in courtyard of different orientation in August (Source: Meir et al. 1995).

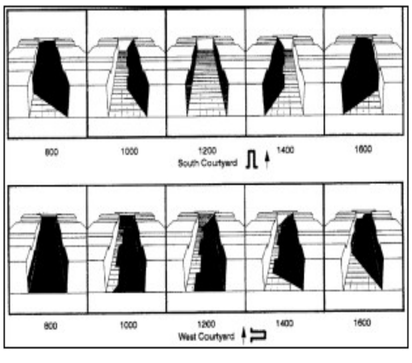


Fig. 2.22. Internal shading of surfaces in courtyard of different orientation in December (Source: Meir et al. 1995).

Study on three urban forms by Ratti , Raydan and Steemers (2003) which comprise of courtyard, pavillion1 and pavilion 2 in the temperate climate of Marrakesh. Amusing results of the building forms were found out with regards to shadow concentration and distribution of day light. The results for shadow concentration were found to be highest in the courtyard. Where as it means low daylight due to high percentage of shadow so the courtyard was found out to be having less percentage (15%) of daylight distribution. If courtyard was taken alone into consideration it was found that it had 19 percent of day light distribution as compared to 10% on the street.

Another study conducted by Thappar and Yannas (2008) on the urban forms and their effect on the micro climate at various locations in Dubai. The study examined the urban built forms in areas like diera , bastakia and dubai marina in July 2007. There were three different types of courtyards in the study, one was low rise courtyard, second was a mid rise courtyard and third one was courtyard accompanied by high rise building strictures. On site measurements were taken and these were supported and validated by software simulations. The various parameters which were examined were the presence of water bodies, vegetation available and the built form structures and their performance. All these augmented in order to influence the thermal comfort of the urban space.

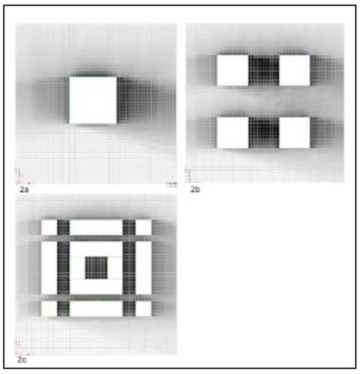


Fig.2.23 shadow cast on the ground increases for a constant built volume (of 57,120m3) as a function of build form from (a) a 63.5m high tower, (b) 35.7m high blocks, (c) 21m courtyard blocks (Thapar et al. 2008)

Each different form has a different effect of shade for the built structures. Figure 2.23 shows that a well shaded area is provided by concentrated development of a courtyard block. The built form plays a role in casting the amount of shadow such as high rise towers have the lowest shadow cast whereas concentrated courtyard has the highest shadow cast.

After the careful examination of the case studies it is found out that the projection of sunlight in hot arid climates should towards the south longitudinal elevation which would help to absorb large amount of heat in winter and very less in summers hence helping to keep the environment warm in winter. Heat gain is prevented by shading hence improving the thermal comfort. An introverted courtyard has always less area exposed to direct sunlight thus has more shaded area. However it should be complimented by proper geometry to have enough shade and daylight. Courtyards which are thin and deep with an orientation towards East-West direction and streched out in the north south direction are very effective in hot arid climate. They help to impart shade from low angle sun in the morning and then in the afternoons.

A ratio between daylight in the interior as compared to exterior at the same time is called the daylight factor. Daylight brings heat with it naturally. This is the reason low daylight is very beneficial for hot arid climate regions. In order to have deeper daylight penetration the size of the windows should be large enough in relation to the floor space. If the distance between end of a courtyard and window is 2.5 times the height of an opening it results in lesser amount of daylight which arouses the need for artificial lighting. Figure 2.24 illustrates the detachment in the interiors which is 2.5 times that height of opening resulting in low daylight.

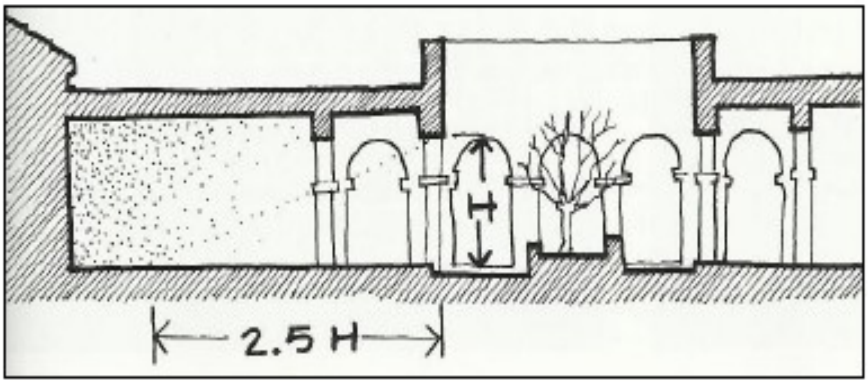


Fig.2.24.1f Daylight penetration from window in relation of window height to the floor area(Source: Reynold 2002).

In order to make available a healthy visual environment the Illuminating Engineering Society of North America (IESNA) made a lighting handbook which had codes and standards for lighting of indoor spaces. To control the daylight leads to control the distribution of light, quantity of light and absorbed heat gain. Visibility of the occupant, comfort, task visibility is all affected due to presence of glare. Depending on the activities of the occupants light designs can be of various types. Similarly glare is also of two types such direct or reflected. In a living room as there are range of activities performed from relaxation, simple to medium tasks etc, natural daylight should be normal lighting for performing these various activities. According to IESNA lighting between 200 to 300 lux should be provided for an area which is occupied for various moderate activities such as relaxing, dinning, reading, entertainment etc (Rea M.S., 2002). Courtyard can act as a barrier to sunlight penetration and glare due to its colour of surface. It has the ability to allow, absorb light and light surface colour which would reflect the light on walls and ceilings producing a glare. In order to reduce the glare in the interior surfaces the surfaces around the windows should arbitrate between the high illuminated window and the dark surface.

2.11.2 Airflow and Ventilation analysis

The direction and movement of air flow in the built form influences the thermal comfort, heat loss and heat gain. The presence of courtyard built form in the hot arid climate regions is very effective for the cooling. One of the benefits of courtyard is that cold breeze is always available no matter in which direction the wind flows. Air density of the exposed area is different than the shaded portion which results in air movement from internal courtyard to external space and also from internal courtyard to internal space of the built form.

There are two types of air flow movements one is cross ventilation and the second one is stack effect. The first one is due to pressure difference of air movement from openings across the space. Stack effect is due to temperature difference where hot air rises up towards the opening and cold air settles down at the bottom. At day time due to high solar radiation courtyard warms up very fast thus resulting in a stack effect due to temperature difference. However this is only possible when the outside temperatures are cooler than interiors with a difference of 1.7 degree Celsius (Kwok and Grondzik 2007,p 145). One more way to increase the stack effect is to raise the height of courtyard and increasing space between low and high ventilation openings. According to Koch-Nielsen (2002 p.126) it is recommended that the openings are at different heights and inlet and outlet area should not be less then 3 to 5% of the floor area. There can be an increase in the cross ventilation due to large opening leeward surface and minute opening on the windward surface. If the courtyard is oriented 45 degree from the existing wind it would to an increase in wind and cross ventilation in the courtyard.

Eddy zones created by orientation and built form configuration inluence the movement of air, figure2.25. The percentage of wind speed in courtyard is influenced by the size of courtyard and opening places within it. Figure 2.26 demonstrates that broad courtyards have very high wind speed which can increase further if the length of the courtyard is also increased. Narrow and tall courtyards result in sheltering of winds.

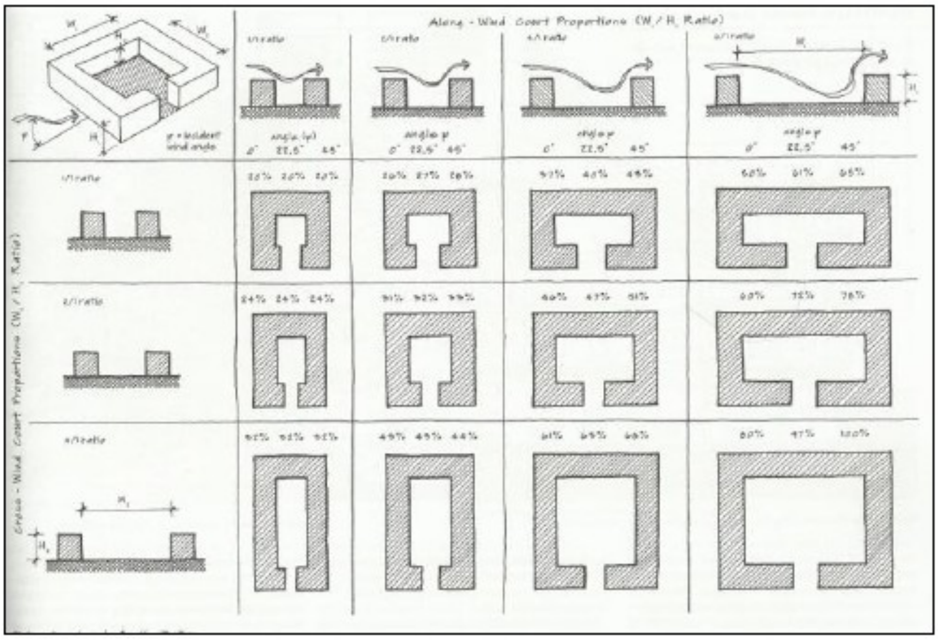


Fig. 2.25 Configuration and orientation effect (Brown 1985).

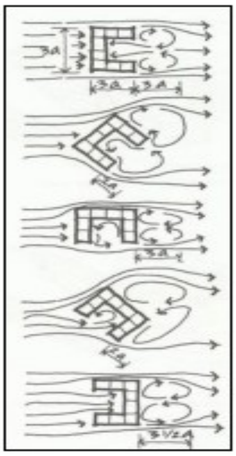


Fig. 2.26 Sizing courtyard for ventilation (Brown 1985).

One of the ways stated by Giovani for wind catching is to increase the height of downwind courtyard wall (cited in Reynold 2002, p90). As the wind comes from lower roof and courtyard opening it will hit against the high wall resulting in wind move over which will create a down draft.

A study was conducted by Sharples and Bensalem (2001) for comparing the air flow rates in courtyard buildings and atrium. Six different pressure systems were tested by a wind tunnel study, Figure 2.27. Six cases were:

1 Open courtyard with positive pressure
2 No openings on an atrium pitch roof causing positive pressure
3 Small openings in the leeward side on an atrium pitch roof resulting in negative suction pressure.
4 Large openings in the leeward side on an atrium pitch roof causing negative suction pressure.
5 Small openings in the wind ward side on atrium pitch roof causing positive pressure.
6 Openings on both leeward and wind ward side on an atrium pitch roof causing both negative and positive pressure.

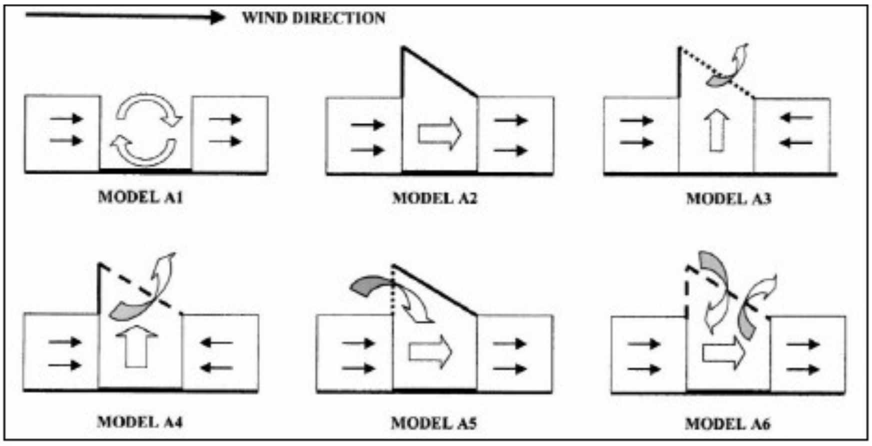


Fig.2.27 Courtyard and atrium roof ventilation strategies used in the study (Sharples et al. 2001).

It was concluded that there is weak ventilation performance in open courtyards where as the best performance of ventilation was when openings of the roof are set perpendicular to the wind facing negative suction pressure system. One more way of having the best ventilation performance is to place the building 45 degree perpendicular to the wind which results in similar effect for all model types. Al Hemiddi and Al Saud (2001) conducted an experiment to check the cross ventilation effect on the thermal performance of the courtyards in Saudi Arabia , figure 2.28.

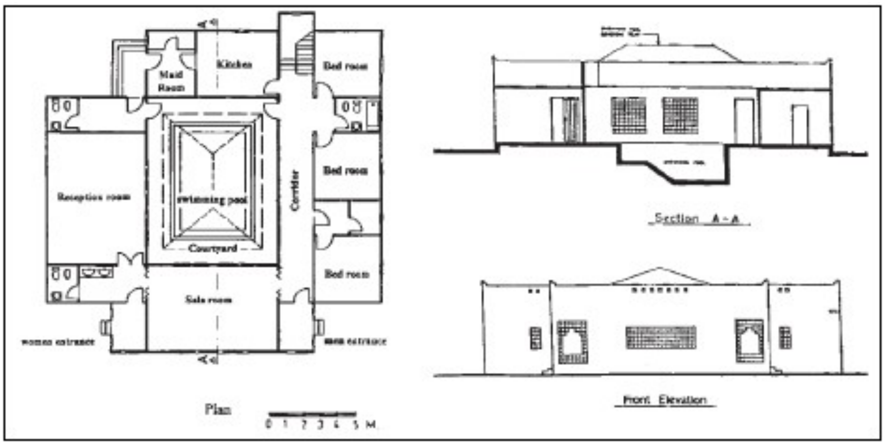


Fig.2.28 Plan and section of the courtyard house in Saudi Arabia (Al-Hemiddi et al. 2001).

There were six phases of experiment as shown below:

1. Courtyard without ventilation
2. Only inner windows facing the courtyard are open
3. Only extroverted windows are open during the night hours
4. Both outer and inner windows are open
5. Both inner and outer windows are open but the courtyard remains closed during the day.
6. Both inner and outer windows are open but the courtyard remains closed during the night.

The findings of the experiment showed that the inner temperature of the courtyards remains cooler than the external temperature thus showing that cross ventilation helps in cooling the internal spaces. Also it was found out that the fifth phase was the best among others as it had maximum time interval for maximum temperatures figure 2.29.

One more study was conducted to examine the passive cooling effect of the courtyard by natural ventilation to minimise the interior over heating. Rajapaksha et al (2003) conducted this study on a single storey building with high mass in a war humid climate. Courtyard was integrated in the building and air flow movement was controlled between the courtyard and its openings. The pattern of the air movement in the interiors influenced the heat exchange between the indoor air and building heating mass. Computer Fluid Dynamics Analysis (CFD) was being used for this study. As shown in figure 2.30 two cases were taken in study, one was where the ventilation of the building takes place through the courtyard only and on all other openings were closed during the daytime. In another case openings were kept open during the day time. It was found out that the courtyard acts as a funnel through which the indoor air flows to the sky through the openings in the envelope. It helps to influence interior thermal conditions.

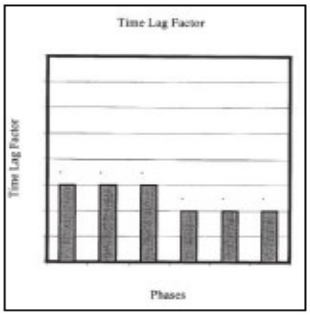


Fig. 2.29. Fifth phase is the best for its largest time lag for maximum temperatures (Al-Hemiddi et al. 2001).

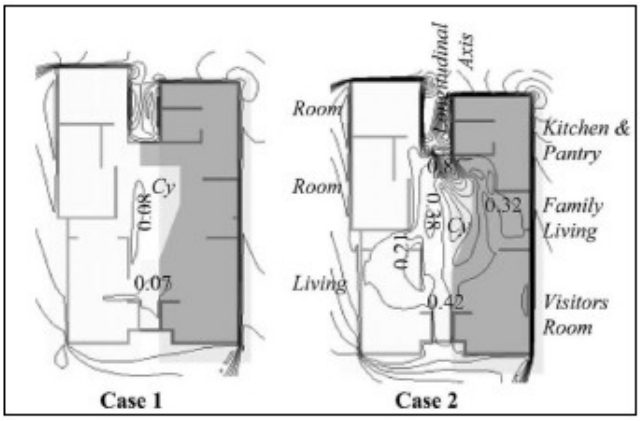


Fig. 2.30 Simulated airflow patterns at human body height 1.1m (Rajapaksha et al.2002).

Going back to the study by Thapar and Yannas on the different urban structures and their influence on micro climate in dubai. In July 2007-2008 they examined the effect of air movement in three different areas Bastakia (low rise buildings), Diera (mid rise buildings) and Dubai marina (high rise buildings). Among all these the courtyard forms in Bastakia were compact. In this study Envi-met software was being used which helped in simulation of these forms as fixed built volume to check air temperature and air flow. The results in figure 2.31 shows that coolest airflow is in courtyard block with courtyard being the coolest area. None the less wind speed was very low in this form and east and west sides were comparatively hot. One of the reasons for this effect could be the shading effect of courtyard form. It was found out the humidity levels were reduced due to courtyards.

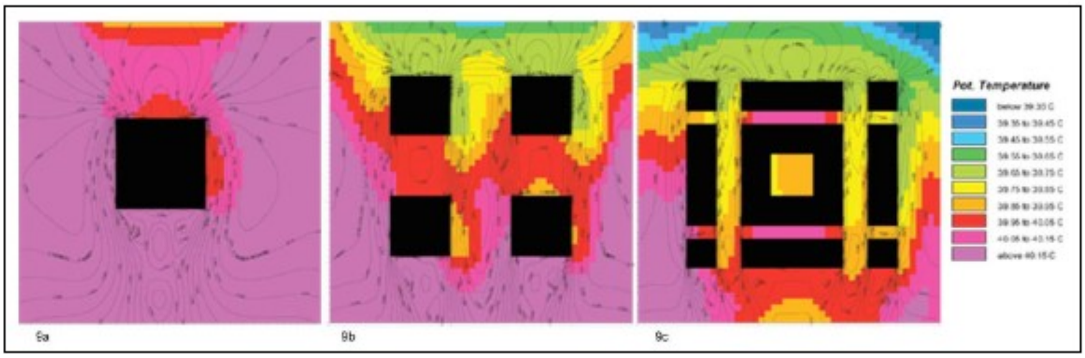


Fig. 2.31 Envi-met predictions of air temperatures for 2.00pm on a July day around a constant built volume (of 57,120 m3) on a 100x100m site as (a) a 63.5m high tower, (b) 35.7m high blocks, (c) 21m courtyard blocks (Thapar et al. 2008).

With regards to natural ventilation and cooling the ventilations needs to be controlled that could be achieved by allowing direct air movement over the temperate surfaces. Openings for ventilation should be placed at different locations and heights and also should be of varied sizes. This would help in stack effect and also in suction effect. Mechanical ventilation is necessary in hot arid regions as it prevents excessive heat gain. Both natural and mechanical ventilation systems can be used in combination where natural would help in winter season and mechanical would help to remove excess heat gain in hot temperate summer time. Mechanical ventilation can be influential in reducing thermal stress in the internal space and doesn't get affected by lighting systems or strategies.

2.11.3. Thermal Analysis

Integration of a courtyard in a built form helps to mediate the thermal conditions between internal and external spaces. Some of the external factors such solar radiation, heat gain and release within the building is responded by the building envelope. Many strategies which are effective such as ventilation, air movement, amount of daylight penetration, orientation, configuration of built form, surface area to volume ratio, material used and interval spaces in vegetation come into play to attain thermal comfort in a courtyard. All these factors have a major role to play in influencing the thermal conditions in the internal spaces within a courtyard.

Traditionally known intermediate spaces called Liwan prevent the inward facing walls from straight solar radiation and excessive heat gain. One of ways to reduce the heat gain would be find an effective balance of surface exposure to solar radiation and shadow. Natural ventilation has a role to play in heat gain and loss, however more the ventilation less will be the heat gain thus resulting in thermal comfort.

The ability of the building to gain or loose heat is mostly dependant on the building volume and the surface area exposed. It is the ratio between these two factors building volume and surface area which determines the heat loss and gain of a building. This ratio can be achieved by dividing total building surface area with its volume. Higher ratio reveals large amount of heat gain during high temperature time and large amount of heat loss during low temperature time. Ventilation and day light surge up if this ratio is high (Raydan et al, cited in Edwards et al, 2006 p141).

In hot arid regions like Bahrain the building mass cools down during the night hours due to heat radiation. Thermal mass affects the air temperature slowly whether it is heating up or cooling down. High thermal mass causes an increase in temperature with time interval between internal and external temperatures. If the thermal mass of East West facing walls of a courtyard space is increased it would result in reduction of heat gain and variance in temperature will have a balance.

The thermal properties of the materials used in built form have a role to play in thermal comfort. Different properties of materials in terms of heat absorbance, reflectance and ability to emit back the heat influence the thermal comfort. For instance material which is highly reflective will reduce the heat gain; where as material with high emissivity will help in heat loss during the night hours. Experiment was conducted by Aldawoud (2008) to examine the performance of courtyard buildings. Several factors were taken into account during the analysis such as climate, height range from 1 to 10 storeys and different glazing types. Test was performed on a courtyard and its nearby zones, figure 2.32.

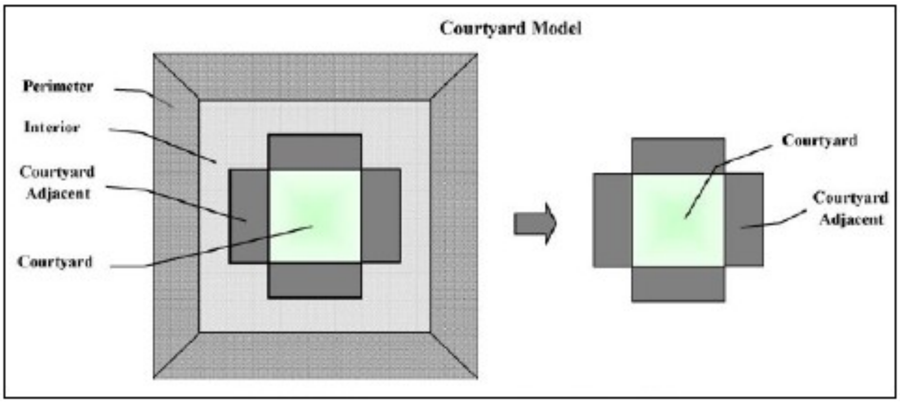


Fig.2.32 Excluded common components for both models (Source: Aldawoud 2008).

It was found out that the integration of courtyard in the building in difeerent climates is always beneficial for the thermal comfort and helps in reduction of energy consumption. Mostly it was beneficial for hot arid regions where thermal stress was reduced due to courtyards and the dependence on mechanical cooling and lighting was minimised thus helping to reduce energy consumption. Materials used for the built form and the glazing type also play their role in affecting the thermal comfort and performance of a courtyard. As shown in table 2.4 there is a decline in the use of energy for artificial cooling and lighting for attaining thermal comfort. It was found out that the courtyard is most effective in low and mid rise buildings to attain the thermal comfort.

Table 2.4 Courtyard thermal performance compared with thermal performance of courtyard having single clear glass with 67% glazing at 10 floors in hot-humid climate (Source: Aldawoud 2008)

Courtyard type	Energy consumption	Reduction in energy consumption (%)
Courtyard/single clear glass	1367.271	
Courtyard/double clear glass	1086.624	−21
Courtyard/double low-e	1018.27	−26
Courtyard/triple glass	971.298	−29

A study was conducted by Sadafi et al (2008) which showed the effect of courtyard on the thermal conditions of the nearby zones in tropical climate of Malaysia. House considered for study was having two storeys. Computer simulations were done using the ecotect analysis. The material input used in the house was from ecotect library. The examination for the thermal performance was conducted in the months of March, June and December. In first case the house considered for analysis was without a courtyard (Mode A) and the second case was a house having a courtyard (Mode B) with dimensions of (2.2 x 2.5 m) integrated in it. figure no 2.33 and 2.34 show the variance in temperature in two cases in June and December.

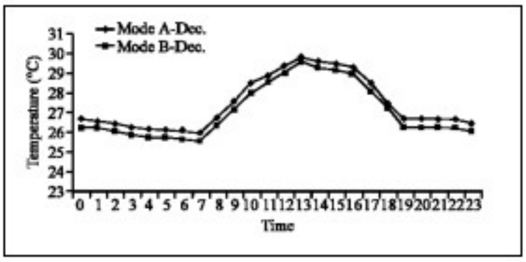


Fig.2.33 Temperature difference between mode A and B for living are in June (Source: Sadafi N. et al. 2008).

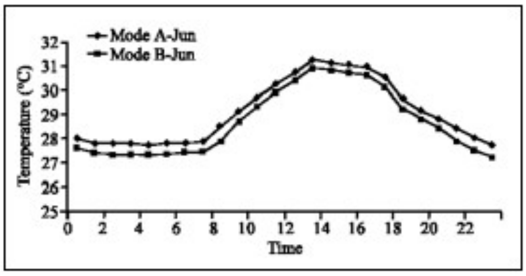


Fig.2.34. Temperature difference between mode A and B for living are in June (Source: Sadafi N. et al. 2008).

It was found out that the thermal stress in the living room reduced in both the months. Dinning area will receive more solar radiation thus resulting in increase in thermal conditions as it doesn't have enough openings to release that heat gain. Results of the study show that courtyard influences the thermal conditions in a positive way and helps to attain the thermal comfort by ventilation and internal heat loss through the windows. It is recommended to have openings on both interiors and exteriors to achieve the best results for thermal conditions.

2.12 Limitations

2.12.1 Limitations of Materials

In an open space the availability of sunlight is enough however it is crucial to check the drawbacks of the same. There is straight contact of sunlight with exposed surfaces of the open space which will result in heat gain by various materials and the same will release the heat in the environment. Hence it is very essential to consider the role of materials. According to Oke et al (1991) the materials present in the urban structure are mostly responsible for heat island effect. These days a lot of materials are available which have different characteristics resulting in heat gain and heat release depending on their emissivity and heat capacity factor. The capability of the material to gain and release heat in the surrounding environment is called the heat capacity of the material. Materials which have a high heat capacity store more heat thus making the surroundings warm. This is suitable in cold regions. On the other hand some materials have low heat capacity and are reflective in nature which results in cooling of the surroundings. This is suitable for hot regions. However there is lack of tools which would measure the suitability and efficiency of the materials resulting in barring of material effect on air temperature.

2.12.2 An Optimum Design Method

One of the most challenging issues which researchers are facing and which hasnt been covered thoroughly in research is to attain the optimum design standard for outdoor thermal environment. One of the major reasons for this is the number of uncontrollable factors and parameters in the outdoor environment and lack of tools for conducting the study in outdoor spaces. According to chen et al (2006) experimenting with the huge number of outdoor parameters in one or two studies is impossible yet are very crucial in field of design. In order to find a desired thermal outdoor environment various studies have been conducted on vegetation, geometry, orientation, and openings and their effect on outdoor environment. all these studies add up to a one common goal which is to have a thermal comfort level within the environment.

According to Chen et al (2006) there was a possibility to achive the desired thermal comfort level in the outdoor environment with the help of an investigation. There were still many factors lacking in the investigation process which could be really useful to form an optimum design standard. Numerical method which used sequential process was being implemented to achieve the desired optimum criterion in different climatic conditions and for this study as well. There were three stages for this research, first stage focuses on the problems of all parameters and the strategy to be used for evaluating and solving them. In the second stage observation of various outdoor parameters such as wind distribution, air temperature, humidity and average radiant temperature were found out. In the third stage combines the previous two stages to find a desired optimum standard. Different methods have been used in this process such as Monte Carlo method, CFD and Genetic Algorithims.

Genetic Algorithim method helped to find out the optimum design method by comparing two inquiries and among the two that would fit more was considered as the optimum design. In order to attain pleasant thermal outdoor environment the optimum array of trees and buildings have gone through the Genetic Algorithm method. The demonstration conducted helps us to attain this goal. The standard size of the buildings were (20x20x30meter)(L x W x H) and the date and time for the demonstration were July 23rd at 15:00h. The results that were found out showed that the building height, orientation and geometry had an impact on the surrounding thermal environment showcasing the orientation factor which influences the thermal comfort. As the arrangement of trees and rotation of buildings is being considered in the test matrix the wind speed will increase if it is allowed to pass through them. The method opted for the study in order to achieve the desired goal is more important than just proving a hypothesis right under analysis.

2.13 Research Niche

Various parameters of outdoor environment have been analysed in this current study and the reason for this was to understand the environment and its behaviour very closely and also to over come problems faced by people due to environmental factors. Many studies have been reviewed to check the various parameters and their effect on the micro climate. However all these parameters have been analysed separately where as no one has done a study measuring the combined effect of these parameters together. Different parameters such as geometry, orientation, vegetation have been found out to have a positive influence on the thermal conditions thus helping to attain the comfort level. This is to be noted that all these parameters have been studied and conducted separately. One still wonders that if all these parameters are incorporated at a single place the amount of effect will be really significant. Lot of controllable and uncontrollable factors come into play in outdoor environment. It is the interaction of these different parameters which influence the micro climate. An open space is comprised of all these three parameters geometry, orientation and vegetation whether they are present spontaneously or designed passively.

According to all the studies all these parameters help in reducing the thermal stress of the environment passively, however the question arises that if all these parameters are put together in one space how would they react. This is not still very clear and needs for analysis by the researchers. In this current study the criteria was to combine all the parameters which lead to the cooling effect and then check the total improvement in the micro climate due to these parameters. This would help in understanding the system and phenomena of the environment and necessary passive design requirements for influencing the micro climate.

2.14 Summary of Findings

The literature review which was presented in this study shows clearly the problem and its characteristics. Knowing the benefits of open spaces for influencing the microclimate over the years it motivated the researchers for further study of it to make better use of these spaces. The main of this study is to figure out the guideline for passive design which would be beneficial for influencing the micro climate of outdoor spaces. The study has analysed various parameters for achieving thermal comfort in outdoor spaces. There are a number ways to analyse these parameters however a particular method has been selected that would help to give the optimum results as described in the literature review. Research examination has been conducted for the most influential parameters which is vegetation as it helps to reduce the thermal stress more than any other parameter. Others parameters which play an important role in influencing the micro climate are space geometry and orientation and these are studied along with vegetation in this study.

Outdoor spaces and their importance for influencing the climate and several others reasons have been reviewed in this study. Achieving thermal comfort in outdoor spaces in this location is quite challenging and difficult as the climate of this place is very hot and humid. Especially during the summer techniques and tools have to be used with very high precision to achieve the goal of thermal comfort. The passive design strategies implemented for achieving the cooling effect during long summers in Dubai always have a vulnerable effect in winters as they result in excessive cooling during winters. In the up coming chapters these ideas and knowledge will be applied. A complete set of passive deign parameters will be shown which will help to develop a set of guidelines for environment in the last section.

CHAPTER 3: METHODOLOGY

3.1 Background

Passive design approaches have gained less credit as compared to active systems cause of being an ancient approach. The current architectural development fails to deliver comfort the warm climate. This current study is based on the research outcomes and suggestions for analysis of environmental performance in courtyards. This chapter defines the outcome of various variables and parameters on which the study investigation is based on, and few methodologies which were used in alike research topics to define the most appropriate methodology which can be used in this study.

This current study will observe the functioning of enclosed courtyard housing in Dubai's hot arid climate with regard to the assessment criteria and variable parameters. The various assessment criteria`` for the current study that will measure the parameters are natural daylight, shading, wind speed and temperature and the parameters are the geometry, orientation, and vegetation as shown in Table 3.1. Fixed variables permit the investigation of the result of the independent variables so that the outcome of the dependent variables can be observed. The method of this study compares the existing courtyard house to an enhanced courtyard form by applying passive techniques, Figure 3.1. The existing courtyard form will be referred to as existing scenario, and the enhanced courtyard will be referred to as enhanced scenario.

Table 3.1 The parameters in relation to the assessment criteria.

Independent Variable/Parameter / Assessment Criteria	Geometry	Orientation	Vegetation
Temperature	**x**	**x**	**x**
Wind speed	**x**	**x**	**x**
Natural Daylight	**x**	**x**	**x**
Shading Analysis	**x**	**x**	**x**

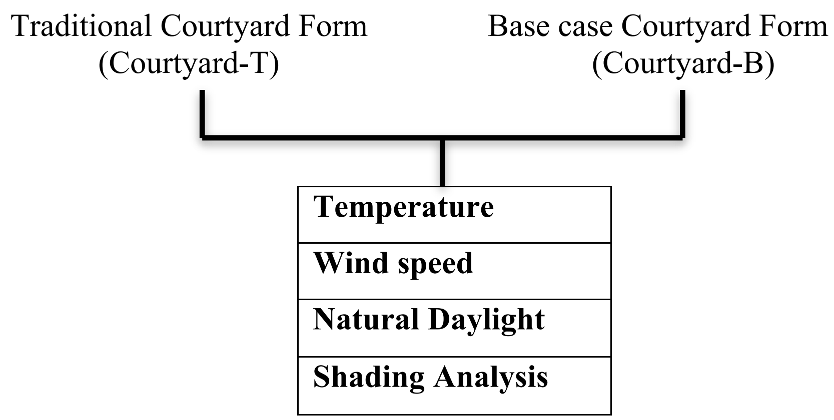


Fig.3.1 Comparison between the existing courtyard form and enhanced courtyard form. Source (Author)

The selected variables will be evaluated in both of the courtyard forms: existing form and enhanced form. The assessment will be done on an outdoor space: the courtyard and indoor space: the rooms around courtyard. To report the outcome of the independent variables on the indoor space, natural daylight will be assessed. Nevertheless, to report the outcome of the variables on the courtyard form environmental performance, temperature, wind speed and shading will be assessed. The assessment will take place on distinctive timing and season for every orientation.

The study steps are as follows:

- Firstly, investigate the fixed variables for the existing form to compare it with enhanced form to achieve ideal environmental performance and examine the suitability of having that kind of courtyard form within the hot arid climate of Dubai.

- Secondly, create a enhanced courtyard form by using varying parameters and assessing their outcomes.

- Lastly, after accomplishing the enhanced performance, compare the two forms on the basis of their performances.

Variable 1: Geometry

The case study will test two dissimilar courtyard shapes to express the outcome of different geometries of courtyard. The first shape will be of the existing courtyard form and the second will be enhanced courtyard form. Both will be tested for each orientation and vegetation. Thus, two shapes will be fixed to assess its impact on all other variables for both seasons and all timings. However, the courtyard shape for enhanced form will be the recommended shape for hot-arid climate by having a longitudinal-narrow shape. The courtyard area percentage in a built area should be 25%-30% of the built area (Reynold 2002, p. 177). The options will be selected from 25% to 30% in order decide the final courtyard area.

Variable 2: Orientation

The courtyard model of the various shapes will be tested on various orientations. The existing courtyard is oriented towards NNE to get the best possible effect of orientation for enhanced form the selection will be done on the basis of best delivery of natural lighting levels, shading, thermal comfort and effective ventilation.

Variable 3: Vegetation

The insertion of vegetation is always one of the suggested strategy for the improvement of heat island effect. Furthermore, such strategy can help in improving the air quality by decreasing air pollution, evaporative emissions, absorbing and storing carbon dioxide. Generally, the use of natural environment improves the quality of life along with human health (U.S Environmental Protection Agency, 2008).

3.2.Study Methodology

To examine and check courtyard environmental performance, various research methodologies have been used over the years. All methodologies have optimistic and oppositional characteristics. Nevertheless, their working purpose depends on the research aim, objectives, parameters, variables, and the resources available such as period of time, equipment, and labor. Current expertise calculates outcomes of high accurate results. These research methods are numerical, computer simulation, social surveys and field experimental methodology. Every one of these methodologies will be investigated as per their benefits and drawbacks to decide the best appropriate research method which can be pragmatic for this study.

3.2.1.Numeric Method

The numerical method engages empirical equations to investigate the courtyard environmental performance; shading percentage, daylight penetration, airflow, and thermal effect in any climatic condition and site location. Data and measurements of the courtyard have to be gathered to formulate the numerical equation and input data for evaluation. The variables in the equations are defined and are in control. The numerical methodology has a risk of human error at stages of collecting, formulating, or processing the data. This is time consuming and the outcomes have to be validated. By using this methodology, few difficulties might occur like the difficulty in captivating measurements for a particular time of the year or full year, and in accutacy of results.

Safarzadeh & Bagadori (2005) examines the passive cooling results of courtyards by the use of the numerical method. The analysis lays emphases on the thermal aspects like airflow, solar radiation, solar absorption climatic conditions, heat transfer, water vapor, soil evaporation. The equations are formulated by gathering and recording data of the latitude, altitude, solar path, and hourly air and sky circumstances. Afterwards, the equations are established through computing the wind flow and pressure. This process needs computer analysis to compete energy and cooling measures and to validate and confirm the results.

3.2.2 Social surveys

The cooling effect achieved by the outdoor parameters has revealed that the human parameter has performed an effective role in examining the qualitative or quantitative data obtained. Thermal comfort described in the first section was one of the main apprehensions which was motivating a lot of studies. Topics linked to the thermal comfort levels based on the human parameter involved social surveys. The main purpose of using such method is to get information about individuals reaction to the outdoor parameters. Questionnaires were used comprehensively to cover the question of outdoor thermal comfort levels. This method is extremely adaptable in terms of time, duration and location. Nevertheless there is a chance it can occasionally lack scientific trustworthiness due to levels of bias found. To escape the downcast side of the method, a fixed sampling criterion can be very analytical and precise towards the digested analytical process to the data obtained. Age, gender, clothing and further factors have an impact on the accurateness of the report collected. Social surveys can occasionally have subjective rather than objective results and that is where it lacks scientific reliability. Recording the psychological levels was cogitated more complicated than the physical measurements because of the vast number of unstable dependent variables.

Baker et el. (2001) focused on understanding the human parameter through investigations about thermal comfort in outdoor spaces. By using a merely physiological model which was found to be scanty in describing thermal comfort levels in outdoor spaces. The tests showed to have distinctive reasons for using the outdoor spaces which controlled their level of recognition for the microclimate. Nikolopoulou and Spyros (2005), instead, used a enormous database comprising of 10,000 questionnaires in numerous cities and confirmed that one parameter as a factor for comfort is insufficient for the evaluation of thermal comfort levels. Whereas Nikolopoulou and Lykoudis (2006) used social surveys along with field measurements method that confirmed a correspondence between the physical and the psychological parameters for examining outdoor spaces.

To synchronize the interrelation between the qualitative data obtained from social surveys and quantitative data measured, some softwares were used to describe the results in scientific units. Physical Equivalent Temperature PET, Physical Mean Vote PMV, Actual Sensation Vote ASV, Predicted Percentage of Dissatisfied PPD were thermal indices settled to systematize thermal comfort levels. Bastos et al. (2006) used PMV as a extrapolation of comfort through the software developed by De Dear (2005) by inserting social survey data gathered. Gaitani et al. (2005) used the Comfa and thermal sensation as bioclimatic indices to specify the levels of agreement and disagreement. The results were used to upturn the outdoor microclimate by employing passive cooling techniques through a simulation method. Altogether studies approved that using social surveys is not sufficient to specify the thermal comfort levels of an outdoor environment.

3.2.3 Experimental Method

Experiments have great scientific reliability and high validity of outcomes due to the great levels of experimental control attained. Experiments are considered the oldest methodologies used throughout history. The idea of repeatability gives the chance of test and mistake which qualified humanity with remarkable innovations. The measured environments attained in a labs frequently promise the level of correctness of the outcomes if accurateness has been achieved through the analysis process. Whereas, this great level of accuracy needs time and money, which indicates trouble in many situations.

Experimental research method can be cogitated as one of the methods for demonstrating the hypothesis of current study. Outdoor spaces can be used as in situ labs, and consequently a lot of arrangements can be made to equate the existing ineffective condition with a enhanced one. Such outdoor experiments have the benefit of presence of various outdoor parameters in the testing model which diminishes the levels of mistakes to a broad extent. Nevertheless, it is cogitated to be more applicable for the enquiry of numerous parameters jointly as it is difficult to isolated one or more variable and test it individually. The outcomes attained in this situation would be more connected with the precise experiment location rather than obtaining a global concept.

Very scarce studies used such method to examine the outcome of outdoor variables that enriches the microclimate. It is mostly old studies that had used experiments severely due to the limits faced. Givoni (1991) discovered six experiments which were used to inspect the thermal effect of plants in urban areas. Experiments done had verified one or two variables top in every study such as spacing between trees, or effect of landscape on cooling energy consumption, or the air infiltration rates from the outdoor environment to the indoor surrounding structure etc. The climatic rules commendation were established as per the earlier enquiries rather than Givoni‘s exploration due to the restricted resources available. Bar et al. (2009) organized an outdoor open space in a hot arid climate to investigate six dissimilar landscape strategies. A precise experiment in two adjacent semi enclosed spaces such as courtyards with similar geometry, orientation, exposure to the environment and material attributes but with distinctive landscapes. The dimensions have been taken instantaneously in the two courtyards delivering each with three landscape conformations. The concept of linking numerous conformations dejects the consistency of the outcomes.

The cooling efficacy has not been measured directly as it involves an estimation of the air change rate which is relatively challenging to measure in an outdoor space. The experimental method is cogitated to be a very analytical one as it needs very challenging experimental situations. The results of such experiments can indicate to unreliable outcomes if the test environment is not coordinated and the hypothesis arranged concerns only a single parameter.

3.2.4.Computer Simulation

This research methodology is grounded upon transmitting all the parameters of the environment correctly into the linguistic that the computer recognizes and accesses it under evident variables. Throughout this change a perilous choice of which of the appropriate variables are to be copied and which will be discharged while making sure those discharged do not have any impact on the outcomes. This method lets the researcher to make some rules that need to be dispensed very carefully. Simulations have the power to quickly run problematic tests with difficult parameters with more efficacy than experimental methods which is why it has been massively used lately. Simulations can calculate circumstances that have not happened so far as well as factors that are intimidating to the environment.

Computations are been used in all most all the fields of study. People find it more easier and cost-effective to run tests and studies in a computer-generated medium rather than realism. Progressions taking place within the obtainable software's is aiding this purely to occur. Identification by certified associations to these programs helps in attaining the authentication of the outcomes acquired. The great level of accurateness of the performance is an additional cause for this authentication.

Reverberation and flexibility of the simulation process makes it a scientifically trustworthy research method if the tools/softwares used are authorized. Computer simulation can be used to test complicated parameters that are in various cases difficult to test, specially in the case of outdoor environment. However, the experimental method, the computer-generated form of data and parameters can occasionally be problematic to the researcher and may indicate to unacceptable results.

Wong et el. (2007) used ENVI-Met, a three dimensional microclimate model designed to simulate the surface-plant-air interactions in an urban environment. The input data was based upon the electronic map and report delivered by the office of Estate and Development. The simulation accompanied, comprised of four dissimilar scenarios including the existing case. Three disparities were simulated, other than the existing situations concurring to the data collected by satellite pictures showing hot spots. A worse case and a better case scenario were tested in localities known to show high thermal stresses throughout night and day time. Field measurements on a precise day were completed to certify the simulation analyses and outcomes. The software used was controlled in terms of simulating the vegetated roof tops which was the case in several buildings that would have presented more potential.

Another study by Robitu et el. (2005) linked the airflow and thermal radiation models to test the impact of vegetation and a water pond on the microclimate, and that proved to be of a affirmative effect. A complicated geometry of urban spaces has been modeled through the SOLENE software for the thermal radiation and the computational fluid dynamics CFD model for airflow analysis in FLUENT environmental software. Two variations have been used in the existing situation, one which enhances it by using trees and water pond while the second one which lacks both. The study needed one week to simulate one scenario lone despite the limitations of the computing method it can deliver suitable quantitative evidence for outdoor design choices.

The cluster thermal time constant CTTC model is another simulation tool used and has been carried out by Bar and Hoffman (2003) to examine the passive cooling effect of geometry, orientation and vegetation in an outdoor environment. The software calculates the air temperature by the computation of the heat received from external sources, mostly net solar radiation and anthropogenic heat release. Muhaisen (2006) have used IES computer simulation significantly in his courtyard studies of thermal performance, solar radiation, and shading performance within dissimilar climatic and physical conditions such as Rome, Cairo, Kuala Lumpur, and Stockholm. Throughout his studies, dissimilar parameters and variables were observed at such as form, proportion, materials, energy consumption, and efficiency. All investigations were done without difficulty. The researchers' selection of the simulation software used to authenticate or fabricate the hypothesis was based on the skills of the tool in question. Each softwares accessible for simulating the outdoor demand dissimilar sorts of data and correspondingly it provides dissimilar outputs. Through papers reviewed, the selection of the appropriate method is grounded on the resources accessible for every study.

3.2.5. Field Measurements

The field experimental methodology examines the courtyard environmental conditions in thru relation to the actual world. So, there is the possibility of fronting environmental circumstances that perhaps are conscious or unconscious of. This methodology has few limits for example repeating the process of the assembling and evaluating data, limitation to a climatic condition, outcomes are not valid to any other condition in terms of courtyard form or region. This procedure is time-consuming that and consumes energy and resources. Moreover, certain scarcities may have an impact on method such as accessibility of the equipment's or technology.

Tsianka (2006) executed an experimental study in Athens by the practice of high technological instruments. The study is to evaluate the courtyard performance in terms of diminishing the cooling load and cross ventilation performance. The field experiment is commenced on every site by evaluating solar radiation and absorption, and the indoor and outdoor temperatures. The study compels a time-consuming phase to conduct and calculate the outcomes. Throughout the procedure of the investigation, authenticating the weather profile and re-checking the outcomes was done. Hence, the study is limited and cannot repeat the procedure and outcomes cause of the outside fluctuating dynamics.

Bastos et el. (2006) used the actual sensation vote ASV, predicted mean vote PMV and the predicted percentage of dissatisfied PPD as the guide to the thermal comfort levels of the outdoor spaces. Field measurements have been complemented by the conducteing questionnaires to inspect the local environment physical circumstance. Operating a blend of scientific methods such as field measurement or simulations in addition to social surveys has reduced the typically subjective results gained from questionnaires if used merely. Gaitani et el. (2007) used simulation and Comfa method in an attempt to advance the outdoor thermal situations. The study acclimated various bioclimatic opinions that resolved the discomposure feeling surveyed in the first stage of the research which authenticated the study‘s outcomes. Numerous studies used the field measurement as an helping tool to their main methodology. Field measurements were the source of the input data essential for simulations.

3.3 Selected Methodology

Cogitating the complications of the parameters in an outdoor environment, the controlled resources and the research objectives, several methodologies were expelled from the current study. Exercising social surveys is not appropriate for analyzing the physical parameters of the environment such as air temperature, Nonetheless the comfort levels established by former surveys would be cogitated as the base line of the heat sensation. Experimental method needs vast financial and time resources that are inaccessible and impractical in the current condition. Thus, the considerable information desirable for the local outdoor environment through the year has been collected throughout authorized weather data stations provided by the UAE government. Such measurements have been used as the basis for the outcomes of the investigation.

Computer simulation has been frequently used in alike studies and was chosen for the current study due to the diverse advantages over other methods. The research hypothesis set previously to examine the passive cooling strategies in courtyard houses to improves the ambient air temperature in the climate of Dubai needs a large alot of analyses to be done. To classify the passive principles that would improve the outdoor air temperature of a space, each of these principles has to be verified individually to certify. Moreover, defining the best orientation for an outdoor space needs to test all risks prior to the collection, therefore examining each of the paramet ers of the passive principles individually involves the exclusion of former variables throughout analyzing to avoid misapprehension. The requirement for a well-organized environment for such analyses has revived the usage of computer simulation for the subject of this study. The simulation process also has the benefit of assessing the extensive amount of variables of the hypothesis in less time and still the results are precise enough to simplify the outcomes for alike climatic situations.

Field measurement will be used as an supporting tool to the main methodology which is the computer simulation. Field measurements will be the basis of the input data needed for simulations. The idea of measurements done to get input for computer software creates the outcomes furthermore genuine than inserting unconditional measurements.

3.4 Selected Software

The necessity for this study is software that is skillful to quantity and simulate micro-climatic condition of an outdoor courtyard space, and an indoor context. ENVI-Met (temperature and wind speed) and Integrated Environmental Solution (IES) (daylight and shading analysis) are computer software's used to calculate the outdoor and indoor climatic conditions. Secondary software used in this study is Eco-tect, for gathering some typical information regarding the climate of study. Compared to the available tools for measuring outdoor and indoor parameters Integrated Environmental Solution IES and ENVI-met softwares were found to be the utmost appropriate for the parameters analysis due to several reasons.

3.5 Integrated Environmental Solution (IES)

This study is accompanied using a simulation software called Virtual Environment (VE), by Integrated Environmental Solutions (IES). It is an integrated building performance analysis platform. IES delivers a Varity of dissimilar evaluation choices and means, by which detailed simulations of the building, such as building loads, carbon emissions, daylight, solar analysis and airflow can be calculated. Moreover, the software evaluates the passive and renewable strategies, as per the energy and environment regulations and codes. The IES software is a set of several modules in which every module does a certain estimate. An synopsis of these modules is presented below:

3.5.1. ModelIT: Building Modeler

The model can be generated and modified as a simple mass or more detailed geometry. Moreover, other files can be attached from diffent software such as AutoCAD DXF files and SketchUp files.

3.5.2. SunCast: Solar Shading Analysis

This module evaluates the solar gains in the building and measures the shading efficacy to decrease the heat gain and direct solar radiation throughout hot days. Moreover, it produces images and animations from a model created by the IES ModelBuilder (ModelIT).

3.5.3. ApacheSim: Thermal Calculation and Simulation

This module is a vibrant thermal simulation tool based on mathematical modeling of the heat transfer processes in and around a building. Results from ApacheSim are checked by using the program called Vista. Data from other modules like SunCast and CFD are combined into the calculations of the simulation outcomes. Nonetheless, the module is skillful enough to produce several outcomes associated with the building's heating and cooling loads, total energy and carbon emissions.

3.5.4. Vista: Results Analysis

This module is share of the thermal group applications. It evaluates and analyzes the outcomes of the simulations carried out using the thermal modeling tools. The data can be presented graphically or numerically on multiple variables at chosen dates or months.

3.5.5. VistaPro BETA: Advanced Analysis

This is an innovative tool for the thermal calculations analysis; bulk airflow visualization and 3D color coded results, in addition to wind rose.

3.5.6. FlucsDL: Day Lighting Analysis

This module allows computing illuminance and daylight levels on every surface of the model. These calculations are combined in the whole energy consumption outcomes.

3.5.7. MicroFlo: CFD

Computational Fluid Dynamics (CFD) model is used to examine air movement in details, evaluates air patterns and visualize temperature distributions in the model. It is connected to the numerical simulation of fluid flow and heat transfer processes happening in and around building set within identified threshold circumstances comprising of the outcomes of climate, internal energy sources and HVAC systems.

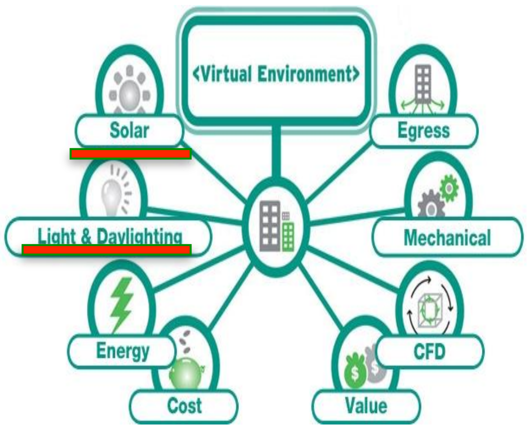


Figure3.2Integratedenvironmentsolutions.Source:www.embp.eng.cam.ac.uk/software/iesve

3.6 ENVI-met

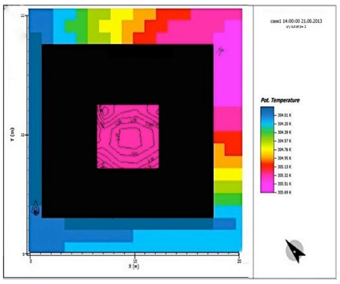
This software is consistently revised free software devoted for outdoor studies which lay emphases on every dimension of the environment such as the atmosphere, the soil and every other surfaces in a space. The software includes all the imperative parameters acceptable in an outdoor environment which achieves authenticated outcomes. The software is a three dimensional microclimatic model created to simulate the surface–plant–air interactions in outdoor environment. The ground surface, vegetation, buildings surfaces and elements in the space are all merged in the estimates of the heat sources of an outdoor space. It also has the benefit of including dissimilar forms of vegetation estimating the foliage temperature, the heat and vapor conversation in the air cover which is one of the crucial variables of the study.

Cogitating the wind effect in the statistical analysis of the outcomes it is important to provide a tool which treats the wind flow field as a normal prognostic variable and estimates each stage. Furthermore, the software is created for micro-scale with a typical horizontal resolution from 0.5 to 10 m and a typical time frame of 24 to 48 hours with a time step of 10 sec at maximum. This resolution permits evaluating small-scale interfaces between individual buildings, surfaces and plants that is suitable for this study (Bruse, 1999).

3.7 Software Validation

A feild measurement was finished by using hygro-thermometer (instrument) as shown in figure 3.3. A hygrometer is an instrument used for calculating the moisture content and temperature in the atmosphere. By calculation and calibration, these dignified measures can lead to a measurement of temperature and humidity.

Figure 3.3 hygro-thermometer.Source:Author



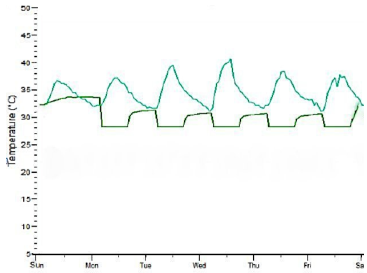


Figure3.4existingscenario:sourceEnvimet Figure3.5existingscenario:source IES

As per the recordings the initial temperature was recorded to be 305.15oK (32 degrees) when recorded during field measurement on 21/8/2013 (Wednesday) and after the simulation for existing scenario it was found to be same in both the software's ENVI-MET and IES (figure 3.4 and figure 3.5). Moreover, peer revised papers used the chosen software as a simulation tool, which support its validity for other studies. Muhaisen and Gadi (2006) used IES (Virtual Environments) to conduct out an analysis on a alike report: The effect of the courtyard proportions on the solar heat gain in buildings. According to them, the IES program is an combined platform of functions with a single integrated Data Model, in this software the data input for one application can be utilized in others. In their accompanied study, only three of these applications were utilized to carry out the investigations, these ModelIt, Suncast and ApacheSim. The IES software is selected to perform the study evaluation because to its accurateness and accessible abilities like progressive thermal calculations.

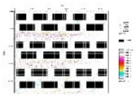
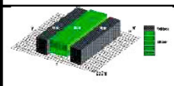
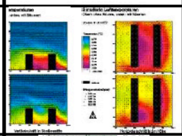
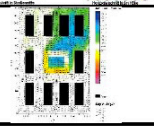
ENVI-met software has been utilized numerous times in scientific researches that occurred to create it as logical publications. Toudert and Mayer (2006) utilized the software for assessing the thermal comfort in an outdoor environment. The software was capable to simulate the effect of the aspect ratio and orientation of a street canyon where the outcomes delivered were in conformity with the outcomes attained by Masdoumi and Mazouz (2004) using the SOLENE software to examine the same parameters. The examination of the same parameters by Johansson (2006) using field measurements in calculating the thermal comfort levels were also discussed conforming with the above cited findings. The building materials in ENVI-met have equated to be in good guesstimate for their standard properties (Fahmy and Sharples, 2009).

Bruse and Fleer (1998) simulated surface-plant-air interactions inside urban environment using ENVI-met using a grid of 5m focusing on the horizontal and vertical wind flow and temperature distribution. The report presented that all inputs are being measured in the simulations such as building a small green area adjacent to the site of study. Another study using the same software associated with the present outcomes of the existing situations in National University of Singapore to the enhanced scenario which proved to give a higher value by 10C (Hein and Jusuf, 2007).

Outcomes achieved by the software have verified to be conforming with reports done utilizing former methodologies or other softwares. The only limitation of the ENVI-met software, is the values of few of the outdoor parameters where some studies argued to be exceeding or below the existing situations. Thanpar and Yannas (2008) investigating the urban form of Dubai where the simulated outcomes were nearly alike to those measured in-situ but with a slight reduction. Toudert and Mayer (2006) summarized that the PET values attained by the software might be overestimated associated with real conditions. Numerous researches suggested the requirement for modifications of the outcomes achieved by ENVI-met (as the case with all computer simulations) with field measurements. The purpose for such disadvantage might be because of eliminating the heat storage of the buildings that would contribute to more heat radiation in the outdoor environment.

Numerous online validation attempts done in 2002 using ENVI-Met tested the abilities of the software to cogitate several variables into the outcomes. The samples accessible online displays the behavior of the software towards some outdoor parameters such as wind, temperature, vegetation, height etc. The demonstrations presented below in Table 3.2 are easy to approach, concise still meaningful adequate to validate software.

Table 3.2 Summary of the online ENVI-met validation projects related to the topic. (Source: ENVI-met.com)

Model	Variable	Image	Outcomes
Street layout in SE Australia	Wind direction, speed and behavior around buildings		The software updates the initial wind direction according to the layout orientation. Wind direction and speed changes with the presence of any obstacles.
Street canyon	Vegetation impact on the space		Trees are being considered as 3D objects incorporating the vegetation characteristics.
Street canyon	Horizontal and vertical air temperature distribution with and without trees		Trees provide a 3D cooling effect rather than affecting the ground surface temperature.
Park	The expanded cooling effect of vegetation		The software simulates the environment as a whole taking into account the presence of an object or a neighbor park.

3.8 Research Procedure

The huge variation in the passive techniques that showed the enhancement in the outdoor air temperature as per former reports and the struggle to examine them all caused the selection of a few parameters for investigation. The selection criterion of the parameters to be examined will be mentioned below. Such parameters will be tested first distinctly to nominate the optimum condition of each parameter which then will be compiled together in an environmentally enhanced scenario. For instance, during the investigation of the height to width factor, a H:W ratio of 1:35, 1 and 1:08 will be examined each to know which of the ratios has contributed to the lowest temperature values. That ratio with the lowest temperature will be included in the enhanced scenario, Furthermore to the other factors that verified to record the lowest temperature in the other parameters. The enhanced scenario will be associated to an existing site in Dubai that has also been simulated utilizing the similar tools and climatic situations to create an fair comparison. The results of the comparison are anticipated to reveal the valid impact of the passive techniques utilized.

Every technique of the this study has gone through a investigation that will be revealed below. The research techniques have been split into three sequential phases; data collection, simulation and the results analysis. The data collection phase will validate all the information collected to generate the simulations done in the next chapter 4. The outcomes and environmental recommendations represented in Chapter 5 are an results of the simulation process that will be examined. Every research techniques has been created as per a scientific principle to certify authenticated outcomes. The tools and methodology of every procedure will be explained and validated consecutively.

Chapter 4
Simulation Methodology

Introduction

This chapter will describe the simulation procedure right from where the outcomes of the analysis were extracted in order to recognize the parameters impact on the current case study. An evaluation of Dubai's weather data will be examined systematically to understand the functioning of the structure in Dubai's climatic situation. Furthermore, the models of the simulated buildings will be established in a way so that they can perform the simulation calculations on them. The simulation procedure will confront all evaluations as per the parameters.

4.1 .Dubai's Weather Data for Simulations

Figure 4.1 UAE location on the world map left and Dubai location on the UAE map right. Source: Online Google maps

Dubai’s coordinates lies between 25°N 55°E its categorized to be a hot arid climate with less rainfall concentration as compared to other cities which are in the subtropical zone. The level of heat stresses is more in summers from the month of June to the month of September with an average temperature around 40 °C (104 °F) andreduces overnight to 30 °C (86 °F). The temperature goes down slowly to its lowest values between the month of December to the month of March with an average temperature of 23 °C (73 °F) and at night its 14 °C (57 °F) with less rainfall concentration. On an average only 28 days in the entire year experience rainfall and rest of the year its sunny shown in Figure 4.2 (Dubai Meteorological office, 2010).

Climatic knowledge about the weather in Dubai was calculated by the Eco-tect software. The report given by the software is based upon the weather data file of a specific city inserted through its database. Ecotect is an authorized software broadly utilized by designers to have an awareness regarding the environmental circumstances in every location.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Maximum Temperature °C (1984-2009)	23.9	25.4	28.4	33.0	37.7	39.5	40.9	41.3	38.9	35.4	30.6	26.2
Average Minimum Temperature °C (1984-2009)	14.3	15.5	17.7	21.0	25.1	27.3	30.0	30.4	27.7	24.1	20.1	16.3
Mean Rainfall (mm) (1967-2009)	18.8	25.0	22.1	7.2	0.4	0.0	0.8	0.0	0.0	1.1	2.7	16.2
Mean # of Days with Rain (1967-2009)	5.5	4.7	5.8	2.6	0.3	0.0	0.5	0.5	0.1	0.2	1.3	3.8
Sunshine Hours / day (1974-2009)	8.1	8.6	8.7	10.2	11.3	11.5	10.7	10.5	10.3	9.9	9.3	8.2
Mean Sea Temperature °C (1987-2009)	20.9	20.6	22.3	25.0	28.5	31.2	32.2	32.8	31.9	29.7	27.1	23.

Figure 4.2 Temperature and precipitation all over the year in Dubai Source: Dubai Metoerolical Office, 2010

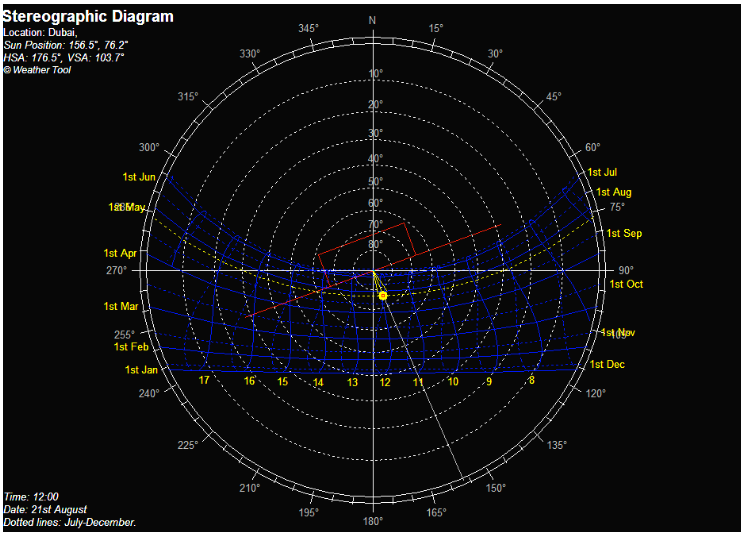


Figure 4.3 Solar position of Dubai at 12.00 on the 21st of August. Source: Climate Consultant software

The Stereographic figure above, Figure 4.3, displays the sun path as per the co-ordinates of Dubai. Blue lines shows the months of the year and the radial lines denotes the sunrise, sunset and azimuth times in the city. The image was recorded at 12.00 o'clock on the 21st of August.

The diagram below, Figure 4.5, displays the climate summary of daylight and temperature of Dubai presenting the month of july. August and September as the highest thermal stress stage with august being more hot with the temperature more than 40oC. These months of summer consume a lot of energy for producing artificial cooling. The cooling consumption is decreased in the month of January which is cogitated as the coldest month with a highest temperature 15oC followed by the month of December and February. Need for heating strategies arise in the winter season.

The month of May and June have the highest solar radiation levels during the year as shown in Figure 4.4. The lower sun position facing the city creates high levels of radiation and daylight over the year which leads to glare. Dubai‘s climate has high humidity levels which create discomfort. The relative humidity levels are up through the year, from 30-50% increasing in coastal areas upto 60% specially between the month of May and September as shown in Figure 4.6.

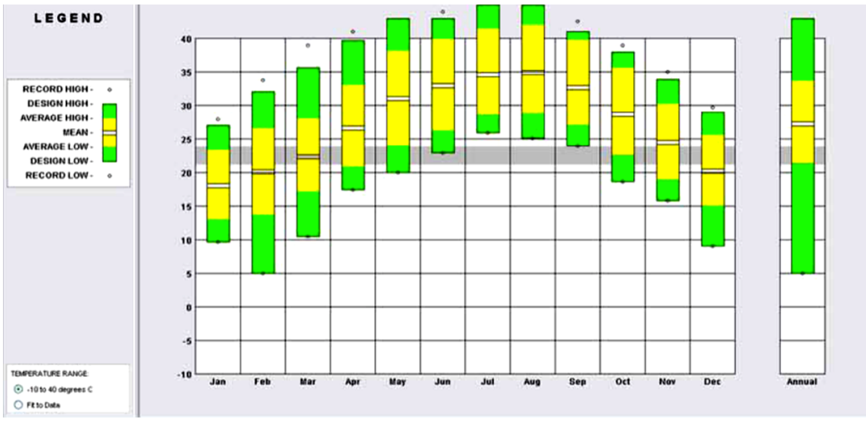


Figure 4.4 Annual and monthly temperature values.
Source: Climate Consultant software

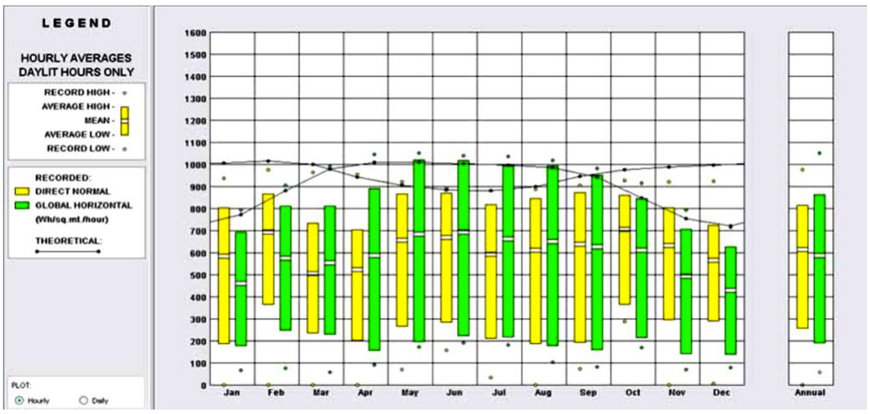


Figure 4.5 Annual and monthly daylight hours representing the solar intensity Source : Climate Consultant software

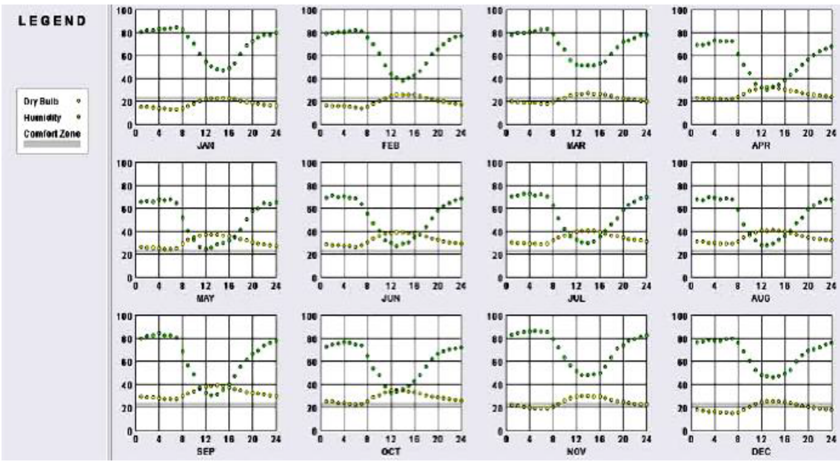


Figure 4.6 Monthly dry bulb, humidity and comfort ranges.
Source: Climate Consultant software

The prevailing wind in Dubai mainly comes from the North West direction generally known as Shamal, chronicling the highest rate of 2.7 to 5.5 m/s. Low levels of winds are blow from various directions all through the year as shown below (wind finder, 2010).

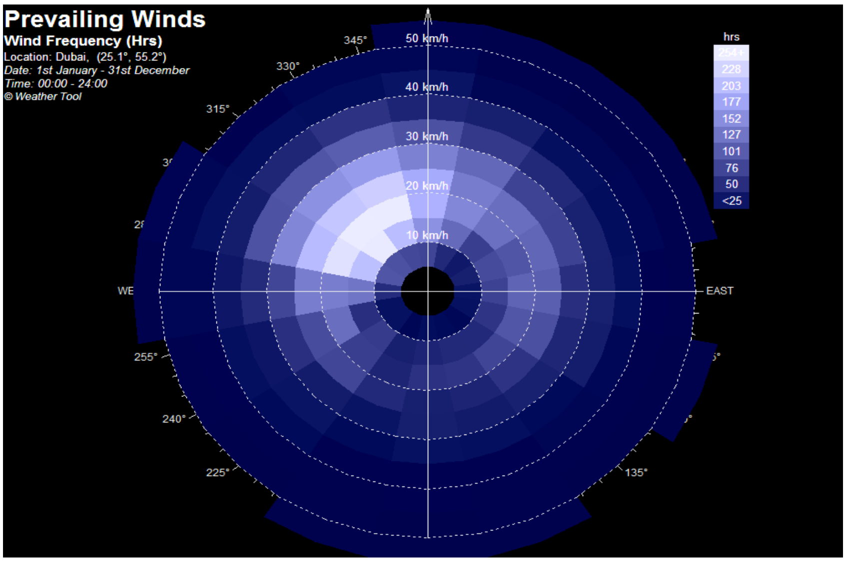


Figure 4.7 Dubai wind rose representing the wind speed intensity and direction emphasizing the prevailing wind. Source: Climate Consultant software

Psychometric charts defines the connection among dry-bulb temperature, and relative humidity, on the horizontal and the vertical axis individually. The Thermal Comfort Zone is expressed as per the temperature and relative humidity, along with the occupant's involvements such as clothing and activity level. The diagram, Figure 4.8, determines that the climate of Dubai is cogitated outside the comfort zone in summer whereas in winter the comfort ranges conform with the climate. The comfort percentages represented in Figure 4.9 shows high ranks of discomfort during summer whereas through winter the comfort levels are more appropriate.

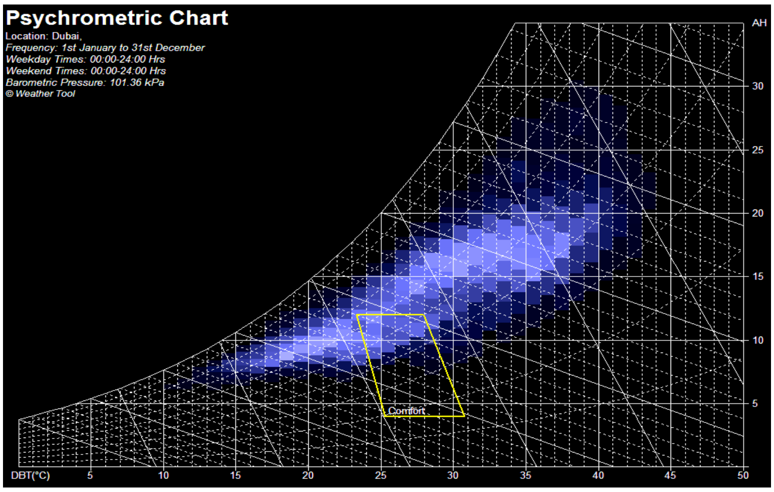


Figure 4.8 Psychometric chart of Dubai indicating the comfort zone. Source: Climate Consultant software

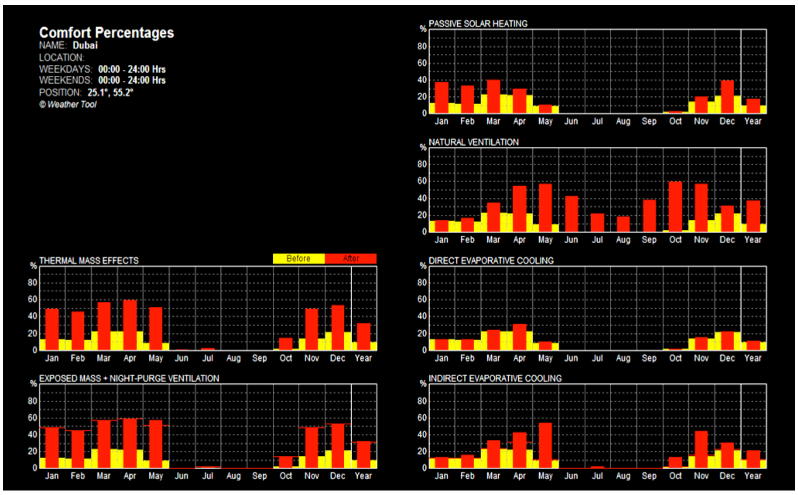


Figure 4.9 Psychometric chart of Dubai indicating the comfort zone. Source: Climate Consultant software

4.2 Building models study

Two dissimilar courtyard conformations are simulated. The first form is the existing courtyard form and the second form enhanced courtyard form presenting a advanced form from the existing courtyard form. Sequentially, to execute the report, first the Dubai modular housing as a three-dimensional model is modeled. Each structure is modeled by utilizing the software IES (environmental integrated solutions) and ENVI-met. Consecutively, to associate both forms, first the performance of the enhanced courtyard will be examined, as per the literature review discoveries. The structure area is fixed in both courtyard forms. Several of variables connect and have an impact on the built form functioning; thus, some variables are consigned as constant. Every model has the same building materials as per the Dubai building regulation. Dubai weather file is overloaded in Ecotect software to evaluate outcomes which are realistic.

4.3 Site Selection

The Villa is situated on the Dubai Properties owned corner plot near to the combining of the new Dubai Bypass Road and Al Ain Roads in the upper right side of the image it is the yellow plot just below as the full length as plot 36 [Falcon City of Wonders] well inside the red Dubailand north eastern boundary line.

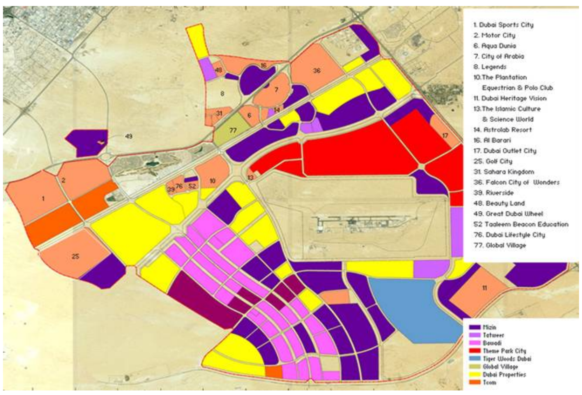


Figure 4.10 Dubai Map:The Villa plot location. Source:www.2daydubai.com

Figure 4.11 Location:The Villa. Source:www.2daydubai.com

4.3.1 Data collection tools

Knowledge concerning site measurements and structure dimensions were attained from online scaled Google maps from worldfloorplans.com. A site survey measurement was completed to assure the precision of the maps available. A hygro-thermometer (instrument) was used for analyzing the temperature. A digital camera was utilized for clicking site photos which were used in site characteristics.

4.3.2 Site Characteristics

The Villa Project, situated in Dubailand, is the newest residential society. Consisting of 1811 villas and plots, The Villa Project is an charming residential shelter, planned & motivated by the sophistication of Spanish-style country housing. Ideal for those looking for peace & quietness, The Villa Project offers free standing 4, 5 and 6 bedroom Spanish type villas, with terraces and lavish sites.

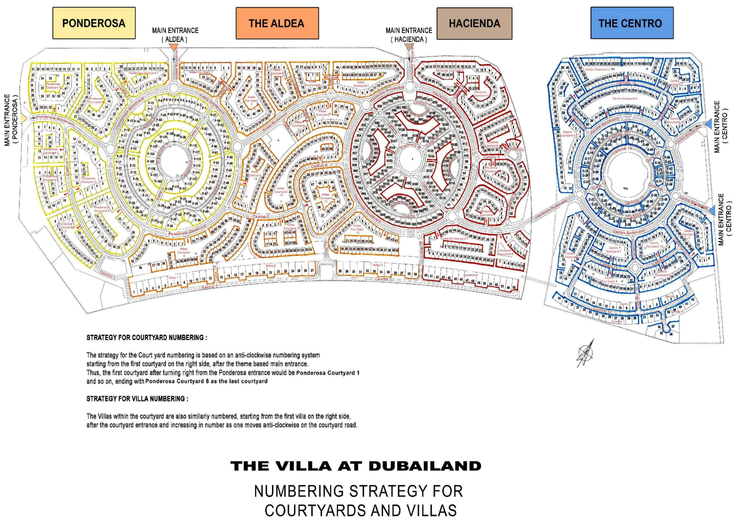


Figure 4.12 Location:The Villa.Source:www.worldfloorplans.com

The society has 4 areas comprising of the following: The Haciendas - an eye-catching garden landscape; The Ponderosa - ranch-style living; The Aldea -closely planned courtyard housing & The Centro. Among the villa types valencia villa which was one of the courtyard housing was chosen as the case study for this study. Valencia villas are bright, large homes perfect for engaging (Approx Size 7114 sq.ft.). Proposed in a

Spanish theme, a central courtyard receives light into the centre of the home & an additional outside area. Upstairs, there are 4 spacious bedrooms: The Master bedroom & other room with a terrace with a garden view. A large Family room is perfect for a kids play area or a gym.

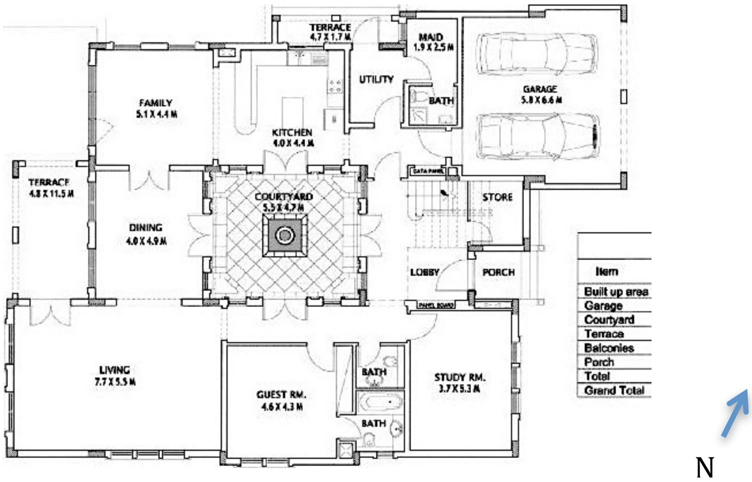


Figure4.13Case study Valencia villa,Ground floor.Source: www.worldfloorplans.com

On the ground floor there is a Guest Bedroom: a Study & a Guest bathroom. The large, bright living & dining room at the back of the home commanding to a terrace & to a private garden. An open plan, high feature kitchen & family room is lively & perfect for families. The laundry room & maids room have a distinct entrance.

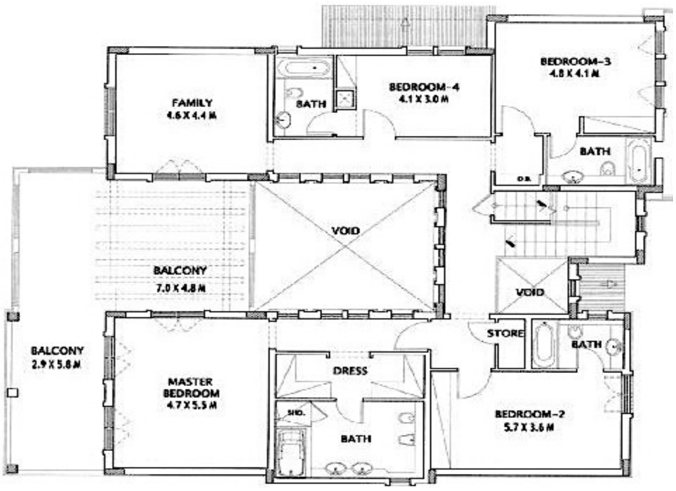


Figure 4.14 Case study Valencia villa,first floor.Source: www.worldfloorplans.com


Figure 4.15 Existing case.Source:Author


Figure 4.16 Existing case.Source:Author


Figure 4.17 Existing case.Source:Author


Figure 4.18 Existing case.Source:Author

Enhanced courtyard form

The second model is the enhanced courtyard form. At first, the percentage of the courtyard is assessed by compelling two percentages to decide which is finest for the house. The percentages are 25% and 30%(Reynold 2002, p. 177) Table 4.1 demonstrates the measurements of the several sizes for both of the percentages. The optimal courtyard percentage and size to be utilized in the study is 30% option B, with an entire area of 86.58m2. As mentioned back in the literature review courtyard geometry section, option B rpresents the finest form cause of its longitudinal form stretched in the North-west direction and the internal space which does not exceed 2.5 times the height to the opening to sustain acceptable daylight diffusion so the continuous necessity of artificial lighting is not required. The report will calculate the rooms around the courtyard as an internal space and the courtyard as the outer space.

Table 4.1. Dimensions for 25% and 30% courtyard proportions

Courtyard Percentage		Built-up Length		Built-up width		Courtyard Dimension	Built-up Area	Courtyard Area
		X Axis	Y Axis	X Axis	Y Axis			
	A			4.625M	3.25M	5.55 M x 13M		
25%	B	14.8M	19.5M	4.16M	4.17M	6.48M x11.16M	216.45m2	72.15m2
	C			3.7M	4.87M	7.4M x 9.76M		
	A			4.625M	1.95M	5.55M x 15.6M		
30%	B	14.8M	19.5M	4.16M	3.06M	6.48M x13.38M	202.02m2	86.58m2
	C			3.7M	3.9M	7.4M x 11.7 M		

The geometry of the area in relation to H/W (height/width) ratio is cogitated as the highest applicable cause domineering the effect of geometry on air temperature. The influence of such factor gives the designer a chance to design pleasing spaces concluded with shade and wind rather than all the other geometry factors such as space enclosure, and shape. The examined proportion parameters are assessed by the ratio of floor perimeter to height presented by R1 and width to length presented by R2. R1 ratio presents the ratio of courtyard floor perimeter P to the height H (P/H), varying from 1 to 10. R2 ratio presents the width to length (W/L), varying from 0.1 to 1(Muhaisen, 2006).

4.3.3 Simulation process

4.3.3.1 Parameters of the study

Aspects that effect the outdoors air temperature were discovered to be abundant. Environmental designs are that which integrate passive cooling methods to the outdoor spaces. Throughout the research of the passive design principles that has a cooling effect on the outdoor spaces in hot regions, the parameters were reviewed as follows:

Materials of the space

Materials have a remarkable role in improving the outdoor air temperature (Bar and Hoffman, 2003 and Ferrante and Mihalakakou, 2001), Nevertheless computer simulations are cogitated to be entirely inadequate in terms of outdoor material collection. Moreover, the materials selection choices fixed by the softwares analysing the outdoors are still inadequate. The selected software ENVI-Met' cogitates the materials mostly such as pavement concrete, brick road, asphalt road, sandy soil, deep water or granite pavement. If investigation was to be done on materials particularly, those varieties available formerly would have not been sufficient. Consequently, the material parameter was expelled from the current analysis.

Geometry: Height to width ratio

The geometry of the area as per height to width ratio is measured to be the most applicable factor monitoring the effect of geometry on air temperature. The handling of such issues gives the designer the choice to design pleasant areas with shade and wind along with all the other geometry features such as space enclosure, and shape.

Geometry: Space composition (enclosed, semi enclosed)

The impact of the space configuration on the air temperature discovered to be reliant on former features in the space geometry such as H:W ratio this feature of geometry cannot be considered individually. Consequently, such parameter was expelled.
Geometry: Form of the space (circular, rectangular, linear, staggered) Former readings for examining the impact of the area's form on the microclimate determined that such factor has an irrelevant impact however the space ratio has a additional effect which made this parameter to be expelled.

Orientation of the space

The other parameter that verified to have huge cooling impact like H:W ratio is the orientation. Orientation parameter has a slight impact but this impact is increased when combined with appropriate space geometry.

Vegetation

The cooling impact of foliage has been overly used and has demonstrated to be one of the utmost effective feature in the passive design strategies. The application of this parameter is cogitated to be crucial for the current study‘s goal.

Water features

Calculating water types to the space is decidedly suggested in hot dry climates which spreads the cooling sensation of wind. Water elements like fountains which has a capability to spread the damp sensation in an arid climate is required to been expelled from the present analysis.

Sheltering elements (canopy, pergolas)

This paper is testing the impact of the natural passive parameters rather than manmade one. If artificial bioclimatic study was to be done such aspect has a promising impact that needs further investigation.

Furthermost, The principles stated above have been examined formerly and have helped in constructing more pleasant spaces. Earlier studies expressed the cooling level of every parameter examined, which supported the selection process of the present analysis. Three among the above stated principles orientation, H:W ratio and vegetation were chosen for an additional research in the climate of Dubai. These parameters have added the most to improve the conditions in a hot arid climate where broad shadowing and ventilation by air movement is vastly suggested (Golany, 1996). The chosen parameters will be examined on two foundations:

· Every parameter would be tested distinctly concentrating on numerous variations within.

· An enhanced scenario will contain the coolest orientation, geometry and vegetation strategy which later will be compared to the existing scenario.

3.3.3.2 Variables of the Analysis Matrix

In the present research the independent variables will be the passive parameters selected formerly (geometry, orientation and vegetation). Every parameter will be focused to examine its impacts on the outdoor space. For example, altering the orientation of the chosen open space would have an impact on the air temperature. Moreover, a N-S orientation has a better impact on the outdoor air temperature than an N-E orientation. In this case the N-S and the N-E orientations are the independent variables being used by the researcher to examine their impact on the air temperature. The dependent variable in this scenario is the air temperature which is the result of the report. A dependent variable will constantly be the result of the report renowned as an impact of the independent variable which is the researcher's input.

Independent variables

· Orientation: North-South, North-west and North-east orientations

· H:W ratio: 1:35, 1:00 and 1:08

· Vegetation: Continuous grass, tree groups and continuous grass and tree groups

Dependent variables

-Air temperature
-Wind speed
-Daylight
-Shading

Throughout the use of numerous variables certain features remained constant throughout the simulation. To check the impact of variables, other variables have to be set as a stable value because they cannot be expelled from the testing. For example, throughout all assessments the parameters like orientation, geometry or vegetation each of the buildings surrounding the area have to be of impartial impact to the space. Furthermore, valuations on the houses facades have proved to cause a cooling effect on the adjacent spaces cause it provided shadow. If such feature is added in the simulation testing of orientation it will have an impact on the outdoor space, this means that the result represented will include the impact of the structures shading due to its façade projections. Thus, for accurate results from precise parameter which are under examination will be assumed stable. The structures will be simplified where the breaks on the facades will not be measured to avoid any confusion in the originated outcomes.

Fixed variables

· Building line is horizontal rather than having a slight curvature

· Flat building facades with no recesses or projections

· Buildings to be of flat roofs

· Building materials unified as Albedo walls (defined by the software)

Test matrix

Numerous number of variables were examined, So a test matrix has been formed to make the simulation procedure easier. The matrix comprises of the three independent variables which were under examination, these are orientation, geometry and vegetation. Dissimilar scenarios were simulated with the base configuration of the existing site scenario. In every simulation performed only one single parameter of each independent variable was tested. Moreover, the itemization of the following matrix is constructed by altering only one parameter out of three independent variables in every column. The variable which will be fixed in the existing scenario when the other variables of the matrix will be tested are represented in red color as shown in Table 4.2

Table 4.2. Test matrix used for the simulation analysis. Red cells represent the fixed variables during simulation.

Independent Variables	**Orientation**	**H:W ratio**	**Vegetation**
Existing scenario	NNE	0:85	No vegetation
Independent variables	NS NW NE	1:35 1:00 1:08	Continuous grass Tree groups Continuous grass and tree groups
Enhanced scenario	NE	1:35	Continuous grass and tree groups

4.3.4 Simulation Initialization

Seventeen simulations were run in two different software's ENVI-Met and Integrated Environmental Solution (IES) for the outdoor and indoor environment investigations in summer as well as in winter along with the inspection of three core parameters of the passive design principles which are the orientation, geometry and vegetation. Every one of these parameters had some variables within, such as there were three orientations (NS, NW, NE) three height to width ratios (1.35,1,1.08) and three strategies for vegetation (continuous grass and tree groups, tree groups, continuous grass). To examine the above mentioned parameters without any confusion, one parameter will be examined at a time throughout the intense thermal stress situations whereas all others will be stable as per the existing case study of THE VILLA.

According to Fabros (2009), the summer season generally starts from the month of June till the month of September with August being the hottest month with the higher range of humidity. Temperature throughout this month can range from 50ºC nonetheless the average monthly temperature ranges from 41°C. The cooler months of winter starting from December to February have average maximum temperatures from 23-26ºC and can reduce to 14ºC at night (Fabros, 2009). The present report aims at examining the capability of the passive design principles to improve the outdoor air temperature throughout the intense situations of the year. If those beliefs ensue to even have a minor impact through the peak situations of the year then they will certainly have a broader impact during the other seasons. Consequently, the independent variables will be examined throughout the worst case situations which are in summer (August 21st from 8am to 6 pm).

Subsequently, the impact of the passive methods differs in summer than in winter, so the three main qualified scenarios along with base case scenario will be examined throughout both summer and winter time through day and night (August 21st and December 21st from 8am to 10 pm).The first models will be of existing case study as shown in figure 4.19. The existing site had a 22.5º NNE orientation, a H:W ratio of 0.85, no vegetation. Simulations were performed on the 21st of August which is the intense summer situation and for intense winter situation on the 21stof december.

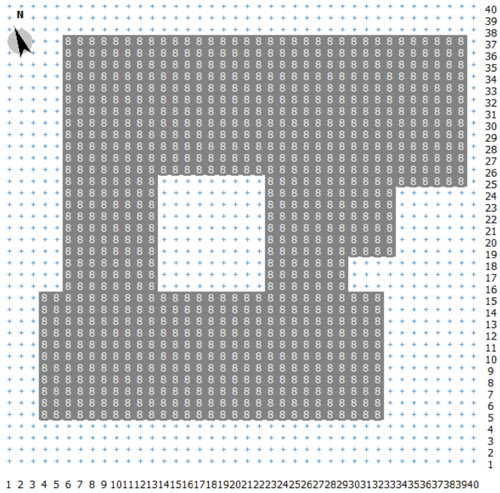


Figure 4.19. The base case scenario courtyard B representing simulations one and two (August 21st and January 21st)

The third simulation was done to examine the NS orientation on 21st of August. Rest all the other circumstances of the existing case model were kept same. The model had a NS orientation, H:W ratio of 0.85, no vegetation as shown in figure 4.20.

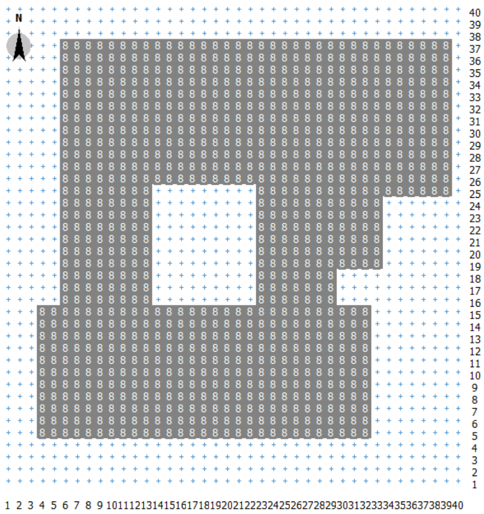


Figure 4.20 The 'NS' testing the orientation variable representing simulation three (August 21st)

The fourth, and fifth simulations examined the NW and NE orientations sequentially as shown in figure 4.21 and 4.22. The models where simulated on 21st of August with a H:W ratio of 0.85, no vegetation as per the existing case site circumstances. The NE oriented model is very identical to the existing circumstances model as both have very alike orientations but with dissimilar tilting. The existing model is tilted 22.5o NNE where as the NE model is tilted 45o.

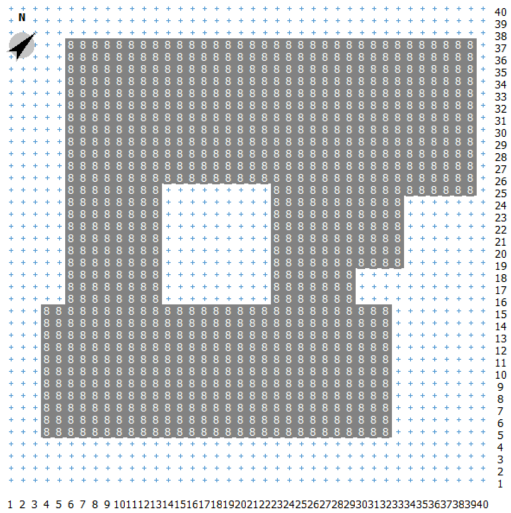


Figure 4.21 The NW testing the orientation variable representing simulation four (August 21st)

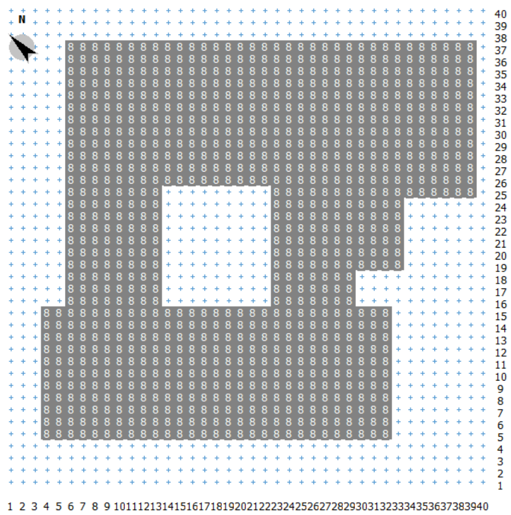


Figure 4.22. The NE testing the orientation variable representing simulation fifth (August 21st)

The next three simulations were arranged with three different H:W ratios on the 21st of August. The fifth model was planned with a 1.35 ratio based upon 7.5m height of buildings and 5.55m width of space as shown in figure 4.23.

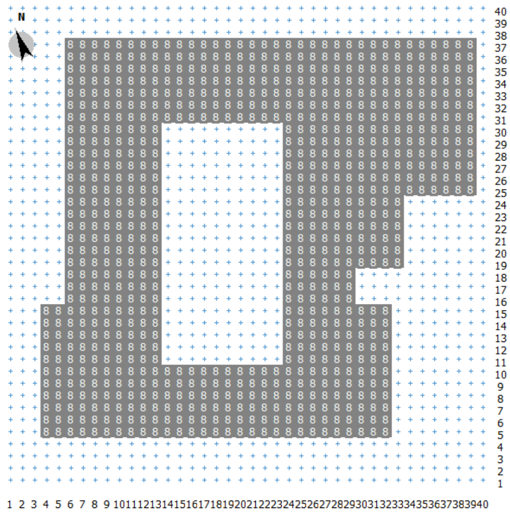


Figure 4.23. The ‘H:W 1.35 ratio testing the geometry variable representing simulation sixth (August 21st)

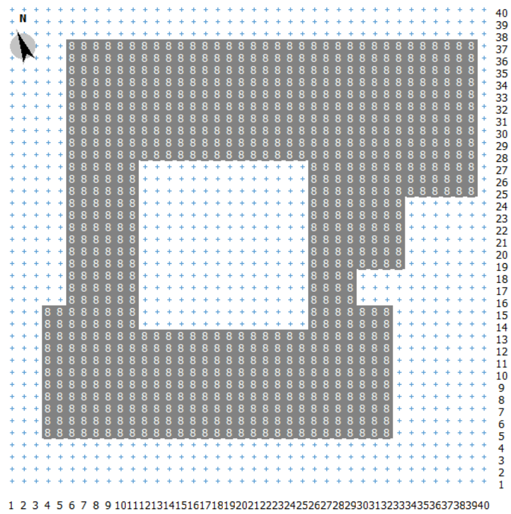


Figure 4.24. The H:W 1 ratio testing the geometry variable representing simulation seventh (August 21st)

The sixth model had a ratio of 1 with 6.5m building heights and 6.48m space width as shown in figure 4.24. The seventh model used a higher ratio of 1.08 with a 8m height of buildings and 7.4m width of space as shown in figure 4.25. The grid space utilized for the drawing was planned in a way to be kept in alike levels in all models to certify the results. Meanwhile, each simulations of the present report are constructed upon a grid of 40x40x20.

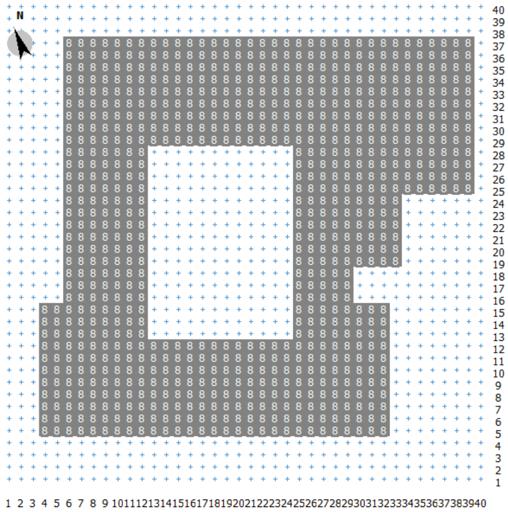


Figure 4.25. The H:W 1.08 ratio testing the geometry variable representing simulation eighth (August 21st)

The next three simulations set were aimed to examine the impact of the vegetation on the outdoor air temperature in summer circumstances on 21st of August. The ground surface of the outdoor space was switched to continuous grass in the eighth model under the same circumstances of a 2.55o NNW orientation, a H:W ratio of 0.85 as shown in figure 4.26.

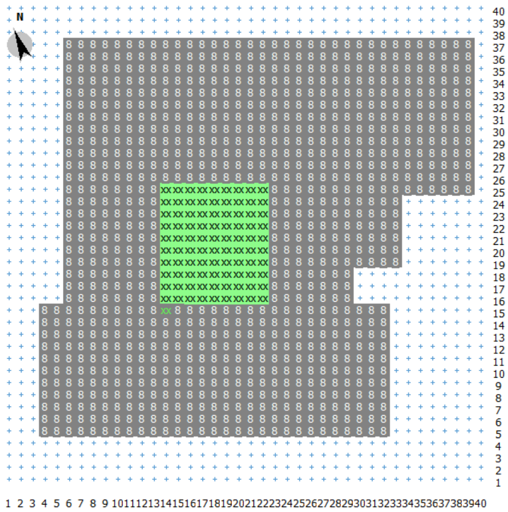


Figure 4.26. The ‘continuous grass’ testing the vegetation variable representing simulation ninth (August 21st)

The conception of tree groups was then examined individually in the ninth simulation with the circumstances of a 2.55o NNW orientation and H:W ratio of 0.85 as shown in figure 4.27. In addition to the scenario of continuous grass and groups of trees was also examined with the same circumstances of existing case in the tenth model as shown in figure 4.28. The three vegetation strategies examined were planned to show the cooling effect level they can deliver.

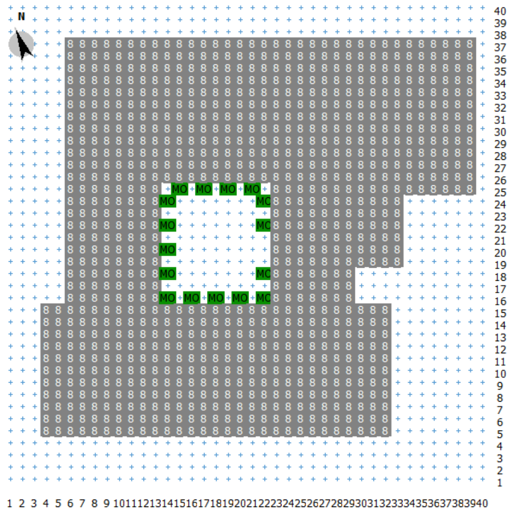


Figure 4.27. The ‘tree groups’ testing the vegetation variable representing simulation tenth (August 21st)

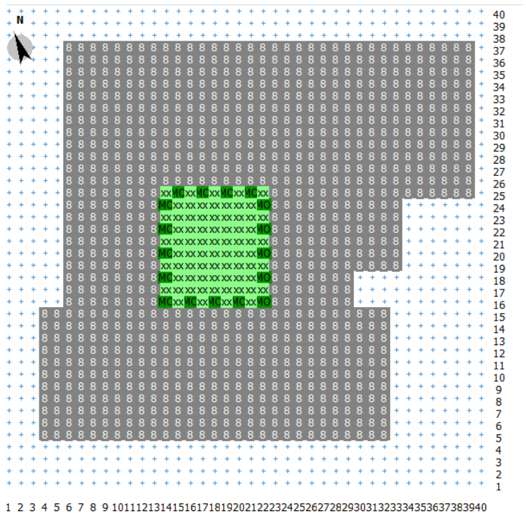


Figure 4.28 The‘continuous grass & tree groups’ testing the vegetation variable representing simulation eleventh (August 21st)

The results of the eleven former simulations will be joined in one scenario known as the enhanced scenario‘ model as shown in figure 4.29. Variables that presented the higher potential to decrease heat stresses were integrated in an enhanced scenario and examined in twelfth and thirteen simulation during both intense summer and winter circumstances on the 21st of August and throughout winter on the 21st of December to compare it with the existing case as shown in figure 4.19 (first model).

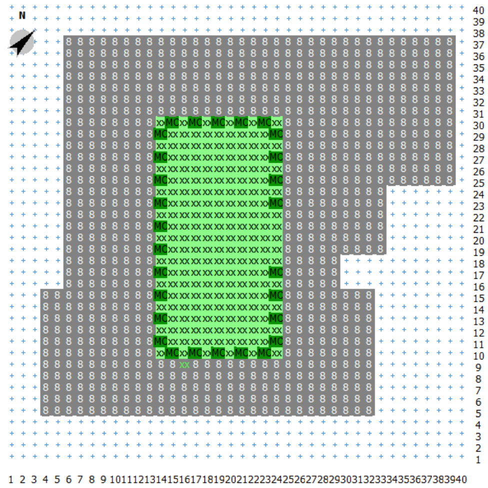


Figure 4.29. The 'enhanced' scenario testing the all the passive principles representing simulation twelfth and thirteen (August 21st and January 21st).

Table 4.3 The simulations were based upon the current fixed data.

Constant information given by the software ENVI-Met that cannot be changed.	Building properties	Inside temperature of buildings simulation 293K. Heat transmission walls 1.94 W/m2k. Heat transmission roofs 6.0 W/m2k. Albedo walls: 0.2 (20% reflectivity) Albedo roofs: 0.3 (30% reflectivity)
	Solar radiation	The shortwave is 100%
	Specific humidity	In 2500m is 7(g water/kg air)
	Background CO2	The concentration is 350 ppm to calculate transpiration of plants
	Timings	Update surface data each 30 sec Update wind and turbulence each 900 sec Update radiation and shadows each 600 sec Update plant data each 600 sec
	Soil data	Initial temperature of the upper layer of the soil is 293K Initial temperature of the middle layer of the soil is 293K Initial temperature of the deep layer of the soil is 293K Relative humidity of the upper layer of the soil is 50%

Table 4.4 The simulations were also based upon some current input data

Set of variable information inserted based upon the climatic data gathered and the conditions of the current investigation.	The geographic position	Dubai, UAE. Latitude: 25.25o and longitude: 55.33o
	Base grid size in X,Y and Z	2,2 and 2 respectively, where each grid cell in the drawing space represents two meters in reality (the default setting)
	Simulation grid size	40x40x20 grid size as a software standard configuration
	Materials	The buildings are surrounded by a 2m concrete pavement from the space periphery. The ground surface of the space was considered as concrete pavement when no grass was available.
	Orientation	The simulation gridline of the existing model was rotated 3.15o whereas the North direction becomes tilted to the left side as shown in the output images. The reason for such amendment is to minimize staggered forms during the drawing process and obtain more accurate results since the software is only capable of drawing vertical or horizontal lines. The North direction input in the simulations is compatible with the existing condition.
	Duration	Simulation duration was total of 10 hours from 8am to 6pm for each of the three independent variables tested.
	Saving intervals	Every 30 minutes there is an output file that contains all information needed about that specific time.
	Wind direction	325o at 3.6m/s speed
	Initial temperature	305.15oK
	Sky condition	Clear sky
	Relative humidity	53%

<u>Simulation Initialization for shading and Daylight analysis using IES software</u>

As per the formerly explained proposal, two forms are created through ModelIt module in IES Software: the existing courtyard form and the enhanced courtyard form models. Typical 3D views for both models are shown in Figs. 4.30 and 4.31

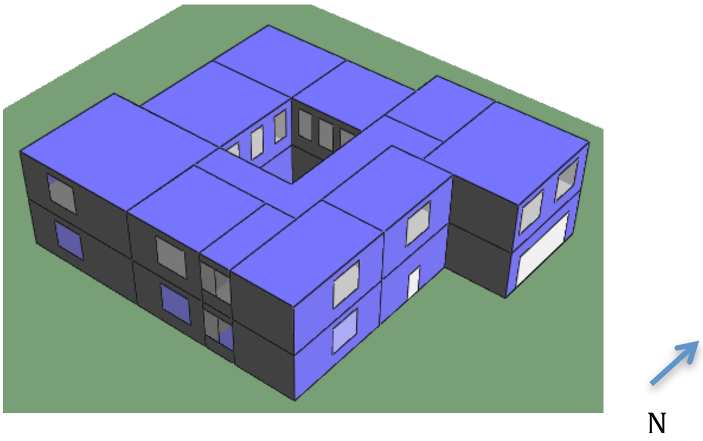


Figure 4.30. The 'base case model' for testing daylight representing simulation fourteen and fifteen (August 21st and december 21st).

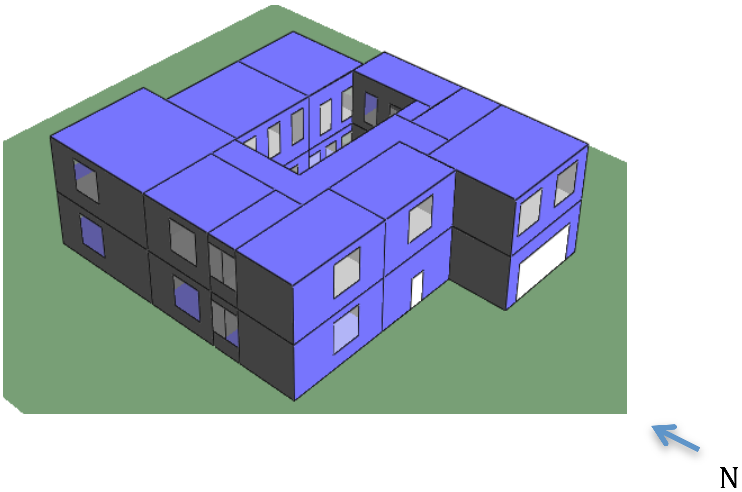


Figure 4.31. The 'enhanced case model' for testing daylight representing simulation sixteen and seventeen (August 21st and december 21st).

4.3.5. Construction Materials

The software suggests broad variety of construction materials categorized into Glazed and Opaque materials. The Opaque materials comprises of roof, ceiling, external wall, internal partition, door and ground floor door, however the Glazed materials available are roof light , external glazing and internal glazing. The construction materials of the considered models are fixed in the software default by the Apache Construction Database within the Building Template Manager, as shown in Fig. 4.32 below. Figure 4.33 shows the external walls construction layers along with their properties: conductivity, thickness, density, category and heat capacity, as this study is mainly concerned with the outer walls properties as shown in figure 4.33.

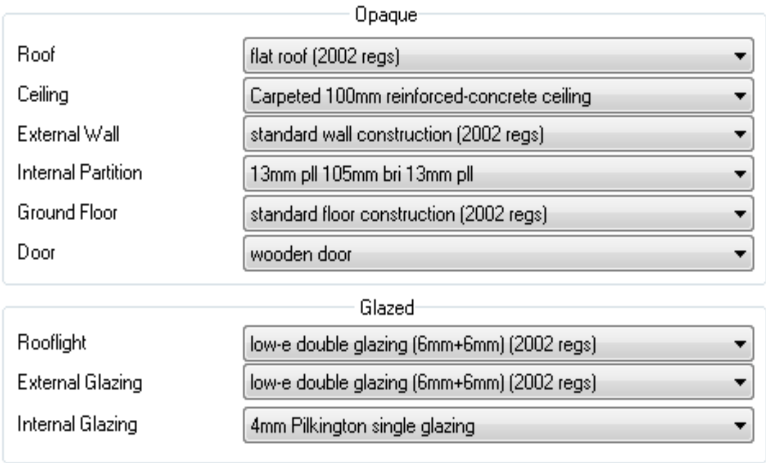


Figure 4.32. The construction materials as per Apache Construction Database (IES)

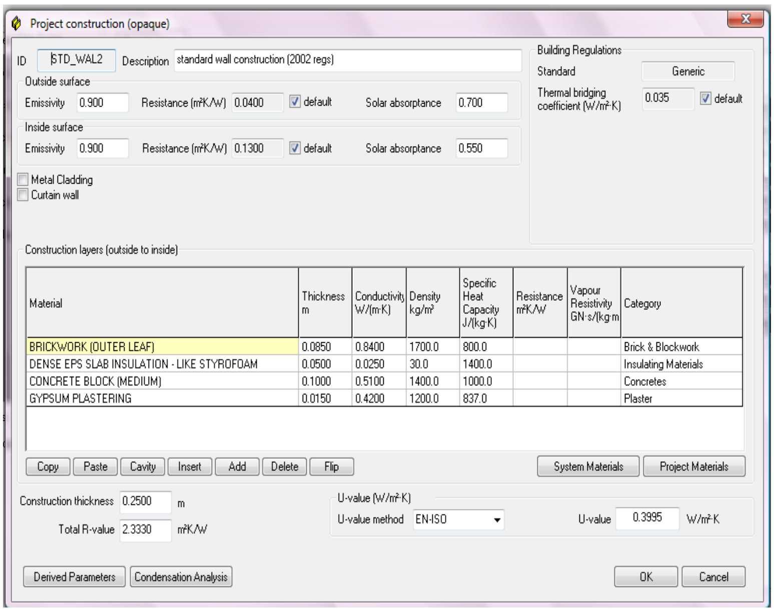


Figure 4.33. The external wall construction materials of the models (IES)

4.3.5 Results Assessment Criteria

The results of the simulations enlightened formerly were combined in a proportional investigation to gain the study recommendations and suggestions. The assessment of the three independent variables (orientation, geometry and vegetation) was completed in an systematized quantitative process and the similar conception was used to the existing case and enhanced case. The output files of the software are essentially data presenting every single grid point of the drawing space for the model. For example, in ENVI-MET the first simulation model utilized a grid of 40x40 which resulted in 3720 grid points with 3720 temperature points and the same number of wind speed points every 30 minutes. The average of the temperature (K) and the wind speed (m/s) for each the grid points was presented in one figure of temperature (K) and one figure for wind speed (m/s) every 30 minutes. The average temperature (K) and the wind speed (m/s) every half an hour in tabularization form were equated to the same outcome of every simulation.

A well-defined judgment among every parameter of orientation is collected to choose the one with the lowermost average temperature. This procedure is used with every parameter of geometry and every parameter of vegetation to get the three parameters that documented lowermost average temperatures throughout summer to be utilized for the enhanced scenario. The core assessment was then lead among the two foremost scenarios; existing, and enhanced grounded on the similar dependent variables utilized in the last simulations (temperature, wind speed, shading and daylight analysis).

Calculation of the results of such assessment will be connected to the former reports reviewed in Chapter 2. Visual maps extracted from the output files of all the simulations by LOENARDO (ENVI-MET) software were prepared. The maps were represented the temperature gradient circulation in the space along with the wind flow in site. Analyses were done among those images and illuminations of the temperature and wind patterns were made instantaneously. The shading and daylight analysis results from SUNCAST and FLUSDL (IES) software were also concluded mainly in numerical and graphic outputs.

4.3.6 Research Challenges and Limitations

The hypothesis under study needs a huge amount of variables to be involved in the present study which needs great level of association and additional time. The investigation of the cooling effect of a passive design approach to the outdoor spaces needs the analysis of every of the variables combined independently resulting in a vast extent of simulations. One of the initial study trials was the collection of the defensible applicable variables. Examining those variables throughout seventeen-simulation model was extremely chaotic as every model has time period of about 20 hours for simulation period only. The saving interval for the output files was every 30 minutes which used to leave a vast amount of output files for extraction for every 15 simulation this took more time then time consumed by simulations itself. Comprehensive accurateness was needed to avoid mistakes and misinterpretation of any of the outcomes.

The software's utilized for simulation (ENVI-Met) and (IES) were cogitated perplexing nevertheless for IES software few workshops were available but for ENVI-MET software self-learning was essential and the online material was inadequate. Inaccuracies happening throughout simulations were like an added challenge, which took more time and energy, still were occasionally indiscernible. Consequently, the reconstructing of the entire model was obligatory in certain cases to block such mistakes, which added the time desirable earlier. This software is very regulated in terms of drawing tools and a performance that drains the handlers to accomplish their goals. Some parameters could have been combined in the present research that may have helped to gain a better cooling impact however were expelled cause of software's limitations.

The foremost trials faced when using ENVI-met was the extraction procedure of the output files. The software output files are files which cannot be edited thus, needed the help of another software to physically extract every data file collected by every simulation, this process was very chaotic. Numerous errors were done throughout the extraction process cause of the huge quantity of work within a restricted time frame but luckily errors were able to be noticed on the former phase that did require validating and recapping the extraction procedure.

The substitute options specified by the simulations tool utilized (same for all outdoor software's) for material selection were very limited for instance materials for pavements and building facades. Such feature would reveal effective outcomes if integrated in a passive design approach which thoughtlessly was not included. The time limit for the present report was cogitated to be comparatively small conferring to the offered tools and required task. Because of the time obstacle and less resources additional examinations were not conceivable nevertheless thorough this research a general foresight about the outdoor environments was attained. Regrettably, lengthier periods of simulated hours for the independent variables and seasonal changes was not integrated as every independent variables were examined through summer days merely. The equilibrium was formed by incorporating those features in the two comparative scenarios; enhanced scenario and existing case scenario. Authentication of the results attained were prepared throughout field measurements. Hence, a evaluation among the attained outcomes, the former authenticated reports and field measurements results were prepared for every conclusions so that misunderstanding of outcomes could be dismissed.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 Data Presentation

This chapter discusses the literature review which was done in chapter 2 and solidifies the findings by supporting them with results and discussion. The procedures that have been explained in chapter 3 and 4 have been described at length in this chapter. Data got from various simulations has been explained at length and presented with major focus on noteworthy findings and behaviours. Various dependant variables such as wind, daylight, shading analysis and temperature have been highlighted in this study.

Three major passive parameters have been examined in this current study in order to fid out the most effective parameter that would reduce the thermal stress in the outdoor environment. Based on the efficient use of these parameters a passive design space was constructed that would respect the environment. These were then examined and compared to the existing case as it helped in quantifying the achievements of the ecological design with regards to influence on outdoor environment.

Exactly as in the chapter 3 and 4 the simulations were run in the exact chronological order in this chapter. The output that was found every 30 minutes has been tabulated and organised and the same been presented in the graphical presentations. The major focus of data extraction was the temperature ranges and this was addressed as potential temperature (POT, temperature in Kelvin). Each model had an excel sheet where the temperature values are recorded every 30 minutes. From each sheet the mean, minimum and maximum values were found out which summarised the comparing values require for each variable. Additional sheets were attached in order to compare the parameters of various variables in different scenarios.

Daylight, shading and wind speed were another set of variables which have been noticed and mentioned in this study. Wind speed plays crucial role in effecting the micro climate in hot and humid areas. Hence it is a vital parameter which affects the thermal feeling of an individual which is the reason it has been tabulated. As there were some strange patterns of temperature found out during the earlier investigations. After a careful analysis it was found out the wind plays a role in it so this became the major reason for involving wind in this study as it had an influence on thermal conditions.

At the time of observation procedure involvement of wind speed outcomes helped to create more logic in understand the temperature findings. Same sheets were being utilised for recording the wind speed measurements which were being used for temperature records having the average, minimum and maximum values. The explanation of the data which is found out from graphical representations is actually the difference of temperature and wind values between average, maximum and minimum. The explanation of different variable comparisons was with regards to difference between the dependant variables (mean wind, mean temperature maximum wind) in analysed parameters.

Results in which the difference of values was observed to be 1K are said to be significant values. The difference in results showed slight bit of standard deviation which has been described and validated in this chapter. At the time of field measurement the real values of temperature and wind speed recorded had more relevance to initial values used and defined in table 3.4. Hence the results of current investigations are explained with regards to simulation conditions which have been shown and validated in third and the fourth chapter of this study. The results that have been found out are presented in graphical and numeric values and images as well which have been extracted from software's. All this is explained in the discussion part of this chapter.

5.2 Existing Scenario

The first base model that was constructed was a replication of the THE VILLA site in Dubai having the same morphological and climatic conditions. It is known as the existing scenario. The model that has been shown below consists of extreme summer temperature on 21st august and extreme cold temperature in winter condition on 21st December . The simulations that were carried out on these two days were between 8am and 10 pm time frame. The current site had no vegetation with a height to width ratio of 0.85 and the orientation of 22.5$_o$ NNE.

On 21[st] of august the mean temperature and the wind speed was 302.795 K and 1.16 m/s respectively. On the other hand temperature on the 21$_{st}$of January was 298 K with a wind speed of 1.12m/s as shown in table 5.1. The maximum temperature values both during the summer and winter have been given importance and mentioned in the table. They have been recorded in time frame between 12 PM to 15.30 when the thermal stress is at its peak. The temperature that was recorded in summer was 305.123 K and the temperature value that was recorded in winters was 301.928 K as shown in figure 5.1. The average wind speed per hour is more in summer as compared to that of winter. In summer the mean wind speed values that were recorded was of 1.16 m/s and in winter the mean wind speed value was of 1.12 m/s as shown in figure 5.2. The stability and consistency in temperature values and wind are more during the winter season as compared to that summer season. On the other hand the difference between the maximum and minimum temperature values during the day is more in summer which is 8.9 K as compared to that of winter which is only 6.7 K as shown in table 5.1.

Table 5.1 shows the average, maximum and minimum temperature and wind values that were achieved by simulations during summer on 21st August and winter on 21st December.

	Temperature Summer	Temperature Winter	Wind Summer	Wind Winter
Average	302.795	298.454	1.1676	1.1286
Maximum	305.123	301.928	1.2317	1.1457
Minimum	297.1	294.2	1.1332	1.1235

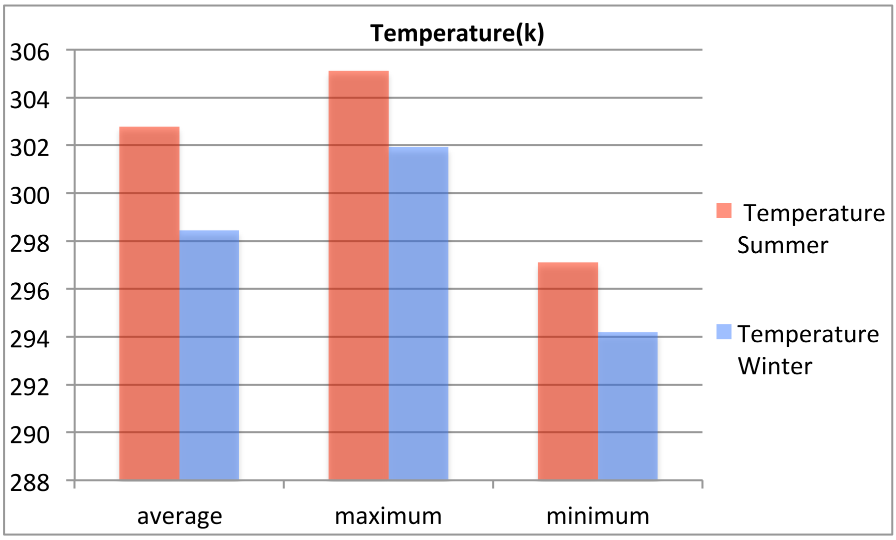


Figure 5.1 The temperature values behavior during summer on 21st August and during winter on 21st December.

The variation between the mean temperature of summer and winter is 3.1K which is less than the variation between the maximum values of 3.4K. On the other hand the variation between the minimum values is only 2 K and is least among all other variations in temperature values as shown in Figure 5.1. This shows that the rate at which the temperature increases both in summer and winter is not same all through the day. As shown by values the stability of night temperatures in summer is more as compared to that of the day time especially during the peak thermal stress hours.

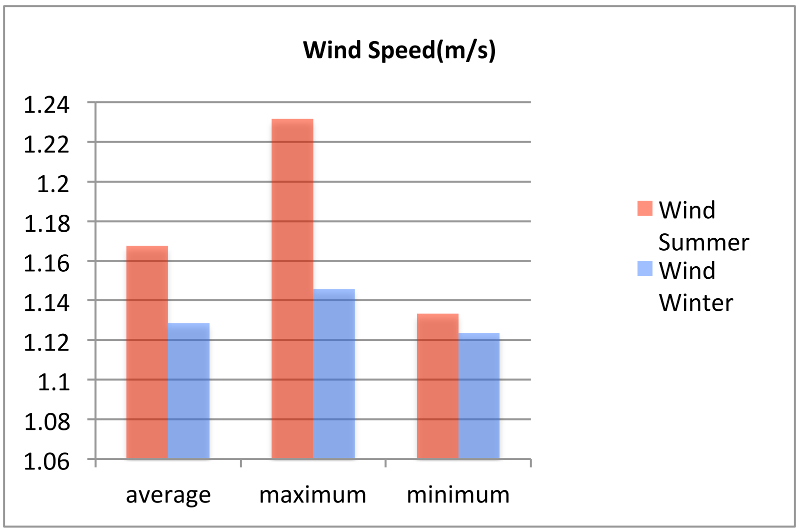


Figure 5.2 The wind speed values behaviour at the time of summer on 21st August and during winter on 21stdecember.

As shown in figure 5.2 the variations in wind speed are more stable than the variations in temperature values. On the other hand wind speed increases more during the thermal stress hour in summers as compared to that of morning and night time. At the time of maximum temperature hour the wind speed pattern is recorded.

5.3 Independent Variables

5.3.1 Orientation

In order to analyse the first independent variable having the same morphology as the existing one three simulations have been carried out with different orientations. The three different models that were constructed had 0.85 as their height to width ratio with no vegetation. However orientations in each case were different such as North-South, North-West and North-East. Simulations on each different independent variable were carried out in extreme thermal conditions of summer that is on 21st august between 8am to 6pm. The mean, highest and lowest temperatures resulting from different orientations were then compared with each other. However the one that was referred to the coolest orientation of all was the one with that had recorded the least average temperature during that time frame from 8 to 6 in summers. The difference in temperature values was very less in three different orientations as explained in the literature review and validated in chapter 4.

All the three orientations were compared to each other and the most suitable among them was integrated in the enhanced scenario. The variation between the maximum average temperature value of the North-East orientation and least mean temperature of North-South orientation was recorded as 0.5 K. Due to this reason north south orientation was nominated for enhanced scenario. However the in North-West orientation the maximum temperature was 304.8 K which was lesser as compared to that of North-South orientation in which the maximum average temperature recorded was 304.9 as shown in figure 5.3. The variation between the lowest average temperature values was 0.5 K and the variation between highest average temperature values was 0.2 K. Examining the highest average temperature patterns among the three orientations it showed that during maximum thermal stress the variation in temperature in all orientations declines similar to what was found in the existing scenario.

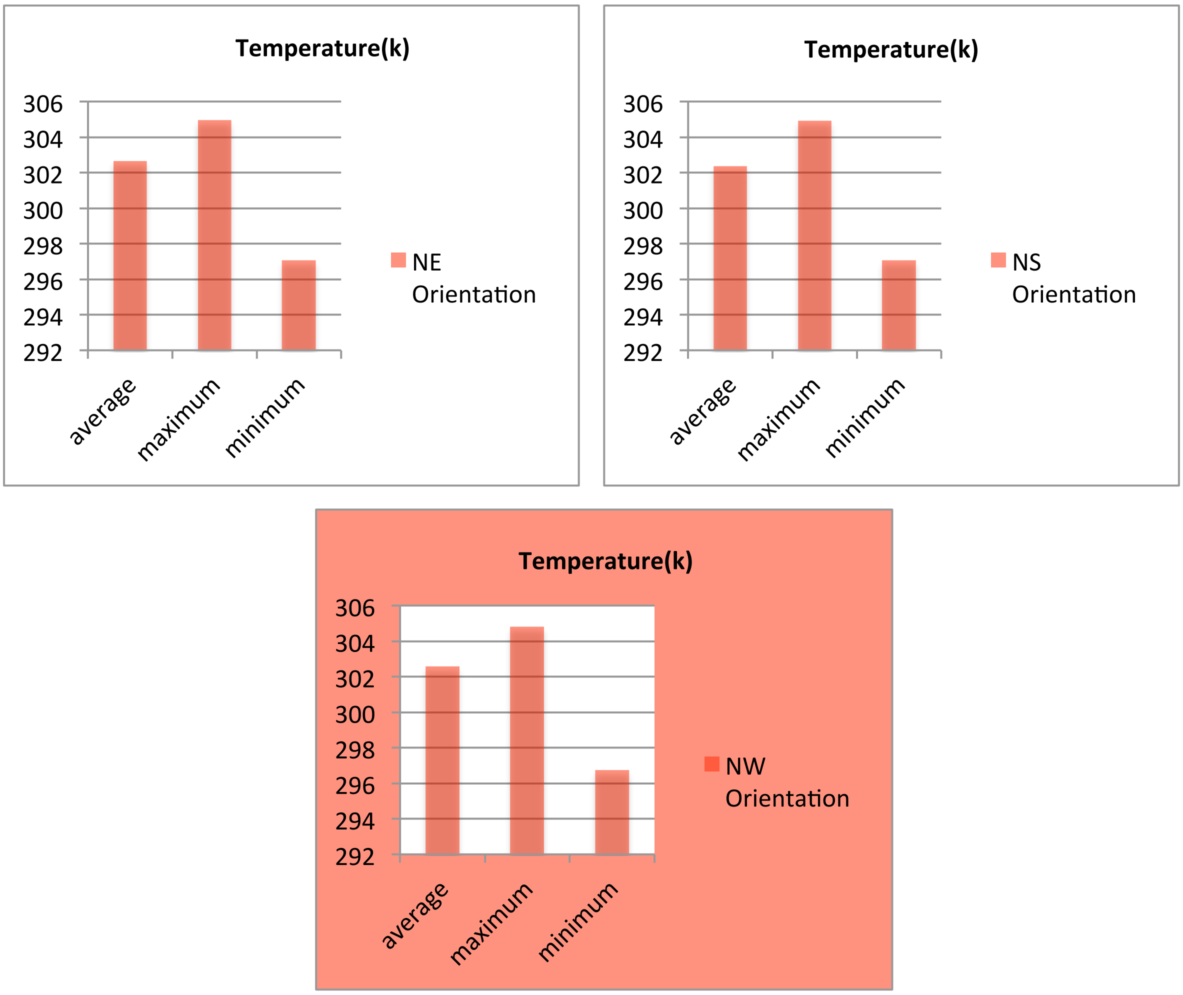


Figure 5.3 The three orientations showing the average, maximum and minimum temperature values mentioning the NW orientation as the selected parameter integrated in the enhanced model.

The difference between the temperature values of the three orientations as shown in figure5.4 is comparatively more than the wind values as represented in figure 5.5. An average wind speed of 1.420 m/s which was recorded in the North-South orientation was the least wind speed among all the three orientations as shown in figure 5.6.

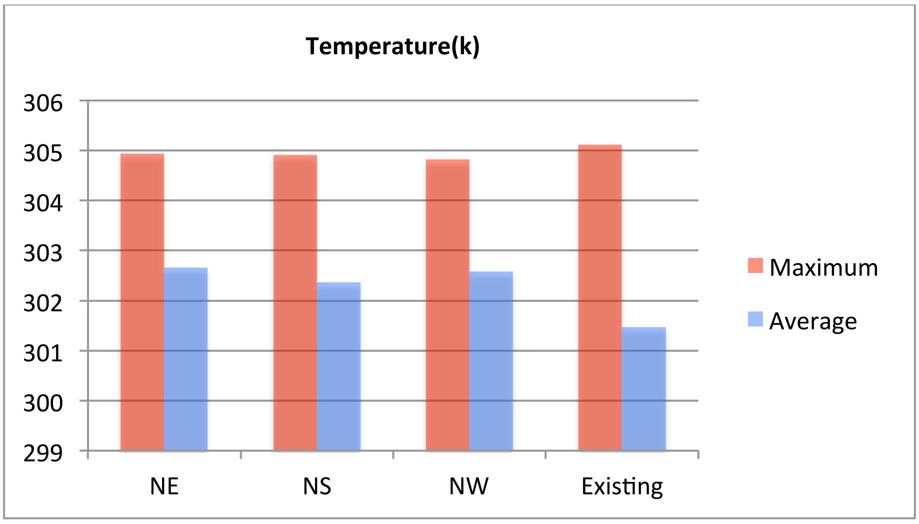


Figure 5.4 The average and maximum temperatures of the three orientations compared to the existing scenario with the lowest average temperature of the of the NW orientation.

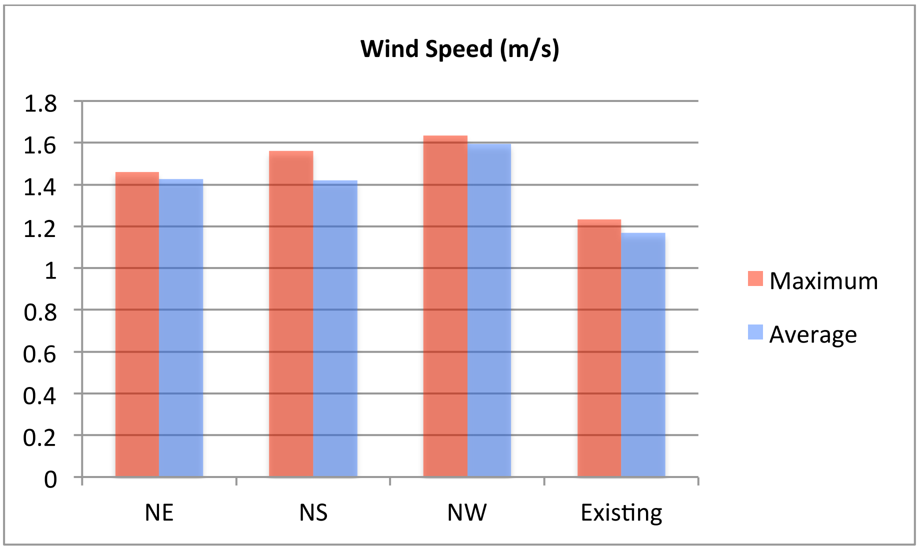


Figure 5.5 The average and maximum temperatures of the three orientations compared to the existing scenario with the highest average and maximum wind speed of the of the NW orientation.

The current scenario had 22.5$_0$ angle towards the NNE compared to 45 degree of the chosen orientation with a temperature difference. The existing scenario which has been shown in figure 5.4 and 5.5 corresponded to a higher average temperature value than the North-West orientation. The difference between the two was recorded to be 0.4 K. the difference between existing and North-South orientation was very less with a difference of 0.1 K. North-South orientation was recorded to have the highest average temperature among all other orientations chosen for comparison. After the analyses it was found out that tilting angle was effective in influencing the outdoor air temperature along with the orientation.

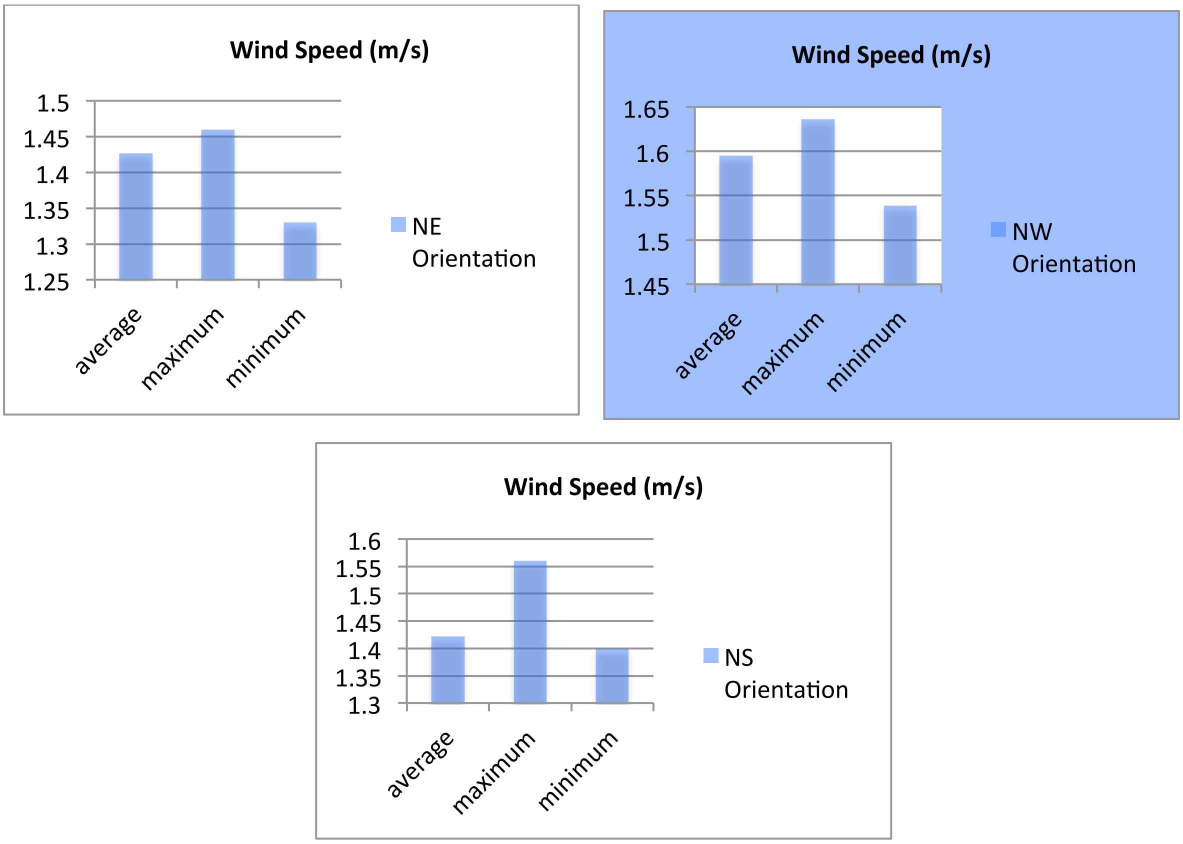


Figure 5.6 The three orientations demonstrating the average, maximum and minimum wind speed values highlighting the NW orientation as the selected parameter incorporated in the enhanced model.

The existing wind coming from the North-West direction helps the North-West orientation to experience the maximum wind flow level with an average speed of 1.595m/s. Next to this orientation came the North-East orientation which had the wind speed of 1.427m/s.The North-South orientation acts as a barrier to incoming wind breeze from the space and thus experiences the lowest average wind speed of 1.422 m/s. The variation between the average and maximum values of wind are very minute as compared to the variations of temperature values represented in figure 5.3. On an average the difference between the highest wind speed values and lowest wind speed values was 0.17 m/s. the configuration of the wind helps to explain that the wind speed is stable at day time during summers. Least amount of wind is experienced in the North-South orientation which also has the lowest average temperature scale which is an indication in itself that the wind doesn't have the cooling effect.

5.3.2 Geometry

One of the factors that was analysed within the space geometry is Height to Width ratio referred as H: W. simulations were conducted for three different ratios which are 1.35, ratio 1 and ratio 1.08. The ratio for the simulated existing model was 0.85 that was compared to geometry results achieved. The building heights for three models were different such as 7.5m, 6m and 8m with 22.5$_0$ NNE orientation and no vegetation. The simulations were carried out at the peak thermal stress conditions on 21st of august between 8 am and 6pm time frame similarly as in other cases.

The analysis of height to width ratio was dependant on both variables height and width. the height and width of the first model was 7.5m and width 5.55m respectively which is equal to a ratio 1.35 as compared to the second model having the height of 6.5m and width of 6.48m = ratio 1:00. The two models were compared to a third model of a 1.08 ratio where Height is-8m and Width of-7.4m in logic sequence based upon the results found out in similar studies demonstrating that the temperature declines as the ratio enhances and this was revealed between the models.

The difference in height to width ratio proved to be less influential on the thermal values as compared to that of orientation values. The variation in the mean temperature was recorded to be 0.2 K and the variation in the average wind speed was recorded to be 0.53 m/s. the highest average temperature was recorded in the ratio 1 and then it was followed by 1.08 and then 1.35 which had the lowest average temperature values as shown in figure 5.7. The ratio and temperature values have an inverse relationship with each other. As the ratio decreases temperature increases and vice versa.

The least average temperature of 302.7 K was recorded in which the ratio was highest with a value of 1.35. The mean wind speed in this case was recorded to be 1.23 m/s. the variation in temperature was 0.4 K as in 1.08 ratio compared to that of 1.35 ratio. The enhanced version was integrated with 1.35 ratio as this was considered to be the best geometry among the others.

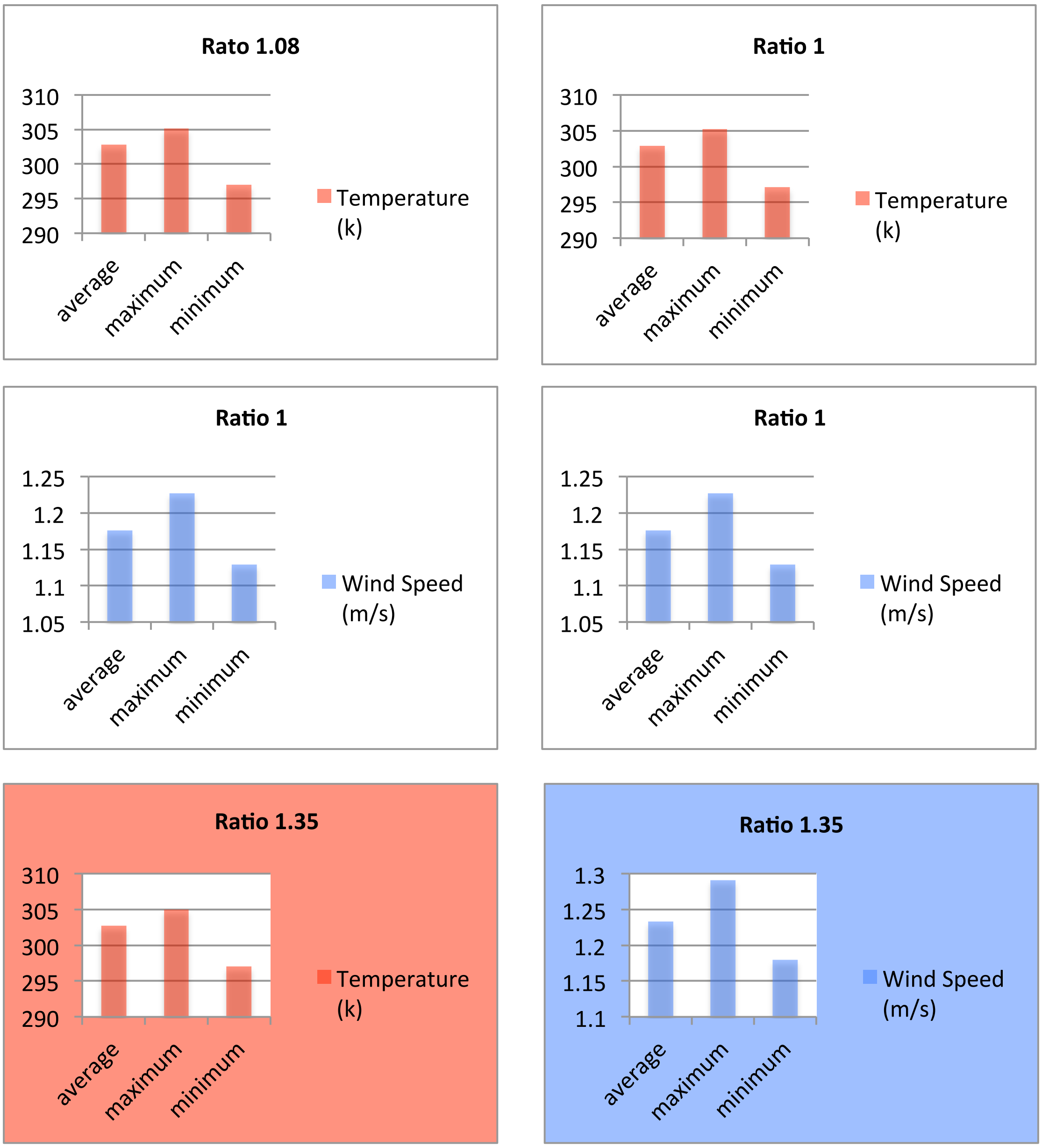


Figure 5.7 Average, maximum and minimum temperature and wind values of the three different H:W ratios where the nominated ratio records the lowest temperature values and the highest wind speed values.

The results that were found in the temperature values with regards to geometry were opposite to that of the orientation factor. It has been observed that the temperature variation in all the three geometries increases during the peak thermal stress hour as the shading works like a cover and avoids excess heat gain.

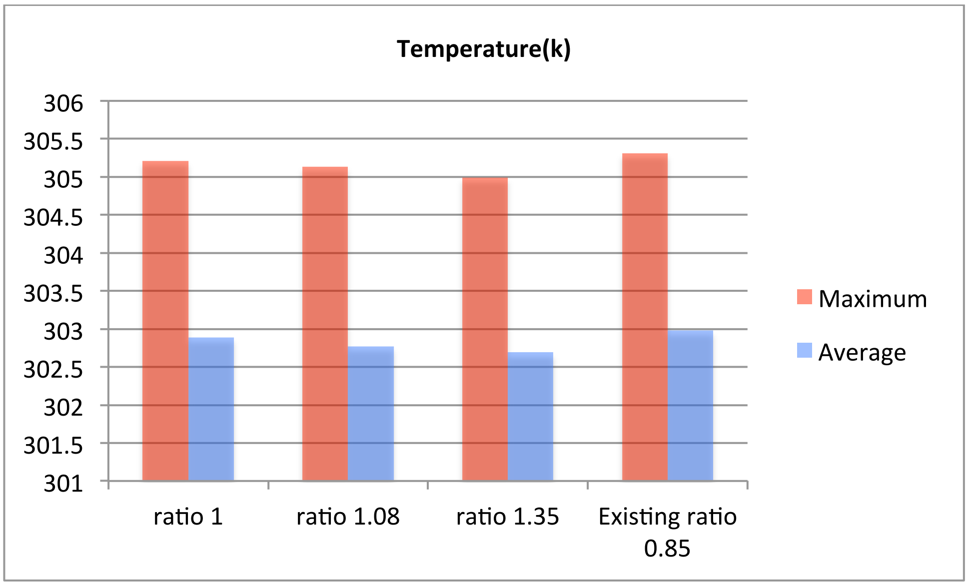


Figure 5.8 The average and maximum temperature comparison between the three tested ratios and the existing scenario presents a logical sequence with the lowest values for the ratio of 1.35

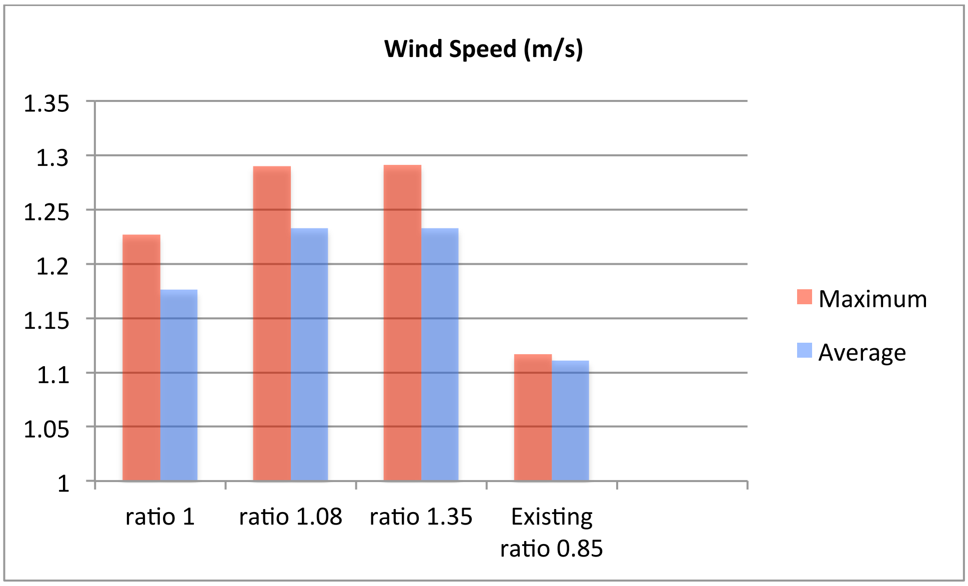


Figure 5.9 The average and maximum wind speed comparison between the three tested ratios and the existing scenario presents a logical sequence with the lowest values for the ratio for existing scenario

The variation between the average and the maximum temperature values was stable in the three scenarios as represented in figure 5.8. The difference between the temperature values was more than the difference between the wind speeds as shown in figure 5.9. The difference in wind speed in all the three geometries was very less. The highest average wind speed value was recorded in geometry with ratio of 1.35. The difference in the wind speed between the ratios of 1.35 ands ratio of 1.08 was only 0.06 m/s. wind has very less effect as dependant variable on height to width ratio as compared to other dependant variable which is temperature. The ratio in the existing scenario was 0.85 in which the average temperature was almost same to that of ratio 1 with very less increase. In the existing scenario the inverse relationship between Height to width ratio and temperature was present.

5.3.3 Vegetation

Various landscape strategies have been tested with the integration of grass and trees in different simulation models which tested the vegetation parameter. Orientation of a 22.5_0 NNE and height to width ratio of 0.85 was present in all simulations. The three vegetation strategies that were proposed were continuous grass, continuous grass with groups of trees and groups of trees only. The aim to implement these vegetation strategies was to influence the outdoor air temperature. One of the main reasons for studying the effect of vegetation was to check if trees have any negative impact on temperature in summer as mentioned in some studies. Large amount of vegetation has a tendency to block the night flush process due to which the heat gained is released in the space.

The vegetation pattern with continuous grass and tree groups was found to have the least amount of average temperature of 304.6 K and a wind speed of 1.12 m/s which resulted due to combination of these two vegetation strategies. The existing case had no vegetation present which resulted in highest average temperature and the wind speed. It didn't had trees which could have helped in shading effect and also would have acted as a barrier to wind flow as shown in figure 5.9 and 5.10. There was a minute difference among all the three strategies. The difference in maximum values was recorded to be 0.57 K with the mean wind speed and the minimum temperature values had very less variation of 0.3 K.

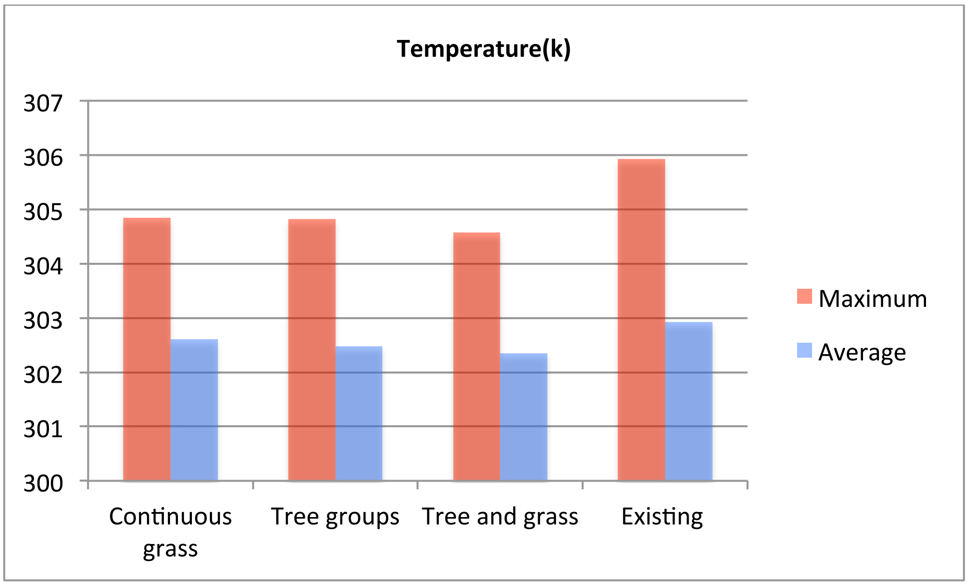


Figure 5.10 The three vegetation strategies average and maximum temperatures and the existing scenario values reveals that the trees and grass proposal has the least values.

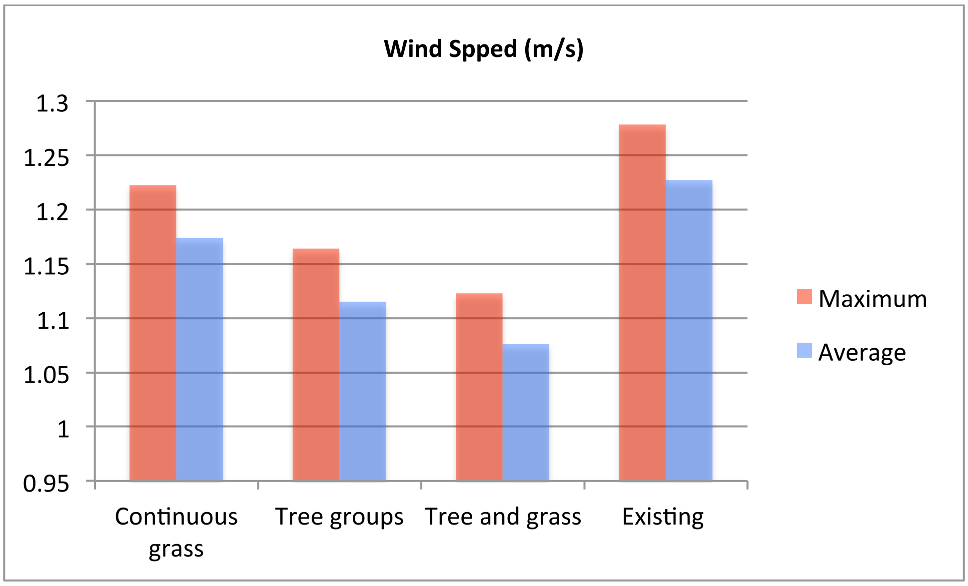


Figure 5.11 The three vegetation strategies average and maximum wind speed and the existing scenario values.

There is very less difference in temperature between continuous grass strategy and tree group strategy. Where as the difference between group of trees and continuous grass and tress was the least among all. The difference recorded was 0.4 K as shown in figure 5.11. During the high stress hours the behaviour of temperature is in accordance with the geometry behaviour in which the difference in values increases at that time where as it is opposite with the orientation behaviour as shown in figure 5.11.

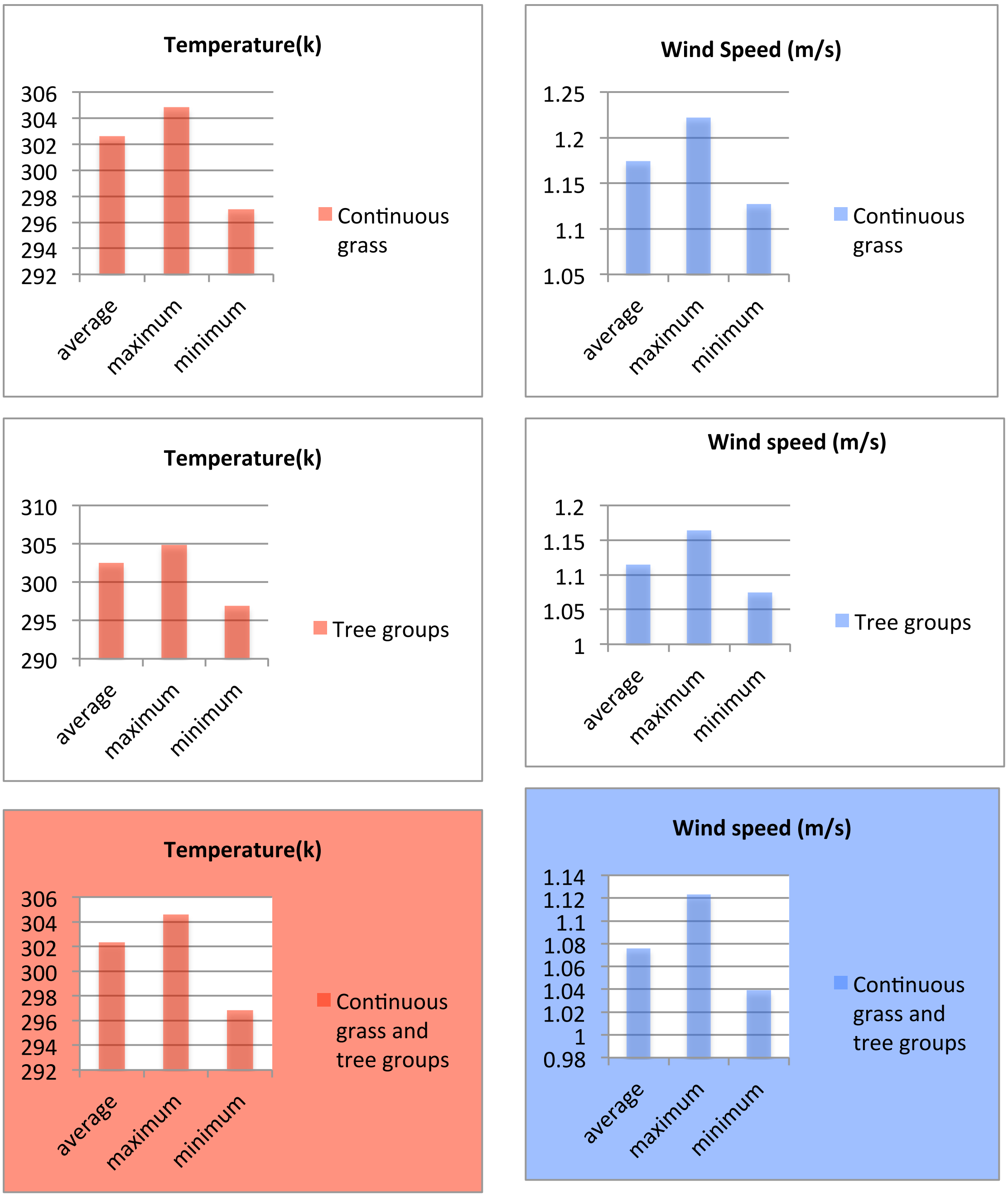


Figure 5.12 the average, maximum and minimum temperatures of the four vegetation strategies

The findings showed some anticipative sequence for various strategies. The more concentrated vegetation results in lowering the temperature only if the continuous trees aren't used which can result in nocturnal heat gain. Trees are more effective than grass as they provide shade and also due to their biological characteristics.

The highest mean and maximum temperature was found out in the existing scenario as it had no vegetation. The average temperature was 302.8 K and mean wind speed recorded was 1.18 m/s. The variation in the average temperature was 0.4 K as compared to that of best vegetation strategy as shown in figure 5.10. The best vegetation strategy was considered to be one with continuous grass with group of trees followed by continuous trees only and then continuous grass at the last.

5.3.4 Comparison of Independent Variables

In this investigation the passive parameters that were chosen illustrated variable results as per the mean and average temperatures observed. The most effective parameter for enhancing the air temperature was found to be vegetation with temperature difference of 0.6 K from the existing scenario and then it was followed by orientation which had a temperature difference of 0.4 K and then geometry which made the difference by only 0.1 K as represented in figure 5.12. Same sort of pattern was found in wind speed however the effect found was opposite to that of the temperature. The lowest mean wind was found out in the vegetation parameter with wind speed of 1.08 m/s and the highest was available in the geometry variable with 1.18 m/s followed by orientation as shown in figure 5.13. The variation in air temperature was very less due to these parameters still they were examined and explanations were derived from these behaviours. A consistent sequential pattern shown by all the dependant variables tested revealed a rational sequence which was not found in the earlier studies. These results will be discussed thoroughly in the discussion part of this chapter. This would be helpful to examine the effect of passive design on outdoor air temperature.

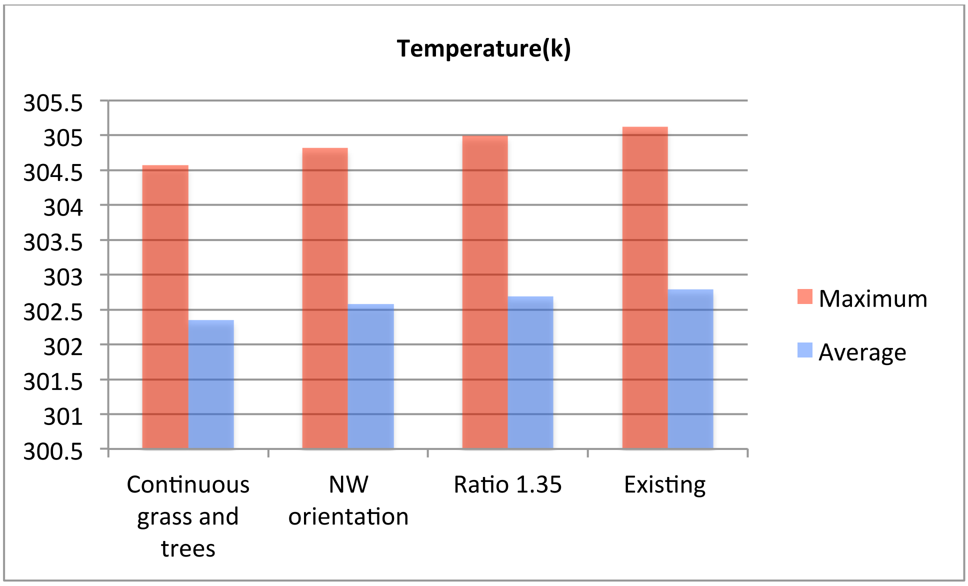


Figure 5.13 The average and maximum temperature values for the most effective independent variable that recorded the lowest temperature values

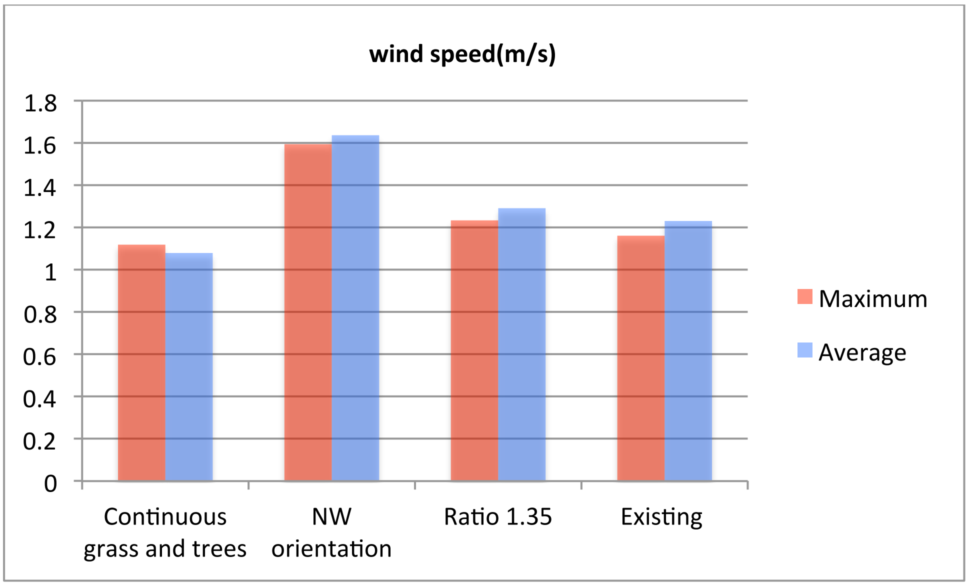


Figure 5.14 The average and maximum wind speed values for the most effective independent variable that recorded the lowest temperature values

5.4 Enhanced Scenario

The last model of this study in which the most efficient parameters of the passive design variables were put together is known as the enhanced model. The findings of this model were examined in order to validate the hypothesis set. The simulations findings are based on the North-West orientation with a Height to Width ratio of 1.35 and with continuous grass with group of tress vegetation. Simulations conducted were similar to one that were conducted on the existing scenario for same duration on 21st of august for summer and on 21st of December for winter from 8am till 10 pm.

The temperature sequence which has been represented in the figure 5.14 has the highest thermal stress period between time range of 12.00 and 15.00 in summers in which the highest temperature recorded is 304.7 K. at this time in summer there was a considerable increase in the wind speed with a highest value of 1.05 m/s as represented in figure 5.15. The variance in temperature was 8.1 K between the maximum and minimum temperature in summer and this would decrease during the winters and was recorded to be 7.4 K as shown in table 5.2. The mean temperature that was recorded in summer for the enhanced case was 301 K and during the winters it was recorded to be 298 K which is comparatively lesser than the existing scenario. Variation in the temperature during the two seasons is very much consistent for average, maximum and minimum temperature even during the peak thermal stress hours as represented in figure 5.14. In case of wind speed the results are not consistent. The variation in the maximum values was much more than the average and minimum values as illustrated in figure 5.15.

Table 5.2 The temperature and wind speed values of the summer on the 21st august and winter on the 21st december

	Temperature		**Wind**	
	Summer	**Winter**	**Summer**	**Winter**
Average	301.052	298.173	0.980	0.941
Maximum	304.698	301.867	1.054	0.960
Minimum	296.527	294.427	0.941	0.933

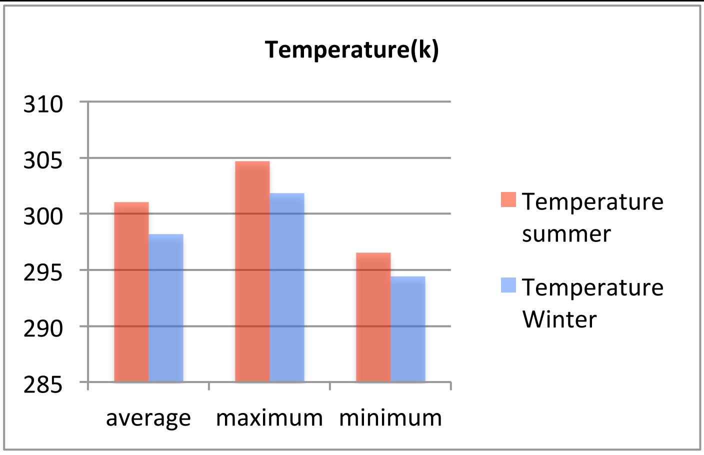


Figure 5.15 The average, maximum and minimum temperature values of the enhanced scenario during summer on the 21st of august and winter on the 21st december

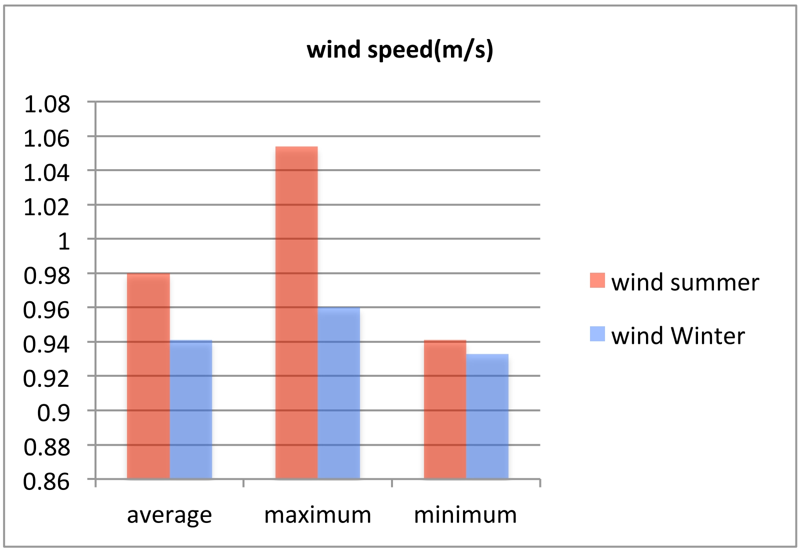


Figure 5.16 The average, maximum and minimum wind speed values of the enhanced scenario during summer on the 21st of august and winter on the 21st december

5.5 Comparative Analysis

The two main scenarios will be analysed and compared to each other in order to check the effect of passive design parameters on the air temperature and outdoor environment. The primary motivation for the enhanced scenario is to have high temperature during the winters and lowest during the summers so that there will be thermal comfort all through the year. Simulations were carried out for the entire day between 8 am and 10 pm so that right balance between the day and night temperatures and wind patterns will be attained. The calculation of mean temperature was done in order to show the balance between maximum and minimum temperature values. On the other hand wind pattern was carefully monitored with regards to these aspects in order to check its impact on the heat behaviour.

The lowest average temperature of 304.7 was recorded in the enhanced scenario during summers and the highest temperature of 301.9 K was recorded during the winters as shown in table 5.3. as shown in figure 5.16 the existing scenario had difference of 0.9 K between the highest values during summer. A logical sequence was the outcome of the order of two scenarios in summer with a little bit of difference with regards to temperature and wind speed values.

Table 5.3 Summary of results of the temperature values of the two scenarios during summer on the 21st of August and winter on the 21st of december highlighting the highest in winter and lowest in summer.

	Average Summer	Average Winter	Minimum Summer	Minimum Winter	Maximum Summer	Maximum winter
Enhanced scenario	301.052	298.173	296.527	294.342	304.699	301.867
Existing scenario	302.040	298.061	297.034	294.427	305.560	301.162

The mean and the highest temperature sequence shows the normal behaviour in which the factors that generally have the lowest temperature values during summer are reversed at winter time to have the highest temperature values except the enhanced scenario. The wind sequence as shown in figure 5.17 in the existing scenario has the highest wind speed in all the cases due to many factors. Small amount of wind is allowed through the spaces in NNE orientation and with no vegetation the wind speed increases in the space thus increasing the maximum values of wind in this scenario. In the enhanced scenario wind is allowed to enter the space with interruption by vegetation and high values of height to width ratio. In the end the results prove that the enhanced scenario has the ability to reduce the air temperature by 1 K.

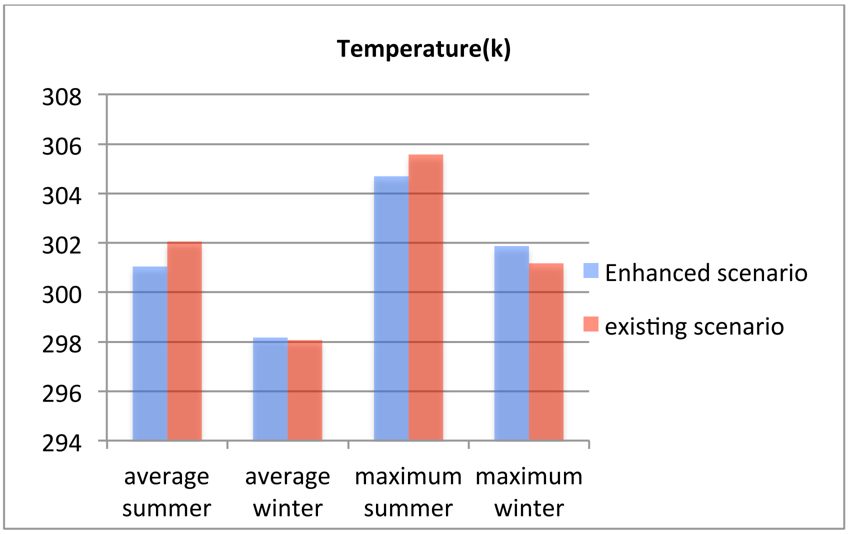


Figure 5.17 The average and maximum temperature during summer on the 21st of august and winter on the 21st of december

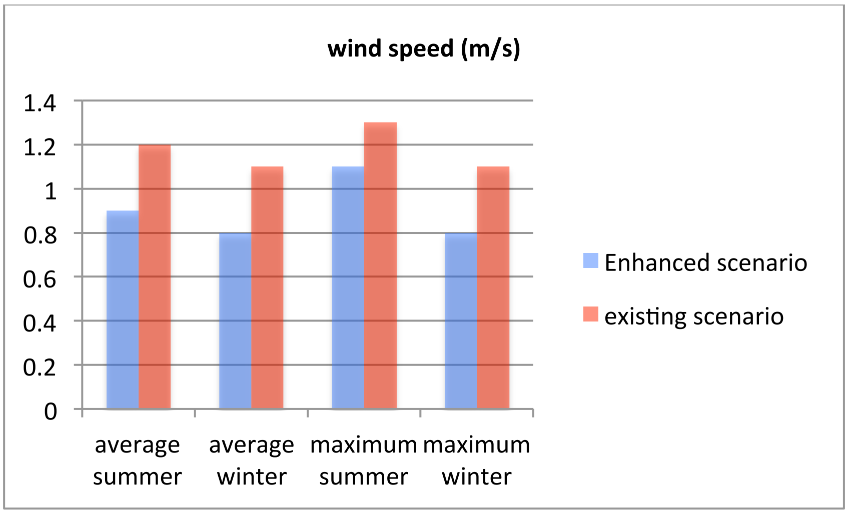


Figure 5.18 The average and maximum wind speed during summer on the 21st of august and winter on the 21st of December with the existing case as the highest value in all cases

5.6 Daylight and Shading Analysis

In order to compare the enhanced and the existing scenario the daylight and shading has been done.

Solar Shading Calculations

As a result unnecessary solar gain the buildings consume high amount of energy especially during the temperate climate. Sun cast module in the IES software is very useful in visualising the solar radiation. The maximum amount of solar radiation is experienced in the months from April to September in the time frame of 12.00 to 15.00 hours. On the other hand no even 50 percent of the model surfaces experience the solar radiation in the months of November, December, January and February. Same applies in the courtyard spaces of existing and enhanced scenario in the chosen climate of Dubai.The calculation of solar radiation for the surface area of existing site at12:00 and 15:00 is 44.03% and 31.77% respectively. On the other hand for enhanced surface area it is 42.99% and 30.62% respectively as shown in figure 5.18.

Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00
Jan	-	-	-	-	-	-	-	10.28	21.74	31.81	39.63	44.03	44.02	39.60	31.77	21.70	10.24	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	1.24	14.25	26.62	37.87	47.07	52.65	52.93	47.79	38.86	27.76	15.47	2.51	-	-	-	-	-	-
Mar	-	-	-	-	-	-	7.39	20.84	33.94	46.28	56.90	63.55	63.10	55.81	44.92	32.45	19.29	5.82	-	-	-	-	-	-
Apr	-	-	-	-	-	1.04	14.42	27.96	41.50	54.78	67.15	75.71	73.03	62.19	49.29	35.86	22.30	8.81	-	-	-	-	-	-
May	-	-	-	-	-	5.21	18.18	31.46	44.94	58.50	71.95	83.81	78.47	65.33	51.78	38.25	24.86	11.71	-	-	-	-	-	-
Jun	-	-	-	-	-	5.55	18.25	31.32	44.64	58.11	71.67	85.06	80.76	67.23	53.69	40.26	27.01	14.05	1.51	-	-	-	-	-
Jul	-	-	-	-	-	3.31	16.19	29.42	42.86	56.41	69.92	82.55	80.57	67.57	54.03	40.49	27.08	13.91	1.10	-	-	-	-	-
Aug	-	-	-	-	-	0.26	13.62	27.15	40.69	54.02	66.52	75.59	73.71	63.08	50.23	36.81	23.25	9.75	-	-	-	-	-	-
Sep	-	-	-	-	-	-	11.03	24.42	37.39	49.43	59.34	64.42	61.91	53.34	41.87	29.15	15.87	2.35	-	-	-	-	-	-
Oct	-	-	-	-	-	-	7.58	20.28	32.12	42.42	49.96	52.99	50.46	43.26	33.15	21.42	8.78	-	-	-	-	-	-	-
Nov	-	-	-	-	-	-	2.92	14.91	25.84	35.08	41.62	44.29	42.43	36.50	27.67	16.98	5.15	-	-	-	-	-	-	-
Dec	-	-	-	-	-	-	-	10.87	21.72	30.98	37.79	41.11	40.23	35.35	27.41	17.41	6.09	-	-	-	-	-	-	-

Figure 5.19. Solar calculations by SunCast in percentage of existing surface area (%) (IES)

Month	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00
Jan	-	-	-	-	-	-	-	10.06	21.36	31.23	38.81	42.99	42.83	38.39	30.62	20.63	9.26	-	-	-
Feb	-	-	-	-	-	-	0.25	13.13	25.33	36.34	45.26	50.61	50.91	46.04	37.43	26.59	14.49	1.67	-	-
Mar	-	-	-	-	-	-	5.94	19.31	32.28	44.40	54.69	61.10	60.90	54.20	43.76	31.58	18.58	5.19	-	-
Apr	-	-	-	-	-	-	13.23	26.79	40.28	53.43	65.46	73.54	71.39	61.24	48.64	35.31	21.77	8.24	-	-
May	-	-	-	-	-	4.68	17.74	31.09	44.60	58.16	71.50	82.67	77.73	64.85	51.35	37.80	24.35	11.13	-	-
Jun	-	-	-	-	-	5.76	18.48	31.56	44.89	58.37	71.93	85.27	80.44	66.92	53.38	39.94	26.69	13.73	1.19	-
Jul	-	-	-	-	-	3.87	16.68	29.85	43.25	56.78	70.32	83.29	81.00	67.76	54.20	40.69	27.32	14.21	1.49	-
Aug	-	-	-	-	-	0.83	14.11	27.59	41.15	54.59	67.43	77.35	75.58	64.45	51.38	37.89	24.33	10.88	-	-
Sep	-	-	-	-	-	-	11.57	25.04	38.19	50.56	61.03	66.76	64.34	55.45	43.69	30.80	17.43	3.89	-	-
Oct	-	-	-	-	-	-	8.38	21.24	33.31	43.94	51.86	55.14	52.55	45.10	34.72	22.78	10.00	-	-	-
Nov	-	-	-	-	-	-	3.84	15.93	26.99	36.34	42.96	45.59	43.56	37.39	28.33	17.46	5.47	-	-	-
Dec	-	-	-	-	-	-	-	11.47	22.27	31.46	38.14	41.28	40.20	35.14	27.07	16.97	5.59	-	-	-

Figure 5.120 Solar calculations by SunCast in percentage of enhanced surface area (%) (IES)

Daylight Analysis

One of the key factor which is very useful in measuring the energy performance and the comfort for occupants is the day light. The amalgamation of direct and indirect sunlight at the day time forms the daylight. According to Kwok (2007) a statistical ratio which depicts the association between interior and exterior light illuminance is known as Daylight Factor (DF). There are various factors which affect the daylight such as size of the opening, location and geometry of the room, spreading of light due to glazing surfaces and the reflective nature of the of the external and internal facades. The illuminanace (lux) of the daylight with regards to daylight factor is measured as shown below.

Daylight illuminance = (DF at point A)(exterior illuminance) (5)

FlucsDL and IES software was used for calculating the illuminanace and day light factor in the existing and enhanced scenarios. As per solar shading calculations done earlier couple of day lighting scenarios were selected. The two extreme days of the year 21 august and 21 December were selected for the investigation purpose. The findings of the investigation for the existing model on 21st of December at noon 12.00 recorded mean DF to be 14.5 % and mean daylight level to be 908.22 lux as shown in table 5.4. using the same time and date for the enhanced scenario recorded the mean DF to be 6.3% and mean daylight level to be 396.28 lux as shown in table 5.5. The daylight factor and mean daylight level for the existing model in summer on 21st august same time (12.00pm) were recorded to be DF 10.1% and average daylight level is 2509.47 lux as shown in table 5.6. For the enhanced scenario the mean DF is 5.6% and mean daylight level is 1394.65 lux.

Table 5.4. Summary of results for daylight in the existing model by FlucsDL, December 21, 12:00 PM

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max. Ave.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=741.000 m. Margin=0.50 m	**Daylight factor**	7.1%	14.5%	40.1%	0.49	0.18
	Daylight illuminance	441.03 lux	908.22 lux	2503.23 lux	0.49	0.18

Table 5.5 Summary of results for daylight in the enhanced model by FlucsDL, December 21, 12:00 PM

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max. Ave.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=741.000 m. Margin=0.50 m	**Daylight factor**	0.5%	6.3%	28.1%	0.08	0.02
	Daylight illuminance	31.30 lux	396.28 lux	1753.75 lux	0.08	0.02

Table5.6. Summary of results for daylight in the existing model by FlucsDL, august 21, 12:00 PM

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max. Ave.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=741.000 m. Margin=0.50 m	**Daylight factor**	6.3%	10.1%	21.6%	0.62	0.29
	Daylight illuminance	1553.16 lux	2509.47 lux	5351.84 lux	0.62	0.92

Table 5.7. Summary of results for daylight in the enhanced model by FlucsDL, august 21, 12:00 PM

Surface	Quantity	Values			Uniformity (Min./Ave.)	Diversity (Min./Max.)
		Min.	Ave.	Max. Ave.		
Working plane 1 Reflectance=0% Transmittance=100% Grid size=0.50 m Area=741.000 m. Margin=0.50 m	Daylight factor	0.3%	5.6%	20.3%	0.05	0.02
	Daylight illuminance	76.35 lux	1394.65 lux	5024.25 lux	0.05	0.02

Table 5.8, and graphs in figure 5.12 and 5.22 below draw a comparison between the existing and enhanced courtyard models in daylight performance with respect to the recommended DF on the selected days.

Table 5.8. Summary of DF on winter and summer days compared to the recommended in the existing and enhanced models

	Existing	Enhanced	Recommended by USGBC
DF on Dec. 21st	14.5%	6.3%	5%
DF on Aug. 21st	10.1%	5.6%	5%

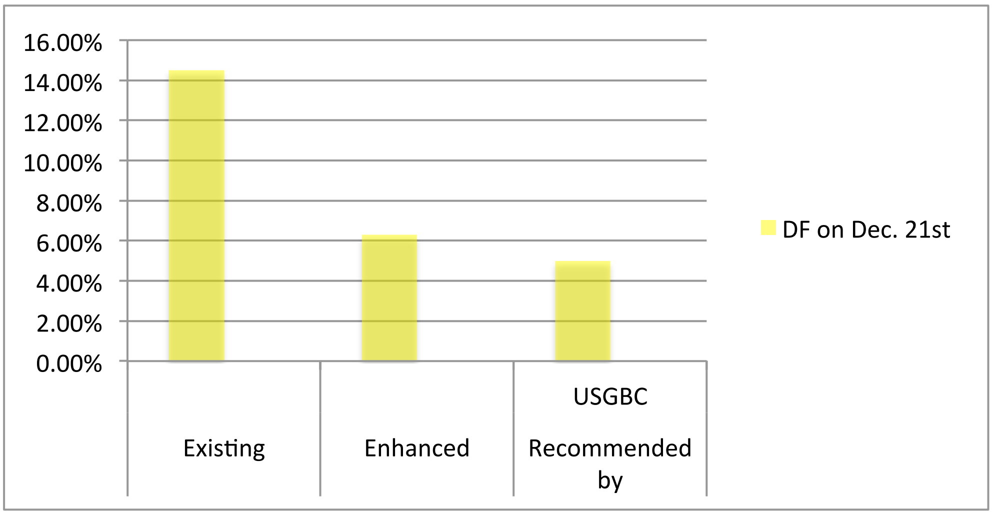


Figure5.21. Daylight factors in both models compared to recommended- Dec. 21

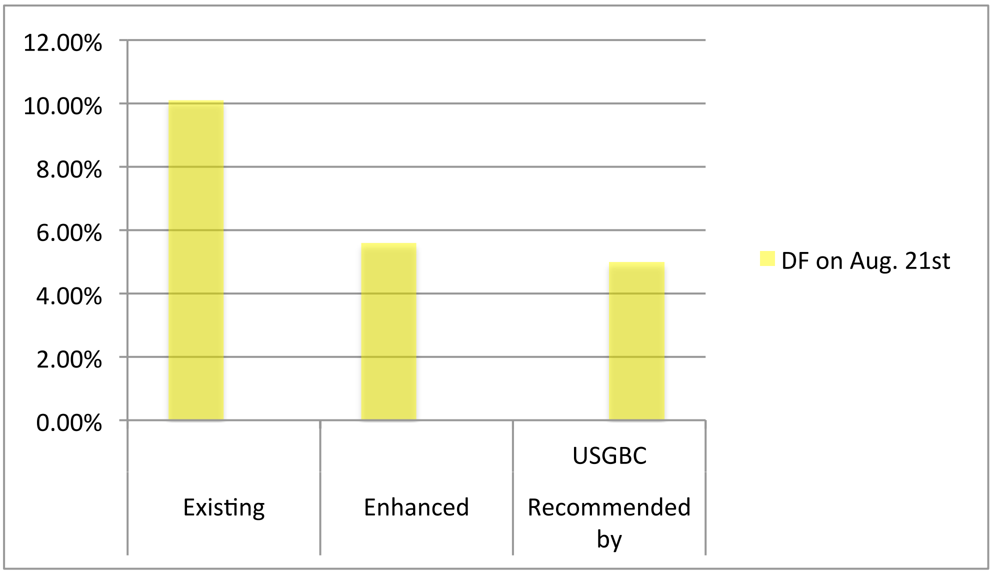


Figure5.22. Daylight factors in both models compared to recommended- Aug. 21

5.7 Discussion

5.7.1 Background

The discussion that has been presented below will relate to chapter number 2 where the literature review of the earlier studies was done and in this chapter the same studies have been proved by simulations. In order to interpret the results correctly it is very important to understand the behaviour and characteristics of each variable analysed in accordance with the earlier research findings that are either in favour the present one or they oppose it. Usually most of the results found were similar to the earlier findings except a few ones which were mentioned separately. The broad series of parameters which have been simulated require a systematic approach of segregation and presentation yet individual vision of each parameter will be discussed. Independent variables will be discussed in accordance with extreme summer conditions. Comparative analysis of two scenarios (existing and enhanced) will be conducted in both summer and winter seasons.

The gradient temperature distribution in a space is shown by visual maps which are extracted from a software Leonardo utilised by ENVI-met. Temperature in visual maps is shown through the colour gradients which are extracted for all the output files and help to form simulations. There is a minute difference in temperature which is not very much clear on those maps especially when time frame between them is very less. This is the reason that temperature and wind pattern are illustrated by large time intervals. The shading, illuminance and daylight factors have been measured in the existing and enhanced models by suncast and FlucsDL, IES Software.

5.2 Independent Variables

5.2.1 Effect of Orientation

The three various orientations that were analysed are North-South, North-West and North-East with 45_0 gradient. The findings showed that North-West had the lowest average temperature among all other orientations which was followed by North-South and North-East. North-East orientation recorded to have the highest mean temperature values. Time frame between 12.00 and 15.00 hours is the peak thermal stress hour in which the sun is centrally placed in the solar path. The surface facing the sun at that time receives the maximum amount of heat. The angle of the sun at this time plays a crucial role as the surface which receives the direct sunrays is more temperate than the one which receives the inclined sun rays. Such conception validates the difference between the results achieved from different studies where the desired orientation is based on the space arrangement and building allotment.

After the comparison of two temperate orientations (NE and NS) as shown in figure 5.3 it validates the cause for values where south surface in North East orientation receives the maximum solar radiation followed by the north south orientation. Based on the findings the space with the North West orientation has the lowest average temperature values. The cause for this behaviour is the presence of current winds and the effect of shading in the space as an effective aspect of orientation. The path of solar radiation at day time imparts shade based upon the space orientation. The more the quantity of the surfaces covered with shade, results in decline of more quantity of heat absorbed. A balance is formed by the NW orientation between the two models making clear of recording the lowest average temperature values.

The three orientations have been discussed by very less studies. Yet, Toudert and Mayer (2006) analysed the NW orientation and confirmed the result of it attaining one of the least values. Although their investigation showed the NE orientation to be one of the orientations with least values. But in the model for this investigation NS orientation has been verified as next, due to the presence sun angle and amount of shade as described.

According to Johansson (2006) the consequence of orientation on the air temperature was less in his study, the difference in temperature was not that significant enough to be considered. The present difference recorded between the three orientations for mean temperature is 0.5 K. although it is very minute still it needs to be contemplated for influencing the outdoor microclimate. Figure 5.23, 5.24, and 5.25 are the visual maps findings from the simulations at 2 pm during the peak thermal stress time referring to the temperature difference in the space at that point of time with regards to the orientation. The mean difference between the three orientations is small yet a broad difference between the distribution of temperature is applicable that shows the significance of the orientation to enhance the outdoor temperature. The maps show less intensity of highest temperature in the NW orientation in Figure 5.25 as compared to that of the NS and NE orientation in Figure 5.23 & 5.24 respectively.

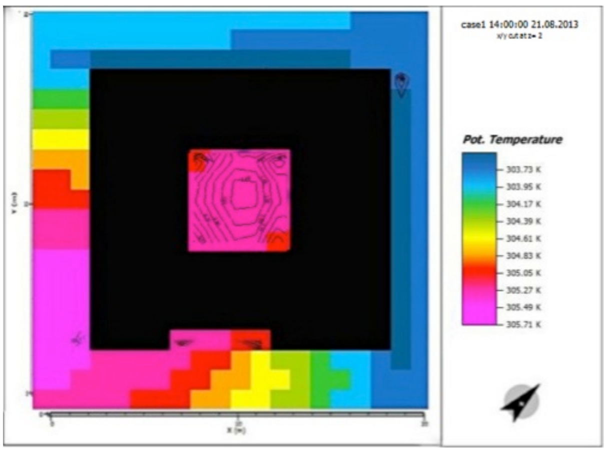


Figure 5.23. The thermal distribution of the NS orientation at 14.00 on the 21st of August indicating the NW wind

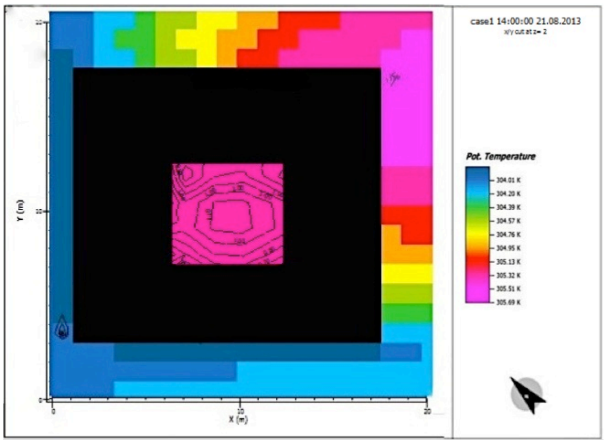


Figure 5.24. The thermal distribution of the NE orientation at 14.00 on the 21st of August indicating the NW wind.

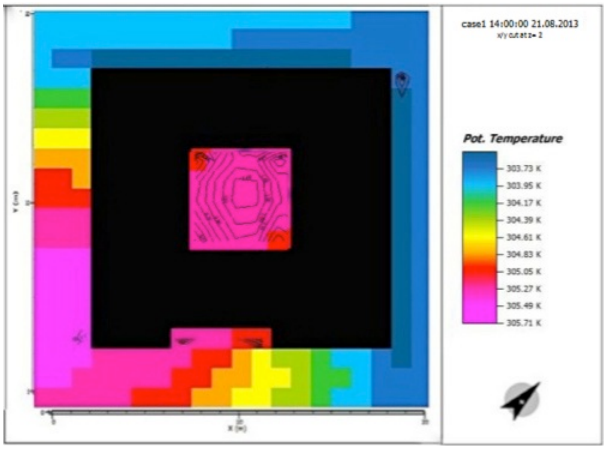


Figure 5.25. The thermal distribution of the NW orientation at 14.00 on the 21st of August indicating the NW wind.

Wind showed a more considerable variation than the temperature difference in the three orientations shown in Figure 5.6. The least temperature was recorded in the NW orientation. The pattern of wind speed values illustrates the independent nature of them from the temperature values. Not only the least average temperature also least average wind speed was found in the north west orientation on the other hand North East orientation is parallel to the existing wind that comes from the NW direction and still registered the maximum temperature values and second lowest mean wind speed, therefore wind cannot be considered a factor in such case which would help in cooling.

Examining cautiously the gradient maps shown above, the wind does not contribute to the cooling effect instead it has a spreading effect .According to Robitu et al.

(2006) the wind can result in cooling only if it is allowed to cool or surpassed over a cold area which would help it to cool down and then allowed to enter the space to be cooled. On the other hand it surpasses a hot area it would result in warming up of the wind and the space it penetrates into will also get warm due to it as shown in figure 5.24. In NW and NS orientation as shown in Figures 5.23, 5.24 the wind plays a role in cooling the temperature as it minimizes the heated zone and the intensity of thermal stress within. This is the reason wind can be dependant on orientation factor, however one needs to analyse the distribution of temperature in order to prevent any warming effect due to wind surpassing the warm area. . In this study, the wind aspect has also played a role to make the North-West orientation register the least average temperatures.

5.2.2 Effect of Geometry

The Height to Width ratio is the geometry parameter examined in the present study which ranges between three arrangements with the three distinct heights of 7.5m, 6,5m and 8m and with different widths of 5.5m, 6.48m and 7.4m therefore having different ratios of 1.35, 1 and 1.08 respectively. Surprisingly this parameter showed a slight difference among the three configurations having the maximum ratio of 1.35 which recorded the least average temperature values. The pattern made known by the results achieved was logical and valid.

Hoffman and Bar (2003), Toudert and Mayer (2006), Mazouz and Masmoudi (2004) and Johansson (2006) backed the present opposite relationship between the Height to Width ratio and the temperature. Broad spaces grasp more solar penetration resulting in more heat gain while deep spaces are prevented from the access of more solar radiation based on the ratio. The H: W aspect ratios decreases the maximum temperature levels at the time of high thermal stress period which is equal to the highest temperature resulting in the decline of mean temperature. As the ratio of the space surpasses 1, the temperature difference decreases comparatively to the spaces with ratios below 1 which are considered to create a balance between the heat gain during the day time and the night time heat loss cycle. The ratio 1 simulations had the medium, highest and mean temperature values among the three configurations. However the least average temperature was recorded during the early mornings due to heat loss at night time. The latter occurrence is and has the similar pattern in various passive parameters. The more closer the buildings or vegetation are the more difficult the process of heat release into the atmosphere at the night time becomes.

Heat emitted into the space is grasped by other entities in slender spaces while the broad spaces capability to radiate the heat absorbed during the day is easy still that quantity of heat is to be considered. It is important to note that wide spaces which have the ability to absorb large amount of heat during the day will take long time periods to release the same heat during the night time where as the narrow spaces which absorb less amount heat during the day it become further difficult for them to release that heat hence both resulting in high temperatures. The variation between the enhancement of temperatures for a ratio of 1 and ratio of 1.35 was minute as a higher ratio to a large extent has a less period of thermal comfort levels especially during the daily peak heat stress. Lengthy and thin spaces impart lesser standard deviation levels between the daily temperatures in the space.

The daily values of the wind speed as shown in Figure 5.7 illustrate the partition between the ratios with values below 1 and the ratios with the value above 1. It is understandable that the more the broader spaces are the more they allow the wind into the spaces. The experience explained earlier, that wind has a spreading effect'rather than a cooling effect' also appears to be valid for the geometry simulation results represented in Figures 5.26, 5.27 & 5.28. Furthermore the maximum ratio of 1.35 that registered the least temperature values also recorded the lowest mean wind speed values same as in the case of orientation wind speed and temperature pattern.

Lengthy and thin spaces provide more shade resulting in less amount of exposure of the surfaces to the solar radiation. This is more effective in enhancing the air temperature as compared to that of the wider spaces. It is essential to keep track of the solar path within the space as it would be really helpful to attain the desired ratio which predicts the relation between the orientation and the space geometry. A slender space has a better ability to enhance the air temperature of the space compared to the broad one having the same orientation. Recognizing the pattern of the temperature and wind is very important and can act as a guideline for explaining the causes behind solar gains. Micro climate can be better if the amount of shaded surfaces is increased due to the geometry parameter.

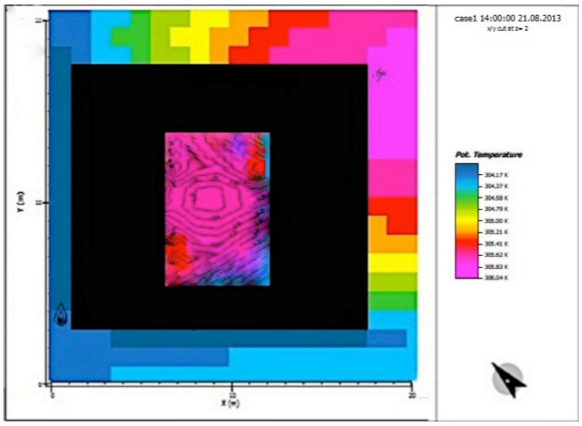


Figure 5.26. The thermal distribution of the 1.35 H:W ratio at 14.00 on the 21st of August

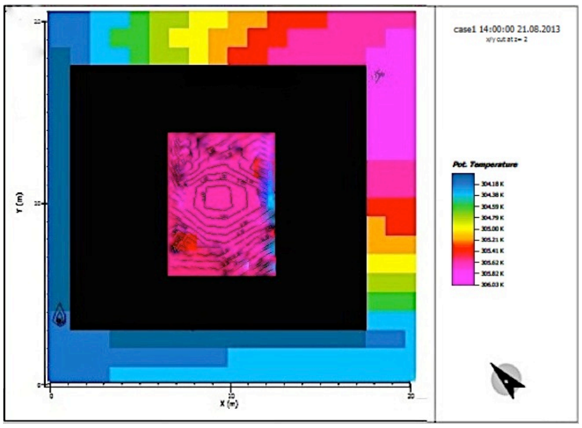


Figure 5.27. The thermal distribution of the 1.08 H:W ratio at 14.00 on the 21st of August

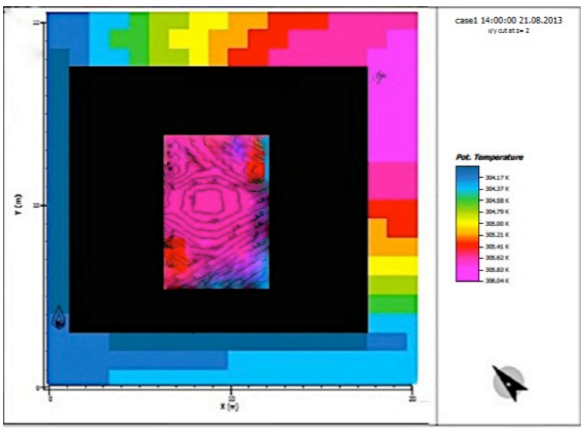


Figure 5.28. The thermal distribution of the 1 H:W ratio at 14.00 on the 21st of August.

5.2.3 Effect of Vegetation

Simulations were done for three landscape strategies to analyse the consequence of vegetation on the outdoor air temperature. The present study tested the cooling effect as a result of the different implementation patterns of grass and trees as vegetation parameters with regards to the concept of heat gain during the day and heat loss at night shown in the geometry discussion earlier. The proper distribution of trees is very essential for the ventilation purposes with regards to this climate. It is very important to consider and analyse the effect of vegetation distribution strategy according to the climate of the area as different planting strategies are required for hot dry climate compared to that of hot and humid climate. In the case of Dubai where the climate is hot and arid it is essential that the vegetation allows the air or wind to enter the space which is possible only if dense vegetation is not applied in or around the space.

According to Hoffman and Bar (2000) the cooling effect attained by vegetation was very much dependant on the temperature around the site that was tested which is known as the back ground effect where the cooling effect augments' as the temperatures around increase. The present study on the landscape chosen to investigate reveals the same results with regards to the background effect as all the strategies have similar conditions. Still such a occurrence shows the importance of other various variables that effect the vegetation parameter. Simulations that were carried out to analyse the vegetation had the identical orientations and geometry ratio as that of the one in existing case. However when the same characteristics of orientations and geometry are changed later for the enhanced scenario this leads to a over all different outcome. For example a North-South orientation utilised by Bar et al. (2009) for different vegetation approaches showed a different effect of cooling of 2K as compared to that of 0.7 K for a North-East orientation for plants and grass implementation. An examination of the Figures 5.28 to 5.30 shows that there is a huge difference between the distributions of temperature in the space although the total average values are very less.

Masmoudi and Mazouz (2004), Robitu et al (2006), Hoffman and Bar (2000), Bar et al (2009) and various other researches confirmed the role of plants which they play to enhance the outdoor air temperature yet many of them differed from each other.

All the studies had dissimilar conditions but still most of them had the same view as in this study and findings that various strategies can result in a cooling effect but with different levels. The two variables that were analysed didn't show much of the difference in temperature due to different strategies of vegetation. However vegetation among all other variables proved to be the most influential in enhancing the outdoor air temperature. The average temperature values were improved by 0.6 K and the maximum temperature values were improved by 0.7 K at the time of high thermal stress. The variation in the maximum temperature was more than the mean temperature difference which predicts that the effect of vegetation on the air temperature is more during the high thermal stress period which is opposite to that of the orientation pattern. However vegetation strategy is in accordance with geometry pattern in the case mentioned above. According to Robitu et al. (2006) vegetation does not improve the air temperature by only one of its abilities. It plays a crucial role in reducing the humidity, variation in air velocity and many other complicated outdoor parameters. Comparing the three vegetation strategies it was found out that the vegetation strategy comprising of continuous grass and tree groups recorded the lowest average temperature as shown in figure 5.11 therefore being a better passive parameter for the cooling effect.

The vegetation strategy comprises of two techniques which aid in the cooling effect one is evaporo-transpiration and the second is shading due to plants. As explained previously shade helps in reducing the amount of heat absorbed by the facades which in turn decrease the temperature of the surface. Couple of other advantages which trees or plants bring in with them are evaporative cooling due to irrigation of the soil, plants or grass thus influencing the surrounding temperature, the second one is the biological characteristics of the plants or grass which result in transpiration process also affecting the temperature. The ability of the plants to convert the solar radiation and air into food for themselves and the evaporation of water in the leaves and stem into the surrounding air results in the cooling effect . Grass also provides the evaporative cooling effect however the trees besides evaporative cooling have an added advantage of shading which helps to improve the temperature further as compared to grass. As shown in figure 5.28 the variation in the outcomes of existing scenario with no vegetation and continuous grass was 0.3 K on the other hand the variation between the existing scenario and tree groups strategy was found out to be 0.5 K (figure 5.29). After the carful analysis and comparison of these figures it is quite obvious that wind is not affected by temperature where as the vegetation strategy applied in the space plays a role in affecting the wind. Continuous grass recorded slightly lower mean and maximum temperature than the tree groups.

As shown in figure 5.29 the groups of trees act as a barrier to the wind flowing from the North West direction thus stopping the cool breeze. On the other hand grass doesn't act as a barrier to wind flow as shown in figure 5.28. The least average temperature and wind values were recorded in the vegetation strategy of continuous grass with groups of trees which predicts that the temperature is not completely affected by the wind alone figure 5.30.

The pattern of wind speed is very much different in different strategies of vegetation. Presence of trees in a space has a major influence on the wind speed. Sometimes the vegetation strategy of grass differs from each other as a result of resistance caused between the facade of the ground and wind. Some times the wind speed is decreased due to the resistance offered by grass on the surface. The amount of resistance depends upon the concentration of grass on the ground surface. Regions having hot arid climate and favourable wind require this type of sustainable vegetation strategy to control the wind speed. As the wind speed is decreased in the continuous grass vegetation strategy it still registers low temperature values than the existing scenario illustrating the fact that wind does not have the complete cooling effect.

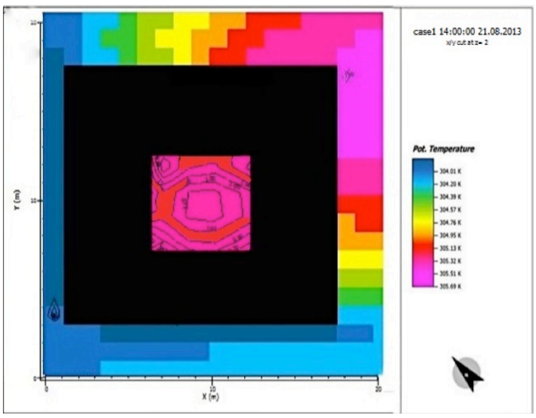


Figure 5.29. The thermal distribution of the vegetation strategy containing continuous grass at 14.00 on the 21st of August.

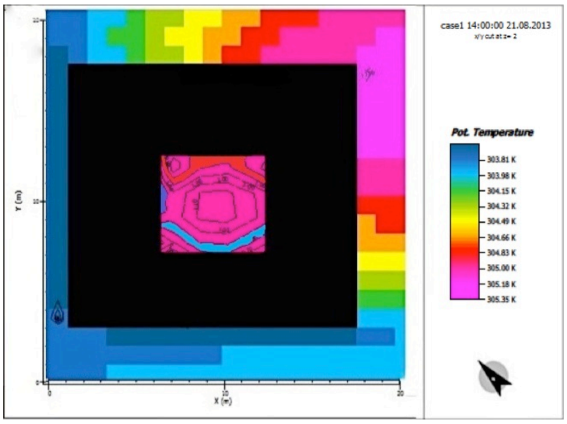


Figure 5.30 The thermal distribution of the vegetation strategy containing trees groups at 14.00 on the 21st of August.

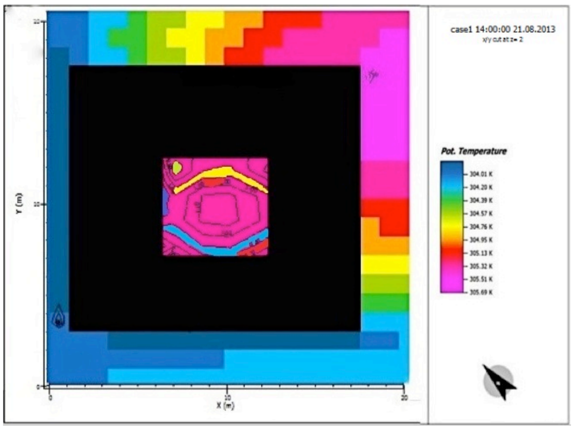


Figure 5.31. The thermal distribution of the vegetation strategy containing continuous grass and groups of trees at 14.00 on the 21st of August.

5.2.4 Summary of the Independent Variables Effect

The criteria for selecting the most appropriate variable that would be integrated in the enhanced scenario was based on the least mean temperature value. Variable having the least mean temperature value would not necessarily have the least maximum temperature value as well. The highest temperature values attained were examined cautiously as they affected the pattern of every parameter at the time of peak heat stress. As shown in figures 5.32, 5.33 & 5.34 the standard deviation STDV among the mean and maximum temperatures had variable values for the simulations conducted on orientation, geometry and vegetation. The best parameter among all was chosen based on the lowest value of maximum temperature. However these values would change in the enhanced scenario as every variable gives different out comes under different environmental circumstances.

The maximum value of STDV was found in the orientation which was followed by the geometry and vegetation consecutively. it is not necessary that the one which has the highest STDV will have the maximum cooling effect as found earlier vegetation has the maximum cooling effect among the three parameters which was followed by orientation and then geometry. Masmoudi and Mazouz (2004) analysed the three independent variable tested under variable circumstances, reinforced the cooling pattern shown in this study. The outcome of the various variables has to be analysed in comparison to one another. It is very important to mention that each site has a different aspect with a different pattern or behaviour. If any of the aspect is changed it becomes difficult to predict the behaviour and can result in giving out different values. In this study, as one variable was tested it was made sure that other variable remains the same so that it would be helpful in evaluating the findings constantly. Still it has been witnessed that the outcome achieved from the geometry parameter under a Northwest orientation would not be similar to an East West orientation even from an enhancement percentage point of view. The pattern of variables with regards to enhancement of the air temperature is the only aspect assumed to stay steady yet is not fixed.

Usually shading is very useful in decreasing the air temperature during the daily peak heat stress especially plays a major role to lower mean daily temperatures. However large amount of shading is not also suggested as it results in decreasing the heat loss due to radiation process causing high temperature (Hwang, 2010). It is also witnessed that more concentrated vegetation is not desired and high height to width space ratio is not most favourable.

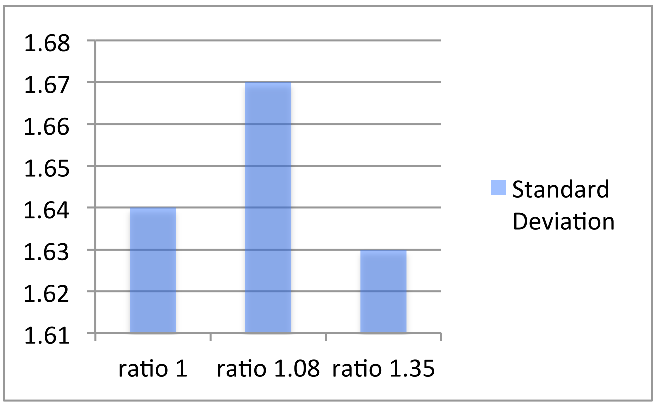


Figure 5.32. The standard deviation between the average and maximum temperatures for the tested H:W ratios.

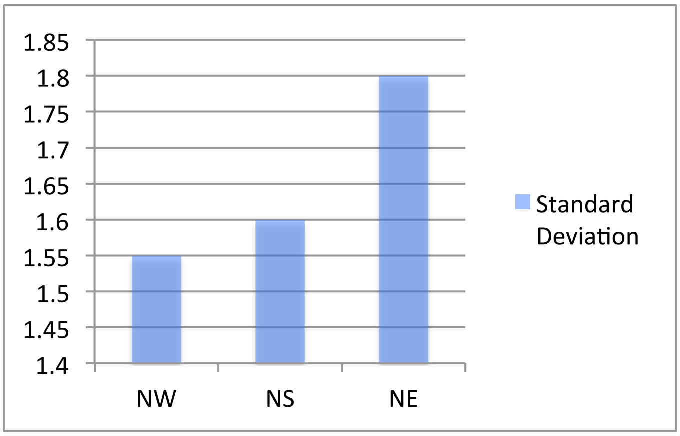


Figure 5.33. The standard deviation between the average and maximum temperatures for the tested orientations.

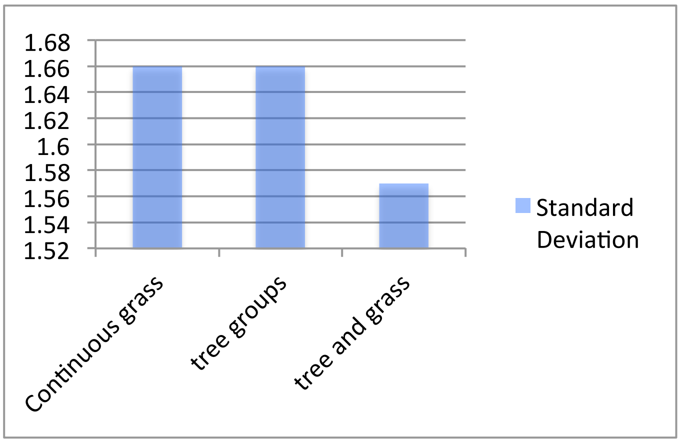


Figure 5.34. The standard deviation between the average and maximum temperatures for the tested vegetation strategies.

5.3 Observations of the Three Scenarios

5.3.1 Effect of Temperature

The findings of the three scenarios were compared against each other in this chapter. the comparison revealed that the implementation of the recommended passive principles brought down the air temperature by 1 K. Although this value is minute still an improvement in temperature is recorded and needs to be verified by further examining.

Having a look at the distribution in the three scenarios both in summer and winter through the visual heat maps it is evident that variations in temperature in the scenarios are much more than the quantitative values achieved. The method utilised to calculate the quantitative values as explained in Chapter 3 was denoted by a mean value for the entire area. More over, the temperature values specified in the output files for every single grid point in the illustration model were standardised into one number that corresponded to the temperature of the entire site during that particular hour. Such method of calculation was planned to be utilised and considered to be more pragmatic in terms of the existing site arrangement with regards to the minimum background effect'discussed earlier where an outdoor open space is never cut off from other factors in actuality. Thus, the values achieved and comparison of the mean temperature was done taken for the whole site after every 30 minutes. At first the two scenarios enhanced and existing will be explained and compared and then the causes for the positive and negative effects will be discussed.

The out door air temperature in the enhanced scenario becomes a little better than the existing scenario. The temperature difference recorded between the two scenarios was 0.5 K at the time of summer and 0.3 K at the time of winter for mean, minimum and maximum values. The outdoor mean temperature of the worst case scenario was made better in the enhanced scenario by 1.1 K at the summer time. The effectiveness of the passive rules which were utilised for the enhanced scenario improved further during the peak heat stress time recording the least values of temperature at the summer time and maximum values during the winter. The equilibrium formed by the enhanced scenario during that time of the day in both the seasons (summer and winter) was very crucial yet its effectiveness at the evening time in winters was comparatively lesser as this time of the year is coldest represented in figure 5.16.

An outdoor space having the passive parameters should be designed in such a way that it would cater to the needs of summer and winter both and also to temperature changes between day and night in a day. This has to be kept in mind since the inception of the design like exclusion of concentrated vegetation or tress in a space or for that matter keeping the Height to width ratio very low. The variation in temperature due to the enhanced scenario is very practical concept in comparison to the real life where improving the outdoor air temperature is a very critical and complex issue. It is very important to implement some variables related to outdoor environment which would be helpful to make a significant difference. The outcomes and findings we got from this study show that there is a limit to which the passive parameters can affect the temperature depending on various factors. Vegetation has a significant effect on the air temperature as compared to other parameter however there is always a difference due to size. For instance a park would be more effective than a front yard garden which in turn will be more effective than a flower pot with shrubs and flowers. As the scale becomes large it brings in huge variance in the improvement level and also rate at which the temperature is enhanced get multiplied. As the scale of vegetation in an out door open space reduces from a park to a courtyard and further to a flower pot having some shrubs and plants on the roof top the effect of vegetation also declines gradually to a point where it becomes almost in significant as shown in figure 5.35. Although little bit of ease feeling might be achieved but it wont be effective at all to change the outdoor air temperature.

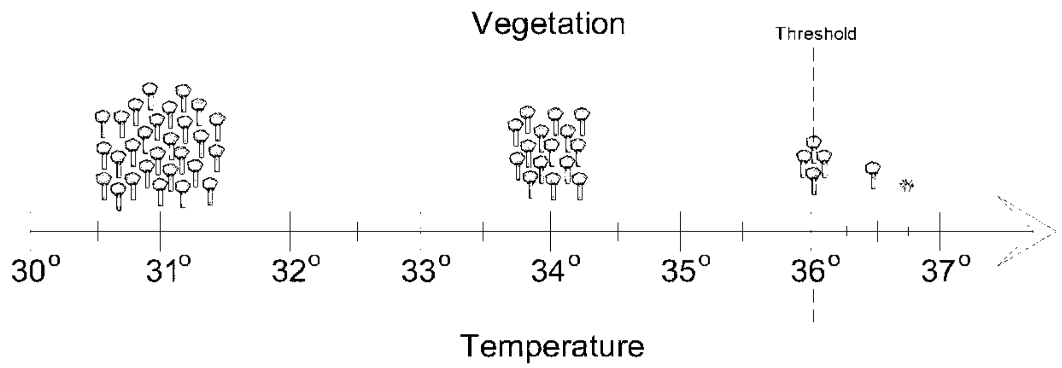


Figure 5.35. The inversely relationship between the vegetation scale and the temperature indicating a threshold of which below it the temperature reduction becomes insignificant.

Usually, the temperature pattern in the three scenarios at the time of summer and winter follows a logical sequence. All the variables which had the maximum cooling effect were integrated in the enhanced scenario thus helping in reducing the air temperature compared to the existing scenario. At the time of peak heat stress in summer the cooling effect recorded due to orientation was 0.7 K and H: W ratio caused 0.6 K and vegetation had the maximum effect of 1 K. On the basis of integrating all the three most effective variables in the enhanced scenario resulted in improvement in temperature by 1.1 K which was almost equal to the cooling effect of vegetation alone. The present investigation supports the earlier explained ideas which have the ability to influence the outdoor air temperature. The pattern of the parameters related to the outdoor environment is very complicated in which the orientation parameter did not prove to be very effective at the time of peak heat stress period where as the geometry and vegetation parameters proved to be very influential during this period. This wavered phenomenon repeats itself again at the time of examining the outcome of every bio climatic principle alone or in combination together.

At last the improvement of the outdoor air temperature is regarded to be very critical which needs further investigation. The pattern of temperature for the various scenarios and variables which are in quest for achieving the ecological design are logical with regards to their chronological effect yet evaluating this impact is impulsive. It is very important to understand the background conditions in order to understand the heat behaviour completely as the outcomes depends on these conditions. No individual parameter should be analysed until and unless the other factors are integrated and set.

5.3.2 Effect of Wind Flow

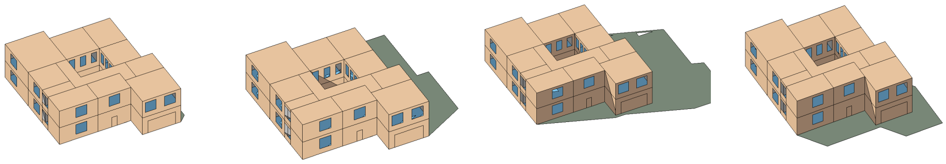
The variables operated throughout the numerous simulations had an effect on the wind speed optimistically in several incidents and adversely in another. A substantial form that outlooks the wind for instance, trees produces turbulence in the area adding to positive pressure zones and negative pressure zones and diminution in the wind speed standards. Building corners also produced the similar result which can be evidently seen on any of the visual thermal maps. Planning a space centered upon the positive and negative pressure and to be able to modify the cool zones to increase consequently is a very encouraging field still needs further explorations utilizing wind flow based software's. The other parameter of vegetation like grass also appeared to decrease the wind speed very marginally owing to the friction made. Consequently, vegetation was cogitated to have an converse relation with the wind speed.

Orientation is essentially the foremost variable monitoring the wind speed feature. Wind can be prohibited or permitted in the site by proper orientation differing whether wind is desirable or not. In hot arid climates wind is an important measure in an environmental design as it enriches the thermal sensation. Nonetheless, it was resolved that wind has a spreading effect rather than a cooling effect as reviewed formerly in which a appropriate orientation and building distribution is needed. Spreading Effect of Wind as described by Robitu et al. (2006) the performance of wind in which wind has a spreading effect in spite of cooling effect depends on its temperature. Cool zones should be faced to the wind to widen the cooling effect whereas hot zones in the area should be isolated by the wind to avoid such impact. In the enhanced scenario the wind breeze appears from the NW orientation the flow of wind can be tilting and played by buildings, wind tunnels and vegetation. The knowledge of the wind performance throughout the early design stage would certainly help to accomplish better rangs of comfort.

The existing scenario noted much superior ranges of wind speed than the existing case with no vegetation and the area is broader with low H:W ratio therefore, improves the wind flow with very less turbulence. The existing scenario had a significant value as compared to the enhanced scenario generating supplementary wind turbulence cause of the trees and grass. The speed of wind remains constant throughout the day and night.

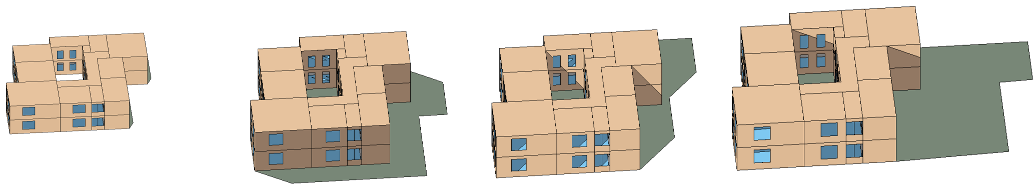
5.3.3 Effect of shading

A sequence of images has been formed by SunCast to envisage where the shadows are formed on the surfaces of the models during a particular time of the year. The dates selected are 21st august and 21st of December; at 12:00 and15:00 hours. Figure 5.36 and 5.37 represents casting of shadow on the existing and enhanced model, it shows that the built form bares maximum solar radiation during summer particularly in August at noon (1200 hours and 15:00 hours), when the altitude of the sun is elevated and the requirement of shade is cherished. In the enhanced model, the exterior walls or envelope (excluding the courtyard walls) bares the solar radiation from the summer sun exactly in the same fashion as explained above. However this envelope experiences more shade in the interiors at 15.00 hours due to lengthy and thin dimension of the courtyard. Thus the walls of the courtyard experience a much lower controlled temperature inside the courtyard. This results in the reduction of solar heat gain which would be helpful in easing the cooling loads during the summer time.



21 AUGEST 12:00 21 AUGEST 15:00 21 DECEMBER 12:00 21 DECEMBER 15:00

Figure5.36. Shading analysis of existing model (IES)



21 AUGEST 12:00 21 AUGEST 15:00 21 DECEMBER 12:00 21 DECEMBER 15:00

Figure 5.37. Shading analysis of enhanced model (IES)

The solar path movement as shown above is based on the rotary motion of the space with regards to the actual positioning that helps to give various strategies of shade based upon that time of the day when the sun is at a high altitude known as peak thermal stress period. North south and the Northwest orientations both help to create the maximum levels of same shading in a space with a minute variation in temperature by 0.3 K compared to the existing scenario which has NNE orientation. The orientation with the maximum cooling effect was found to be NW. One of the main causes for this variation is the wind speed impact on the space. NW has a very high level of wind speed and this orientation is parallel to the direction from where the wind blows. It is important to implement the strategy to cool down the wind particularly in hot arid climate region or else if it blows over the hot area due to its spreading effect it can result in increasing the temperature of the space.

The influence of the building geometry and form on the intensity of shade in a courtyard has been examined previously. The presence of shade is always very influential for enhancing the human thermal comfort level in a courtyard at the time of summer. The geometry of the built form in both the existing and the enhanced scenario helped in casting of shadow in a better way. The orientation for both the buildings was variable where as the proportion of the courtyard with regards to built form was similar. It is important to mention that the area in the enhanced model bares higher solar radiation as compared to the existing form. Thus the courtyard of the enhanced form should experience more solar radiation as more surfaces is exposed to sun resulting in low shading but the findings above illustrate the inverse results. It is found out that the higher the ratio the better the shade in the courtyard. The less amount of shade during the winter and early spring season in the enhanced form as comapred to the existing form is beneficial for the people at that time when temperatures don't go above 20 degree Celsius. According to Muhaisen (2006) the desired shading can be attained if the courtyard building height is a three storeys building in hot and humid climate type.Where as if the climate is hot and arid, the courtyard building height should be two storeys. In this study a two storey villa has been investigated which suits the hot and arid climate of Dubai.

5.3.4 Effect of daylight

It is very crucial to control the direct sunlight. Controlling strategies for straight solar radiation should be kept in mind at the inception of the design process or else later installation of expensive solar control techniques have to be used. Orientation has to be checked although incident sunlight is less, secondly geometry is essential, as the positioning of the walls has an impact on the direct sunlight and would be helpful for the ncessary cut-off angles and at last vegetation plays a role in shading which necessitates the need of daylight. The Collaborative for High Performance Schools (CHPS) (2006) stated the significance of controlling heat gain due to solar radiation by controlling the straight sunbeams infiltrating into the space. Many techniques were recommended to attain that purpose by utilising various techniques of shading like lower level floors and the tactical location of stairwells or less crucial constituent to act as sun shading rudiments.

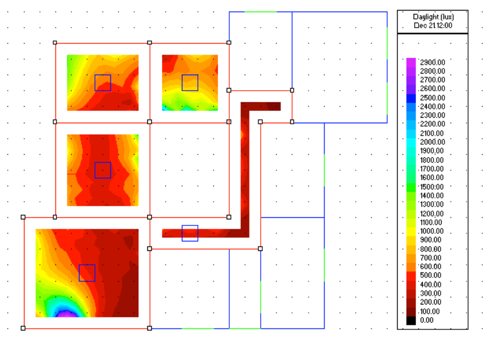


Figure 5.38, Daylight levels (lux) in existing model, December 21, 12:00 pm(IES)

The US Green Building council suggests a minimum Daylight Factor of 2 percent for 75 percent of engaged spaces as a necessity for the LEED day lighting credit. Rooms or interior spaces which have less than 2 % day light factor look dark and require artificial lighting. Rooms or interior spaces that have daylight factor between 2% and 5% have enough daylight yet sometimes artificial electrical lighting might be required. on the other hand a DF more than 5% has more than enough day light coming into the room and requires no artificial electrical lighting during the day. (Kwok et al 2007, p. 60). Figures 5.38 and 5.39 represent level of daylight and DF for the existing model on 21st of December at 4:00 PM. Figures 5.40 and 5.41 represent daylight level and DF for the enhanced model on the similar date and time. Level of daylight and DF for the existing model on June 21 at 12:00 PM are represented in Figures 5.42 and 5.43 below. Figures 5.44 and 5.45 show daylight levels and DF for the enhanced model on the same date and time.

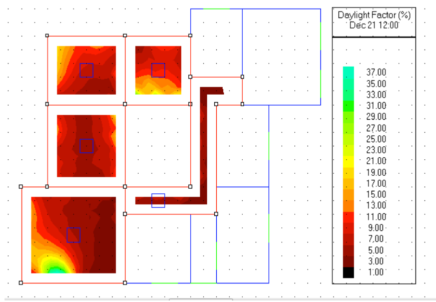


Figure 5.39, Daylight factor (%) in existing model, December 21, 12:00 pm (IES)

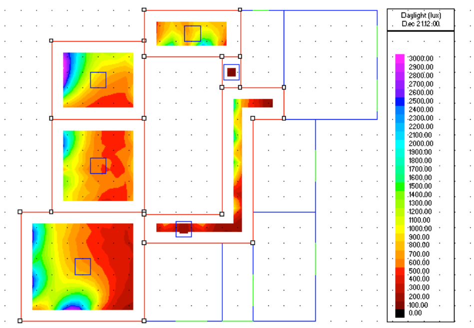


Figure 5.40, Daylight levels (lux) in enhanced model, December 21, 12:00 pm (IES)

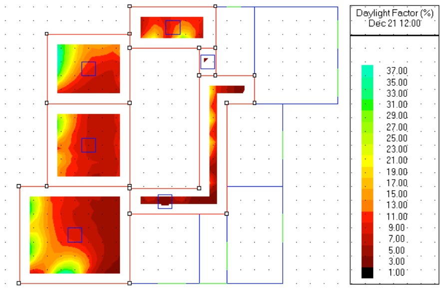


Figure 5.41, Daylight factor (%) in enhanced model, December 21, 12:00 pm (IES)

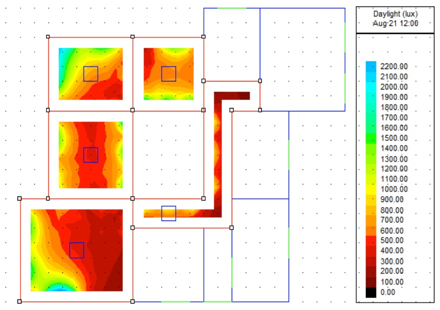


Figure 5.42, Daylight levels (lux) in existing model, august 21, 12:00 pm (IES)

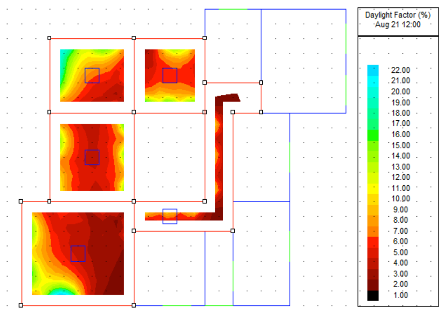


Figure 5.43, Daylight factor (%) in existing model, august 21, 12:00 pm (IES)

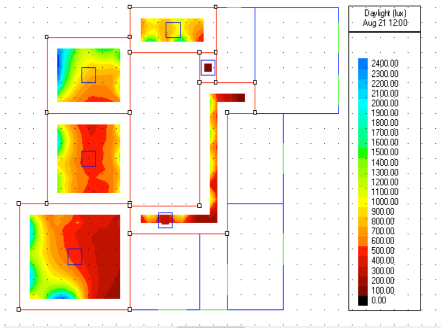


Figure 5.44, Daylight levels (lux) in enhanced model, august 21, 12:00 pm (IES)

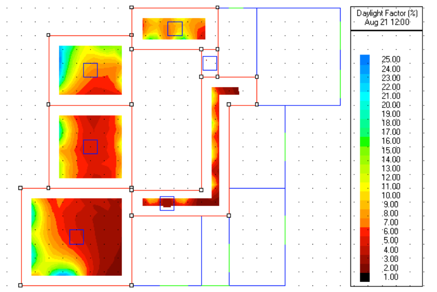


Figure 5.45, Daylight factor (%) in enhanced model, august 21, 12:00 pm (IES)

The findings presented above demonstrate that the performance of the enhanced model with regards to day lighting is better both in winter and summer days, which proves that the enhanced model has less glare in the interiors as compared to that of the existing form. It is important to mention this that the mean DF for the enhanced form is 6.3% and 5.6% for winter and summer days respectively which is very close to USGBC recommended DF level of 5 percent.

5.4 Validation of Findings

Researches and studies done previously testing the same parameters utilized various methods such as field measurements, simulation and experiments. The outcomes that were achieved in the previous studies were in accordance with the current results with regards to effectiveness and pattern followed. However values were different due to input of different values which verifies the findings achieved. All the previous verified studies analyzing the similar variables showed to have a broad range of variations in the end results still most of them consented on the same concepts. The difference achieved between the previous and the present investigation will be justified always as they investigations carried now and then have different circumstances resulting in difference of values. Justification for this investigation is shown through the previously published studies which confirm the validation of their outcomes with regards to scale, date, and simulation time period and measurement criterion of every investigation. The studies have been reviewed and the same have been discussed in chapter 2 of this investigation

5.4.1 Cooling Effect of SW-NE Orientation

Mayer (2006) stated that Northwest orientations have the ability to attain better thermal comfort level due to large shading coefficient. Moreover, Haggag and Elmasry examined substitute passive strategies for decreasing the energy consumption in built form in UAE and they also stated that SE-NW axis has the ability to capture the cooling breezes, endows with shading and lessens thermal loads on building surfaces (Haggag and Elmasry, 2011).

5.4.2 Cooling Effect of geometry

Mayer (2006) registered the variation between the 0.5 ratio and 2 of about 0.2 K and between the ratio 2 and ratio 3 variation of about 0.1 K was found out. The investigation validated the inverse relationship between geometry and temperature where ratios are high temperature becomes low. The minute variation verifies the outcomes achieved in this present study for the three geometries.

5.4.3 Cooling Effect of Vegetation

Till now all the studies which have investigated the effect of vegetation on the outdoor air temperature have mentioned that vegetation has the highest cooling effect among all other passive cooling parameters. The values for the cooling effect were dissimilar in different studies still they had the same pattern and within the defined range. In the present paper vegetation was found to be the coolest parameter among all other variables which was in accordance with the earlier studies. Bar et al (2009) utilized an investigational methodology to analyze the effect of vegetation on the outside air temperature. The effect of vegetation on a same size of an outdoor space was found to be 2 K using the six different vegetation strategies. However in this study the cooling effect due to vegetation was recorded to be 1.1 K. The time period and date of the test was not pointed out.

Wong et al. (2007) coincidently utilized the same tool EMVI-met as the present study which was helpful in supporting the findings by the field measurement method still the use of application was comparatively bigger than the present study. The field measurement was useful in supporting his findings which showed that the concentrated vegetation on a bigger scale would increase the air temperature by 3 K The findings were similar to this present study.

Bar and Hoffman (2000) stated that the cooling effect of the vegetation to be of mean 2.8 K which is dependant on the coverage due to shade and background effect of the space or area. Masmoudi and Mazouz (2004) stated the variance between a space with no vegetation and a space with three bands of trees in center was to be 1.7 K. This is same value achieved with regards to size and date of simulation.

CHAPTER6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

It is very essential for the urban open spaces to exist as it will lead to the existence of sustainable cities. As Dubai is a region where the climate is hot and humid for most of the year and outdoor spaces weren't of much use during summer. However people used these spaces in winter to enjoy the pleasant weather during that season of the year. In order to use these urban spaces for a longer period of the year various studies and experiments were conducted to achieve the thermal comfort in these out door spaces. The motivation for this study was to use these spaces for maximum time and reduce the air temperature using proper climatic guideline that would help to achieve it.

Different parameters were analysed comprehensively which would help to reduce the air temperature and increase the usage of courtyard spaces. At the beginning many parameters were examined in order to select the most effective ones among them for the cooling effect. The method used for the investigation used a set of fixed variables such concealed flat buildings and flat roofs in order to avoid any confusion in the results. The date considered for the experiment was in extreme summer conditions (21 August) and different parameters such as orientation, geometry, vegetation were analysed on site. In order to avoid any vulnerable situation during winters and create a balance throughout the year, parameters were analysed in extreme cold conditions as well (21st January). The experimental findings of the simulations showed that behaviour of temperature, daylight, shading, wind speed were of different patterns and phenomena which were later on justified.

The most effective orientation which had the most cooling effect was North West orientation which was followed by North South and North East. These findings were mainly due to three reasons, amount of shade each orientations causes, the temperature of the vicinity facing the prevailing wind and the third one is the south facades position with regards to angle of the sun in different orientations. Among all North West orientation had better balance then any other orientation which resulted in lowest temperature values.

Geometry with the highest aspect ratio of 1.35 has the most cooling effect. On the other hand height to width ratio was found to be inversely proportional to temperature. Very less difference was found out between the ratio of 1.35 and 1.08 as compared to the variation between the ratios 1 and 1.08. This was due to tight spaced faces which radiated their heat to environment hence the inverse relation earlier stated reaches it final point and then it falls back resulting in the temperature increase.

The vegetation strategy which provided the most cooling effect was the one with grass and trees. Trees played a role in benefitting the outdoor space with shade and evaporative cooling. Grass on the other hand helped to reduce the surface radiation and also added to evaporative cooling effect. There is a huge scope for studying the landscape strategies and it isn't possible to explain all strategies in one study. The strategies studied are based on the recommendation from earlier research.

In the end it was stated that achieving the thermal comfort level in hot and humid places like Dubai was next to impossible however by implementing these passive design strategies little bit of improvement can be witnessed in the micro climate of outdoor urban spaces. Keeping the orientation as North West and an aspect ratio of 1.35 and the vegetation strategy of grass and trees resulted in influencing the air temperature by 1.1K. This slight bit of change was a small successful step towards achieving the thermal comfort in outdoor temperatures as big changes in temperature in outdoor environment aren't expected. The positive results obtained proved that there is scope for passive cooling techniques. Some of the findings which were significant and needed a mention are shown below in table 6.1.

Table 6.1 Some of the findings which were significant : source Author

Results	Observations	Implication
Temperature was influenced by 0.6K by orientation and same value of 0.6 was reduced by geometry and vegetation improved it by 1K at the maximum temperate hour of the day. Bioclimatic design reduces the temperature by 09.K on an average using the same parameters.	It is found out that it is not the application of heavy amount of parameters which influence temperature; rather it is their composition and their alignment or positioning in accordance with outdoor space. Many outdoor parameters are not very predictable to some extent.	It is the quantitative proof rather than the theoretical proof which would help to determine if there is an influence on outdoor air temperature. Simulations were helpful in saving the time and energy for conducting analysis for preliminary courtyard designs. It also requires passive parameters to be given priority in accordance with their impact on environment.
At the time of high thermal stress which corresponds to maximum temperature the difference between orientation variables declines.	One of the main benefits of having a north west orientation is that it is very effective even during the peak hot hour of the day as a result of solar path cycle.	In an environmental outdoor space this kind of parameters is given priority as its effectiveness is required all along the day rather than just midday.
At the time of high thermal stress which corresponds to maximum temperature the difference between geometry and vegetation variables increases.	The main benefit of having a proper geometry and vegetation is that it is very effective even during the peak hot hour of the day resulting in some reduction in air temperature	In an environmental outdoor space this kind of parameters is given priority as its effectiveness is required to achieve the thermal comfort at that time of the day.
The temperature recorded was higher in North east orientation where the space is adjacent to the wind as compared to NS orientation where the built form acts as a barrier for wind to flow through the space.	Wind always has spreading effect. If it goes over the cool area it will result in decline in temperature, however if it passes over hot area it will have a warm effect on the space	One of the passive cooling techniques should be wind. If the orientation results in a warm effect then in that case wind should not be allowed to pass over it or else the orientation should be changed.
Disparity between the temperature values of the ratios 1.08 and 1.35 are lesser than compared to 1 and 1.08.	Narrow spaces always experience the thermal comfort for a very less amount of time as the heat loss due to radiation is very difficult.	The length of the narrow spaces should be minimized. The least and the maximum width of a space should always be taken into consideration

		in accordance with shading coverage. A close scale is always preferred as it helps to achieve more shade.

6.2 Climatic Design Guidelines

It is very important for the urban planners, designers and general public to understand the benefits of applying the urban climatic guideline in the urban design here in Dubai. Application of this guideline will have numerous benefits economically, ecologically and also health benefits due to increased usage of outdoor urban spaces. the environmental design guide lines for outdoor urban spaces should be utilised and integrated in the early stages of design not at the end when the design is ready to be implemented. After a careful analysis of certain outdoor parameters and the behaviour a set of design guidelines have been presented below. It is difficult to suggest guidelines for all the outdoor parameters yet some findings from the current study have been mentioned. Passive design should strike a balance between the heat gain and heat loss and the same should accommodate the needs of various seasons of the year. More attention is needed to be given to natural factors which are integrated in an outdoor urban space such as trees, grass, orientation of the built form, geometry. These play an important role in influencing the thermal comfort of a space, either they will lead to positive effect if applied properly or else they will have a negative effect if not applied properly.

- Different levels of shade and distribution in a space to get the maximum benefit of the urban outdoor space during summer and winter both. The space users' should be provided with a choice depending on the parameters which are effective in achieving the thermal comfort level.

- If grass is applied as a vegetation parameter it should not be shaded with continuous trees or mesh in order to reduce the thermal stress. Grass has the ability of high level of water consumption and continuous tree strategy will not help in reducing that (Bar et al , 2009).

- Trees with high trunk and broad canopy should be utilised as it wouldn't act as barrier to winds. On the other hand usage of shrubs should be avoided as they result in blocking of winds and increase the humidity levels (Givoni , 1991). However shrubs can be used for orienting the wind for a visual purpose.

- Group of trees should be oriented parallel to wind direction. If the wind is not effective in reducing thermal stress, rather increases the air temperature due to its spreading effect then in that case trees should be oriented in such a way so that they act as barriers to wind. Buildings and other physical object besides trees can also be used to block the wind in this case.

- Wind should be used to maximise the cooling effect. Different passive cooling techniques should be applied in the path of wind so that when the wind flows over this path or space it brings in the cool breeze due to its spreading effect.

- Use of materials which have the ability to absorb solar energy should be minimised as they result in heat gain. Usage of grass as a vegetation parameters is very beneficial in this case however as this parameter has the need for high water absorption so it has to be supported by good irrigation system.

- It is essential to understand the mechanics of various outdoor parameters before they are chosen and applied. The effect of these variables is bound to be different in different scenarios and testing conditions. Right balance between these variables should be applied which would help to achieve the desired results.

- Hotspots in an outdoor space need to be identified and then the most appropriate strategy should be applied for solving that problem before any changes to environmental design are to take place.

- Based on the background effect phenomenon any changes that influence the microclimate of an outdoor space will have an effect automatically on the surrounding spaces as well.

6.3 Recommendations for Future Investigations

The current investigation is influential for carving a path for future recommendation which would be helpful in filling up the gap of knowledge. The findings of this study which have been mentioned in the earlier chapters are based on various criteria's limited by resource availability. Time constraint and lack of testing tools had an effect on many circumstances forming the test matrix for variable analysis. Some of the variables like vegetation selected in this study had broad range of study and could not be studied completely hence leaving a space for future research on that. Lot of questions were raised with regards to previous researches and findings which requires some action to rectify the issues raised. For any future work that would be done on similar sort of investigation, some suggestions have been mentioned below in this study which would be helpful for that.

- A lot of research and experiments should be conducted with regards to various parameters which would help to upgrade a broad database and knowledge about our environmental designs. This would be very beneficial to form ecological cities and help in reduction of carbon foot print on earth.

- A test was conducted for a span of 10 peak hot hours in august on various independent variables such geometry, vegetation and orientation. This was conducted to note the temperature patters in which nocturnal patterns need to be investigated more to validate the coolest parameters chosen.

- Independent variables need to be further investigated in winter in order to suit the temperature needs for that season.

- The investigations were carried out during the peak hours of both season's summer and winter and the results were presented for same. The idea behind it was if any achievement is found out in these hours that would lead to better environment for the rest of the year. More investigations are needed all through the year which would help to see effect in all seasons of the year.

- The geometry parameter should be investigated in accordance with SKV parameter instead of the air temperature.

- Some of the field measurements which were done in earlier studies followed the pattern of point measurement as compared to average value for the entire space with the help of computer simulations and some other software's which could perform it. This kind of method using these simulations and software's should be used in future to validate the results.

- Larger spaces should be examined using the same parameters in order to check the efficiency of these parameters on the threshold level based on size

- The test matrix which has been shown in the 3rd chapter of this study can be broken-down further into various variables with different manipulations. This would be helpful to know more about the pattern of outdoor parameters.

- Wind speed aspect can be made more useful if it is incorporated with a proper design with regards to scenarios which have been examined.

- More software should be developed which would help to make outdoor investigations very simple and ample study material should be present in the libraries. It is also important to study the material effect where fixed variables are integrated such as buildings, colonnades, projections and shading devices and also their impact on the outdoor urban space.

- The effect of enhanced and existing scenarios on the interior cooling loads should be investigated and also the thermal performance of the built form during summer and winter which would be helpful in adding the financial value to work.

- Investigation of these various passive parameters should be conducted in different locations of the same space in the Villa especially the space in centre.

- The nearby surrounding area of the VILLA site along with current site should be examined in order to check the background effect identifying exact cooling impact.

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