Achieving Sustainable Outdoor Thermal Comfort in the American University of Sharjah Campus

تحقيق الراحة الحرارية الخارجية المستدامة في حرم الجامعة الأمريكية في الشارقة

by

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ABSTRACT

There are many factors that impact and influence the success of an urban space. Numerous physical and social environment components and location of the given space in the city are all key components that play part. This study however, mainly focuses on one physical environmental aspect known as the thermal environment. Thermal environments are components of physical environments that dictate the human thermal comfort. The control of this comfort is conducted through exchange of energy between the body and its consequent surroundings, and it can generally be stated that it exists in the circumstance that a body can readily sustain a constant and deep temperature of approximately 37°C. Therefore, thermal comfort can be defined as the relationship between the thermal condition and an individual's awareness of warmth that makes the impression.

The study will carry out a comprehensive research on the layout of the American University of Sharjah (AUS) campus in Sharjah, United Arab Emirates (UAE). Multiple data categories will be collected from the campus users through a series of surveys and interviews to obtain an understanding of the site conditions and their comfort levels. Human thermal comfort is an environmental quality that is directly impacted by the outdoor conditions of the university's campus. It is among some of the most affected qualities of the environment in the urban outdoors. Since the microclimate of AUS is hot humid, the thermal adaptation of the university's occupants is quite challenging due to exposure to variation air temperatures.

Despite the control the outdoor thermal environment being difficult, there is a need to avail thermal comfortable conditions, which are able to cater for the outdoor activities such as walkability, driving, parking, greenery, shades, water features among others. This study is based on investigating the problem of lack of sufficient thermal conditions to facilitate comfort amongst the University's occupants. It's aimed at solving this problem by recommending new improvised design elements for the campus' thermal adaptation through creating areas with sufficient shades as well as outdoor sophisticated space planning.

كثيرة هي العوامل التي تلعب دوراً في نجاح المساحات الحضرية، ومنها العناصر البيئية المادية والاجتماعية وموقع المساحة في المدينة، ولكن هذه الدراسة تركز بشكل رئيسي على جانب واحد من البيئة المادية ألا وهي البيئة الحرارية، كونها تؤثر على راحة الإنسان الحرارية التي تخضع لعملية تبادل الطاقة بين الجسم ومحيطه، والتي تعتمد على ظروف يستطيع فيها الجسم الحفاظ على حرارة ثابتة تقارب 37 درجة مئوية. وبناءً على ما سبق نستطيع أن نعرّف الراحة الحرارية على أنها العلاقة بين الظروف الحرارية وإدراك الفرد لدرجة الدفء التي تترك انطباعاً عليه.

سيتم من خلال هذه الدراسة إجراء بحث شامل حول مخطط الحرم الجامعي للجامعة الأمريكية في الشارقة في الإمارات العربية المتحدة، وسيتم جمع فئات بيانات متعددة من روّاد الحرم الجامعي من خلال سلسلة من الدراسات الاستقصائية والمقابلات لفهم ظروف الموقع على نحو جيّد. إن راحة الإنسان الحرارية من السمات البيئية التي لها تأثير كبير على الظروف الخارجية للحرم الجامعي، وهي من أكثر السمات البيئية تأثراً في الهواء الطلق. وبما أن المناخ المحلي في الجامعة الأمريكية في الشارقة حارٌ رطب، يصعب على روّاد الجامعة التأقلم مع الحرارة نظراً لتعرضهم لدرجات حرارة متباينة.

وعلى الرغم من صعوبة التحكم بالبيئة الحرارية الخارجية، يجب التوصل إلى ظروف حرارية مناسبة للمساحات المتواجدة في الهواء الطلق مثل المماشي والشوارع ومواقف السيارات والمساحات الخضراء والمظللة والمسطحات المائية وغير ذلك. يستند هذا البحث على التحرّي عن مشكلة غياب الظروف الحرارية الكافية لتأمين راحة مرتادي الجامعة، ويهدف إلى حلّها من خلال اقتراح عناصر تصميم جديدة للتكييف الحراري في الحرم الجامعي من خلال إنشاء مساحات مظللة والتخطيط الجيد للمساحات الخارجية.

DEDICATION

I am grateful to many individuals – this dissertation has been a tremendous long overdue journey that has finally come to an end.

Mum and Dad, for whom without, I wouldn't have enrolled in my Masters. Thank you for the support, for always wanting us to be better humans, and pushing us to reach the skies. I hope I make you proud one day.

Ali, the most patient husband in the history of husbands; it's now over. PhD is next.

To my sisters and friends who nagged, helped and threatened to disown me if I don't finish; you have sparked the fun in this.

And finally, my beautiful M&M's, you taught me the true meaning of multi-tasking. Thank you for being so good with me through it all.

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Thank you, Dr. Ahmad Mokhtar – Associate Dean in AUS, college of Architecture – for imparting his time and expertise on this study, and granting me access on campus to conduct my research.

To all my other professors in the Masters and Undergraduate programs who have taught me and crossed paths with; you will always be an inspiration.

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CHAPTER ONE: INTRODUCTION

1.1 Background

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) is believed to have established the globally acknowledged definition of thermal comfort. The ASHRAE standard (ASHRAE 2010) outlines thermal comfort as a state of mind which communicates satisfaction with the thermal surroundings, and it is gauged by subjective measurement. This definition is therefore built on the suggestion that thermal comfort labels a person's psychological state and condition of mind. Moreover, there are six major features that should be tackled when outlining conditions for thermal comfort (ASHRAE 2010): clothing insulation, air temperature, metabolic rate, radiant temperature, humidity and air speed. Metabolic rate and clothing insulation are subjective while the rest are environmental. This six features are autonomous but when joined they add to an individual's thermal comfort.

Thermal comfort is an environmental quality that has a huge impact on the outdoor conditions of the UAE. According to Al Jawarba and Nikolopoulou (2009), thermal comfort can be defined as the relationship between the thermal condition and an individual's awareness of warmth. Cheng (2006) states outdoor ease is simply easy to detect; too cold or too hot. Human thermal comfort is among one of the most affected qualities of the environment in the urban outdoors.

However, there are some personal factors such as clothing and level of activity that also have an impact on thermal comfort. The open-air environment may not in all circumstances be enjoyable, yet provisions and developments of microclimates allow for individuals to overcome the discomfort. According to Angelotti et.al (2007), through modifying patterns of carried out activities and clothing used, people are able to adapt to ambient thermal conditions.

1.1.1 Impacts of Vegetation and Trees

Vegetation has cooling properties that reduce the harsh effect of radiation. The influence of flora on human thermal pressure was experimented in a hot-arid area in two semi-bounded metropolitan places that have a variety of mature grass, trees, paving and overhead shading wire (Giridharan, 2005). In the city of Sharjah, where the research will be conducted, circumstances of an unshaded courtyard are known to be very unsuitable during the daytime hours due to extreme uneasiness. Each and every setting must be studied and designed well when it comes to achieving thermal relief.

Hence, in the presence of any kind of shading, whether by artificial mesh or by trees, comfort levels would increase and uneasiness is tremendously reduced for a certain period of time, as extreme conditions are being avoided when any kind of covering is situated above open paving (Robitu, Musy, Inard and Groleau, 2006). When shading elements are merged with vegetation, both systems produced pleasant conditions at most the hours of the day no matter the severity of temperature. In addition, pavements with shaded grass receive a lower radiating temperature on the surface level.

Since it is very difficult to control the outdoor thermal environment, it is imperative to provide thermal conditions that are conformable; they should as well satisfy the expectation of the occupant. Nonetheless, because the local publics are cold-tolerant below par, areas that are too shaded may bring high levels of discomfort in winter due to the low air temperatures. This indicates that the thermal adaptation characteristics of the local climate and local public spaces should be well thought out in urban planning and outdoor shading.

According to Giridharan, Lau and Ganesan (2005), wind, infrared radiation and solar radiation are essential to the open-air relief of human beings in urban spaces. It also suggests that they can be regulated through site design. All throughout hot periods, trees and other flora can be used as a means to provide shade to decrease solar energy input to the user’s body. Still, if spaces are employed throughout cooler periods, shading should be placed in a specific analyzed manner in order to allow for proper usage in all climatic conditions.

Flora can be used as a means of screening the user from infrared radiation sources like streets and heated walls in the course of the warm season.

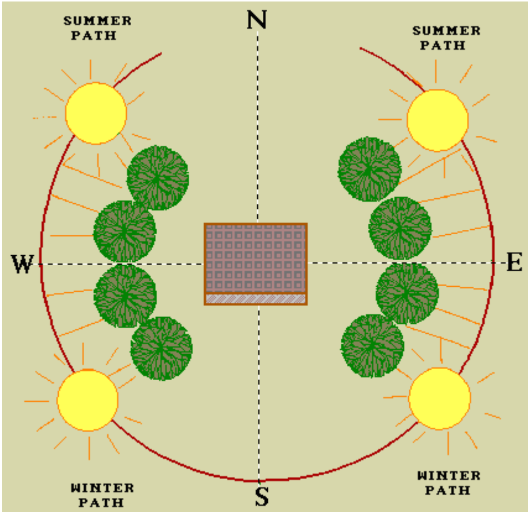

Figure 1.1: Trees placement and orientation in affecting solar heat gain. (Source: Web: http://dnr.louisiana.gov)

Figure 1.1 illustrates how the placement of vegetation clearly impacts the effect of direct sunrays into a space. In this case, trees placed on the east and west elevations would reduce summer heat and provide shade and allow for winter heat gain respectively.

It can also be used to limit the loss of infrared radiation to cold surfaces, for instance the sky, throughout cold periods (Smith and Levermore, 2008). Even though it is not that vital in warm cities, wind speed can play a very significant role throughout the cold season as is pointed out by the prevalence of wind-chill factors in weather reports during winter. Several arrangements of structures and flora, which could be utilized to lessen the loss of heat as a result of high winds during winter, would not have a significant effect on the same spaces in the summer.

1.1.2 Importance of Outdoor Thermal Comfort

The world is continuously evolving and currently there is an escalating interest in sustainability and structure design considerations. As such, outdoor thermal comfort is perceived as a vital factor important in improving quality of life in urban settings. During recent years, it has received significant attention with numerous research studies focusing on defining and expounding on this concept (Smith and Levermore, 2008). It is considered a key concern especially since it has significant impact on numerous phenomena such as public health, particularly in an arid region such as Sharjah where summer temperatures can rise up to 50^{o}C and may result in heat stroke after continuous exposure.

Moreover, excessive exposure to such harsh conditions ensures that the ability to perform outdoor activities is significantly reduced and as such poor conduct is noted. Urban spaces form the bedrock for various activities and traffic movement, which enhances the vitality of a city. As such, the microclimate of urban regions is significant to the quality of urban spaces, especially in areas that exhibit rapid economic growth such as this one. Thermal comfort experienced by users of open spaces significantly determines the extent of habitability of urban spaces. Urban life and outdoor activities of a region highly depend on favorable microclimates and thus thermal comfort.

Based on recent researches, outdoor spaces in a region which are considered comfortable in context of outdoor thermal comfort possess increased social and economic advantages mainly because they attract a host activities and individuals, i.e. residents and business ventures, thus positively impacting social interactions and the monetary aspect of the regions. In actual sense, outdoor spaces perceived as thermally comfortable in a city usually end up as public gathering places, promoting high-quality urban life (ASHRAE 2010).

Thermal environment relative to outdoor spaces determines quality of life in a region. The environment has direct influence on the behavior of habitants and how individuals utilize outdoor spaces. Regions that are thermally uncomfortable have various negative effects and among them is negatively impacting the quality of life and increasing energy demands of building structures (ASHRAE 2010). Numerous activities take place in outdoor settings; as such outdoor thermal comfort is a significant phenomenon which determines how habitable and lively a region will be.

The open-air thermal environment is influenced by the constructed environment like plants evapotranspiration and evaporation; anthropogenic environment; earth surface covering; and trees and artificial objects shading (Robitu, Musy, Inard and Groleau, 2010). Since shade can obstruct incident solar radiation, a number of studies have looked at the effect of shading on thermal environments, using the height/width ratio and street orientation. Earlier studies have mostly carried out field experiments on just a few days to examine how shade enhances thermal comfort.

Nonetheless, the results yielded by these experiments simply explain the characteristics calculated on a certain day and may not signify yearly thermal conditions (Smith and Levermore, 2008). Conversely, outdoor thermal environments tolerance also differs for individuals in dissimilar climates; specifically, they would not have the same experience when given similar thermal environments. Thus, one is required to discuss long-term thermal comfort with regard to the thermal characteristics and requirements of local people (Robitu, Musy, Inard and Groleau, 2006). For example, since the residents of UAE are used to its humid, hot climate and comparatively less accepting of cold temperatures; thermal comfort in winter season is a major concern for outdoor spaces.

Outdoor thermal environments affect people's outdoor thermal comfort, while the outdoor thermal environment is mainly affected by the constructed environment design (Smith and Levermore, 2008). Therefore, it is essential to comprehend the link between outdoor thermal comfort and urban design to determine bioclimatic urban design guidelines. So as to measure the significance of adjusting the outdoor climate in a certain direction by particular design details, it would help if the designer is able to predict the effect of a specific change in a weather element on the comfort of people staying outside.

Outdoor environment should not in any way be confused with thermal sensation. It is simply a psychological elucidation relative to the psychological body state. There is a correlation between a sense of comfort, neutrality or pleasantness and the state of thermal neutrality (Smith and Levermore, 2008). Skin temperatures in cold settings and increased sweating by the skin in hot provisions best relate with discomfort. The behavior of both comfort sensations and temperature is not identical to that of changing environments, that is, for temperature sensations; they change more rapidly compared to comfort sensation (Emmanuel, Rosenlund and Johansson, 2007). Additionally, cold comfort changes more rapidly as compared to warm discomfort.

To effectively study and assess thermal comfort, the indices standards each have to be given consideration depending on the state of regional climate and urban settings and thus it is impossible to use just one index value worldwide. There are many factors that impact and influence the success of an urban space (Hamdi and Schayes, 2007). Numerous physical and social environment components and location of the given space in the city are all key components that play part. This study however mainly focuses on one physical environment aspect known as thermal environment. Outdoor environmental conditions are components of a physical environment that influence the human thermal comfort (Angeloti, 2007). The control of this comfort is done through exchange of energy between the body and its consequent surroundings and generally it can be stated that it exists in the circumstance that a body can readily sustain a constant and deep temperature of approximately 37.0 C.

1.1.3 Dissimilarities between Indoor and Outdoor Thermal Comfort

Outdoor thermal sensation is distinguished in a different way from indoor thermal sensation. Furthermore, thermal comfort standards cannot be applied to outdoor settings (Smith and Levermore, 2008). There are three dissimilarities between outdoor and indoor comfort: differences in heat balance, psychological differences and thermo-physiological differences. The psychological characteristics for the dissimilarities between outdoor comfort and indoor comfort are correlated with expectation (Angeloti, 2007). Persons can to tolerant with a larger difference in outdoor climatic conditions than indoor climatic conditions, on condition that the outdoors has likelihoods for adaptive behavior and proper social spaces.

The tolerable outdoor temperature range ought to be broader than that of the indoors' range because of dissimilar expectations. For instance, people are more tolerant with warmer-than-usual conditions in street canyons, beach resorts and urban parks (Tan and Kosonen, 2003). The thermo-physiological dissimilarity between indoor comfort and outdoor comfort originates from the dissimilarities in clothing, exposure times and the levels of activities. In warm climates, people have a tendency to wear less clothing, do lighter activities and spend more time indoors than outdoors (Tan and Kosonen, 2003). Generally, exposure to outdoor climate lasts for minutes whereas exposure to indoor climate lasts for hours.

The third dissimilarity between outdoor thermal comfort and indoor thermal comfort is the differences in heat balance (Angeloti, 2007). Even though it is possible to have steady state conditions indoors, they are not often possible in urban outdoor situations. In real life conditions, the thermal steady condition is under no circumstances reached even after people have spent a lot of hours outdoors (Tan and Kosonen, 2003). Therefore, the steady comfort model cannot present applicable valuations under outdoor states. From the differences discussed above, it can be established that there is dissimilarity between outdoor thermal comfort and indoor thermal comfort (Angeloti, 2007). As a result, a purely heat balance thermal comfort index cannot forecast the outdoor thermal comfort. In the section that follows, dissimilar outdoor thermal catalogs employed up to the present time will be presented.

1.2 Statement of the Problem

The microclimate of Sharjah, UAE, is hot-humid. The thermal adaptation of the city's occupants is quite challenging due to exposure to variant air temperatures. Despite the fact that controlling the outdoor thermal environment is quite difficult, there is a need to avail thermal comfortable conditions which are able to cater for the outdoor elements such as walking, driving, parking, greenery, shades and water features among others (Smith and Levermore, 2008).

This research is based on investigating the lack of sufficient efficient thermal conditions to facilitate comfort amongst the city's occupants. It aims to solve this problem by recommending a new improvised design for a certain part of Sharjah that will encompass a modular element for thermal adaptation, for instance through creating areas with sufficient shades as well as outdoor sophisticated space planning. The study will conduct a comprehensive research on a specific area in the city that will be further determined in the duration of the research.

1.3 Research Questions

In order to achieve the objective of this study, which includes suggesting means to achieve sustainable outdoor thermal ease in Sharjah, this research will aim to seek answers to the following questions:

- What open space environmental circumstances would be thermally comfortable for occupants in Sharjah, UAE?
- What design approaches can be used in outdoor thermal conditions in Sharjah to increase thermal comfort?

1.4 Research Aims and Objectives

The main aim of this study is to examine thermal comfort in open-air of a certain area in the city of Sharjah, UAE. The following are the objectives of the study:

- To study the levels of thermal comfort in specific locations in the UAE during different weather and climatic conditions.
- To look at the impact of thermal adaption on outdoor thermal comfort and compare people's requirements for thermal comfort in open-air urban spaces.
- To establish an outdoor thermal comfort prediction model for Sharjah, UAE by bearing in mind both human thermal adaptation and macroclimatic factors.

- To assess the effect of the outdoor spaces design on outdoor thermal comfort in Sharjah and suggest an outdoor thermal comfort modular element that can be used to improvise in new areas.

1.5 Motivation of the Study

The main motivation of this study is drawn from the fact that it will be solely dedicated to examining one largely populated and specific space in Sharjah, UAE. Additionally, the results generated from the study will give a better understanding of the comprehensive thermal environments as well as the user's perceptions of thermal comfort in open-air urban spaces in the UAE (Nikolopoulou and Lykoudis, 2006). It is my objective that the study may as well have a major impact on thermal adaptation understanding of open-air thermal comfort in urban spaces. I wish to provide planners and urban designers with a modular design that could use the open-air thermal comfort prediction to assess human thermal comfort in other Universities as well (Smith and Levermore, 2008). Lastly, planners and urban designers can also use the findings of the study as strategies to propose/design more comfortable urban thermal milieus in UAE and other comparable climatic contexts.

1.6 Significance of the Study

Knowledge of the thermal conditions of the outdoor spaces in relation to human interactions is very essential for the planning and development of the region and would also be helpful to the planners and designers seeking to improve the quality of these spaces.

This study can be considered significant because it's quite important to obtain a clear understanding of outdoor thermal comfort conditions and focus on making better adaptable spaces for the users during all climatic seasons. As there is difficulty in modeling the outdoor environment's thermal conditions in a way that achieves the same level of comfort as indoor environments, this study aims to help in understanding more about outdoor environment thermal comfort. People and users are spending more and more time in the outdoors doing various activities and thus the importance of having well designed spaces for them (Lin Tzu-Ping et al, 2008).

1.7 Research Outline

The study is arranged as follows: chapter one presents a broad view of the study background and concisely describes the main problem of the research and what the study intends to achieve.

Chapter 2 - Literature Review/Theoretical Background

The second chapter will analyze the theoretical framework needed for carrying out this research study. It will elaborate the most imperative parts of relevant theory that are found in electronic sources and academic literature.

Chapter 3 – Research Methodology

The third chapter will introduce the research methodology used in this dissertation. The practical and technical features of carrying out the research will be described as well as the material used in the study (documents, interviews and charts). Additionally, the study will continue with the limitations of the research methodology.

Chapter 4 – Results, Analysis and Discussion

The fourth chapter will explore and analyze the results and findings of the study as well as the empirical data which were gathered via the interviews. The data will be collected in themes, following the structure of the theoretical framework. It will also develop a discussion on the grounds of the interview research and academic review. Here, the study will elaborate concepts, articulate views and sustain the suggestions.

Chapter 5 – Conclusion and Recommendations

The fifth chapter will conclude the research study where the answers to the research questions will be summarized. Furthermore, the most imperative factors will be emphasized and the outdoor thermal comfort in the Sharjah, UAE and ways to improve it outlined. It will also include recommendations for future studies to be conducted on similar topics.

CHAPTER TWO: LITERATURE REVIEW

2.1 Key Concepts in Outdoor Thermal Comfort

This chapter presents a comprehensive literature review relevant to outdoor thermal comfort. The key areas that this literature concentrates on are the objective definition of outdoor thermal comfort, thermal comfort modeling, and outdoor thermal comfort in the university setting among other aspects. In this literature a comprehensive definition of outdoor thermal comfort is presented. Moreover, the literature review also attempts to define the differences between outdoor and indoor thermal comfort. In the final section of this chapter, knowledge gaps founded on literature review will be also identified.

2.2 Sharjah Climatic Conditions Relative to Outdoor Thermal Comfort

In the United Arab Emirates, located in the southeast end of the Arabian Peninsula along the Arabian Gulf northern coast, comes the city of Sharjah – the third largest and highest populated city within this country. It has a typical hot and arid climatic conditions characterized by mild warm winters boasting 23 degrees' temperature highs, and warm and humid summers with an average of 42 degrees. Sharjah has two distinct seasons, a summer and winter (University of Sharjah, 2013). Winter commences in November and goes all through to March with characteristic temperatures falling but rarely below 6 °C. Summers are normally hot characterized where high temperatures can be recorded at 48 °C and more, with a combination of humidity levels that rise to almost 90%.

Sharjah, just like its neighboring city Dubai, has high solar radiation levels. Statistically, the highest and lowest month average figures for Global Solar Radiation are mainly 14.67 MJ/m2 and 27.74 MJ/m2 which occur in the months of January and July correspondingly for each season (Ahmed and Shaikh, 2013). In the context of outdoor thermal comfort, during hot summer day, individuals in exterior settings feel very hot and uncomfortable throughout the day and more intensely during noon time, thereby, heat stress is usually anticipated. Sunshine hours last an average of 8.10 to 11.50 during winter and summer respectively (Ahmed and Shaikh, 2013). Regardless of these high consecutive hours, daily activities normally go on due to the nature of lifestyle in the city regardless of lack of comfort.

Sharjah is a 24-hour operational city and thus activities mostly run in periods such as mornings and evenings where heat stress and discomfort are least likely to influence activities. Based on the fact that day times are characterized by high temperatures, heat fatigue is normally expected because of outdoor activities and prolonged exposure to solar radiation and direct sun ray contact. Discomfort and Heat Stress – where the ability of the body to cool itself is reduced – are a consequence of high temperatures and humidity. These discomforts lead to reduced individual and personnel productivity and at times may result to ailments especially for aged individuals. During hot summers and particularly in regions such as Sharjah, users experience high outdoor air temperatures as well as high humidity levels and intensive solar radiation.

Nonetheless, despite the hot and arid climatic conditions experienced in Sharjah, the numerous outdoor activities and initiatives indicate that outdoor thermal comfort is not a major setback or problem for both the natives and tourists. Sharjah is a popular tourist destination with a host of interesting outdoor activities. One of the tourist attractions is the Souq Al Markazi, or Blue Souq. This is a structure comprising a gold souq, clothing souq and, on its first floors, antiques and jewelry shops. Moreover, Sharjah is host to a number of recreational areas and boasts having more than 50 attractive landscaped parks, such as Al Montazah park, National park, Fun Park, and Al Buheirah Corniche all which are outdoor settings where individuals hang out to escape the city bustles and where tourists come to enjoy their time. Sharjah is also site conducive for water sports owing to its ideal environment and climatic conditions. The climatic conditions support sporting activities such as jet skiing and watersports which take place in regions such as Al Khan Lagoon and Al Mamzar Lagoon. Such activities indicate that despite arid conditions, the outdoor thermal comfort is acceptable and individuals have adapted to it (University of Sharjah, 2013).

2.3 Factors Influencing Thermal Perception and Comfort

Outdoor environmental conditions are components of the physical environment that dictate human thermal comfort. The control of this comfort is done through exchange of energy between the body and its consequent surroundings and it can generally be stated that it exists in the circumstance that a body can readily sustain a constant and deep temperature of approximately 37.0 C. Latent cooling uses free, renewable wellsprings of vitality, for example the sun and wind, to give cooling, ventilation and lighting requirements for a family unit (Ghazizadeh et.al, 2010). This further emphasized on the need to utilize mechanical cooling. Applying latent cooling means decreasing differences in the middle of open air and indoor temperatures, enhancing indoor air quality and improving the building, making it a more agreeable environment to live or work in.

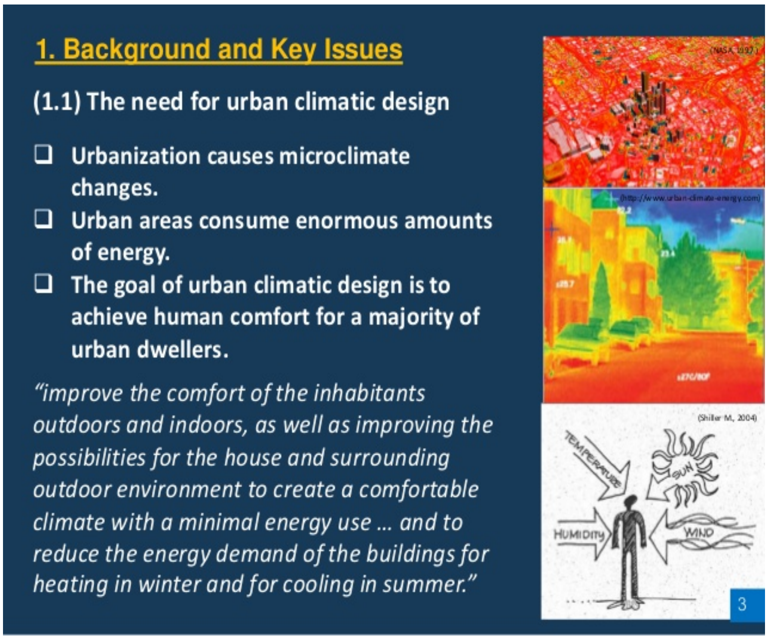

Figure 2.1: Summary of the impact of outdoor conditions on the human comfort. (Source: Srivanit and Auttarat, 2015)

In the course of the last ten years, interest in the measurement of thermal comfort has increased owing to the climate changes and augmented heat stress in towns. However, the number of studies on thermal comfort of open-air surroundings has been somewhat limited (Behzadfar and Monam, 2011). Conversely, there have been a lot of studies conducted on thermal comfort specifically for indoor environment. Climatic chambers started becoming obtainable more often after the 1960s. This allowed for the separate evaluation of influences of the four major climatic parameters on thermal comfort: air humidity, ambient air temperature, airstream velocity and radiant temperature. They facilitated wide-ranging studies for interior thermal comfort and discomfort.

In theory, indices established for indoor settings can be applied to outdoor surroundings. The key challenge for measuring thermal open-air conditions is that climatic variables may be increasingly diverse in contrast to indoor environments. The PET (Physiological Equivalent Temperature) was established to account for this challenge in an attempt to get an enhanced assessment of open-air conditions (Bentz and Peltz, et al., 2011).

Even though indoor surroundings can be effortlessly altered by artificial means such as air-conditioning, altering the outdoors is a much more tedious process (Hedquist and Brazel, 2014). Outdoor comfort indices founded on the body's energy balance ought to use human factors (metabolism and clothing) and meteorological variables (temperature of the air, radiation, the speed of wind, humidity) as well.

In researches on open-air thermal comfort, Standard Effective Temperatures (SET), PET (Physiological Equivalent Temperature) and Predicted Mean Values (PMV) are the most generally used indices. This study will review the existing applications to open-air states of PMV, PET and SET indices.

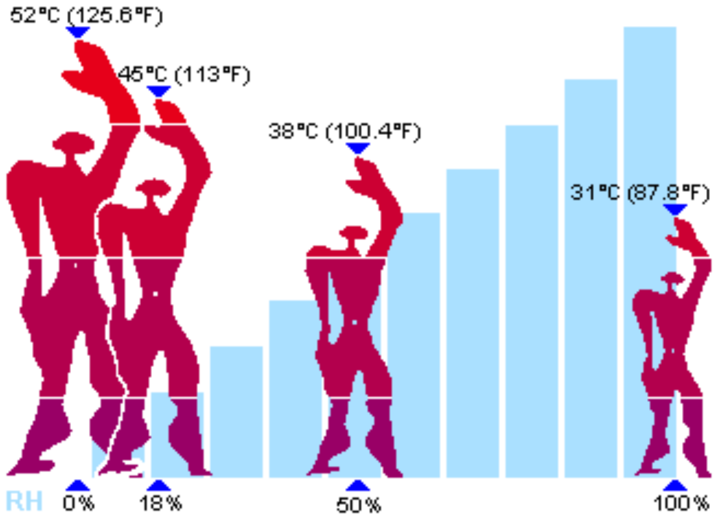

Figure 2.2: Variation in Human Comfort with respect to changes in temperature and humidity. (Source: Shakir, 2009)

Shakir (2009) has stated that there are other factors that also come into play when discussing human outdoor thermal comfort, and it is simply not enough to base on the climatic conditions alone. For instance, psychological factors and human adaptability affect how a person feels, and bring about different levels of comfort. A person living in cold regions has quite different perceptions of outdoor comforts when compared to a person living in hot regions. Figure 2.2 above indicates how the level of human comfort tolerance is affected when an inter-relation between different environmental factors, such as temperature and relative humidity, occur.

Therefore, based on several researches (Nicol and Humphreys, 2007), it is safe to presume that in order to assess the outdoor comfort levels, the physiological and psychological conditions of a person should be accounted for in addition to the thermal environment. An adaptive approach, which is a type of behavioral approach that takes into account the individuals' status, clothing, and more into account, is more appropriate when assessing the level of outdoor thermal comfort (McCartney and Nicol 2002). This approach will be used in this research to obtain much accurate results from the users of the assessed spaces.

2.3.1 Solar Access Outdoors/Indoors

Based on various researches and studies relative to this aspect, the conclusion derived was that the thermal sensations of both the outdoor and indoor settings are viewed differently. The studies further identified that standards for both aspects are also distinct and are only applicable to a certain specific aspect (Middel et al., 2014). There are three distinct aspects that define the differences between both settings (Lide, 2010). They are follows:

- Psychological
- Thermo-physiological
- Heat balance difference

For the psychological aspect that defines the difference, it is centered on the expectations of individuals. According to Peng and Jim (2013), in actual sense it is easier for individuals to tolerate bigger climatic conditions variation in an outdoor setting as compared to indoor setting on the condition that that outdoor setting has promises for adaptive behavior and proper social spaces. The standard temperature range for an outdoor setting ought to be bigger in comparison to the indoor setting because of the different expectations (Ghazizadeh, Monam and Mahmoodi, 2010). In the research, it was also found that warmer-than-usual conditions in settings like urban parks, beach resorts or street canyons for individuals were easier to adapt to even though the environmental conditions were outside the comfort zone.

The thermo-physiological difference between comfort systems outdoor and indoor is founded on differences in factors such as exposure time spans, activity levels and clothing. For example, people tend to choose less clothing or undertake relatively lighter activities in warm settings and hot climatic conditions (Shahidan et al., 2012). For outdoor climate, the exposure times are in ranges of minutes as compared to that of indoor settings which go on for hours.

The heat difference between both outdoor and indoor thermal comfort conditions is the third aspect in relation to the differences of both concepts. According to Wang et al. (2014), despite the fact that in indoor settings there can be steady state conditions, for outdoor settings they are seldom possible situations. In actual normal life, it is impossible to achieve a thermally steady state even in circumstances where individuals spend several hours outdoors. As such it is impractical to provide actual evaluations in outdoor settings even with the application of a steady comfort model (Berry, Livesley and Aye, 2013).

Based on the simple analysis and comparison presented above, it is correct to state that outdoor and indoor thermal comforts are both distinct and different components. Therefore, based on this and the information provided in the differences, it would be impossible for a purely heat balance thermal comfort index to calculate the outdoor thermal comfort.

2.3.2 Impact of Vegetation and Trees on Thermal Comfort

Vegetation has a significant effect on the atmosphere in urban regions, and the relative absence of vegetation in numerous urban areas has been referred to as one of the primary drivers of increased urban heat (Berry, Livesley and Aye, 2013). Vegetation and shade trees create a cool and serene atmosphere and a wonderful space in an urban setting that is populated where individuals can enjoy the outdoor atmosphere. The significance of vegetation and shade trees goes further than this since they not only cool buildings and home environments naturally, they also efficiently block direct sun rays in shading parks and walks and further lower temperatures of the outdoor setting. Other benefits that the presence of vegetation brings include: enhancing the quality of air and increasing circulation of air.

The temperature-reducing effect trees have spreads over in the neighborhoods and urban regions and parks. In an area with numerous trees, the outdoor air temperatures can be reduced to a cool 9°C through the natural process called evapotranspiration. Observations state that in regions characterized by mature trees with canopies, the temperatures were significantly lower and cooler as compared to areas without the canopies (Berry, Livesley and Aye 2013). The average daytime temperatures could go as cool as 3 to 6°C. Trees in areas such as large urban parks contributed in creating a cool "oasis" condition which consequently had a resulting impact on the local wind patterns. The various alterations experienced between the cooler dense air in parks and the warmer air in urban settings consequently resulted to the formation of cooling breezes which spread out in the surrounding regions thus creating a cool atmosphere in a neighborhood.

a. Shade Effect

The atmosphere in shaded regions is significantly cooler as compared to un-shaded areas and as this study illustrates, shading protects against direct sunlight and consequently has a reducing effect on the overall temperatures by a temperature range of 2-5°C lower than peak temperature ranges experienced in un-shaded regions. Strategically planted trees in a home setting and around building structures have a cooling effect on indoor air. For instance, planting trees around windows can efficiently block direct sunlight from hitting the building structures.

According to Morakinyo, Balogun and Adegun (2013), it has also been observed that vehicles which are parked in regions that have tree shading exhibited cooler temperatures in comparison to the cars parked in exposed parking lots; these cars were 7.2°C cooler after the comparison. Even very simple shading created a huge cooling effect to the surroundings, and one such example is vines covering a wall facing to the west. They effectively shade the wall from direct sun rays and during a typical summer setting, the cooling effect is significant in reducing temperatures up to 3.6°C.

b. Trees

Trees and surrounding vegetation use the process of evapotranspiration to lower the surface and air temperatures. Regions that have shading in comparison to peak temperatures of un-shaded regions can be 2-6°C cooler. The peak summers can be considerably reduced by 3-7°C through a combination of both evapotranspiration and shading or even by the former alone.

c. Wind Speeds

Wind speeds can vary and this is due to an increase in the overall urban vegetation. A row of trees in a region can both block summer cooling breezes and at the same time shield houses against cold in winters (Berry, Livesley and Aye 2013). A wide spread tree setting for instance in an urban parking space can have various beneficial effects such as enhancing the air circulation in a region and generating cooling breezes all which can impact an entire community.

d. Evapo-transpiration:

Evapo-transpiration is a collective process inclusive of transpiration and water evaporation from the soil. Transpiration is the process whereby plants absorb water from the ground and release it through their leaf pores as vapor. All these processes cannot go on without applying heat from the surroundings and as such in the process, the air is cooled.

A study conducted by Morakinyo, Balogun and Adegun (2013) evaluated the effect of vegetation on the thermal conditions discussed above in and around two distinctive buildings (Building A and Building B) on a university campus in Nigeria as shown below. The Federal University of Technology Akure experiences a warm and humid climate. In their study, two buildings of comparable designs and layouts where selected to be analyzed for their study.

Figure 2.3: The two buildings of the university campus in their outdoor conditions (Source: Morakinyo, Balogun and Adegun, 2013)

As the above figure shows, Building A was shaded by trees whereas the other Building B was not. The aim is to assess the impact of vegetation (tree shading) on outdoor and indoor thermal comfort. Relative humidity and air temperature were gauged concurrently in both buildings (both indoors and outdoors) for a period of six months (Sep 2010 – Feb 2011). The results revealed that Building B (unshaded building) is normally less comfortable compared to the tree-shaded building (Building A), especially in daytime. Building B starts becoming less comfortable as early as 10:00 a.m. in the course of the dry season, and can even prolong till around 18:00 a.m. in the course of the wet season.

Furthermore, the outdoor environment around Building A is more thermally comfortable in contrast to the outdoor environment around Building B, regardless of the season. The results also showed that there existed a strong relationship between indoor and outdoor comfort conditions, regardless of diurnal or seasonal changes and thermal comfort index. Even though the positive function of tree shading in thermal comfort has been long standing, this study gives further substantiation from an under-studied sub-Saharan region like Nigeria. The study points toward the requisite for greening (tree planting) as a way of improving thermal comfort not only in Nigerian cities but also in cities all around the world.

2.3.3 Importance of Achieving Sustainable Thermal Comfort

Temperature increase is one of the anticipated effects of climatic change. The global mean temperature changed for the phase between 2016 – 2035 is projected to be around 0.47 – 1.0°C. The projection shows that many regions around the globe are expected to be significantly warmer, which points towards the need for creating and maintaining thermally comfortable outdoor and indoor urban settings (Berry, Livesley and Aye, 2013). Such projections, even with seemingly small numbers, create a disturbing negative impact on Earth and raise several alarms affecting the oceans, wildlife, and humans.

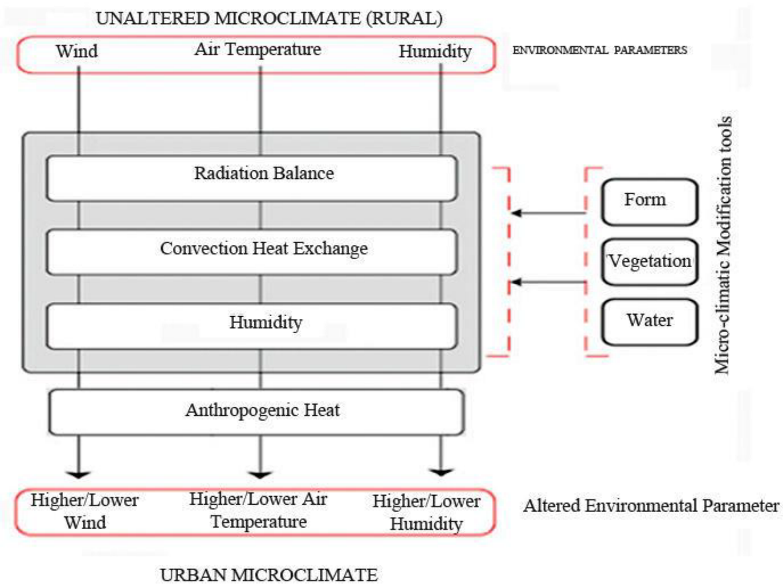

Figure 2.4: Climate modification process (Source: Thapar and Yannas, 2008)

There has been a fair amount of researches evaluating elements that would help reduce temperature rise and enhance air quality. Vegetation created a notable impact on thermal comfort/discomfort in outdoor and indoor urban settings. Among these studies, ones examining the role of vegetation generally establish that evapotranspiration and plant evaporation via vegetative multitudes create major parameters in solar thermal comfort in public spaces, and in the interior and exterior of buildings (Morakinyo, Balogun and Adegun, 2013). As a form of vegetation, trees increase thermal comfort and microclimatic control. Earlier studies agree that tree-planting (greening) typically brings about cooler and more thermally comfortable surroundings.

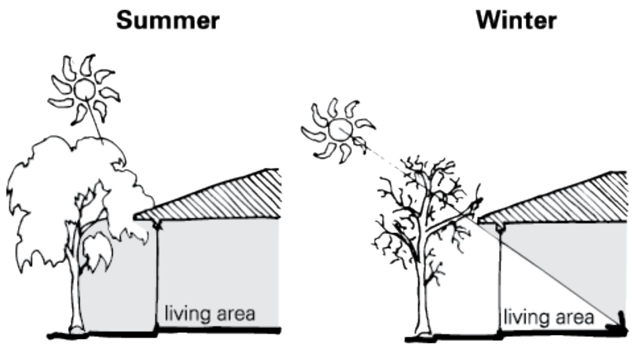

Figure 2.5: Impact of trees on a space during different seasons. (Berry, Livesley and Aye, 2013)

Past studies demonstrated that the extent of dispersed inactive warmth is specifically identified with the 'complete vegetated portion', or the proportion between the aggregate vegetated range and the complete three-dimensional urban surface zone. This shows that evaporative cooling depends not just on the degree of urban green spaces but also on the stature and thickness of structures inside of the urban fabric (Hedquist and Brazel, 2014).

Vegetation adds to comfort by specifically shading a man as well as diminishing long-wave discharge from yard surfaces and restricting the measure of sun oriented radiation reflected from them (Hedquist and Brazel, 2014). Therefore, correlations between microclimatic conditions and comfort levels indicate that only good sensible designs would allow for a better use of the outdoors, specifically when integrating the climatic conditions and with regards to certain levels of exposure and shade (Nikolopoulou et al, 2001).

2.3.4 Defining Outdoor Thermal Comfort

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) is the setting that best defines thermal comfort and its definition of this concept is globally acclaimed and accepted. According to Ashrae (2010), thermal comfort is best defined as the mind condition that expresses satisfaction with the thermal settings and which is evaluated by subjective assessment. In reference to the definition presented above, thermal comfort can be said to expound on the psychological mind state of an individual "that expresses contentment with thermal environment" (Park et al., 2012). In the definition of thermal comfort conditions, it is essential to take into account six key factors and the factors are as follows:

- Radiant temperate
- Clothing insulation
- Air speed
- Metabolic rate
- Humidity
- Air temperature

Metabolic rate and clothing insulation are both personal factors while the rest are factors related to the environment. Every factor mentioned above is independent but the combination of all of them creates, defines and individualizes thermal comfort.

Value	Thermal Scale
+3	Hot
+2	Warm
+1	Slightly Warm
0	Neutral
-1	Slightly Cool
-2	Cool
-3	Cold

Figure 2.6: The ASHRAE 7-point scale (Source: images.google.com)

The PMV-PPD index is used in predicting thermal comfort, and in recent times it has become the most popular and commonly used evaluation index (ASHRAE, 2010). This index comprises all the six primary variables, which have the ability to influence thermal sensation, and is founded on the balance of human heat. It also works by predicting a large number of individuals mean response which are relayed on a scale referred to as the ASHRAE 7-point thermal sensation scale.

2.3.5 Thermal Settings

The field of microclimatology is concerned with the layer of air that is found directly above the surface of the earth where surface effects in this case such as frictions, heating and cooling can be experienced within time frames of around one hour. Furthermore, there are turbulent motions that are responsible for carrying substantial heat, momentum or matter fluxes (Shahidan et al., 2012). The mentioned layer stretches to about 2 or 3 km over the surface and is commonly referred to as the atmospheric boundary layer ABL. The air above this layer responds gradually relative to changes occurring close to the ground and is subsequently influenced by macro-scale processes (Wang et al., 2014). Urban settings are classic examples of modifications relative to local climate and are popularly referred to as the urban canopy layer UCL, which stretches out from the ground level to building top heights.

The surface on which the urban structure is located and set up is rough and inhomogeneous, and based on these characteristics the turbulent processes are enhanced and also inspire high variability in both time and space relative to all climatological quantities and especially so to an assortment of microclimates occurring in a significantly restricted range (Shahidan et al., 2012). These kinds of modifications are some of the factors that should be considered in the process of designing comfortable urban spaces. The main assumption is that there is a clear comprehension of the interrelation between climate and urban geometry which is then converted to simplified and easily understandable guiding principles for the concerned designer that allows for the inclusion of climatic dimensions in the design process inclusive of all the design essentials such as functional, economic, aesthetic and socio-cultural aspects (Hedquist and Brazel, 2014).

This literature is a theoretical background that presents the most substantial studies and researches all concerned and centered on the analysis of an urban street microclimate and individuals' thermal sensation in outdoor settings (Berry, Livesley and Aye 2013). In comparison to indoor thermal comfort, which is well documented and expounded on, the outdoor comfort is not well documented due to shortage of understanding. Based on this, the methods of assessing comfort have been altered to conveniently address the outdoor comfort and have been derived from indoor measuring processes. In this literature, the most critical concerns relative to this topic are discussed. Thermal comfort has a number of definitions and among them is one put forth by The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) which defines it as the mind condition that expresses satisfaction with the thermal settings and which is evaluated by subjective assessment (Hedquist and Brazel, 2014).

This is just one definition; however, there are others such as one which describes thermal comfort by relating it to losses and gains of energy, where the state of comfort is said to be attained in circumstances where there is heat flow to and from a human's body and where these flows are in a state of balance. This state is attained when body data which occurs on the form of provisions such as sweat rate and the temperature of the skin are all within a comfort range. A human being's thermo-physiological regulations partially direct these body data provisions (Park et al., 2012). The assessment of human thermal comfort is neither a ground-breaking discovery nor an uncommon thing and this can be supported by the fact that individuals are always cautious of their wellness and have been looking for various methods for calculating their heat or cold sensation.

In describing a thermal setting and the influence it subsequently has on the body of a human being, it cannot be defined as a function of a sole factor and this is due to the fact that the body does not have single sensors relative to every factor and it experiences thermal setting as a whole. Despite the fact that the method is easy to apply, it is probably suited only for open spaces. Diffuse short-wave radiation modules and surface temperatures are mandatory. Applying a device known as integral radiation instrument is the best option since it allows one to avoid various difficulties as highlighted above (Ghazizadeh, Monam and Mahmoodi, 2010). This kind of device is best suited and appropriate for indoor functions such as a globe thermometer.

The following are the qualities, dimensions and specifications of a globe thermometer. It comprises of a hollow sphere which in dimensions is roughly 15 centimeters' diameter wise, a thermometer bulb at its center and a flat black paint coating. A balance between two components mainly heat gained or lost in the form of convection and radiation establishes the ground from which temperature is presumed by the globe at equilibrium (Shahidan et al., 2012). It's mainly applied in the calculation of comfort in work settings.

The named instrument is suitable for calculating indoor temperatures. In an indoor setting, heat radiated from the surrounding environment is constant. Despite its proper applicability in indoor settings, it is however not suited for outdoor settings and among the reasons why is the radiant environments' non-homogeneity aspect which is prompted by supplementary radiation from solar beams. Additionally, its spherical shape is best suited for an individual in a sitting position because it averages the absorbed radiation from all directions (Wang et al., 2014). For a standing individual, it is rather complex since the dominating components are the lateral fluxes. The mean radiant temperature (MRT) intrinsically gained, presumes similar energy absorption in both long-wave and short-wave range from a human body and the color black overrates the short-wave radiation absorption, except if it is swapped with a grey globe which is better suited to define normal clothing.

Another reason as to why the globe thermometer is not suited for outdoor setting is the fact that it requires relatively longer time frames to attain equilibrium ranging between 15 to 20 minutes (Ashrae, 2010). For better and hastier responses, a smaller and light-colored sphere can be used. Notwithstanding the setbacks, this device has been adopted in assessing outdoor settings concerns for instance outdoor gathering spaces. Though numerous trials and steps have been made in relation to assessing outdoor comfort, a dependable device has yet to be designed (Shahidan et al., 2012). In terms of outdoor settings, the difference is significantly larger for the MRT relative to both time and space and the speeds of wind are significantly higher not forgetting a diverse environmental model level.

Despite the fact that there is variance in the methods and conditions generally applied in measuring outdoor comfort and indoor comfort, there are notable common findings discovered. One of the research papers conducted about this was in Cambridge, UK, where it focused on a variety of recreational settings in varying seasons (Ghazizadeh, Monam and Mahmoodi, 2010). It included in the measurements all the basic climatological aspects and a total of 1000 individuals who were surveyed and evaluated on their behaviors. In this study, the individuals were to sit outdoors with a pre-condition that they were not altering their route on comfort grounds. A comparison was done to quantify the values of the Predicted Mean Vote Index (PMV). The researchers confirmed the relevance of thermal environment in dictating how individuals use space. Microclimate subjective response was discovered to be a subconscious act resulting in outdoor settings frequentation patterns which are seasonal (Ghazizadeh, Monam and Mahmoodi, 2010).

It was, however, noted that in the characterization of outdoor comfort, a psychological approach is not sufficient since psychological adaptations are also significantly important. As a perception of the subjective physiological condition, thermal comfort is impacted by environmental factors such as RH (relative humidity), air temperature, velocity and radiant temperature. Moreover, it is impacted by personal factors like clothing and metabolic heat activity. This study mainly focuses on the environmental factors (particularly relative humidity and air temperature) since personal factors are largely dependent on environmental factors. Thermal comfort is significantly impacted by microclimatic conditions (Morakinyo, Balogun and Adegun, 2013).

2.4 The Adaptive Thermal Comfort

One of the largest elements that influence thermal comfort is human implementation. It can be simply described as "the regular decrease of the organism’s reaction to recurred exposure on an incentive, including all the activities that make them better proficient to endure in such a situation” (Bentz and Peltz, 2011). On the term of the adaptive thermal comfort concept, the thermal solace achieved by people in a non-air-acclimatized circumstance is reflected as the outcome of the combined effect of ambient physical environmental inducements and non-physical subjects (Lide, 2010). Individuals tend to apply various adjusting methods without any kind of restrictions in terms with their own thermal preferences inorder to acquire thermal comfort.

Modification adaptations can be categorized into three main parts, which include: psychological, physiological and behavioral adaptations. These classifications allow individuals to restore their thermal comfort condition under several settings (Bentz and Peltz, 2011). Each form of thermal adaptation is considered significant for examining the subjective limitations in investigating human thermal comfort surroundings in outdoor and semi-outdoors places (Shahidan et al., 2012). The explanation of behavioral (or physical), physiological and psychological alteration constructed on past investigations is illustrated briefly in the following:

2.4.1 Physiological Adaptation

Physiological change is described as any physiological amendment in reaction to circumfused thermal situation modifications. It is divided into two categories: acclimatization and generic adaption. The attention on generic adaptation is problematic and unrealistic because of populations’ mobility. In disparity, various studies evaluate acclimatization through practicing an operational field measurement together with a particular in surveying numerous conditions (Wang et al., 2014). Some of the body changes include the average skin vascular events, temperature, shivering and sweating. These modifications function with an aim of reducing or intensifying the heat interchange between the surrounding environment and human body to help sustain the steady core temperature of the objective organization.

2.4.2 Behavioral (Physical) Adaptation

The most familiar adaptation is the physical one because it incorporates all human changes in order to alter the conditions in a setting grounded on the inclinations. In a research conducted by Ghazizadeh, Monam and Mahmoodi (2010), evidence showed that behavioral modification was divided into three sections: personal (e.g. changing the clothing), cultural response (e.g. resting during heat time of day) and technological (e.g. turning air condition on or off). A person's adaptive character is a vibrant technique and the consistency of this type of acclimatization is altered by compound elements such as culture, finances, climate, and accessibility of control/level of obtainability, regulatory activities and individual thermal contextual.

Additionally, Kodur and Ashrae (2010) noted that physical modification can be categorized as interactive and reactive alteration whereby the reactive change only comprises of personal correction that includes improving the clothing level, position and posture or drinking, while interactive acclimatization necessitates adjusting the conditions in order to improve the heat state.

2.4.3 Psychological Adaptation

Since people have several opinions about different thermal occurrences, their response about physical status considerably relies on their experience in terms of the situation. Psychological factors hinder the thermal assessment of a certain area. There is a positive connection between thermal relief and satisfaction, and although psychological adaptation cannot be supervised clearly and certainly examined and depicted, various scholars have made an effort to explain it thoroughly.

For example, naturalness, expectations, time of exposure, perceived control, environmental stimulation and experience are contemplated as some efficient features for psychological modification (Lide, 2010). Even though the consequences of psychological alteration on the thermal sensations of a person, both short and long term, are essential, currently the amount of research based on the duration of time the psychological adjustment would take is scant. This can occur due to differences in living state, race, etc., which brings an outcome of diverse thermal experience conditions and cognitive processes.

2.5 Human Thermal Comfort in Open-Air Spaces

Based on previous studies, calculations of open-air spaces and physical environments in university campuses were used to compute the physiological responses of humans who use the spaces (Ghazizadeh, Monam and Mahmoodi, 2010). Following this, these measurements were used to pinpoint the environmental variables vital to both human comfort and subject to control by site design. Even though humidity and air temperature are essential to human thermal comfort, the variables were established to have no relationship with site features. They were actually found to be undeviating over space. Additional variables determined to be vital to human thermal comfort are solar radiation, infrared radiation and wind speed in that order. It has been established that these variables can be regulated by site design to a certain extent; therefore, site design can be used as a human thermal comfort controller in open-air urban spaces (Park et al., 2012).

The success of an urban outdoor space is influenced by a lot of factors. The many constituents of the social and physical environment and the positioning of the space within the city's construction all have major functions. This study lays emphasis only on one feature of physical environment; that is, thermal environment (Hedquist and Brazel, 2014). Thermal environment is regarded as the physical environment feature that determines the thermal comfort of humans. This comfort is regulated by the exchange of the energy between the body and its environs, which can general be said to be in existence when the body can with ease maintain a relentless deep body temperature of approximately 98.6OF (Lide, 2010).

Therefore, the thermal environment comprises features which control heat exchange between the body and its environs; air humidity, temperature, infrared radiation, wind velocity and solar radiation. Obviously, a person's activity plays a role because when activity upsurges, metabolic heat production also upsurges (Berry, Livesley and Aye 2013). The purpose of the research is to determine the relationship between human thermal comfort and different physical components of urban outdoor spaces through their effect on the environmental components. The foremost question is “What thermal environment components (human thermal comfort) can be regulated by site design?” This research is an introduction for the formation of design guidelines, some of which surface in other chapters in the proceedings.

The study’s environmental design focuses on the realization of human thermal comfort in different urban outdoor spaces with dissimilar components (Park et al., 2012). The function of several site features was realized from the exploration of how they impact the variables that determine thermal comfort. Comfort was measured via a model of human’s physiological response to the environmental settings as calculated as each site. Therefore, it would be possible to infer physiological comfort from the projected physiological condition.

2.6 Impact of Activity on Human Thermal Comfort

It is important to note that thermal comfort is a psychological elucidation of the body’s physiological state and is not the same as temperature sensation (Lide, 2010).

Thermal sensation and comfort can be recapped as follows:

a. For people who are seated or resting:
    - A sense of impartiality, satisfaction or comfort always accords with a state of thermal impartiality (maintaining a deep-body temperature of human thermal comfort at 98.6OF with no struggle using vascular contraction or sweating or dilation).
    - Discomfort relates best with the temperature of the skin in cold surroundings with more sweating in hot surroundings (Lide, 2010).

- Comfort sensations and temperature sensations have different behaviors in fluctuating surroundings. In comparison to comfort sensation, temperature sensation fluctuates on a much higher and faster rate.

b. In circumstances where a person is active, the following fluctuations in sensation take place:

   - In cold and warm surroundings, temperature sensation relates best to the skin and air temperatures, as the level of activity has no effect on it.
   - Warm discomfort relates best to increased sweating of the skin. It is apparent that sweating and the temperature of the skin are the vital sensible physiological reactions of the human body to a thermal stress (Shahidan et al., 2012). Thermal stress comes about when a person's thermal energy net loss is not equivalent to the production of heat by metabolism within their body. For the deep body temperature to maintain a relentless state, the balance of gains and heat losses ought to be achieved.

In cold surroundings, losses normally surpass the gains, and a number of physiological systems act to minimize the loss of heat from the body. Vascular contraction minimizes the flow of blood to the skin and thus the temperatures of the skin drop (Ashrae, 2010). The production of heat can be increased by either involuntary shivering or voluntary activity. In warm surroundings, the body gains more heat than it can get rid of without trouble, and thus vascular dilation takes place, which makes the skin warm. In cases that the action is not enough to balance the heat budget, the result is occurrence of sweating (Lide, 2010). If the rate of sweat occurrence surpasses the ability of the surroundings to evaporate the moisture, the skin becomes wet.

The heat exchange between the body and the surroundings can occur in different ways. For every heat flow the study has listed the governing environmental factors and states which determine whether the heat flow in the direction is away from or toward the skin. To be able to project the body's thermal state in any given surrounding, it is a prerequisite for equations to be written for every single route, and the set of concurrent equations which are found must be solved for the state of interest: wetness and/or the temperature of the skin (Bentz and Peltz, 2011). The study has used a moderately longstanding physiological model that was established in 1955 by Belding and Hatch and later enhanced in 1963 by Lee and Henschel. This model works out an RS (Relative Strain) for any given level of activity and environmental state. Lee and Henschel connected the different Relative Strain levels to psychological states of failure, comfort, and discomfort among many others. Nonetheless, because each of these connections has been established for indoor subjects, cautiousness ought to be taken when using the comfort ranges to subjects in open-air spaces.

2.7 Strategic Adaptations to Hot Climates

In order to well understand the theoretical part of thermal comfort, it has to be translated into something physical and adaptable to the human level. In a few hot climatic regions around the world, with similar conditions to the ones of Sharjah, designs were implemented in open space areas to make the outdoors more bearable to the users.

2.7.1 Masdar City, Abu Dhabi, UAE

One example with the closest climatic condition is the city of Abu Dhabi, UAE, where the Masdar Institute of Science and Technology can be found. Masdar's design has taken many aspects into consideration, one of which is the simplest and most important; shading. Masdar's plaza has good sky visibility and is the key step toward ensuring optimal maximization of thermal losses. Low apparent temperature relative to the sky is the factor that most inspires major losses due to thermal radiation. As such, it is vital for the shading devices to ensure the concealing of the sun path in an appropriate manner which does not cover the entire sky (Eugenio et.al, 2015). The remaining open areas require being both open and free of concealment to guarantee thermal energy loss by both people and the built environment of the urban systems. Shading minimizes heat gain through solar radiation and thus promotes increasing thermal sensation.

Masdar’s plaza has a hot-humid climate, and as such ventilation relative to thermal temperature is vital and important. In regions such as the open sea that are typically characterized by abundant ventilation, it is possible to obtain comfort conditions even in provisions of intense solar radiation (Nazanin et al, 2013).

Figure 2.7: Shading devices and wind cooling towers implemented in Masdar City Campus. (Source: images.google.com)

Moreover, in other outdoor open provisions, shading is required and mandated owing to the fact that natural ventilation is inconsistent and not guaranteed, and to ensure that comfort is optimized even in low ventilation conditions. In such regions, it is possible to incorporate on-site solutions which ensure sufficiency relative to shading, ultimately enhancing comfort conditions even in circumstances where ventilation is insufficient. Such an example is the cooling towers located across the Masdar campus plaza. These towers, which rise well above the neighboring buildings, are simply hollow core cylinders with adjustable louvers at the top. Their function is to provoke a convection current as hot air rises above them (Aster, 2011), thus creating a natural current of air flowing from the street level to the top of the cooling tower. A breeze gets generated when hot air gets pulled out of the plaza and up and out through the tower, making a continuous air flow which makes the climate within Masdar a more pleasant and bearable one.

2.7.2 Clarke's Quay, Singapore

In Clarke's Quay in Singapore, the challenge was to redesign the urban street market by not opting for the typical air-conditioned enclosure solution, but rather maintaining the existing waterfront and also addressing the persistent climate problem.

The idea was to find ways to alleviate the Singapore ambient temperature and heavy rainfall. They started out by adding large canopies which aid in the shading and cooling process, and as well protect the visitors from the climate extremes. These umbrella-like canopies, which cover the internal streets and central courtyard space, are made out of ETFE (Ethyl Tetra Fluro Ethylene) and are supported by steel frames (Alsop, 2006). They rise above the roofs of the nearby shop houses, and provide solar shading and rain protection.

Figure 2.8: The Clarke's Quay Canopies covering the streetscape. (Source: Alsop Architects, 2006)

Furthermore, mechanical ventilation was added to the site through the frames of the canopies to allow for a breeze within the streets. The large whale-tail slow speed fans that were designed to fit into the canopy structures aided in further reducing the site temperature into a mean of 28 degrees Celsius. The wind breeze generated can move up to a speed of 1.2m/s (Alsop, 2006).

Figure 2.9: The figure showing the mechanical fans within the Canopies. Source: Alsop Architects, 2006)

Planting trees in Clarke's Quay also proved to be efficient despite the fact that it does not block all direct solar radiations. It is the best method relative to reducing thermal radiation and facilitating convective exchanges which ultimately reduces and prevents heating of shaded regions. Since built coverings re-emit a significant amount of the thermal radiation received, they require being cautiously and warily used (Eugenio et.al, 2015). An installation of water fountain in the middle of the busy courtyard brings further visual and cooled environmental advantage to the space.

2.7.3 Seville EXPO 92 - Avenue of Europe and Palenque, Spain

One of the most important things to be considered in urban design is the effect of immediate surroundings on urban thermal comfort. Relative to thermal exchanges in urban settings, more complex dynamic characteristics have been seen in the settings of Seville Expo 92, Spain-Avenue of Europe and Palenque. Shading as a main element was provided through high rise cone-structures, which also function on cooling towers. Depending on weather conditions, these towers provide continuous ventilation by dragging the hot air out and bringing in air which is cooled by the aid of the misfires located at the base of the towers (Brophy, et al., 2000). Thus, the usage of the surfaces can provide better and enhanced comfort conditions compared to what is experienced in open areas. Similarly, in provisions where solar radiation amounts are significant and areas less densely occupied, surface heating will typically occur, leading to higher thermal radiation gains in the process (Wei, 2014).

Figure 2.10: The Seville Expo 92, Spain-Avenue of Europe, showing the cooling towers. (Source: images.google.com)

As the designers of the expo pavilions focused on creating a comfortable outdoor space, they also further established a criteria to reach natural and passive cooling through the use of vegetation and water. Wide spread planting took place across the site, the pavilions were strategically located closed together to allow for wide open public spaces and natural air movement. There was significant reduction in outdoor temperature, claimed to be up to 10K (Brophy, et al., 2000).

Figure 2.11: Vegetation and shading used across the pavilion. (Source: images.google.com)

Strategies used for microclimate control throughout the EXPO ’92 site included the design of:

- Vegetation
- Shading
- Ventilation
- Water evaporation
- Thermal inertia of the ground, landscaping features
- Heat dissipation systems
- Air filtration systems

The next chapter will introduce the case study of this research, the American University of Sharjah (AUS), and its hot-humid microclimate. The thermal adaptation of the university’s occupants is quite challenging due to exposure to a variety of air temperatures. Despite the fact that controlling the outdoor thermal environment is quite difficult, there is a need to avail thermal comfortable conditions which are able to cater for the outdoor elements such as walking, driving, parking, greenery, shades, water features among others (Bentz and Peltz, 2011). The next chapter will cover the methodological approach through which data was collected in order to help address this research problem. The methodology will aid in the findings which are useful in the recommendation of sophisticated outdoor space planning.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The research methodology can be defined as the steps followed to reach a research's aims and objectives. This section will try to thoroughly explain the steps followed by the researcher to conduct the current study, and will mainly be based on how the field work was conducted, and the various data collection methods adopted for the study and techniques employed to ascertain relevant data for the study. This study will focus more on the collection of empirical data and discuss other major areas including: research philosophy, research design, research strategy, instruments adopted in the study, participants and limitations of this methodology.

3.2 Background of Case Study

Even though earlier research carried out to improve the outdoor air temperature and reach an enhanced microclimate, it has been established that various methodologies were assumed. The primary objective of this study is to look at the impact thermal adaption has on outdoor thermal comfort and compare people's requirements of thermal comfort in open-air urban spaces in other Universities in the UAE. In order to achieve this objective this study entails some elements of descriptive purposes. The researcher makes an in-depth study in this institution by discussing thermal adaptation through a comprehensive comparative analysis on thermal response and thermal adaptation. Previous outdoor thermal comfort studies are used to compare neutral temperature arrived at in the study (Cooper and Schindler, 2006). Understanding of human thermal adaptation on thermal comfort in outdoor urban spaces will greatly be boosted by this study's findings.

The study will base its assumption on the mere fact that in American University of Sharjah, knowledge will always exist irrespective of awareness or unawareness of its existence, and it is subject to be interpreted and passed by the researcher. Truth or common reality is highly vulnerable to interpretations of each person even though it exists as a common reality (Burke & Mackay 1997) an assumption that this study assumed as a realist hypothetical viewpoint. In line with the literature review section (Chapter Two), attempting to comprehend the several parameters of bioclimatic approach, there were mainly used three research methods. Interviews, social surveys and field measures were particularly followed for studies looking at outdoor parameters.

3.3 Research Approach

This study adopts a mixed methodology as suggested by which combines both qualitative and quantitative research approaches. Mixed methodological approach is characteristic of the kind of method of study and instruments employed in data collection (Creswell & Plano Clark 2007). Creswell (2009) asserts that a mixed methodology best begins by a research question which is to be answered by both methods of study. Both quantitative and qualitative research methodologies were found relevant tools of research (Creswell and Plano Clark, 2007), as each method of study performed a different function. With a mixed methodology, the study will first begin with a question that will be answered by both quantitative and qualitative methods of data collection. This study employed both the quantitative and qualitative methodologies which are considered to be relevant in facilitating the research questions of this study are answered.

Furthermore, this study proposes that quantitative method will help in addressing the objectives of the main study through empirical assessments (Saunders, Lewis, & Thornhill, 2009). Through the use of various numerical measurements and analysis approaches it will be possible to achieve findings through the use of statistical entities. Quantitative methodological approach is also proposed because it will give a room for a large number of respondents for assessment in the main study course (Creswell, 2009). Qualitative method on the other hand was highly recommended because it helped in the collection of exploratory data in a more organized form (Creswell and Plano Clark, 2007). It also helped in understanding of the various methods and strategies employed by the university.

3.3.1 Advantages of Quantitative Method to the Study

- It will help this study to use various numerical measurement and analysis approaches to achieve findings through the use of statistical entities (Saunders, Lewis, & Thornhill, 2009).
- It also gives way to a large number of respondents in the assessment of outdoor thermal comfort in AUS.

3.3.2 Advantages of Qualitative Method to the Study

- This method helps this study in understanding the various means and strategies employed in AUS' thermal comfort adaptation
- It will also help in collecting explanatory data in a more unorganized form (Creswell and Plano Clark, 2007)

3.4 Methodologies Used in the Study

3.4.1 Social Surveys

Topics associated with thermal comfort levels founded on the human parameter entailed social surveys. The aim of assuming such method is to collect information regarding the response of people to thermal comfort levels. Appendix 1 and Appendix 2 contain the sample of questionnaire forms and interview guide respectively being used for field survey. Physical measurement of microclimatic conditions at the immediate surroundings of the subjects is what is entailed in the environmental monitoring (Zikmund, 2003). For double checking and other information which seemed likely to influence the results, the researcher preferred the use of observation sheet to record the following:

- Environmental parameters
- Weather conditions
- Location
- Data and time
- Respondents clothing and

- Double checking activity

3.4.2 Field Measurements

This method has a scientific dependability since it is simple. When the fields' measurement method is assumed for examining a case, it follows that thermal comfort records are anticipated to entail the different climatic conditions. In order to provide an understanding to the people on subjective thermal perception towards different microclimatic conditions in urban spaces (Cooper and Schindler, 2006), the researcher found it necessary to correlate the results of the questionnaire with the microclimatic data obtained through physical measurement in the subsequent analysis.

For quantitative evaluation and comparison on the effects of various urban design strategies used in improving thermal comfort in the AUS urban spaces, a numerical simulation and the proposed outdoor thermal prediction model was put into practice. Different outdoor spaces were used to conducts the field study in AUS. This study chose May 2010 to October 2011 to carry its field survey. Due to different microclimatic conditions, locations and functions of the city, the study was very keen in selecting the study areas. Thermal environmental conditions that people are likely to encounter in their daily life in urban Sharjah was obtained and represented in the survey. The areas chosen for the study are mainly utilized as resting places for studying or working, lounging or resting, or eating.

3.4.3 Interviews

Qualitative data was collected through an interview guide. The interview was semi-structured and had open-ended questions. This increased the validity and reliability because the bias nature of the researcher in the survey questionnaires was balanced out with the bias nature of the interviewee.

3.5 Sources of Data Collection

Cooper & Schindler (2006) assert that there only two sources of data collection:

- Primary
- Secondary

In order to answer the research questions, this study will employ both data sources in achieving the required.

3.5.1 Primary Data sources

This data was collected from students, management and employees of American University of Sharjah. Information gathered through interaction with students as they are the frequent user of the plaza at a rate averages every hour or two, moving from 1 class to another. Primary data is data collected for the main purpose of study (Zikmund, 2003). It performs the following main functions:

- Helps in improving understanding of the research question (Crotty, 1998)
- Performing direct assessment of the topic with the use of a survey questionnaire and an interview guide (Yin, 1993).

The questionnaire was mainly adopted in order to:

- It gives a highly feasible mean from which a large number of respondents can be assessed.
- It allows data to be collected in a structured manner as the interview adopts a semi-structured format for data collection.

This semi structured model makes the researcher believe that it is not in strict accordance with any other model discussed in the literature review section of the study. Primary data was gathered using the questionnaires. The biggest advantages of using questionnaires in data collection method include:

- There is a high level of anonymity and confidentiality with the use survey questionnaires as suggested by Robson (2004).
- Compared to other means of research, questionnaires are cheap to administer

- In examining of the participants' attitudes, values, believes and motives questionnaire tends to be a simple and uncomplicated mean of data collection (Blaikie, 2000)

Some disadvantages due accrue from survey method of method of data collection too, they are as follows:

- As stated by Bryman (2004) questionnaires are expensive in terms of designing and the time spent in operation
- There can be a low respond rate, if the respondents have no special interest with subject being interviewed about
- Where the respondents experience difficulties with the questionnaires at times there can be misinterpretation of data.

It is possible for a researcher to ask questions that are mainly based on what, using the questionnaires. By doing this the employees were guaranteed that no one would see their comments and ratings.

This study also used an interview guide for collection of primary data (Appendix 2). This helped overcome the limitations of using the questionnaire as discussed above and helped in understanding of various methods and strategies employed by the management.

3.5.2 Secondary Data Sources

This is information that is already in existence (Sekaran, 2003), and one does not to conduct further research in order to gain this information. In establishing conclusion of the study secondary data is very important. A researcher will always find it easy to collect and use secondary data. However, it is important to note that secondary data may not be able to meet all the researchers' expectations as per the study questions demands from him/her (Cooper and Schindler, 2006). This study accessed secondary from:

- Community library
- Year projects by former students of the institution

- Various online data bases of journals
- Books

It should be noted that, in the collection of primary data, secondary data played a very important role towards answering of the research questions in this study.

3.6 Data collection

3.6.1 Sharjah Climate

Subjective assessment and physical measurement were the two main methods of data collection.

The research took place over a span of 9 months, to enable to analyze the two main climatic seasons of Sharjah; Summer and Winter. They were conducted in June/July, December/January respectively. This enabled the research to cover wide data range and obtain more accurate feedback over different climatic conditions from the same users.

Furthermore, site visited varied according to the daily weather conditions in order to have a larger variety of the data collected, such as mainly cloudy or sunny days, and hence site visits were repeated multiple times. Rainy days were avoided when conducting the field survey; the survey was only carried out on conducive suitable weather days.

Throughout those two seasons, site and climatic analysis were divided into four sections a day, and were found to be the most appropriate alternative in accounting for the daily changing climatic conditions.

- Morning (9-11am)
- Midday (12-2pm)
- Afternoon(3-5pm)
- Evening (8-10pm)

3.6.2 Site Selection

The American University of Sharjah (AUS) is an internationally recognized educational organization for higher education in the Gulf region. It was established in 1997, as an independent and non-profit making organization. It avails a wide range of academic and learning opportunities to students globally. The university offers twenty-five majors and fifty-two minors at the undergraduate section. Additionally, the university has fourteen master degree programs. The campus is highly populated and thermal comfort is a major concern. The campus covers over one million square meters of land.

The university can be sub divided in three major areas: the student residential accommodation known as dormitories, academic area and faculty area, which houses the staff. Each area has more divisions as below:

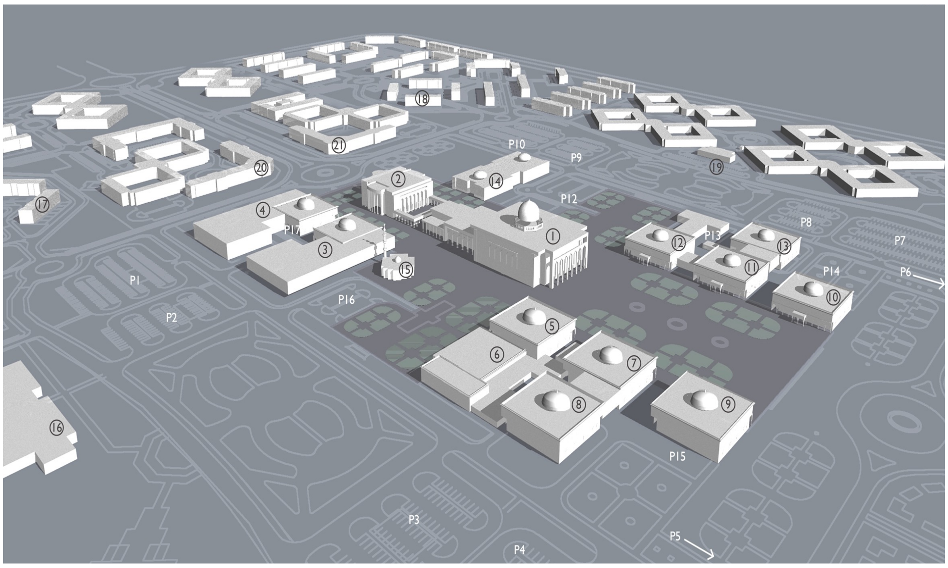

Figure 3.1: The American University of Sharjah campus (Source: www.aus.edu)

AUS has an urban architectural design inspired by the Versailles Architecture, which has widespread green landscaping, large open spaces surrounded with the schools, domed college and support buildings. The community of the University comprises of the faculty, staff, students as well as their families. The university is very unique due to the operating mechanism of the buildings designed to accommodate the dissimilar cultures present in the University. Outdoor environmental conditions are components of physical environment that dictate on the human thermal comfort.

Microclimatic parameters such as global temperature, air temperature, relative humidity, global radiation, air temperature and wind speed are to be collected using the physical measurements. Air temperature, wind speed and relative humidity were measured. Additionally, solar radiation and reflected solar radiation from the surrounding commonly known as global radiation was tracked using the pyrometer. There was no doubt as the accuracy of the instruments used conformed to ISO environmental standards.

3.6.3 Site Characteristics

This study will examine the shading effect on the long-term thermal environment on the basis of local residents' comfort range. Outdoor thermal environments affect people's outdoor thermal comfort, while the outdoor thermal environment is mainly affected by the constructed environment design (Smith and Levermore, 2008). Therefore, it is essential to comprehend the link between outdoor thermal comfort and urban design to institute bioclimatic urban design guidelines. To be able to measure the significance of adjusting the outdoor climate in a certain direction by particular design details, it would help if the designer is able to predict the effect of a specific change in a weather element on the comfort of people staying outside.

Responses to a questionnaire survey, which are to administered simultaneously with physical measurement during each survey, is based on this study's subjective assessment for using the ASHRAE standard questionnaire for indoor thermal comfort study (ASHRAE, 2010) as well as previous thermal comfort field studies (Spagnolo and de Dear, 2003a; Wong and Khoo, 2003; Yang and Zhang, 2008) were used to base the scope of the questionnaire. The questionnaire is to be divided into three sections. The respondents are required to assess the following in the first section:

- Thermal sensation,
- Thermal preference, and

- Thermal acceptability.

a. Thermal Sensation

Thermal sensation is a traditional ASHRAE 7-point scale. It gives out the following measurements:

- hot
- warm
- 1 Slightly warm
- 0 neutrality
- -1slightly cool
- -3 cold

b. Thermal Preference

The thermal preference used here the 3-point McIntyre preference scale.

- Cooler
- no change and
- prefer warmer

c. Thermal Acceptability

In thermal acceptability, the researcher chose to use direct assessment, i.e. acceptable and unacceptable. Based on a 5-point scale and three 3-point preference the respondents were also required to indicate their sensation on solar radiation intensity wind speed and air humidity.

Humidity sensation rate is as follows:

- very humid
- 1 humid
- 0 ok
- -1 dry

- -2 dry

Wind speed sensation rate:

- too much wind
- 1 windy
- 0 ok
- -1 little wind
- -2 stale

Sun sensation rate:

- too strong
- 1 little strong
- 0 ok
- -1 little weak
- -2 too weak

The questionnaire survey approach played a crucial role in this causal study, as it will mainly try to examine on the relationship of outdoor thermal environment and comfort in the American University of Sharjah. In this combined qualitative and quantitative approach, the study will adopt both the questionnaire and interview guide, as its main instruments of data collection. In order to collect data from a large number of respondents which will in turn guarantee concrete evidence in establishing conclusions for the study, this study has considered the survey strategy method. The survey method of study permits collection of data in large volumes (Yin, 2003).

3.6.4 Data Collection Tools

This study will consider the survey strategy method mainly because of its appropriateness and for its cross-sectional data collection technique (Saunders, Lewis, & Thornhill, 2009) and last but not least for its high anticipation of a large respondent. The study will also reflect on the two main sources of data – secondary and primary sources. Collection of primary data helps in the following ways (Cooper and Schindler, 2006):

- It helps the researcher to understand more on the research question

- It also helps in the implementation of direct evaluation of the subject using both the survey and interview guides.

This study intends to use questionnaire and an interview guide in order to ensure that there is regularity. This study proposes to acquire primary data through the following (Blaikie, 2000):

- Journals
- Books
- Previous projects from students and
- Online data sources

a. Population of Study

<u>Sampling and participants</u>

The data collection instruments to be used in this study for both quantitative and qualitative methodologies are:

- Survey questionnaire
- Interview Guide
- Psychometric chart would be used to relate to the level of human comfort (Creswell and Plano Clark, 2007)

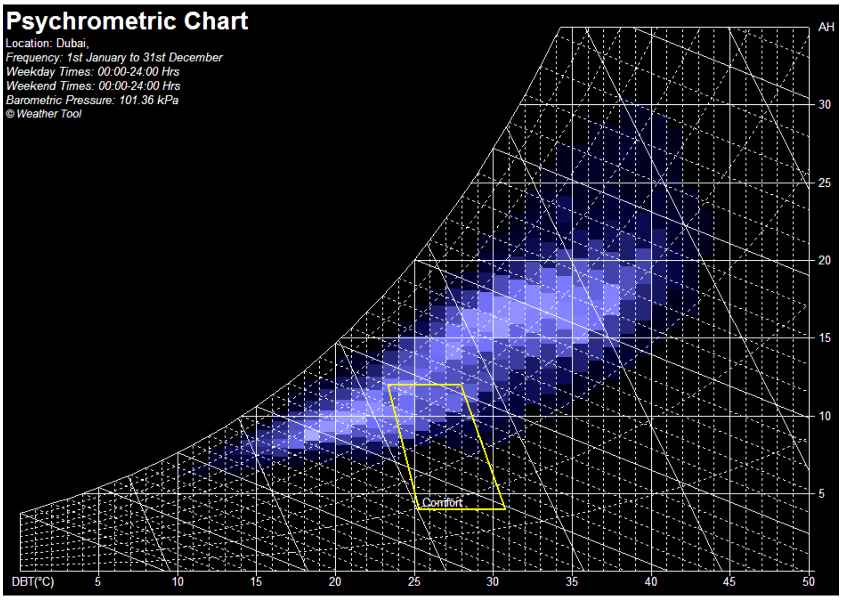

Figure 3.2: Psychometric chart of Sharjah indicating comfort zone (Source: Climate Consultant Software)

A preliminary letter is required to gain permission in order to collect data from both the respondents and the institutions of research as well. The researcher will handle the questionnaires herself.

Sampling Frame, Size and Sampling Location

There was a need to adopt a sampling frame for data collection due to the application of random sample selection in addition to selective sampling. The faculty interviewed will consist of members from the architectural college. Interviewees included Dr. Ahmed Mokhtar - Associate dean of College of Art, Architecture and Design in AUS, along with Professor Kevin Mitchell and Professor Erik Heintz. The students from different departments who utilize the campus' open areas were randomly selected as survey respondents. They studied in this institution and were selected based on the convenience sampling method. Qualitative data was collected from the management with the help of interview guide while quantitative data was collected from students with the questionnaire.

Instruments and Analysis Section

In studying thermal comfort, de Dear (2004) argues that it is normally conducted in actual thermal environmental conditions; these studies often involve real occupants who are usually in large number and in diverse samples. In the collection of necessary data for thermal comfort in this study, field surveys have been applied as the medium of examination. This study has chosen structured interviews with questionnaires together as well as environmental monitoring, as a mode of field survey. The questionnaire survey in the interview has specifically dealt with subjective thermal comfort data such as:

- Thermal preference
- Thermal sensation
- Thermal acceptability
- Demographic background
- Activity level during the survey and
- Clothing

The climatic conditions of the site and architectural design of the buildings at the university will be profiled. The study used hand held measuring instruments for temperature collection around certain areas in the campus. According to Sekaran (2003), the total number of people that a researcher wishes to examine in his study is what comprises of the study population. This study mainly tried to:

- Examine thermal comfort in open-air American University of Sharjah, UAE
- To establish an outdoor thermal comfort prediction model for AUS by bearing in mind both human thermal adaptation and macroclimatic factors.

Using random sampling, this study selected a target population who constituted of both faculty and students of American University of Sharjah.

b. Data Collection Instruments

The interview guides and self-administered questionnaires have been used in the collection of primary data in this study.

Survey Questionnaire

Various components are defined by the design of the questionnaire in the study. These components including brand trust measurement scales, which provides an elucidation of the set ups used by the organization and also the questionnaires in pretesting procedure.

Chapter two of this study reviewed literature review from which the structured survey questionnaire is mainly based. Based on secondary data review, a clear and easy to comprehend questionnaire was constructed. In order to ensure that questions are well observed and answered the questionnaire was arranged in a vertical format (Zikmund, 2003), a pilot study was also conducted and respondents' views of the various questions sought so as to ensure that the layout of the questionnaire was simple end easy to understand. The researcher found it important to divide the questionnaire into different sections, as can be seen in appendix 1.

Interview Guide

This study adopted a semi-structured interview guide as can be seen in appendix 2. The interviews were done to understand the design of the new campus in an improvised design that will encompass a modular element that can be repeated around the campus thus providing outdoor thermal comfort. Additionally, a complete design that will cover the area is likely to be recommended.

Administration and data collection

Site analysis was the first step embarked in the research. Collection and analysis of data in the survey and interviews then followed up. it was important to prepare on some of the best methods to understand challenges that might come ahead in the research. The researcher herself personally administered the questionnaires to site users as well similarly conducting the interviews. The respondents were required to read and give their views on specific questions which only pertained to this study.

3.7 Data Analysis

Quantitative data analysis will first be carried out using tables and graphs. Microsoft Office Excel helped in analysis of quantitative data. In order have easy manipulation of data and avoid too much confusion it is important to first organize the data in a clear and consistent manner. Tables and graphs were used in analyzing quantitative data. Interview guides data was analyzed qualitatively. Pertaining to each research question qualitative analysis was done alongside quantitative analysis. Furthermore, it was important to conduct on-hand site analysis to understand the conditions of the university campus. Schematic figures and analytical diagrams were done to show different aspects of the site, where conditions such as circulation, traffic, zoning, and climate conditions were studied. Site analysis diagrams were done by combinations of hand sketches and computer generated drawings with the aid of software such as Adobe Photoshop and Auto-Cad.

3.8 Limitations

One bigger challenge that the researcher encountered was the short period of time given on which the study must be completed. Large efforts were required to ensure the completion of the project given the challenging nature of the researcher's tasks. A strict timetable with clearly stated milestones was to be achieved during the process to avoid delays. Time was a major constrain as tremendous work had to be done, and multiple methods were conducted in the research as previously discussed. Furthermore, the stretch of the research the took over two different climatic seasons played a role in pushing back the time frame. Minimization of cost during the data collection phase was enabled through adoption of a survey questionnaire. Another limitation was the survey respondents' answers and reactions to the questionnaire. Some respondents did not want to fill out the survey, or answers were contradictory that they had to be removed from the final toll when reviewed.

CHAPTER FOUR: RESULTS, ANALYSIS AND DISCUSSION

4.1 Data Presentation

This study found it necessary to transform the knowledge acquired in the literature review in chapter 2 into this current chapter, and the knowledge remains consistent with the current findings in order to help the researcher reach a solid result process. The study also made assumptions and interpretations that are consistent with the previous studies. By analysing the results attained here, the study was able to identify all the sufficient details on the procedures explained in chapter 3. Focusing on the significant findings and behaviors, this study tries to make a thorough explanation on the data extracted from all the procedures. Outdoor temperature is the dependent variables as observed in the study hence the need for this parameter to be highlighted.

It was crucial to conduct this current investigation in order to properly understand the conditions of the site; this is significant in terms of it helping in identifying the most effective factors that can enhance thermal outdoor temperature. There was need of analysing the different spaces that are frequently used by the students and staff, which were then put under test and compared to different elements and worst-case scenarios. These comparisons are essential especially when one wants to evaluate the designs that are responsive to the environment in a qualitative method. They were based on the existing areas and zones found on site to preserve the campus qualities and try to improve on the present mainly because the existing conditions encompassed several factors of the bioclimatic elements taken into account in this research.

Using graphical representations, the researcher was able to make tabulations on all the surveys executed in both weather seasons tested – summer and winter. All the attention was diverted towards temperature during all the data collection exercise. An excel sheet was used for each scenario, to recorded temperatures extracted from the Airport Weather Data. Each sheet had its own average, minimum and maximum values that summarized all the comparative values required for each specific variable. To compare the parameters of each variable, more sheets and variables were added between each other and between the different conditions.

4.2 Survey Process

4.2.1 Analysis of the Space

To quite understand the usage and the density of the AUS campus, it was crucial to conduct on-site analysis and study the effects the space has on the users. The research time was split into two seasons, summer and winter, where movement, surveys and interviews were taken place to give an accurate result.

a. Zones and Districts

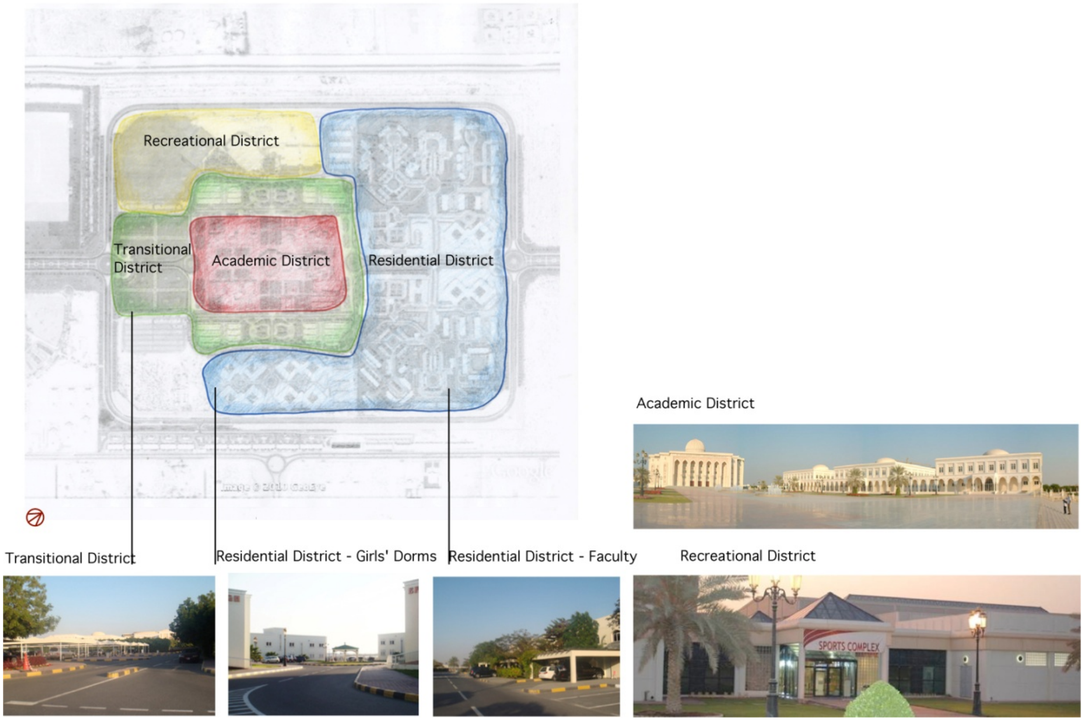

Figure 4.1: AUS campus broken down into different zones and districts. (Source: author)

To better understand the scale of the site, AUS campus can be broken into 4 different zones and districts with different characteristics surrounding each:

- Academic District: Pedestrian Active, having mixed programs and uses, with a variety of architectural typology
- Residential District: More active at night, is used by specific people (ones who reside on campus), and has low buildings placed with in large open spaces.

- Transitional District: The main drop off/pick up and parking areas, has low-density pedestrians, and less intensity of usage.
- Recreational District: High activity during nighttime, however, low density of uses, compromises of diverse population, private/secluded areas, with greenery and open spaces.

Recognizable areas and zones provide a sense of orientations and strategic spots to know where you are. The AUS campus, due to its symmetry, lacks distinctive qualities to orient first time users and visitors.

b. Circulation - Car

One of the first elements analyzed was the circulation on and around the campus. The AUS campus is a relatively large scale one, 1,340,000 sq.m. of land, with over 4000 students present at any given term of the year. Therefore, movements of the users around the campus space was reviewed to pinpoint the areas that needed development. Circulation on the campus can be broken down into two parts: Car, and Pedestrian Circulation.

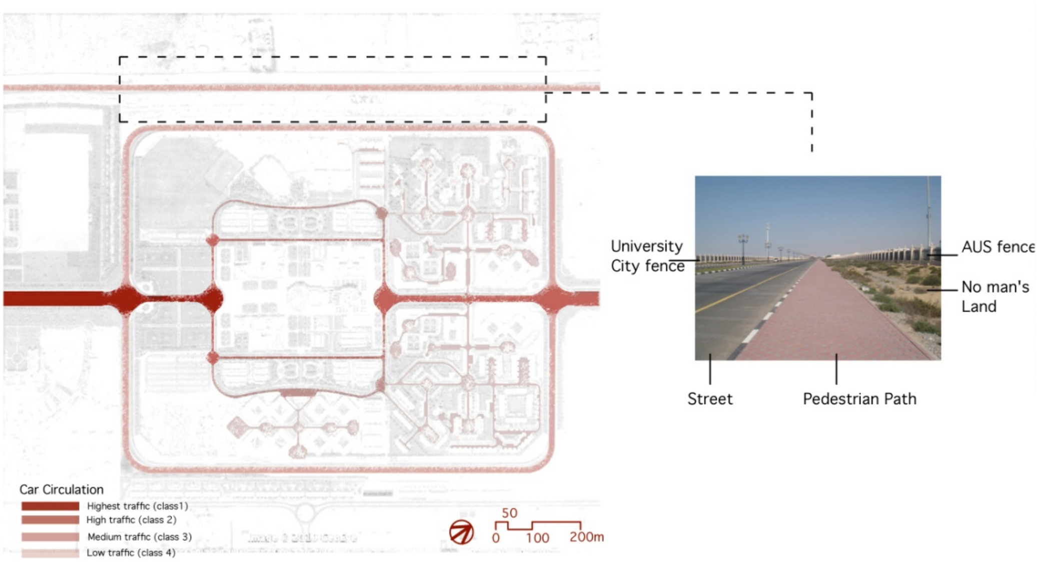

Figure 4.2: Analysis of the traffic circulation at AUS' campus and borders. (Source: author)

The AUS campus is surrounded by a fence, and has only two car/motor main accesses to it only. Long boring pathways separated from the campus by barriers including: The AUS Fence, University City fence, no man's land (that is not being utilized) and streets without pedestrian crossing opportunities. Traffic tends to be high and condensed at the two said entrances, while the remaining internal streets have lighter traffic as the number of cars using them gets distributed across the campus as their users' head to their targeted buildings.

c. Circulation - Pedestrian

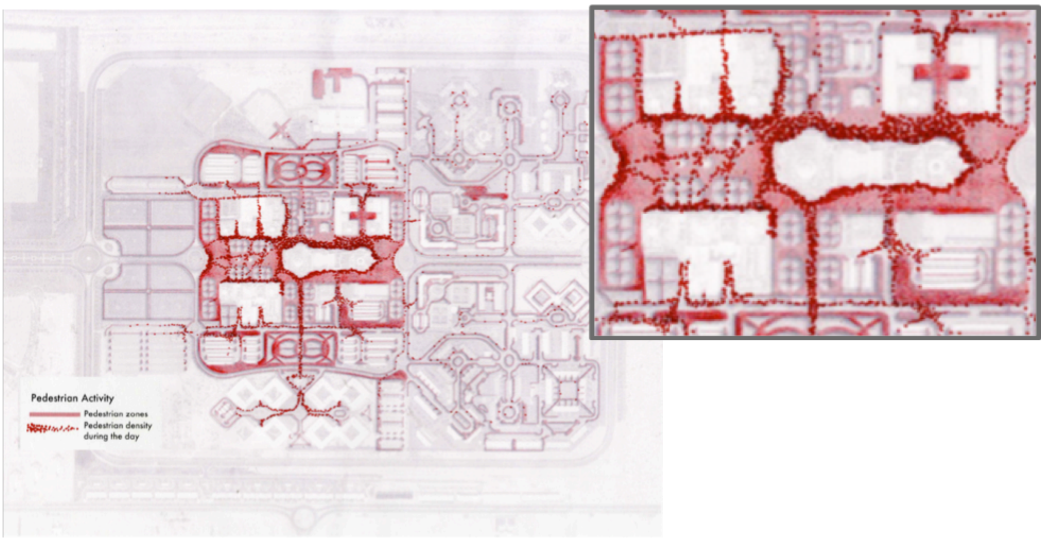

Figure 4.3: Pedestrian circulation on campus - Density during the daytime; 8 am to 2 pm. (Source: author)

Since car circulation around the campus is limited, students rely on moving around by feet; whether coming from their dormitories, dropped off by the public buses, or simply coming from the parking.

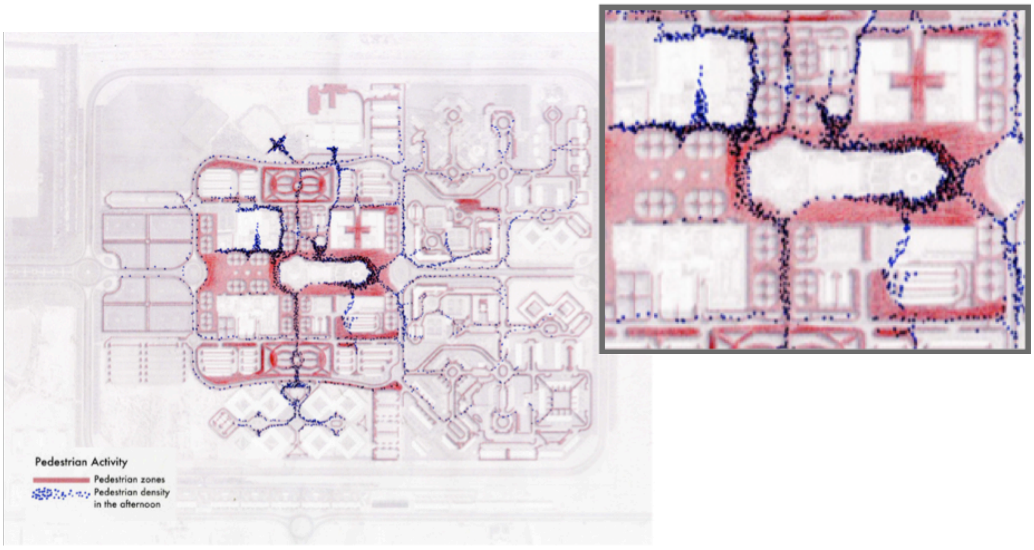

Figure 4.4: Pedestrian circulation on campus - Density during the afternoon; 4 pm to 8 pm. (Source: author)

As can be noted from figures 4.3 and 4.4, pedestrian traffic is quite heavy most of the day, with users circulating across the campus in and out of buildings, with a great focus on the main central plaza.

d. Nodes and Landmarks

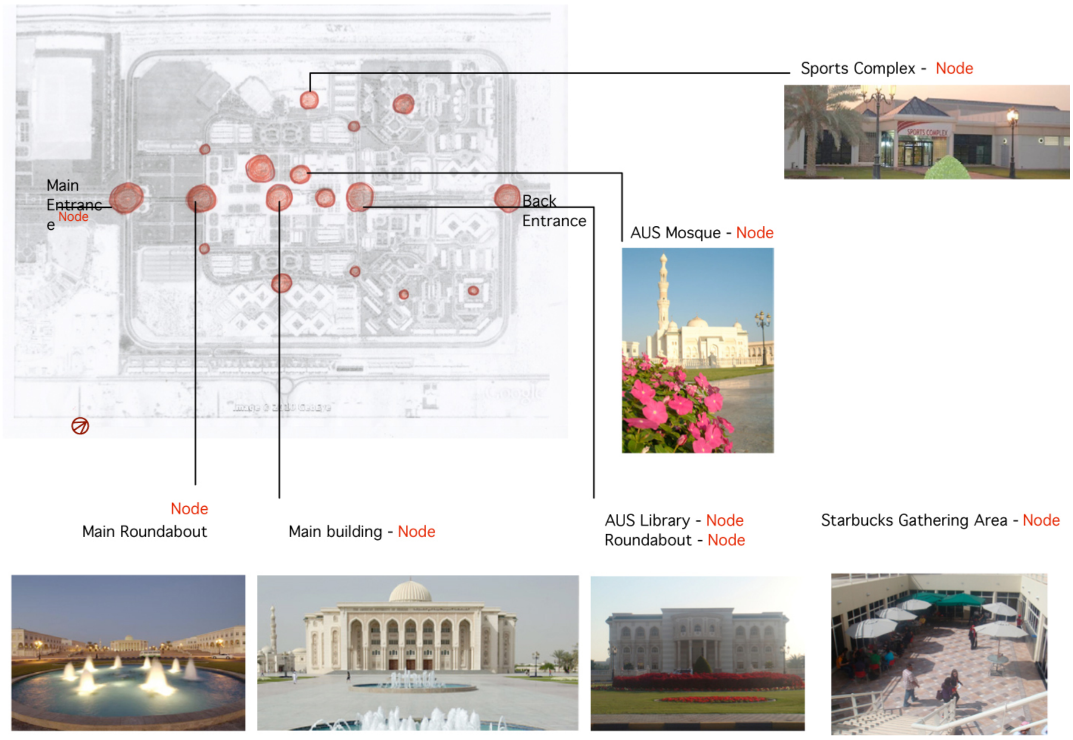

Figure 4.5: Nodes and Landmarks around the campus that are used as location identifiers. (Source: author)

Nodes and landmarks are what characterize a space. They give a sense of definition and direction to user and make the space a more humane scale. AUS's campus due to its vastness has a few nodes that can be noted. As can be seen in diagram 5, they are labeled by either the usage of a building (example: The Library), or by an element of design, (example: The Main Roundabout).

Therefore, more landmarks or foci points should be added in order to break away from the confusingly similar campus environment and create distinctive areas to help pedestrians orient themselves.

4.2.2 Parameters of the Study

Outdoor air temperature is affected by a number of factors. Environmental designs are made in a way that they just perform the same function performed by indoor cooling techniques. Bioclimatic design analysis on the cooling effect of outdoor spaces in hot regions was conducted and the parameters outlined as follows:

Figure 4.6: Analysis of AUS' Green areas and Vegetation. Arrows and Numbers indicate real images of spaces below (Source: author)

a. Material of the Space – Soft-scape and Vegetation

Vegetation is overwhelmingly believed to be the most influential factor in all the bioclimatic principles. This study also considers vegetation as a crucial parameter in obtaining these studies goals. As can be seen in the figure 4.6, despite the large areas available on the campus, the greenery and vegetation is mainly found in the space that are not frequently used by the students and faculty, such as the sports fields and dormitories, and are actually grass patches that would be ineffective in reducing the outdoor thermal heat. The main plaza and buildings, as would be found from images 1 to 7, are the areas where students tend to spend most of their time in. As can be seen from the above diagram, very little greenery is found in that area, and that tends to cause a lot of discomfort and heat, making the space very unusable for the students.

Figure 4.7: Soft scape Materials of AUS campus: The Main Plaza (Source: author)

In figure 4.7, images 1 to 3 show some of the better places on the campus, where some shade if provided by a group of grid-placed trees. However, it is not sufficient as can be seen from the images, as there are large open un-shaded areas where students have to pass through causing thermal discomfort.

b. Materials of the Space – Hard-scape

Bentz and Peltz (2011); Berry et.al (2013) all believe that materials play a large role in determining outdoor air temperature. The AUS campus' materials mainly consist of the following: concrete, brick pavements, asphalt roads, marble and granite pavements, and a few patches of grass and Palm trees. It is crucial in this research to consider the materials as they cause a large effect on the outdoor thermal comfort of the users.

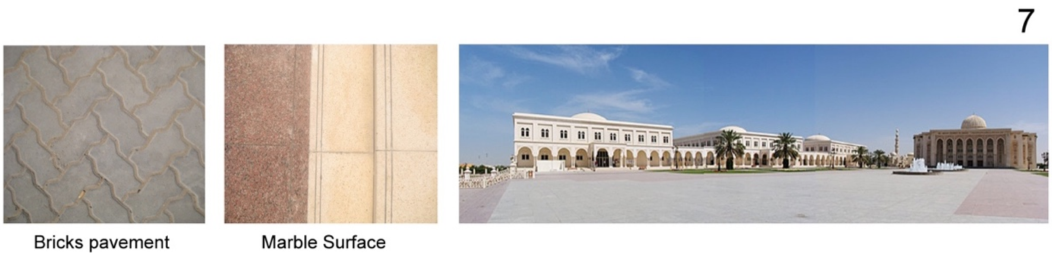

Figure 4.8: Hard scape Materials of AUS campus: The Main Plaza (Source: author)

Site analysis indicated the materials used around the campus are inefficient in deterring off the harsh heat. Since the main plaza acts as a focal point, with very little green areas, and more hard-scape made of marble, students tend to avoid that space as much as possible, only using it for circulation and movement between one building to another.

c. Geometry to Width Ratio – Softscape and Hardscape

This is the most effective factor in controlling air temperature. The designer should be able to create pleasant space using shade and wind more than any other factor such as space inclusion and shape. The geometry of the space in terms of height to width ratio is considered the most effective factor controlling the impact of geometry on air temperature. The manipulation of such factor gives the designer the chance to create pleasant spaces through shade and wind in spite all the other geometry factors such as space enclosure, and shape.

Figure 4.9: Walkways and paths around campus and towards the main building (Source: author)

As in figure 4.9, the images 4 to 6 show the scale of the walkways and paths between Main buildings and girls' dormitories. Most of these paths are lined up with palm trees that are too large of a scale to provide sufficient shade (image 5), and are placed in a grid-like manner that makes it uncomfortable to pass through. Furthermore, the materials that make up the campus are of harsh reflective composition that does nothing to lessen the intensity of the heat, in fact, increases it even more.

d. Geometry: Space Composition (Surrounded, Semi Surrounded and Edges)

Space composition plays a role on the outdoor temperature, and remains dependent on all other factors such as H:W ratio of the buildings' form.

Moreover, previous studies conducted to investigate on the effect of space on the microclimate revealed that, spatial alignments affect temperature changes, and the space ratio made even more significant impact on thermal comfort, something that is essential to consider in this research.

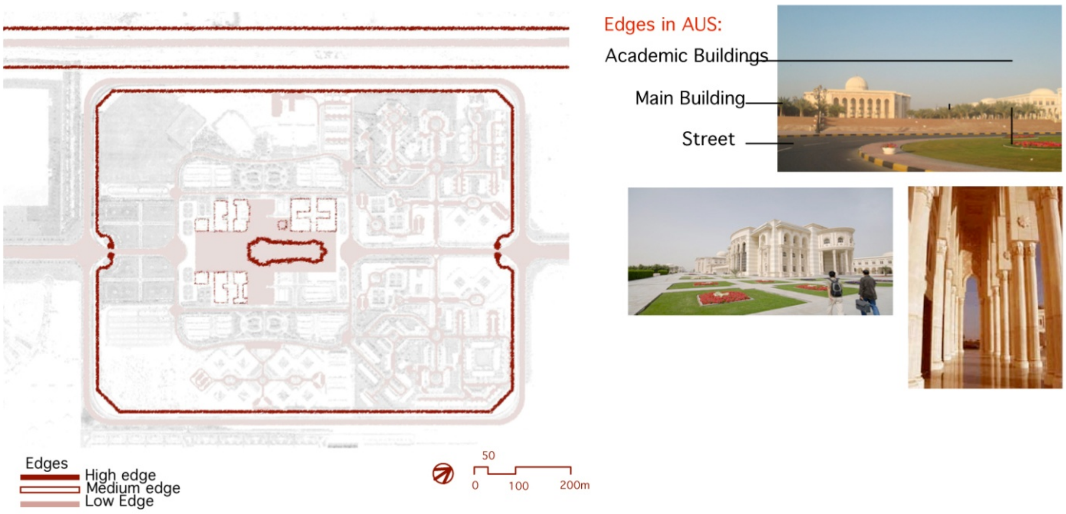

Figure 4.10: Edges and buildings around campus define the spaces. (Source: author)

According to Bentz and Peltz (2011) size of the space factor often has an impact on temperatures. The campus' buildings are surrounded by open spaces and consequently are not effective in defining circulation paths. Such vast areas allow for heat island effect; raising the temperature higher than it should, making it unbearable to walk in during the summer seasons. As can be seen in figure 4.10, the AUS campus is basically a big block surrounded by edges, and can be broken down into three part; High Edges – The surrounding fence and Main Building, Medium Edges – The Academic Buildings, and the Low Edges – the Streets. The great variation that is found in the scales impacts the outdoor conditions, as these buildings, even thou large, do not provide enough shade to make the spaces more bearable. Though they define the edges and mark spaces, their scales are exaggerated.

Furthermore, buildings' orientation proved to have significant impact on the cooling effect alongside the H:W. Microclimate effects seem to vary greatly according to the different orientations and ratio volumes in space.

e. Water Features

Cooling sensation of the wind is rapidly increased when water features are added from the space during hot dry climates. This normally applied in such climates. The AUS campus has only three water fountains, which are located on the Main Plaza. In winter times, students can be seen sitting on their edges for short periods of time. However, due to the large scale of the site, and their small number in comparison, these fountains do not have a significant cooling effect on the outdoor thermal comfort. These water elements need to be placed strategically in order to help reduce the hot temperatures during the summer times.

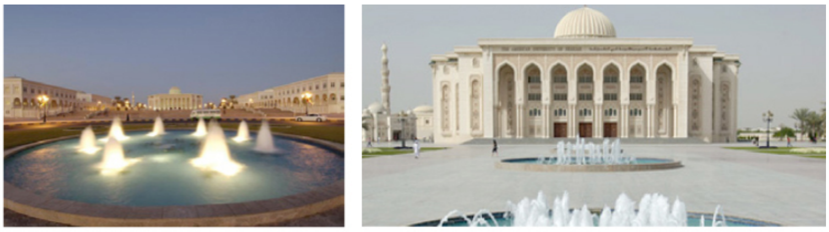

Figure 4.11: Water fountains placed on the Main Plaza. (Source: author)

f. Sheltering Elements (Canopies and Pergolas)

The campus as discussed is very exposed, open to harsh weather conditions and direct sunlight. Regardless of these conditions, the campus doesn't offer many artificial man-made shaded areas or elements, such as pergolas, canopies, etc.

Therefore, in this study, the focus will be mainly on considering the existing certain parameters, or the lack of their-of, in analyzing the conditions of the outdoor thermal comfort. Some of these parameters will be: temperature, location, site conditions, and more, which will be further discussed in the surveys.

Previous studies tried to give actual descriptions of the cooling level in each of the parameters to be investigated, which in turn helped in this research process. Dubai climate investigators considered the three above mentioned parameters: Orientation, H:W ratio and vegetation for further investigation. Berry et.al (2013) asserts that these three factors have made immense contribution in hot arid climate particularly where extensive shadowing and ventilation though air movement is recommended.

4.3 Climatic Site Conditions

4.3.1 Data Collection

Climate data of Sharjah was not readily available through research and inspection. Thereby, this research will be based on Climatic weather data of Dubai, a city that shares borders with Sharjah and has roughly the same weather conditions throughout the year.

The information collected was based on two resources, Climate Consultant v5.1 software, and Dubai Airports website. Climate Consultant v5.1 software produces the data based on a weather file inserted into its system. It's a validated software used by many professionals to obtain weather and environmental conditions needed for certain locations.

Dubai Airports website provides weather data charts that show the yearly averages of temperatures, rainfall and humidity. These numbers are essential for airports to estimate weather conditions for flights.

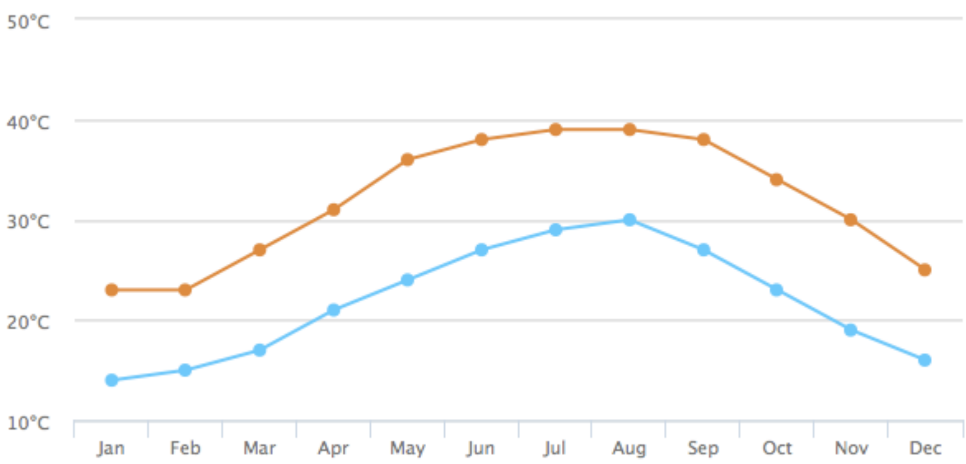

Figure 4.12: Highest and lowest monthly average temperatures in Dubai. (Source: Dubai Airports, 2015)

Finally, based on the data collected from the resources, they will be used in this research and applied to the AUS campus site conditions and analyzed accordingly.

The data in the graph above was collected based on the average temperatures found in Dubai across the year. Given these numbers, the research can estimate the temperatures found in open areas across Sharjah. However, temperatures tend to rise much higher than such averages during the peak summer months, which is July, and lower in the winter, where January is considered the coolest.

Table 4.1: Climatic conditions monthly average in Dubai. (Source: Dubai Metoerolical Office, 2010)

	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.

The above table extracted from Dubai Meteorological office, shows the average temperatures, humidity, rainfall and sunshine. It rains an average of 28 days throughout the year, where most of the remaining year experiences sunny days.

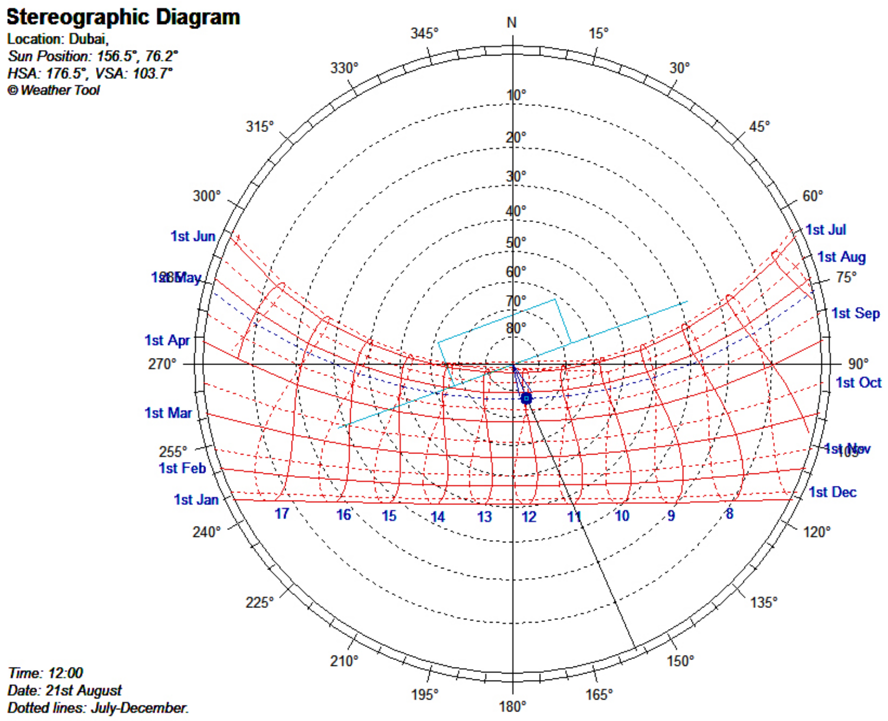

Figure 4.13: Solar position of Dubai (Source: Climate Consultant Software)

Figure 4.13 known as The Stereographic diagram, represents the Sun Path according to the Dubai co-ordinates. Red lines indicate the months of the year while the radial lines indicate the latter that presents the sunrise and sunset times and azimuth in the city. The image is recorded at 12.00 PM on the 21st of August.

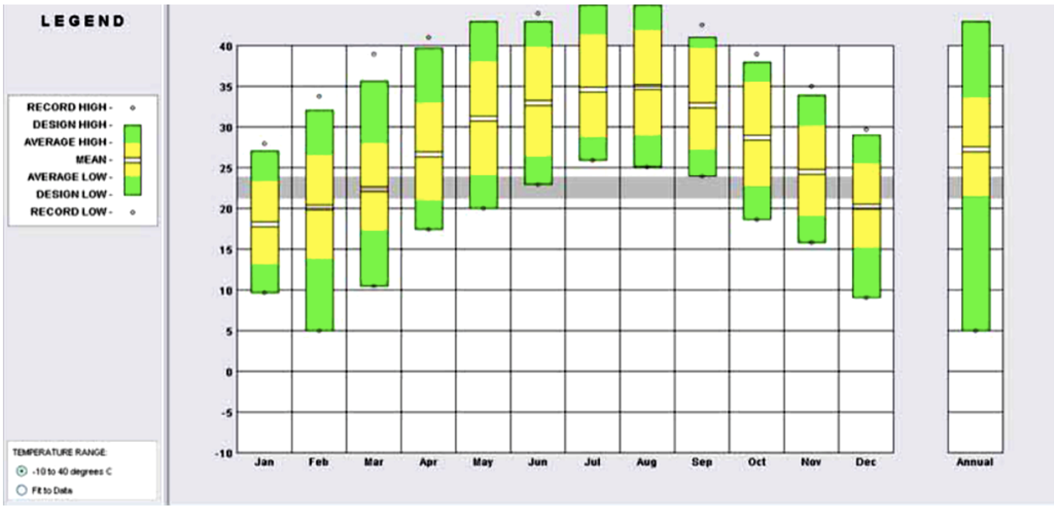

Figure 4.14: Annual and monthly temperature values. (Source: Climate Consultant Software)

As previously mentioned, the weather in Dubai/Sharjah is known to be a harsh hot one. The figure above shows a summary of the temperature conditions of Dubai, with August being the peak hottest where highest temperatures above 45 C are recorded, with similar conditions starting May to September. During these summer months, the outdoor spaces are avoided as a general rule, used for circulation and movement purposes only. Cooler months are generally between November to February, with December considered the coldest, temperatures going down as low as 5 C. These months are considered the most favorable outdoor weather conditions, where users are often found outside when possible.

Solar radiation is generally high throughout the year, with May and June recording the highest as shown in Figure 4.15. Due to the low sun position that faces the city, high levels of radiation and daylight all over the year causes discomfort, heat and glare throughout the year.

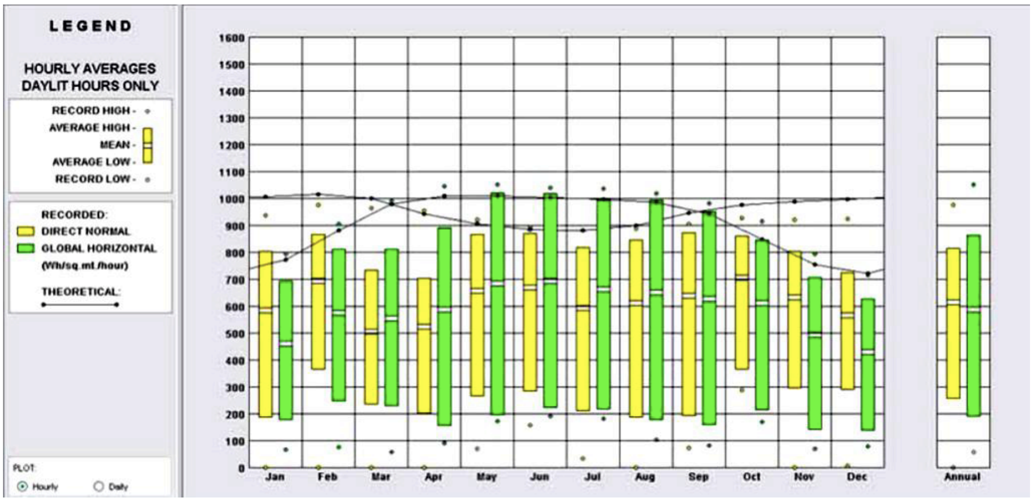

Figure 4.15: Annual and monthly daylight hours representing solar intensity. (Source: Climate Consultant Software)

Furthermore, humidity is a key player in the harsh outdoor climate of Dubai. Due to its location close to the Gulf, the city suffers from high degrees of humidity most of the year, ranging from 30-50% and reaching up to 70% during the summer months as can be seen in Figure 4.16.

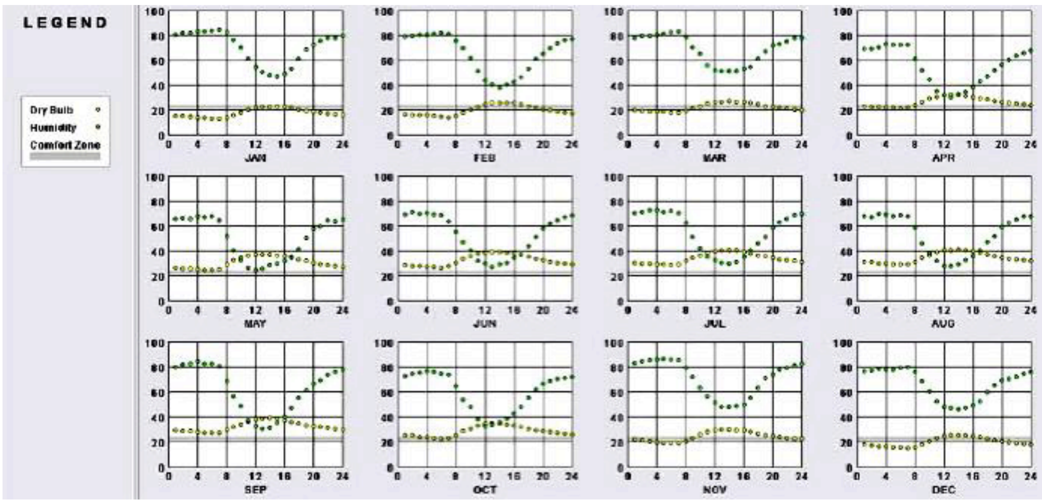

Figure 4.16: Monthly dry bulb, humidity and comfort range. (Source: Climate Consultant Software)

The dominant Dubai wind direction comes from the North-West, as can be noted from the Wind Rose Figure 4.17. The highest recorded is 2.7 to 5.5 m/s. However, due to the open geographical nature of the city, low wind levels blow from different directions throughout the year.

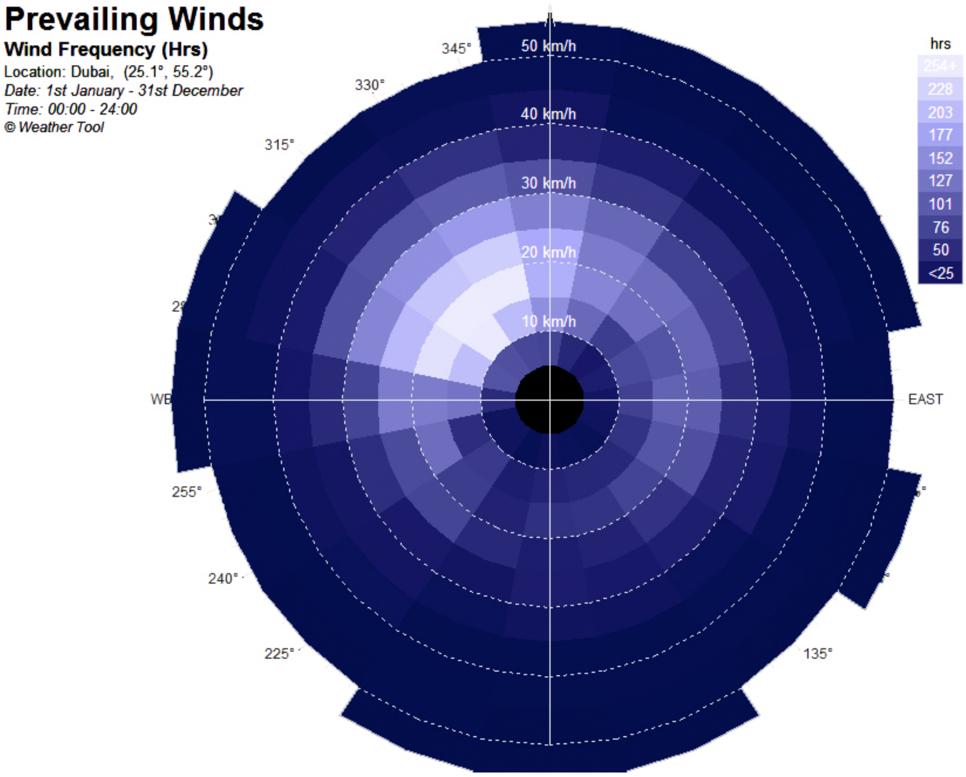

Figure 4.17: Wind Rose diagram of Dubai, showing the speed and intensity. (Source: Climate Consultant Software)

A Psychometric chart is often used to illustrate the relationship between relative humidity and dry-bulb temperature. The Thermal Comfort Zone is identified according to the users' activity and clothing, in accordance to the temperature and relative humidity. The chart in Figure 4.18 shows that Dubai's climate lies well out of the comfort zone during the summer times, while complies with it during the winter.

Figure 4.19 shows that during summer months there are high levels of discomfort when crossed and compared with several elements such as Thermal Mass, Passive Cooling and Natural Ventilation. However, these as well improve vastly during the winter months and obtain higher percentages of comfort.

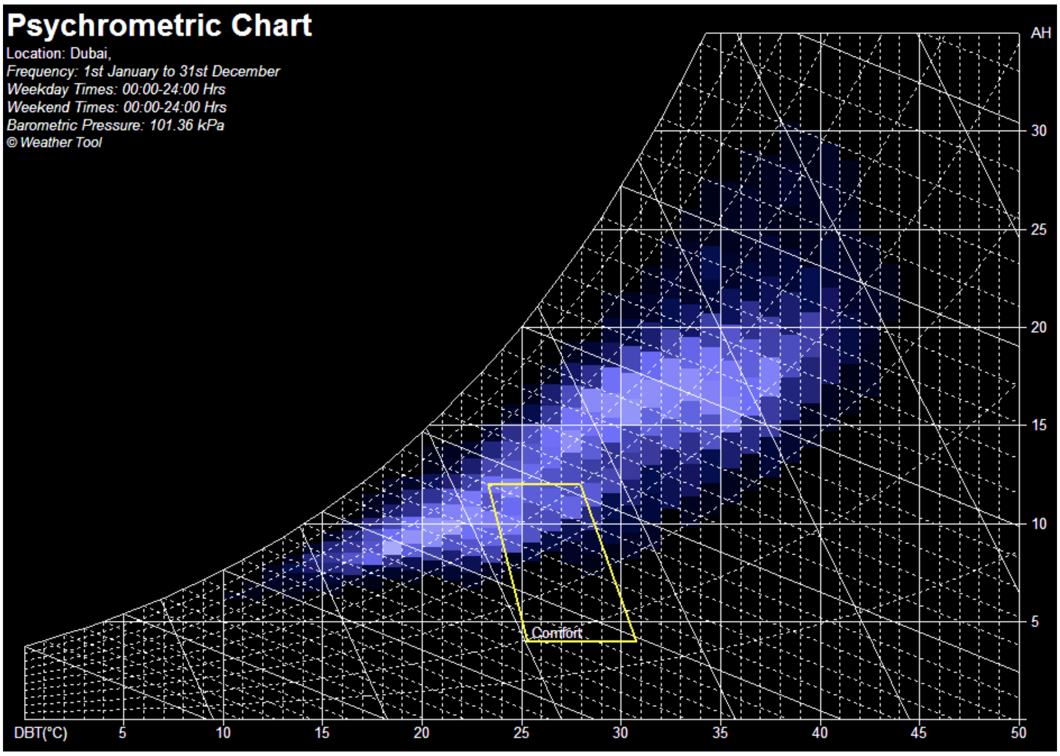

Figure 4.18: Psychometric Chart of Dubai Indicating Comfort Zone. (Source: Climate Consultant Software)

Figure 4.19: Psychometric Chart of Dubai Indicating Comfort Zone percentages. (Source: Climate Consultant Software)

4.3.2 AUS Site Climate Analysis

Based on the climatic analysis conducted above, the data collected was applied to the AUS campus in order to understand how much impact does the outdoors thermal conditions have on the users themselves.

The Site Climate Analysis was split into three seasons; Summer, Winter and Spring. It was necessary to cover these three seasons to get a clear image of the yearly overall on-campus weather and climate. Using the Stereographic diagram and the AUS campus map with reference to the Main Building, the analysis below will indicate the sun path and location, and the solar intensity it has on the site.

a. Summer Season

During June, the sun is high in the sky, and there is no rainfall to be recorded. Most open spaces are exposed to direct solar rays, making simple tasks such as walking between buildings a big discomfort.

Since the flooring material of the campus is made of marble, it absorbs a large amount of the solar heat, causing a raise of temperature on the already hot site.

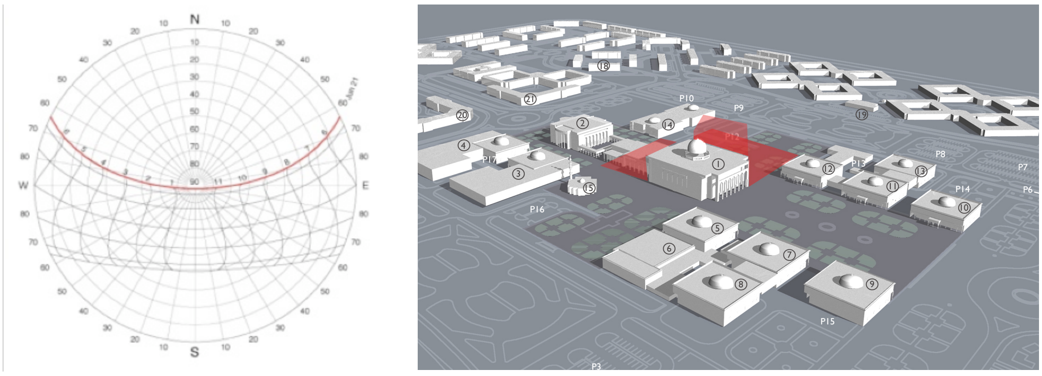

Figure 4.20: Summer Solstice, June 21, 9-12-15 Hrs. (Source: author)

Furthermore, humidity also plays a role in further intensifying the discomfort level on campus. Summer in Sharjah is known to be hot-humid, since the geographical location of the city lies close to the sea.

The vast and far apart orientations of the buildings are also factors in minimizing shade and channeled wind that would help lessen the heat and humidity intensity. Therefore, the AUS campus is a typical case of an under-designed site in regards to the outdoor thermal conditions.

b. Spring Season

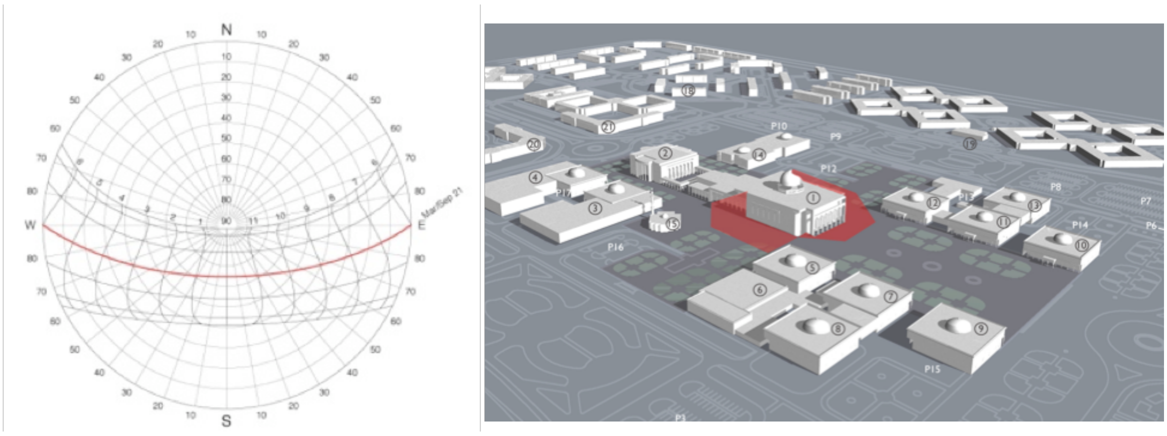

Figure 4.21: Vernal Equinox, March 21, 9-12-15 Hrs. (Source: author)

March has a lower sun altitude and a significant amount of rainfall. It's considered one of the best months of the year in terms of thermal comfort, where the weather is suitable for outdoor activities. Students are often sited around campus, using the benches and stairs to spend long periods of time in various actives. March months are a suitable environment for exterior space.

c. Winter Season

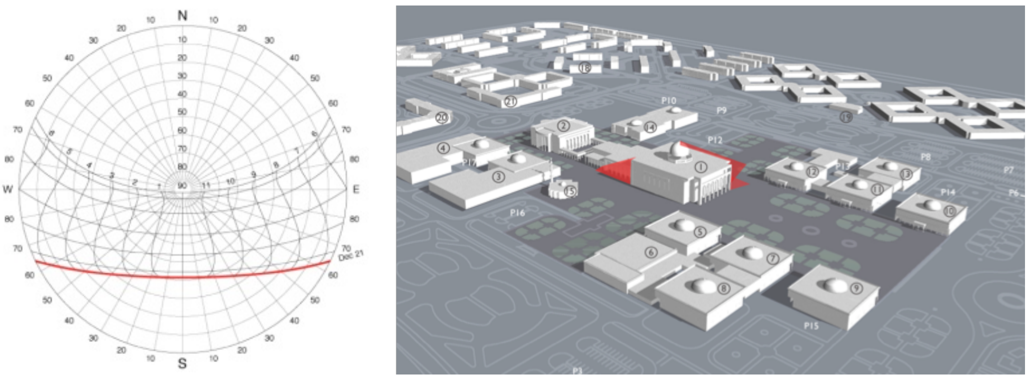

Figure 4.22: Autumnal Equinox, December 21, 9-12-15 Hrs. (Source: author)

During the month of December there is a lot of rainfall and the sun is very low in the sky. Primary factors for consideration is the amount of rainfall as they cause puddles around the site which makes movement difficult. Since December is the one of the cooler months of the year, students often spend frequent hours outside, and solar intensity is tolerable due to the low altitude angle of the sun.

4.4 Surveys and Interview Initialization

Further to the information gathered about the AUS Campus site and the Climatic data, they need to processed and analyzed in accordance to the parameters previously discussed. The surveys, which will be discussed in the next section, have been formulated based on the conditions that the research has reached to so far. To be able to evaluate them clearly, they have tabularized as below:

Table 4.2: Site and climate conditions during the conduction of the surveys (Source: author)

Site properties	- Large open areas - Lack of shade - Large H:W ratio of buildings - Minimal water features - Minimal vegetation
Median outdoor temperature [Summer]	42°C
Median outdoor temperature [Winter]	23°C
Relative humidity [Summer]	60%
Relative humidity [Winter]	30%
Wind direction [Summer]	Wind circulated in all directions
Wind direction [Winter]	North-West
Sky conditions [Summer]	Sunny clear with no clouds
Sky conditions [Winter]	Clear with a few clouds
Timings	Morning: between 8 am and 11 am Afternoon: between 3 pm and 6 pm
Site Materials	The campus ground surface is made up of Granite and Marble
The geographical position	Sharjah, UAE. Latitude: 25.25°, Longitude: 55.33°

4.4.1 Surveys Breakdown

A total of 46 students have undergone the survey. 24 were surveyed in the winter season, and the remaining 22 in the summer season.

- Gender

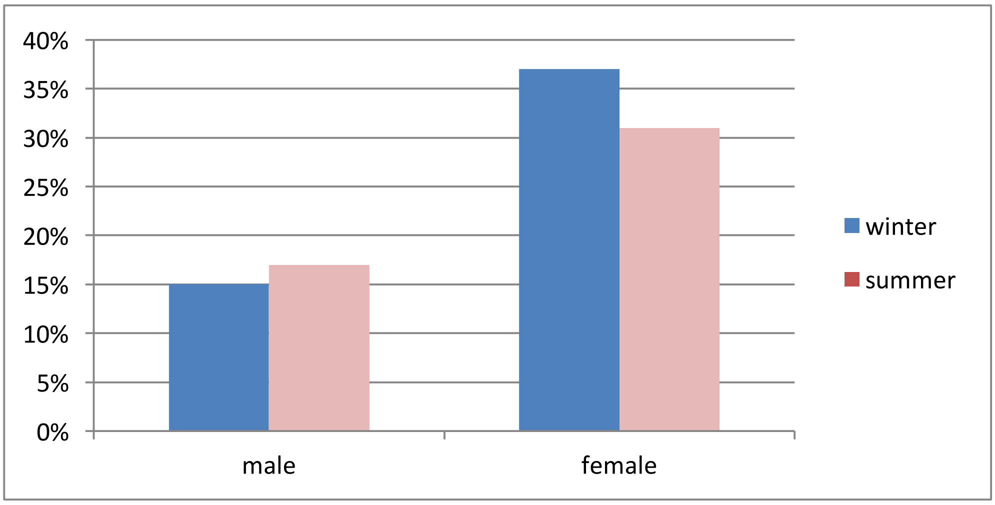

Figure 4.23: Gender. (Source: author)

Figure 4.23 above discloses the gender of the study's respondents both in winter and summer - labeled in percentages. Females made up the highest percentage with 37% in winter and 31% in summer. On the other hand, male respondents were 15% in winter and 17% in summer.

- Age in years

Figure 4.24 below shows the age of the study's respondents. The highest percentage was made up by respondents aged 20 years with 45%, followed by respondents aged 21 years with 22%, then by respondents with 19 years with 17%, and finally respondents aged 18 years with 11%. The remaining 4% was split in half by respondents aged 22 years and 24 years, with each accounting for 2%.

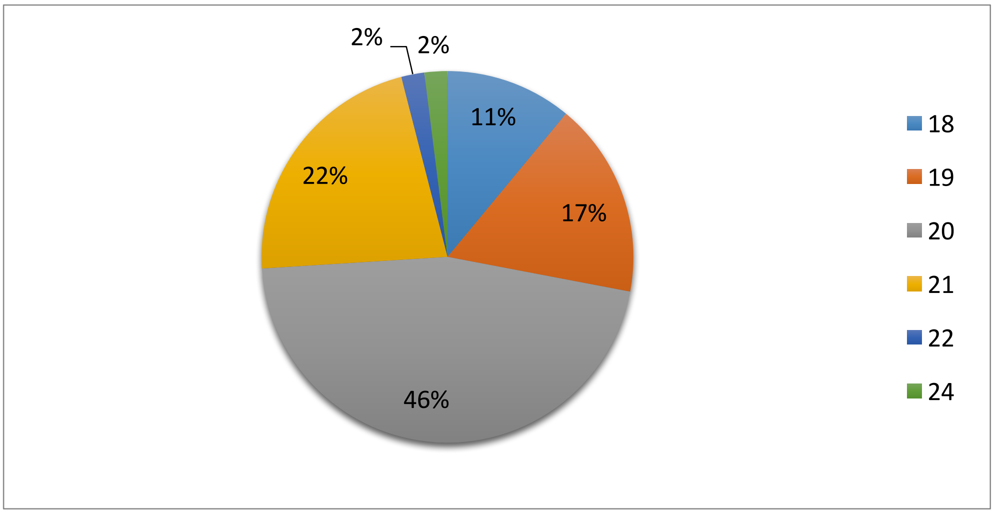

Figure 4.24: Age in years. (Source: author)

- Ethnicity

The study also took into consideration the variety of races of the respondents. Respondents who were non-UAE nationals made up the highest percentage – 96%, and the remaining 4% were formed by respondents who were UAE nationals, who are considered a minority in the student population in the American University of Sharjah, as indicated in the figure below.

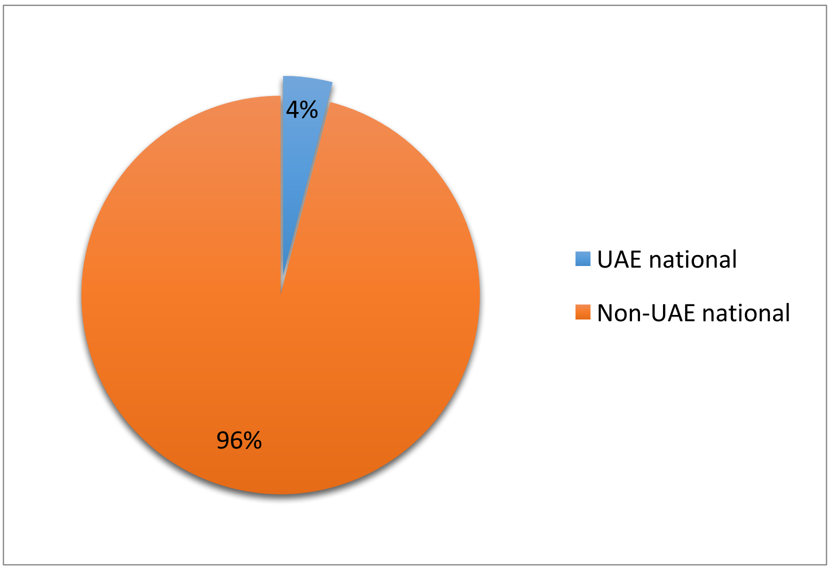

Figure 4.25: Ethnicity. (Source: author)

4.4.2 Locations and Space Usage Analysis

The survey took place at several locations on the AUS campus. Since the site is fairly large one, the survey areas were limited to 5 main areas where students often outside the buildings.

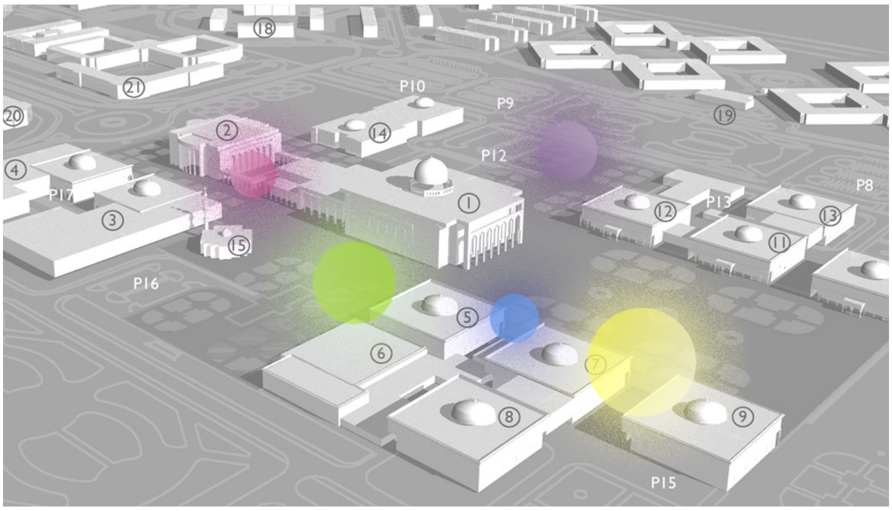

Figure 4.26: Survey outdoor locations in AUS. (Source: author)

The figure above shows the areas where the surveys took place, these locations often witness gatherings and grouping of students and campus users. The same locations were used in both winter and summer surveys.

- Area between College of Architecture Building and Student Center
- Plaza
- Area between library and main building
- Area outside the Student Center
- Plaza space between Main Building and Business School

The following sections of the survey were conducted to understand the uses of indicated locations, time spans and preferences of the environments. The results were averaged out across all 5 locations.

- Reason of using the space

Figure 4.27 below discloses the response of the students when asked why they use place they were surveyed in both in winter and summer seasons

The highest number of respondents claimed to use the outdoor spaces for social or cultural activity (meeting friends, taking photos, doing course work, etc.) was in both seasons, with 13 using the outdoors during the winter, and 11 during the summer. Studying came as the second highest outdoor activity in both seasons as well. The remaining 4 respondents said that they went to the place they were in to rest, with 2 in summer and 2 in winter.

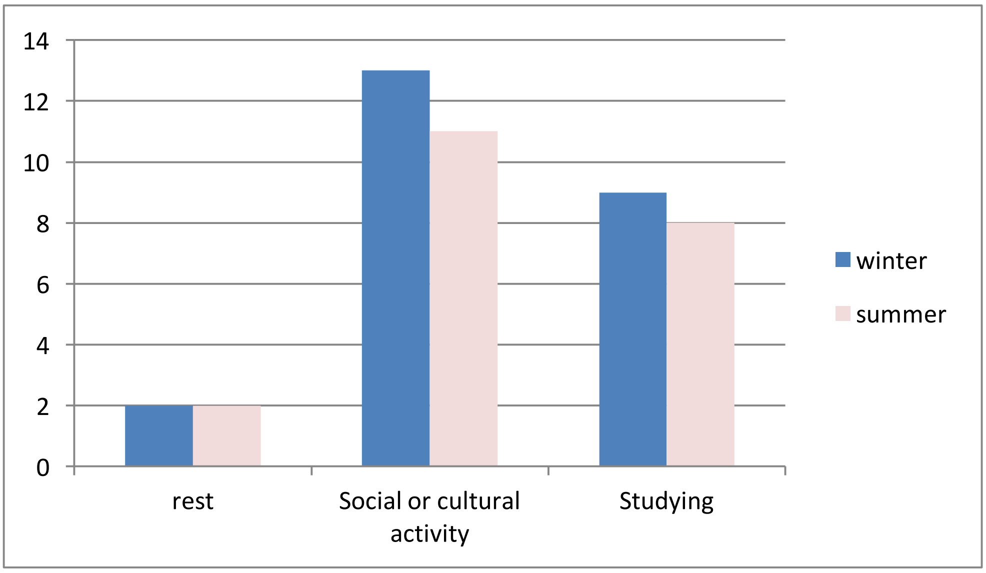

Figure 4.27: Reason of space usage. (Source: author)

- Time span

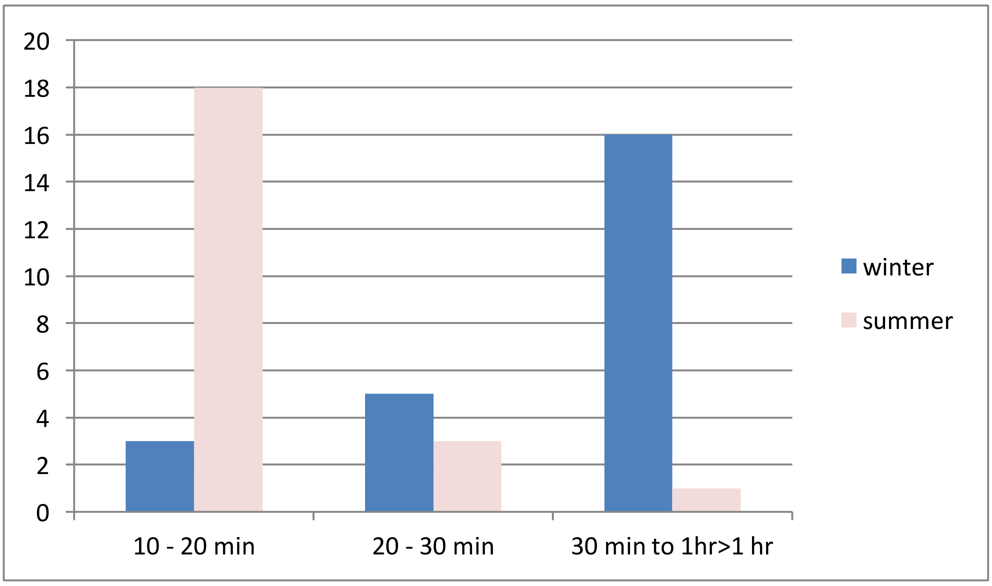

Figure 4.28: Length of Stay. (Source: author)

Students were also asked about the duration of stay in their respective locations. The highest number of respondents was tied between 10 – 20 minutes, and 30 minutes to 1 hr>1hr. Summer times were the lowest, with students spending only a maximum of 10 – 20 minutes outdoors, while 16 respondents spent up to one hour and more outdoors during the winter season. The remaining students surveyed remained for an average of 20 to 30 minutes outside, with 5 in winter and 3 in summer. This indicates that students can comfortably stay for lengthy period of times in the winter season where weather conditions are ideal, however, it is not the case during the summer times where the air is hot and humid, making users unable to utilize the outdoor campus.

- Frequency of AUS campus visits

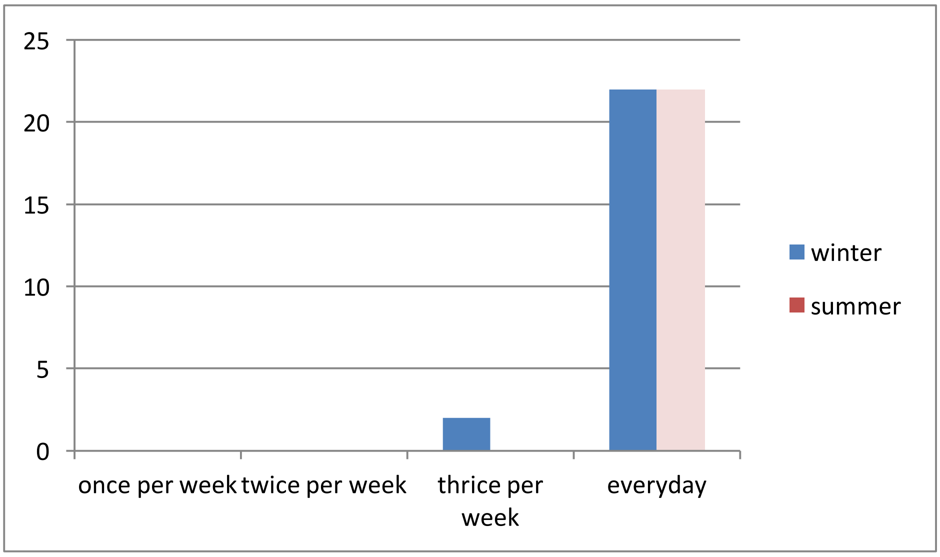

Figure 4.29: Attendance to AUS. (Source: author)

Campus visits' frequency was also questioned, however, results indicated that regardless of the season and weather conditions, almost all respondents came to the campus almost every day of the week, as can be seen from the figure above. On the other hand, the duration of stay per specific space differed from winter to summer. It was clearly noted that most of the spaces in which the surveys were conducted in the winter were occupied on daily basis, while during the summer, students reduced their visits to said locations to almost once or twice a week to avoid the heat and humidity, only using the outdoors for circulation between buildings and spaces. Figure 4.29 shows that out of the 22 surveyed in the summer, 2 of them used the outdoors on daily basis, while 21 of the winter respondents were outside daily.

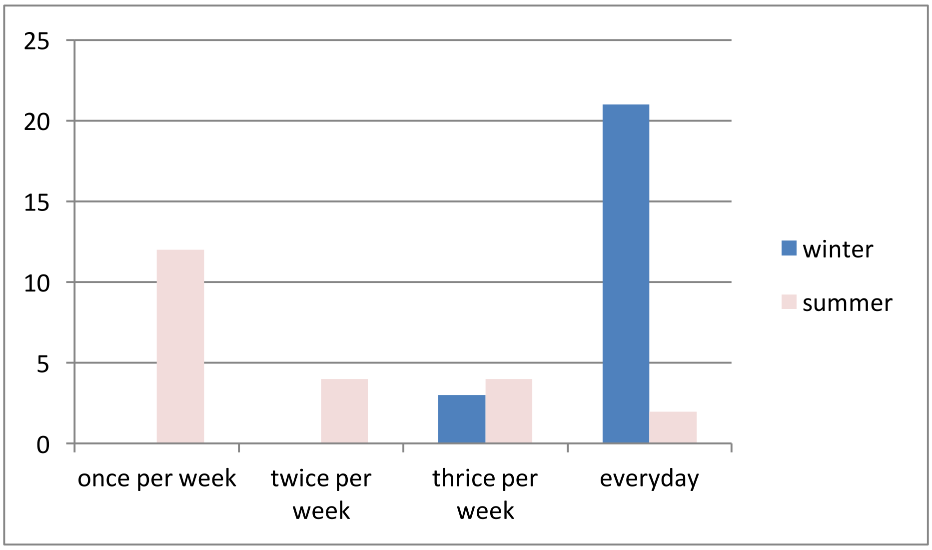

Figure 4.30: Frequency of outdoor space usage. (Source: author)

- Current Activity

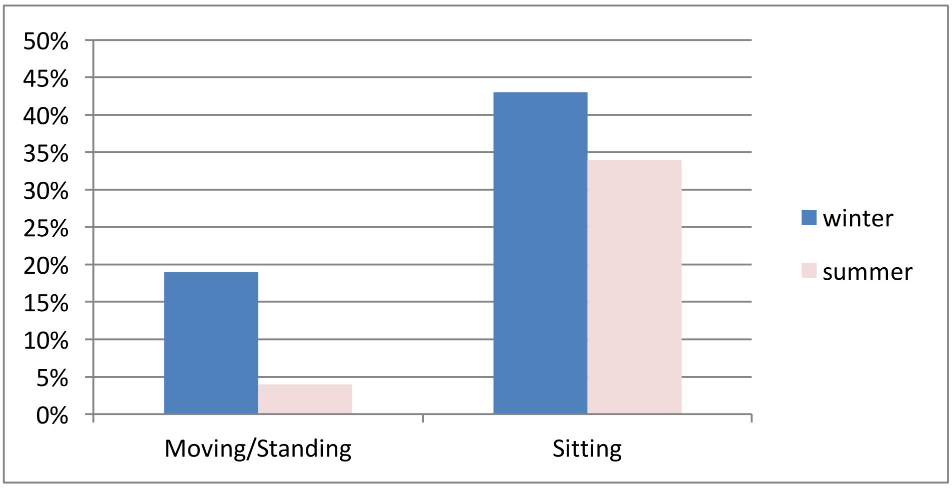

Figure 4.31: Current Activity of the study's respondents. (Source: author)

Figure 4.31 discloses the current activity of the study's respondents both in winter and summer surveying sessions. The respondents who were sitting made up the highest percentage with 43% in winter and 34% in summer, indicating minor active movement from the students themselves throughout the year. On the other hand, respondents who were moving/standing made up 19% in winter and 4% in summer. There is a strong correlation between both the activities and outdoor temperatures, as it indicates that students prefer to spend their time in activities that would consume less effort from their side during the summer, rather than undergoing actions that would cause discomfort to their selves.

4.4.3 Clothing Analysis

- Shirt/Blouses and Trousers

Clothing was also an important factor to take into account during the surveys. The figures below Figure show the number of students in a variety of clothes types - shirts/blouses, pants/shorts both in winter and summer. Respondents dressed in long sleeve shirts/blouses made up the highest number with a total of 14 respondents in winter and 11 respondents in summer. Respondents dressed in short sleeve shirts/blouses followed with a total of 7 respondents in winter and 10 respondents in summer. It indicates that in a way to seek relief from the heat, students tend to wear lighter clothes during the hot seasons. Furthermore, jeans, a heavy fabric for pants, was shown to be worn more during the winter months as it would provide warmth, as reported from the surveys 15 respondents in winter and 7 respondents in summer, as opposed to cloth pants and shorts, which were frequented more during the summer, which allows for more comfort during the hot-humid weather.

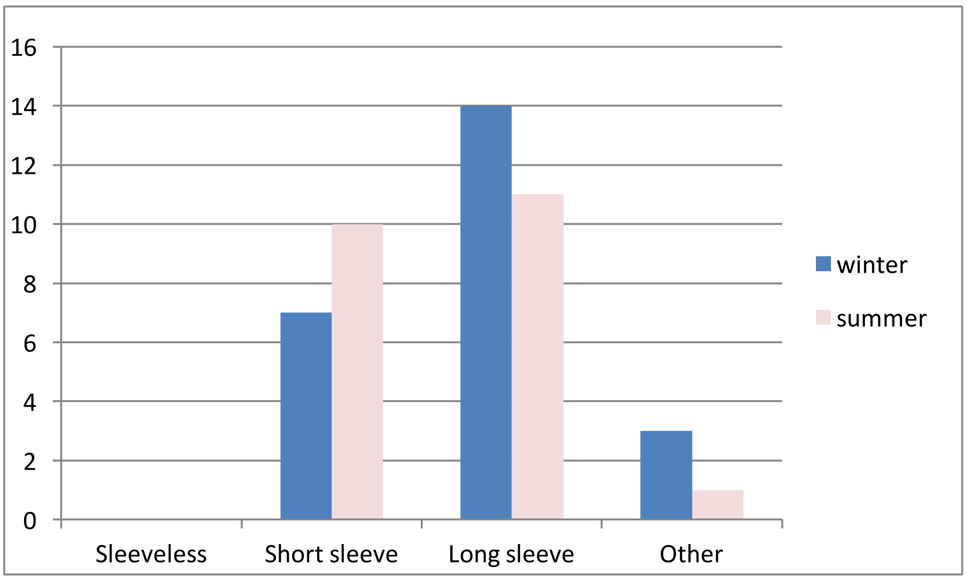

Figure 4.32: Type of Shirts. (Source: author)

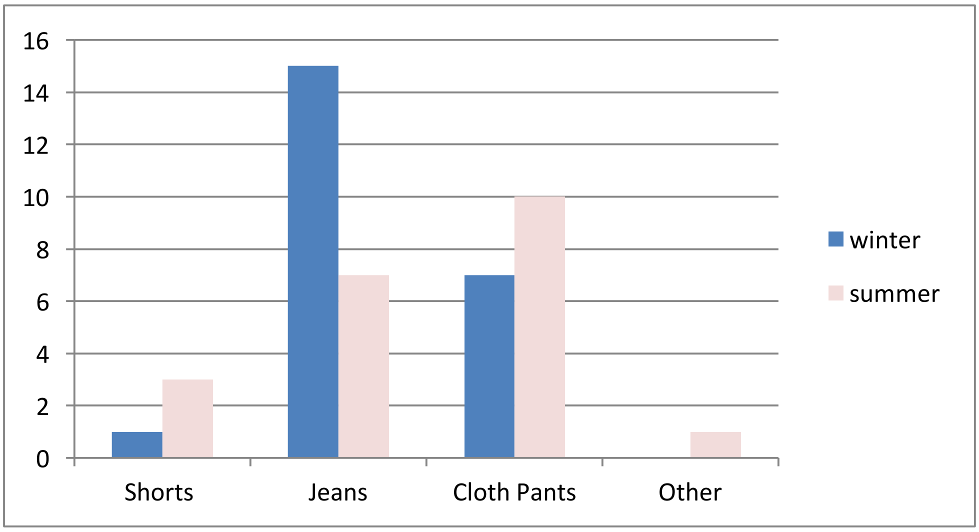

Figure 4.33: Type of trousers. (Source: author)

- Footwear

Footwear was also analyzed, as show in in figure 4.33. Most used shoes were loafer and ballerinas on an average across both seasons. Sports shoes followed with a total of 8 and 5 respondents in winter and summer respectively. Slippers/sandals were popular in the summer season, and finally boots, which were only found during the winter. Again, this shows a strong correlation between footwear and thermal comfort, where similar to the clothes, respondents preferred to wear lighter, more open aired shoes to provide cooling sensation in the summer as opposed to more closed heavy footwear during the winter seasons.

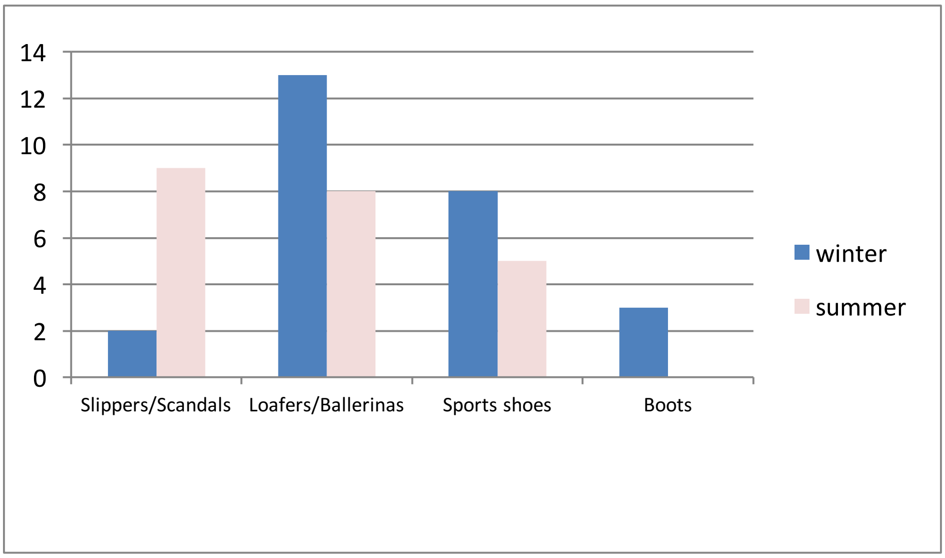

Figure 4.34: Type of footwear. (Source: author)

4.4.4 On-Site Thermal Comfort Analysis

As mentioned previously these surveys were taken place during winter (February) and summer (June) months. The surveys were collected at various outdoor locations across campus in order to obtain as much accurate data as possible. This section will discuss the users' thermal sensation when surveyed on the AUS campus. The recorded temperatures then were 23 C in February and 42 C in June.

- Thermal Sensation

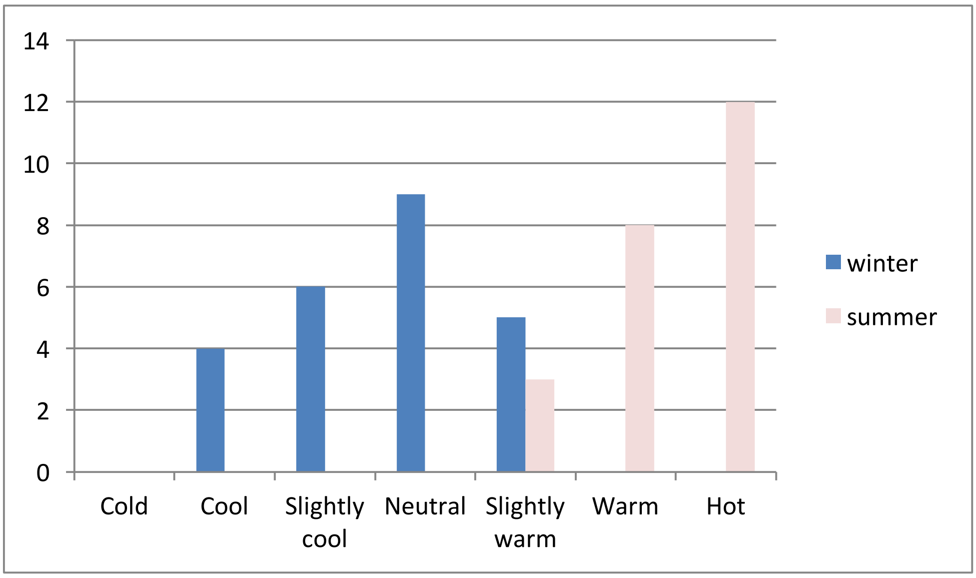

Figure 4.35: Current sensation. (Source: author)

Figure 4.36 discloses the current sensation of the respondents (in number of people) when asked how they felt at the moment both in winter and summer. The highest number of respondents, 12, claimed they were feeling "hot" during the summer season, following with 9 as the second highest number during the winter season were students surveyed said they were neutral about the weather. This indicates that the recorded temperature then, 23 C, is a somewhat ideal one where most users feel comfortable in. There is a strong and positive relationship between the current sensation and outdoor thermal comfort. The higher the temperatures reach to, the less the thermal comfort is, and it can be noted from the results of the summer sensation were none of the students surveyed was comfortable enough to indicate a neutral feeling.

Furthermore, a large number of the respondents preferred to have a change in the outdoor temperatures, where over 22 students wanted to have a cooler environment during the summer time. As previously discussed, winter season temperatures where comfortable enough with the respondents that more than half of them preferred not to have any change in the outdoor thermal environment as it was an ideal weather for them, as can be noted from figure 4.36 below.

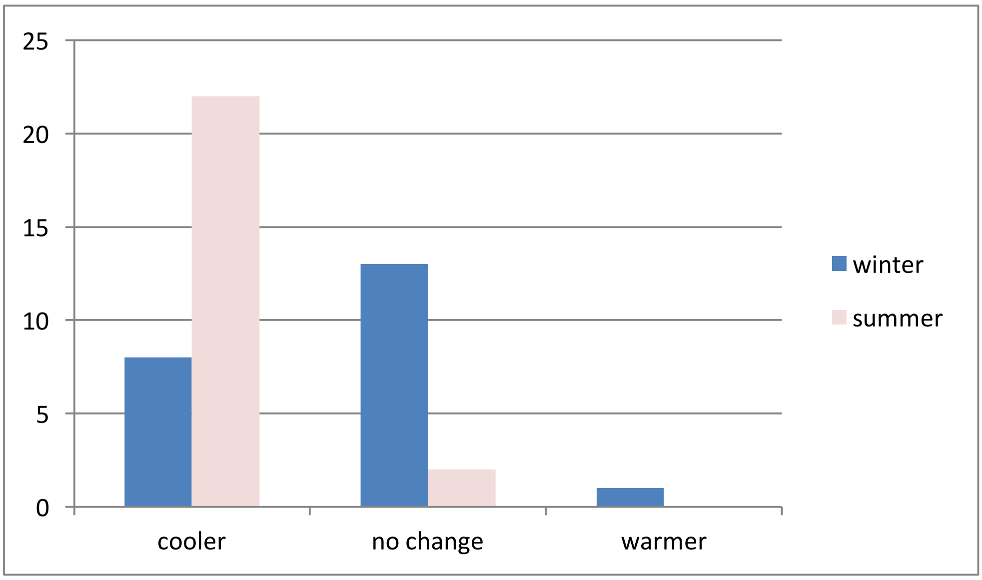

Figure 4.36: Preference of Environment. (Source: author)

- Humidity

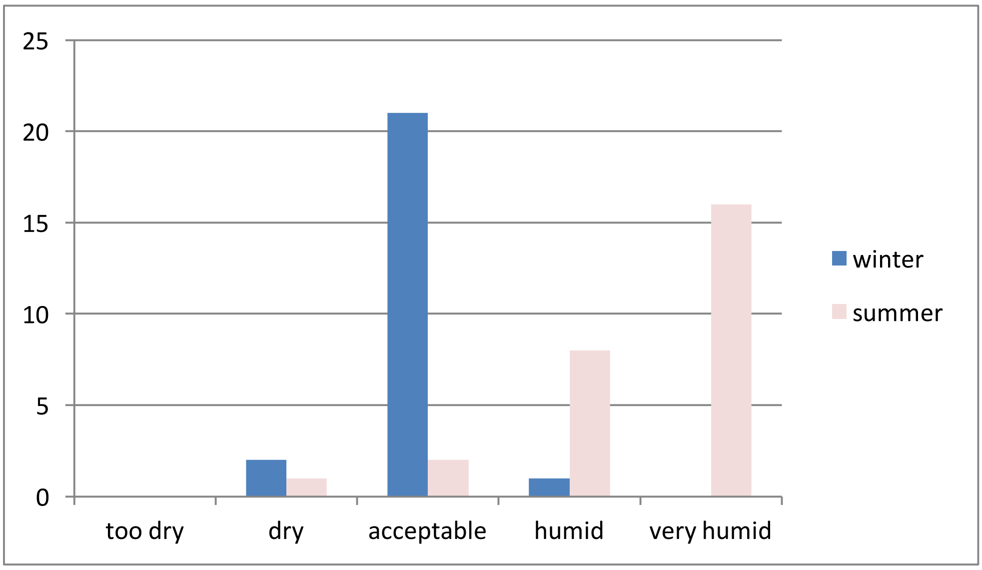

Figure 4.37: Humidity sensation. (Source: author)

Figure 4.37 discloses the current humidity sensation of the respondents during both in winter and summer surveys. The highest number of respondents who were comfortable with the current level of humidity was in the winter season, where it is usually low and acceptable according to the weather data analysis. Respectively, summer survey's respondents claimed the worst levels of humidity then. This goes hand in hand with the rise in temperature during summer seasons, as the climate in Sharjah is often described as hot-humid.

Furthermore, the students were also asked to record their humidity preference in regards to the current weather, and as shown below in figure 4.39, all summer respondents wanted a change in the humidity levels then. A couple of students found the winter air to be a bit dry and preferred to have more humidity in the weather. Overall, humidity and outdoor comfort are related irreversibly together in order to achieve thermal relief; the higher it goes, the lower the outdoor thermal comfort is.

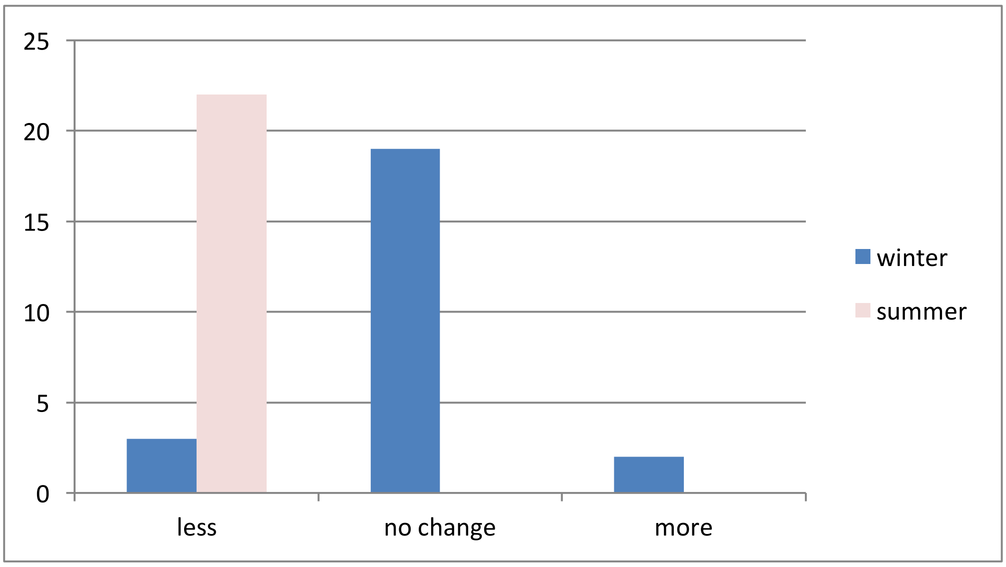

Figure 4.38: Humidity change. (Source: author)

- Air flow

Air movement also plays a role in determining the level of outdoor comfort. High cold winds, as well as very low, almost non-existent ones are not preferred. According to the survey results indicated below in figure 4.39 below, most summer respondents found the wind to be stale and dry. This decreases the comfort levels and as it does not aid in reducing the humidity. However, in the winter survey results, students found the airflow to be much higher and cooler, where 13 respondents claimed to be comfortable to the wind speed. Only 3 respondents said that the airflow was windy, in winter.

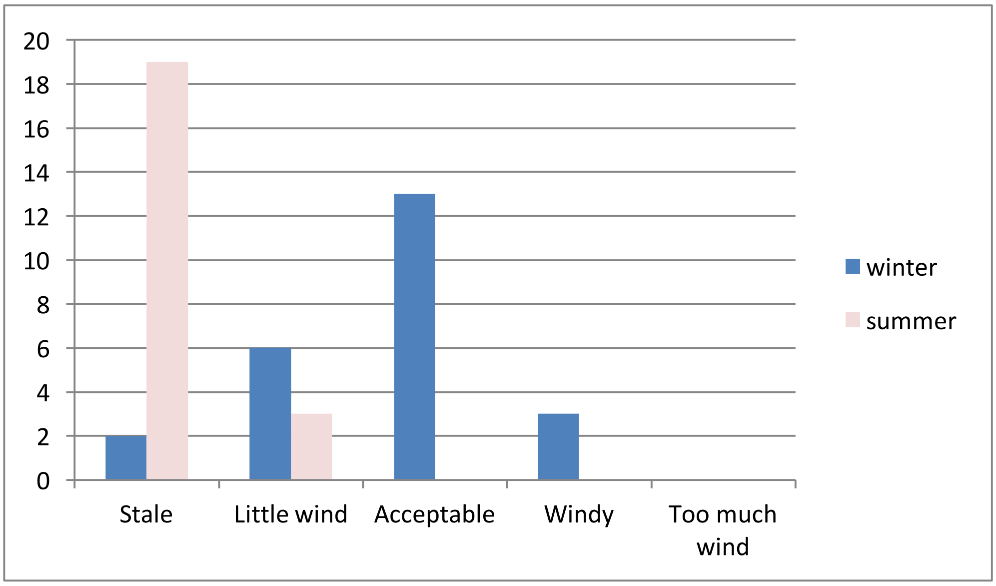

Figure 4.39: Air Flow. (Source: author)

Students preferred to have much higher winds during the summer times. Moving air, or simply a breeze, helps in reducing heat sensation and reduces the high humidity sensation.

As can be noted from figure 4.40, survey respondents indicated that with over 21 of them needing greater wind speed during the summer to make them feel more comfortable. Winter survey respondents were satisfied overall with the existing airflow, however, 8 of them greater wind speeds, to help obtain a cooler effect.

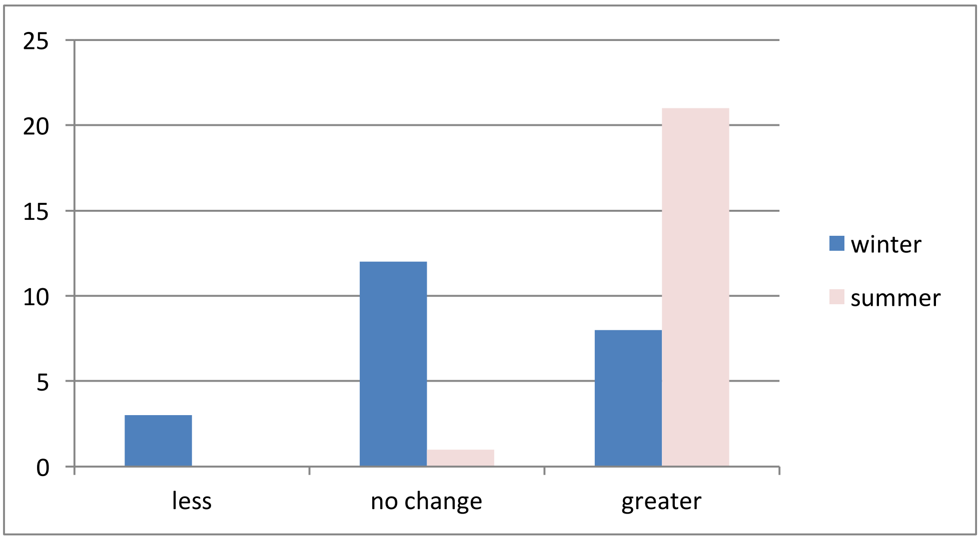

Figure 4.40: Air Flow Preference. (Source: author)

- Solar intensity

Figure 4.41 below discloses the current sensation of the respondents when asked how they felt about the sun at the moment both in winter and summer. Most of the respondents admitted that the sun was too intense during the summer time, causing great discomfort, and this is due to the high sun position in the sky. Winter season respondents found the sun acceptable and more tolerable then, with 15 of them wanting it to remain the same intensity, and only 6 found it a little strong. This is attributed to the low solar position in the sky.

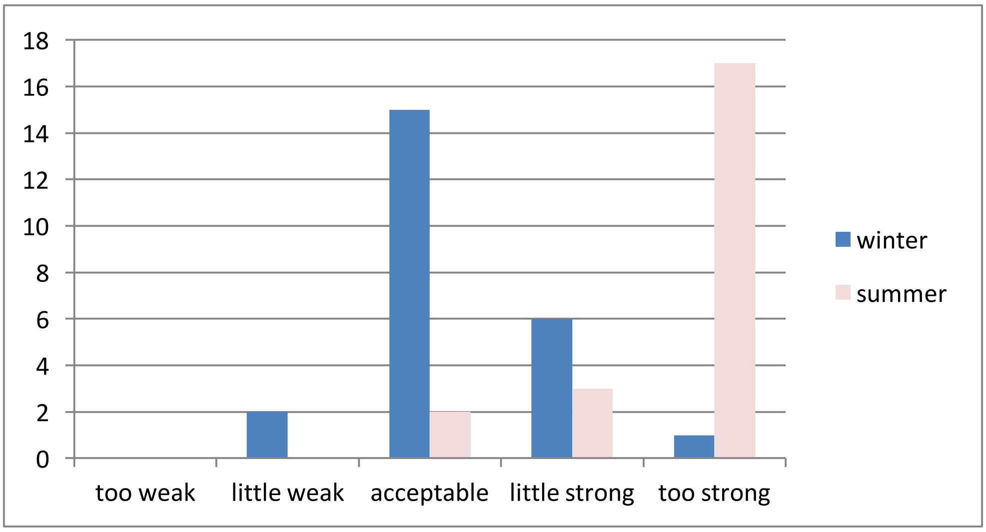

Figure 4.41: Sun Tolerance. (Source: author)

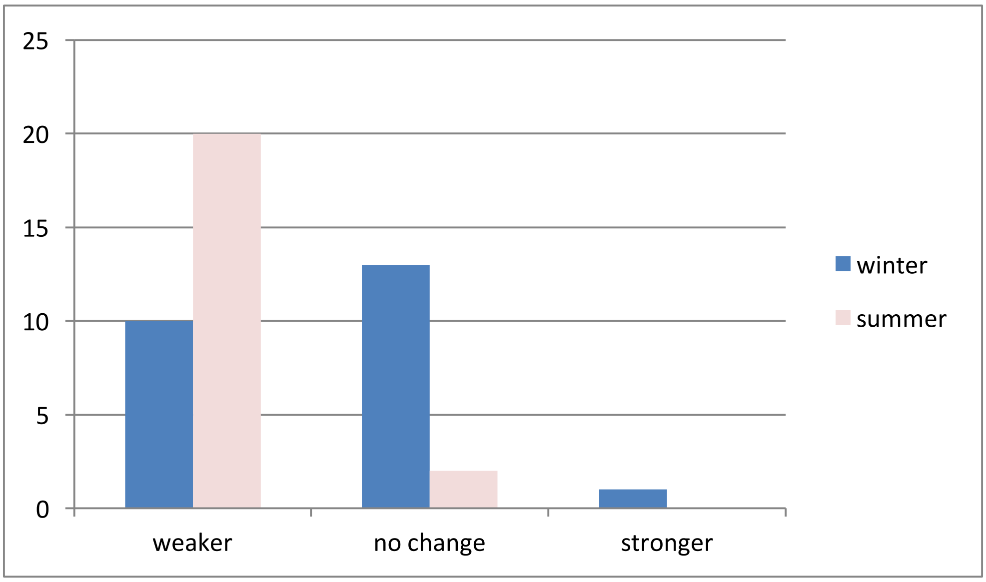

Figure 4.42: Sun Preference. (Source: author)

Thereby, most students surveyed in the summer season wished to have weaker solar intensity. As figure 4.42 above discloses the current sensation of the respondents when asked how they would prefer the sun to be both in winter and summer. Even though most of the winter survey respondents were fine with the current sun and did not prefer any change, 10 of them wanted to have a yet weaker sun then. As with most of the environmental elements questioned in this survey, solar intensity affects the outdoor thermal comfort very strongly, as the higher the sun is in the sky, the greater the discomfort is.

- Tolerance of the existing thermal environment

Finally, on an overall view, respondents were asked in both seasons whether they found the current outdoor thermal conditions to be acceptable or not. As can be noted from Figure 4.43, the results were split to almost equal responses in both seasons. Most summer respondents, 21 of them, found the outdoor conditions unacceptable. On the hand, as expected, winter respondents were satisfied with the weather conditions, with only a minor number of 4 admitted that they would prefer a better thermal environment. The indicates, with the previously discussed climatic elements in accordance to AUS campus, the main discomfort comes during the summer season, however, improvements have to be done on the site in order to have a better and more comfortable thermal outdoor conditions.

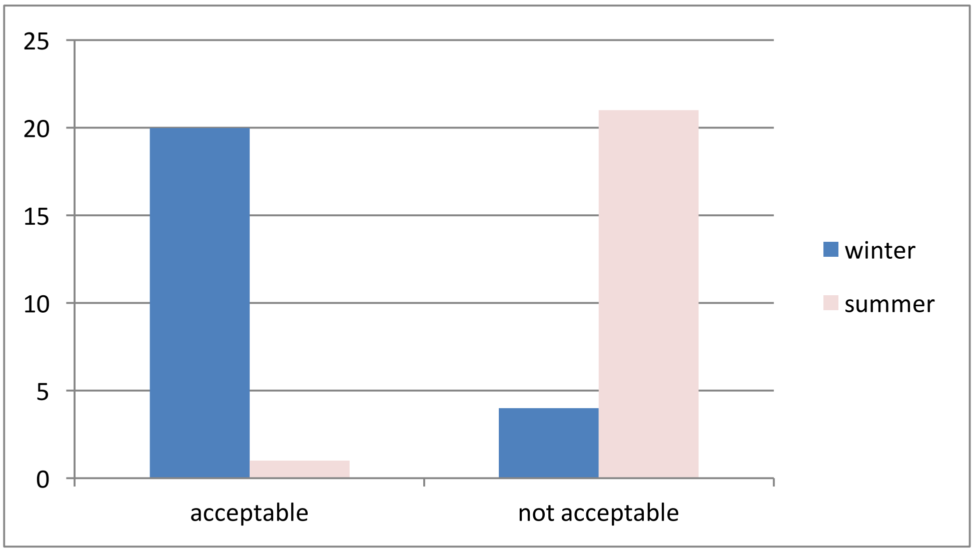

Figure 4.43: Tolerance of Thermal Environment. (Source: author)

- Thermal relief response

Figure 4.44 below discloses the response of the students when asked if they felt it is too hot when outdoors, and what measures do they prefer to take in response both in winter and summer. Most respondents indicated that when they felt that it was too hot, they preferred to move to shaded trees or areas, with equal 8 responses in both seasons. As can be seen, other thermal relief measures were getting more cold drinks, wearing lighter clothes or head covers. A last resort was simply leaving the outdoors and moving to an indoor environment.

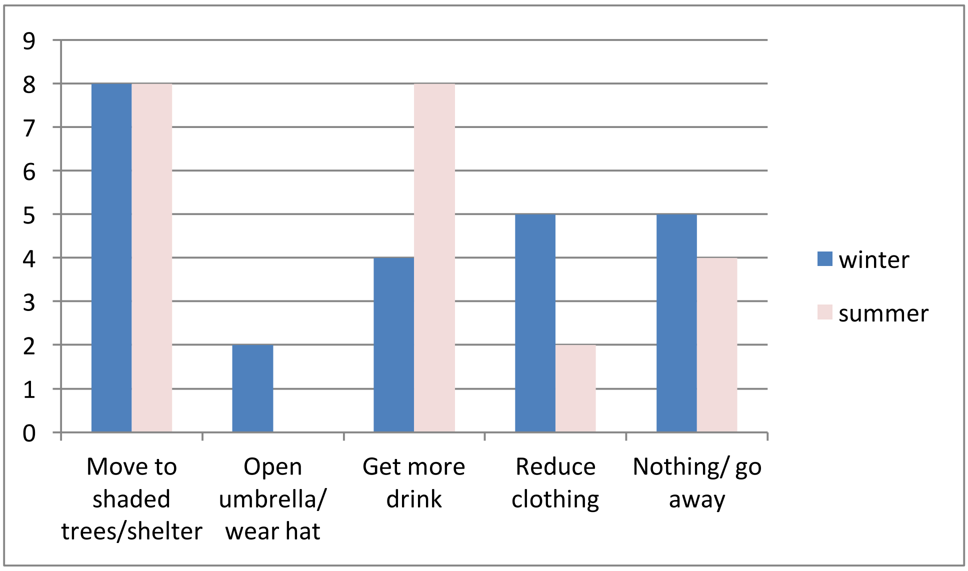

Figure 4.44: Thermal relief measures. (Source: author)

4.4.5 Interviews

To further obtain a deeper understanding of the thermal comfort issue on the AUS campus, interviews were conducted faculty members of the College of Architecture. Three interviews were done with professors that is, Dr. Ahmed Mokhtar, Associate Dean of the College and teacher, Professor Erik Heintz and Professor Kevin Mitchell, both teaching faculty in the college as well.

The questions and their responses are as below:

a. *In your opinion, what outdoor environmental circumstances would be thermally comfortable for occupants in AUS?*

Professors Heintz and Mitchell both suggested that the first basic solution to the problem would be adding shading areas and more zoned gathering seating areas would allow students to sit outside comfortably. That would have a significant impact during the summer when temperatures are very high. Dr. Mokhtar added as well as shading there needs to be a potential for cross ventilation as moving air and breeze help in reducing the humidity levels during the hot temperature months.

b. *In your opinion, what design approaches can be used in AUS to improve outdoor thermal conditions for an increased thermal comfort?*

The interviewees suggested the following approaches:

- Change the campus flooring material as marble is a very poor reflective material and becomes very hot during the warm seasons. Low thermal storage capacity needs to be placed instead.
- Provide for mechanical ventilation such as fans as it is the best way to minimize the humidity.
- Increase natural shadings (trees).
- Fabric movable shading is also preferable to hard stiff shading devices. Fabric can be opened and closed depending on the time of day and season
- Allow for adequate airflow
- Provide misters/low-energy fans in high-use areas

c. *If you feel it is too hot in this place, what measures do you prefer to take in response?*

The interviewees responded:

- They try to wear light clothes, but when becomes too hot they go indoors.
- They limit the amount of time outside.

d. *What is the main outdoor thermal condition that leads you to rest in this place? [The best outdoor location on the campus in your opinion]*

Professor Mitchell suggested that the small "hidden" area between the library and the main building is one of the most well-designed outdoor places on campus. It is zoned between two buildings, therefore creating shade, as well as it is filled with trees that are small in scale and are laid out in an organized manner, giving more shade than the palm trees, and enabling a cool breeze to pass through. Furthermore, there are seating areas created from the "pots" around the trees, where the space users can use them as benches, as can be seen from figure 4.46.

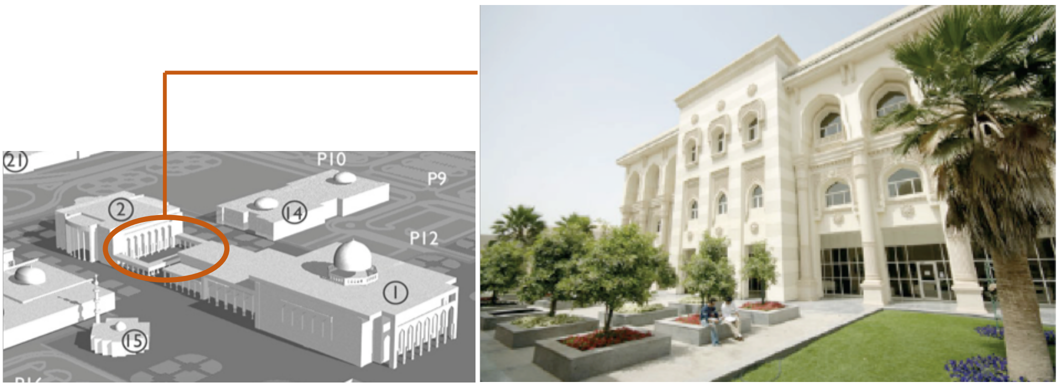

Figure 4.45: Courtyard between Main Building and Library. (Source: author)

The overall scale of said space, being a semi-enclosed courtyard, takes into consideration the human scale, thus making it a successful one. Dr. Mokhtar that shaded area with access to prevailing breezes are his favorite outdoors location on campus where it is best found in the afternoons on the side of the Student Center facing the Mosque, shown in figure 4.46.

e. *What outdoor thermal condition inspires you to spend your time in this area during the weekdays? What are your ideal conditions?*

All three interviews agreed on that the ideal conditions would be shaded areas with an occasional breeze within the human comfort temperature of 20 to 25 degrees. Moreover, they claimed that during the morning before the sun is too high in the sky or late afternoon, solar intensity would be the most bearable. And finally, spaces that have temperatures/relative humidity within the thermal comfort range are of the utmost ideal conditions.

Figure 4.46: Space in front of the Student Center opposite the Mosque. (Source: author)

f. *What would you recommend to ensure that this area has the best ideal outdoor thermal conditions?*

The interviewees stated the following recommendations:

- Provide adequate shading
- Allow for adequate airflow through zoning the building and adding mechanical equipment for increased air movement
- Change to flooring material that has low thermal storage capacity
- Provide misters/low-energy fans in high-use areas

4.4.6 Best and Worst Climatic Conditions

Table 4.3: Temperatures and wind speeds on campus across the 2 seasons during the surveys. (Source: Dubai Airports, 2015)

	Temperature		**Wind**	
	Summer	**Winter**	**Summer**	**Winter**
Average	39 C	19	1.95 m/s	3.07 m/s
Maximum	47	24	2.03 m/s	4.20 m/s
Minimum	30	13	1.84 m/s	1.94 m/s

Upon gathering the information and obtaining survey outcomes, data was compiled to secure an idea about the worst and best outdoor climatic conditions on the AUS campus. As can be noted from Table 4.3 and Figure 4.47, the temperatures and wind speeds are what can be expected in a typical day on site. These results, specifically the summer, are of high values, thus making the outdoor spaces uncomfortable.

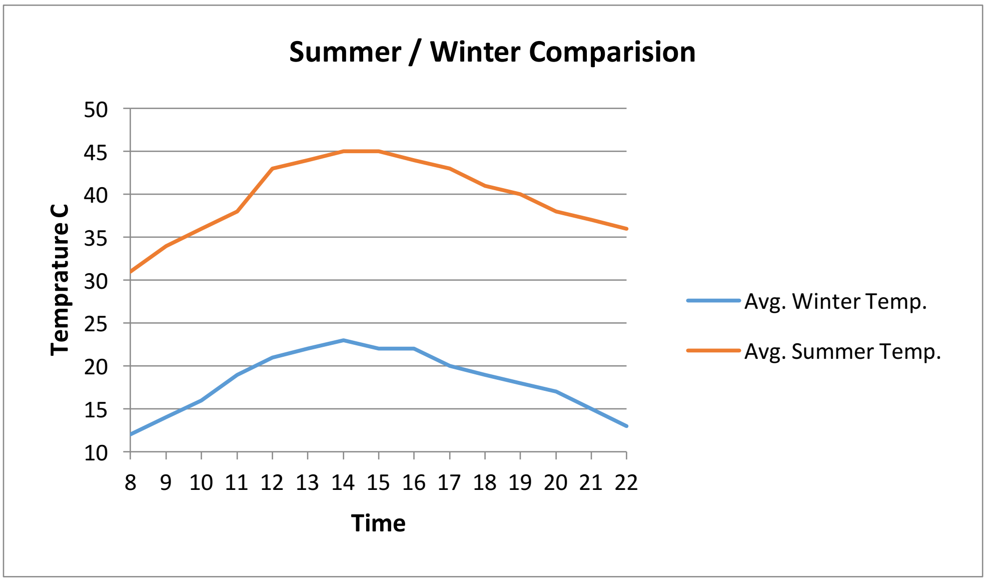

Figure 4.47: Summer and Winter temperature comparisons. (Source: author)

The survey questionnaire incorporated the previously evaluated bioclimatic scenarios for temperature in AUS campus. Few elements on site such as trees and orientation were already being taken into consideration while analyzing the data. It was concluded that the areas with open exposed spaces, even with the existence of Palm trees around, had the highest temperatures during the summers and winters, while the more closed spaces had much lower temperatures and higher wind speeds, making them more thermally comfortable.

4.4.7 Summary of results

Despite the control of outdoor thermal environments being quite difficult, there is a need to avail comfortable conditions which are able to cater for the outdoor activities such as walk-ability, sitting, driving, parking, and so on. Greenery, shades, and water features are among many elements that can be used to help in reducing the heat. Outdoor human thermal comfort is mainly affected by six microclimatic parameters namely: humidity, air temperature, solar radiation, wind speed and mean radiant temperature. They impact human thermal comfort by affecting heat balance within the human body.

4.5 Discussion

4.5.1 Findings

From the above results conducted the following summary can be made:

- This person will normally experience a sense of balance, comfort or pleasantness all as a result of thermal neutrality. This kind of a person is able to maintain intense body temperature at 37^0 c without much exerting much effort via vascular constriction or dilation or even sweating.
- Human beings record discomfort through their skin in cold temperature conditions and hot conditions which increases skin sweating.
- Even with a simultaneous change of environment, both temperature and comfort sensations would not behave the same way. This is mainly because temperature sensations normally change at a rapid rate as

compared to comfort sensation, while on the other hand cold discomfort changes faster than warm discomfort.

- Air temperature remains the main determining factor for skin temperature in both warm and cold conditions and not a person's level of activity.
- Increased sweating is a result of warm discomfort. The body best responds to thermal stress through sweating mostly as a result of warm weather. When the net loss of thermal energy from a human body fails to correspond to production of heat by its own metabolism, then this whole condition creates what is commonly referred to as thermal stress. Obtaining balance may help relieve the body from this stress. In cold temperatures, the losses normally exceed the gains, forcing the body to activate several systems aimed at reducing this rapid heat loss. Skin temperatures are normally automatically dropped by vascular constriction of blood flow to the skin. Shivering weather voluntary or involuntary is one of the activities stimulated by the body to increase heat production.
- In warm weather it is the vice versa, the body gains more heat more than it can dispose. Warming of the skin normally causes vascular dilation of the skin. In case this proves to be futile then the body automatically activates the sweating mechanism. The body eventually becomes if the sweat rate exceeds the ability of the environment to evaporate the moisture. At this stage, it is now possible for one to tell weather heat flow is from the route source or away from the body using the environmental factors.

To achieve optimum thermal comfort for the urban outdoor thermal spaces it is important to observe the certain aspects such as solar radiation, temperature, humidity, and wind. All these elements can be easily controlled, or simply manipulated, through proper analyzed site design. Ways in which to obtain a better thermal outdoor comfort through simple design strategies are discussed below:

a. Shade

Trees play the important role of providing shade during the hot periods, hence reducing the input of solar energy on the user's body – directly implying that more trees and vegetation cover should be planted for this purpose. However, the main problem with trees is that they may need more space to provide sufficient shade and reduction in heat. They also need to be arranged in a peculiar analyzed manner so their benefits can be obtained, as placing them without prior arrangement can render them useless, as observed from the trees places on the AUS campus. As can be noted from Figure 4.48a, the existing trees around AUS campus are mainly Palm Trees. Their placement, and size, is not helping in reducing heat and providing good shade. Thereby, wider trees are proposed instead to provide a narrower and human related scale.

Figure 4.48a: Existing trees scenario around the AUS campus. (Source: author)

Figure 4.48b: Proposed trees scenario around the AUS campus. (Source: author)

Trees controls infrared radiation in the following two ways, they help in shielding a person from infrared radiation emitted by walls and streets during the summer season while during the winter seasons they help prevent loss of infrared radiation through the cold surface. The wider the tree diameter is, and the leafier it is, the more shade it is likely to provide. Table 4.4 shows a comparative analysis of local type of trees that can be used on the AUS campus. As can be noted, even though that the palm tree has the wide leaves, they are largely spaced apart, and don't provide enough shade as compared to the Rolla or Ghaf tree. A simple sketch as in figure 4.48b proposes how wider, and shorter trees can be used across the campus to facilitate better thermal and scale conditions.

Table 4.4: Comparison between Local trees in UAE that can be used on AUS Campus. (Source: author)

Date Palm

> Height	:	15 - 25 m
> Diameter	:	6 - 10 m
> Habitat	:	Dry and arid regions of Arabia.
> Leaves	:	3 - 5 m long. leaflets are 30 cm long and 2 cm broad.

Al Rolla Tree

> Height	:	8- 15 m
> Diameter	:	8- 15 m
> Habitat	:	Dry regions.
> Leaves	:	Evergreen
> Wood	:	Chestnut brown. Heavy and decay resistant.

Ghaf Tree

> Height	:	10 - 16 m
> Diameter	:	4 - 12 m
> Habitat	:	Dry and arid regions of Arabia.
> Leaves	:	Evergreen, thorny lightgreen leaftlets.

Furthermore, the usage of odd numbered groupings (1, 3, 5…), for the tree placements allows a more natural look to the landscape. The spacing of plants properly to ensure easy maintenance and efficient use of water is critical in such scenarios.

Using low-growing plants or groundcovers helps tie the trees together and unify groups of taller shrubs placed around.

b. Wind

The wind plays a very important role during the all seasons, but it depends on its speed and temperature to determine its efficiency in providing comfort. Certain arrangement of buildings, structures and vegetation can be used to enable better wind flow. In a typical summer season, the temperature and humidity levels are quite high, and the survey results reveal that the university users remain uncomfortable using the outdoors then. This condition should not be left unattended to considering that they're some actions that can be taken to rectify the situation.

As can be noted from 4.49 figures, the building height to path width ratio plays a major role in determining the frequency and entrapment of airflow between outdoor spaces. It can be seen from the diagrams a to c above, the wider the path width, the lower are wind entrapment possibilities.

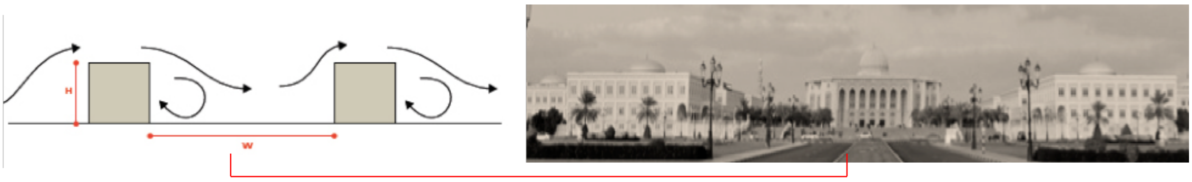

Figure 4.49a: Building height to path width - Width to Height ratio high (Source: author)

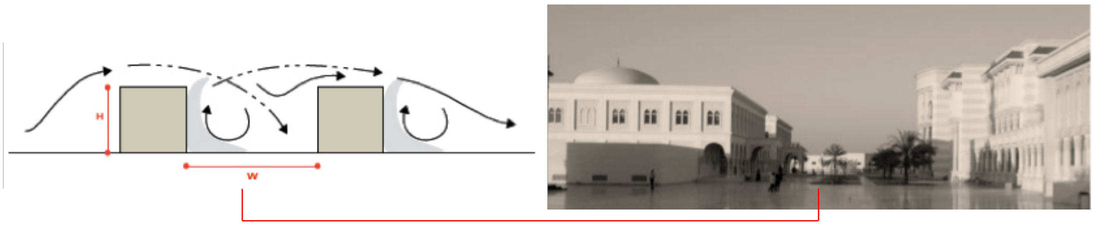

Figure 4.49b: Building height to path width - Width to Height ratio medium (Source: author)

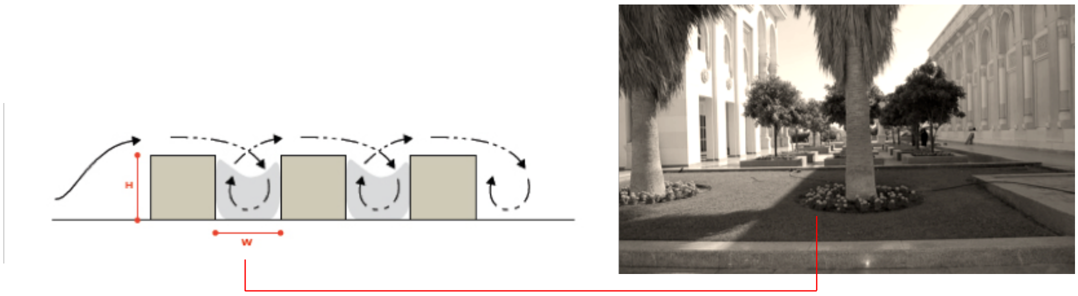

Figure 4.49c: Building height to path width - Width to Height ratio low (Source: author)

Most of the campus consists of spaces that are very open and have wide circulation paths, such as in figure 4.549a, and though some spaces between buildings start to get narrower, as in figure 4.49b, where wind circulation becomes stronger, they still do not provide enough wind entrapment that would help reduce the heat. The only area on the AUS campus where the height to width ratio is reasonable is shown in figure 4.49c where the two buildings shown are quite close together, forcing the wind to pass through in a strong speed enabling a much cooler space and a thermally comfortable one.

In theory, to enhance the wind circulation on campus, the buildings would actually have to be “moved” to create narrower paths, bringing them closer together and make the paths more of a humane scale.

However, that is not a practical option. A more feasible option would be to install pathways that would have shading structures, oriented towards the wind direction to force the breeze in and have cooler areas. Cooling spots with seating installed to make use of the open spaces that are practically wasted.

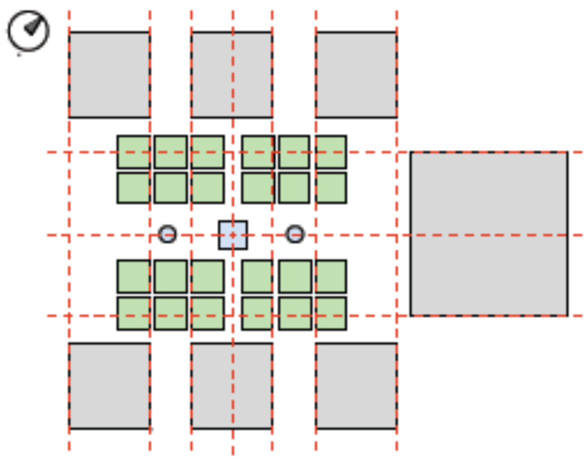

Figure 4.50: Sample shading paths to reduce the large scale on AUS Campus Plaza - Plan (Source: author)

A simple proposal can be applied where different forms of transport (pedestrian and cycling paths) are introduced and co-exist in a shaded atmosphere where shade elements and greenery become the only buffers.

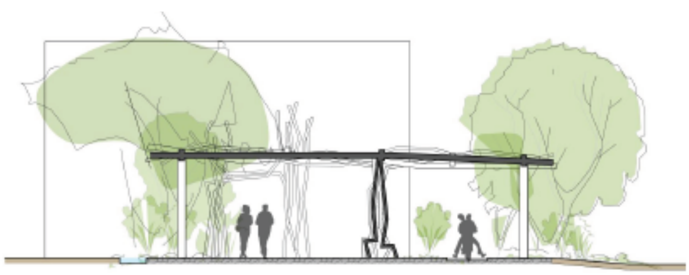

Figure 4.51: Sample shading paths to reduce the large scale on AUS Campus Plaza - Section (Source: author)

Figures 4.50 and 4.51 indicate how the large plaza in AUS can be broken down to create user-friendly paths.

Different seating arrangements can be installed to fulfill the varying preferences of the users, catering to their comfort and also creating many interaction opportunities. The trail becomes a zone of interaction as well as a method of comfortable transport from one node to another and one site to another.

4.5.2 Implication of the Results in Analysis of Weather in Sharjah

Outdoor thermal comfort is one of the new emerging issues mainly brought about by rapid growth of cities, which mainly impacts on weather pattern of the place. Even if technology has devised ways of bringing indoor thermal comfort they still need to come with ingenious alternatives too aimed at addressing outdoor thermal comfort. This is because indoor thermal comfort models cannot be in any way applied for outdoor comfort situations. Nonetheless engineers have done great achievements in solving outdoor thermal comfort conditions mainly after the introduction of Thermal Sensation (TS) outdoor model, which is capable of predicting accurate outdoor comfort conditions using its own environmental parameters totally different from the indoor ones. As winter in Sharjah is considered bearable of consists of good thermal conditions, the focus would be on manipulating summer conditions at the university and enhancing the outdoors experience, where the highest levels of discomfort where recorded.

As ASHRAE (2010) defines radiant mean temperature as the unchanging temperature enclosure whereby the radiant heat transfer from the human body equals the radiant heat transfer in the actual uniform enclosure. Many people are well familiar with what radiant temperature does in affecting thermal comfort.

Where earlier mentioned in Chapter 1, the microclimate of American University of Sharjah (AUS) is hot-humid. The thermal adaptation of the university's occupants is quite challenging due to exposure to variation air temperatures. Based on Sharjah weather reports collected, one of the major microclimatic concepts that affect thermal comfort is the air temperature. The human body temperature has ability to respond towards environmental temperatures. An increase in air temperature causes heat loss to the body and also decreases the respiration rate that eventually causes heat loss too. During cold conditions humidity is often low bringing little effects on thermal conditions. To maintain thermal comfort during hot conditions the human body is normally forced to increase heat loss. According to Park et al., (2012) this whole process is usually achieved through sweating and reduction of clothing on the body.

The environment is highly humid which brings a relative decrease in evaporation too, hence making the whole concept of relative humidity a much stronger determinant of hot weather (Lide, 2010). Both the temperature and humidity play a large role in convective and evaporative loses, wind has long been identified as a major factor affecting both temperature and humidity hence wind should not be excluded in any conversation touching on thermal comfort (Shahidan et al., 2012). It is crucial to understand first how a body cools down, as that will mainly be determined by the following main factors: temperature, humidity, radiation and wind speed that need to be manipulated artificially to sustain a more comfortable environment.

High wind speed is more likely to cause an accelerated loss of sweat through evaporation hence taking away the heat faster from the skin. This aspect is very important as people can tolerate this even with high temperatures, provided the whole process works as stimulated. Lide (2010) and Shahidan et al. (2012) both agree to the fact that the human body energy balance is largely affected by mean radiant temperature, which play a large role in determining thermal outdoor sensation in sunny conditions.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The American University of Sharjah has a Versailles Architecture inspired urban architectural design which has an extensive green landscaping and large open spaces surrounded with support buildings, domed college and schools. AUS' community consists of the students, faculty and staff along with the students' families. AUS is very distinctive because of the buildings operating mechanism, which is designed to accommodate the diverse cultures available in the University American university of Sharjah in the UAE.

The aim of this research was to study and analyze that campus and its users. It was necessary to understand how the outdoor thermal factors can be used to achieve quality environmental conditions that are thermally comfortable. Outdoor thermal comfort is all about balancing outdoor temperatures, wind speeds, humidity and more to fit that of the individual in an external environment. Since that the American University of Sharjah (AUS) campus has demonstrated dramatic success in controlling indoor thermal temperature, it was time to take it to the outside. The study found out that the university has lacks good outdoor comfort but has the potential to achieve it through good design elements and factors in order to deem it successful and sustainable for the entire university.

The study was based on the following two questions:

- What open space environmental circumstances would be thermally contented for occupants in AUS in the UAE?
- What design approaches can be used in outdoor thermal conditions in AUS in order to increase thermal comfort?

In an effort to answer the questions, the campus as discussed is very exposed, open to harsh weather conditions and direct sunlight. Using the six microclimatic parameters namely: humidity, air temperature, solar radiation, wind speed and mean radiant temperature the researcher was able to assess the outdoor human thermal comfort. They impact human thermal comfort by affecting heat balance within the human body. From the research, it is evident that proper vegetation plays the important role of providing shade during the hot periods hence reducing the input of solar energy on the user's body.

AUS' hot-humid climate did not simplify matters. The thermal adaptation of the University's dwellers is rather challenging because of exposure to variation air temperatures. In spite of the control of outdoor thermal environment being rather difficult, it is essential for there to be availed thermal comfortable conditions that are able to cater for the outdoor activities like walk-ability, cycling, driving, parking and more. The current study was based on examining the problem of lack of adequate thermal conditions to enable comfort among the dwellers of AUS. From the previous chapter, respondents and interviewees suggested creating areas with enough shades and outdoor sophisticates space planning in order to overcome discomfort during summer season in AUS campus.

The outcomes predicted and recommended are to favor added design elements of the existing campus. Simple improvements would make large differences, such as adding modular aspects that can be repeated around the campus, therefore achieving higher outdoor thermal comfort.

The human body temperature has ability to respond towards minor environmental changes. An increase in air temperature causes heat loss to the body and also decreases the respiration rate, which eventually causes heat loss too. The environment of the case study is highly humid during the summer seasons which brings a relative decrease in evaporation too, hence making the whole concept of relative humidity a much stronger determinant of hot weather.

5.2 Climatic Design Guidelines

This study had to conduct its own analysis and experiments to ascertain the effectiveness of shading on thermal outdoor comfort in this university. The predictions of effectiveness were more through the extensive analysis of the data collected, interviews conducted by experts in the field, and personal interaction on the site itself during both winter and summer seasons. They are potentially considered effective as they cover the elements that are harboring the discomfort factors that users suffer from.

The research observed that during the summers, the most uncomfortable locations were the ones that were under less shading, while the highly-shaded locations were uncomfortable during the winter. Occasionally people are often forced to perform differently in different thermal environments and hence the emergence of adaptation theory. It was observed that it is necessary for designers to come up with different levels of alternative factors that would aid in outdoor comfort. This philosophy was also supported by Hwang et al. (2011) who also advised for similar measures in mitigating thermal discomfort in the urban areas. One of the recommendations came about planting of deciduous trees that are capable of providing shade in the summer and allowing access in winter, in order to have more shade across the open spaces.

Literature has always articulated on the importance of vegetation in mitigating outdoor thermal conditions. It is believed that flora helps in lowering the temperature of adjacent air and surface. Flora have the ability to mitigate solar radiation, allow smaller heat capacity and lower rates of evapo-transpiration, hence proving to be excellent performers of outdoor thermal mitigators. Wei (2014) observed that the cooling effect of flora mostly works to the optimum during night period, as this is the time when the wind is calm with clear skies. Trees have mostly dominated most researches on thermal temperature (Bentz and Peltz, 2011).

Normally the body can gain or lose heat to the surrounding through convection. This means that when the air temperature of a room increases the occupants are more likely to feel warmer temperatures and vice versa. Outdoor and indoor temperatures vary greatly up to 21^0c during summers. This large gap has a negative impact on the users, and leads to potential harm to them when the body is exposed to sudden changes in the weather, such as humidity. Therefore, it was difficult to simply rely on air temperature as an indicator for outdoor conditions. Wei (2014) observed that despite the effective role played by air temperature in influencing outdoor thermal comfort, the design of the external spaces often plays a large part.

Air temperature can only be increased and manipulated through maximization of solar energy heat through the use of dark and thermally absorbent materials. The heat from the sun is often transferred through the following main methods, immediately it lands on any object: reflection, absorption or transmission. This simply means that an object in outdoor thermal space is subject to all these three means through direct solar radiation from the sun, diffused radiation from the sky, and reflected radiation from the environment.

It is important to observe all these factors when designing an outdoor thermal environment. There should be minimum access to solar radiation when cooling is required. Modification of solar radiation should not be a hard task but rather a simple one considering that their techniques are available for modifying solar radiation towards acceptable limits. That was the case on the AUS campus itself as it was composed of marble and granite, very poor heat reflective materials, causing increase in the radiant temperatures. An obvious solution is to replace the mentioned material into a more thermally heat reflective one in order to reduce the temperatures.

Certain studies performed by Eugenio et.al, (2015) and Nazanin et al (2013) revealed that trees inside the street canopy it was possible to reduce the harsh wind speeds by 51%, which is significant during cold winters, and allow only for cool breezes that effectively reduce heat during harsh weathers.

Trees also play a large role in controlling solar energy input in a person's body through shading. Furthermore, they help in reducing the global temperature by reducing radiation flux through shading. Sidewalk trees were found to be more effective as compared to normal vegetation, this mainly due to their ability to provide shade. Interactions between major meteorological components of climate such as air temperature, solar radiation, wind and humidity remain the cause for hot climatic conditions experienced in semi-arid areas.

According to Ghazizadeh et.al (2010) flora performs two main functions in controlling outdoor thermal temperatures:

- Can screen a person from infrared radiation sources like streets and heated walls in the course of the warm season.
- By limiting the loss of infrared radiation to cold surface, for instance the sky throughout cold periods

Warm countries and regions do not often consider wind speed as a significant component in the design of a space. However, by carefully planning the placement of flora and making correct arrangement of structures it is very possible to control it in a manner that would give positive effect in both seasons. Wind being an environmental factor, remains a key determinant between outdoor and indoor thermal comfort. Wind influences thermal temperature in two ways; either through direct mechanical force such as fans, or indirectly through manipulation of the thermal conditions by adding manmade shading structures.

Furthermore, the orientations of buildings in respect to their height and width ratio affect the current and strength in which wind passes through. When high buildings are designed with large open surrounding spaces, they create changing diverting strong winds from the top to the bottom. This is often observed by people walking at the bottom of these buildings and causes an undesirable condition. The described scenario is observed on campus and thereby there was a need to rectify the existing by proposing elements that would help enforce the wind in a desirable comfortable condition. In other outdoor open provisions, shading is required and mandated for owing to the fact that natural ventilation is inconsistent and not guaranteed to ensure that comfort is optimized even in low ventilation provisions.

To all humans, clothing adjustments are a significant and innate behavior of improving comfort. The researcher observed that in winter and summer, both genders in the American University of Sharjah, wore clothes that were mainly influenced by the weather, for instance dressing in lighter clothes especially in summer with shorts, T-shirts, and short skirts. The average clothing insulation value in winter was not as great in winter as it was in summer.

The small variance in thermal neutrality in summer shows that all dwellers of the AUS campus had the same anticipations to weather conditions in the hot season. It was noted that campus users had the tendency of tolerating high temperatures during the hot seasons. Nonetheless, provisions had to be suggested for improving the external conditions.

The significance of cultural differences, which plays a role on the use of outdoor space under particular climate conditions, was also studied. The study monitored and evaluated activities, time and attendance. In American University of Sharjah, users tended to visit the outdoor spaces in small groups mainly and took part in activities like reading, having lunch and so forth. They would move indoors to the areas that had air-conditioned spaces. The study shows that solar radiation is key parameter that influences the use of outdoor spaces in AUS. The escalating intensity of mean solar radiation is linked with lessening of the time spent in an outdoor space in a climate that is hot arid.

The fall of solar radiation levels brings about a decrease in the entire heat gain of the human body. Thus, there is a need to more thermally comfortable seating alternatives in public outdoor space for dwellers and visitors of American University of Sharjah to choose from. The sum of activities and people in the studied urban public spaces in AUS had a negative and strong relationship with the solar radiation levels in every season. Thus, as solar radiation intensifies the sum of activities and people lessens, taking into consideration the relatively high air temperatures in regions that are hot arid. Another imperative implication of the study's findings is that inadequate consideration to design may give rise to abandoned non-shaded seating areas. However, it is not impossible to alleviate the impact of solar radiation in outdoor spaces in climates that are hot arid. In a hot arid climate, the design of outdoor open space ought to eradicate the direct sunlight.

5.3 Recommendations for Future Studies

Upon starting this research, there was a clear plan and certain aims targeted to fulfill. The findings obtained and demonstrated in the previous chapters were based upon specific criteria, however, they research was limited by some aspects. The tight time frame, testing tool, and broadness of topic are a few to name, which defined the extremities of such a research. The vastness of the case study's site played another factor. However, some of the questions and information collected raised further raised more queries and thus would require future investigations, such as how detailed can the design of the campus be manipulated.

Certain elements such as the below need to be taken into consideration before commencing further work:

- The next phase would to go further in the designs proposed being tested by either physical installations or computer simulations that can predict their effectiveness.
- In controlling outdoor thermal temperature, the designers must be able to first consider the following: air temperature, air humidity, means radiant temperature and air speed. Other minor aspects that also influence thermal comfort include clothing and level of activity in human a human being. One reason that makes human beings want to achieve their own microclimate is mainly due to any discomfort brought about by open-air environment. Pattern and clothing modification are normally done in order to adapt to ambient thermal conditions.
- In order to effectively study and evaluate thermal comfort, it is important to consider each of the indices standards depending on the urban settings and state of regional climate. Therefore, it is impossible to use only one index value globally. However, the current study mainly focuses on one physical environment aspect referred to as thermal environment.
- Outdoor thermal conditions are physical environment aspects that dictate on the thermal human comfort. This comfort is controlled through

exchange of energy and heat between the human body and its consequent environment. Normally, it can be specified that it exists in the state that a human body can readily a constant and deep temperature of roughly 37.0 C.

As per previously mentioned during the peak hot seasons, the study observed discomforted reported by campus users, thus making the following recommendations for on-site modifications:

- Change the flooring material as it becomes very hot during the warm seasons. Put one that has low thermal storage capacity. Change to flooring material that has low thermal storage capacity
- Provide for mechanical ventilation such as fans as it is the best way to minimize the humidity.
- Increase natural shadings (trees). Fabric shading is also preferable to hard shading devises. Fabric can be opened and closed depending on the time of day and season
- Provide misters/low-energy fans in high-use areas
- Allow for adequate airflow through zoning the building and adding mechanical equipment for increased air movement

Trees and surrounding vegetation use the process of evapo-transpiration to lower the surface and air temperatures. Wind speeds can vary and this is due to an increase in the overall urban vegetation. A row of trees in a region can both block summer cooling breezes and at the same time shield houses against cold in winters.

In conclusion, vegetation and shade trees create a cool and serene atmosphere and a wonderful space in an urban setting that is populated where individuals can enjoy the outdoor atmosphere. The significance of vegetation and shade trees goes further than this since they not only cool buildings and home environments naturally, they also prevent efficiently block direct sun rays in shading parks and walks and also lower temperatures of the outdoor setting. Shading protects against direct sunlight and consequently has a reducing effect on the overall temperatures.

Strategically planted trees in a home setting and around building structures have a cooling effect on indoor air. For instance, planting trees around windows can efficiently block direct sunlight from hitting the building structures. A wide spread tree setting in an urban parking space can have various beneficial effects such as enhancing the air circulation in a region and generating cooling breezes all which can impact an entire community.

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APPENDICES

Appendix 1 - Questionnaire for Field Survey

This survey was used to obtain data from users of the AUS campus, specifically students, regarding the outdoor thermal comfort for thermal comfort evaluation.

Survey on Outdoor Thermal Comfort in the AUS Campus

Kindly fill out the details as indicated below with the best response to how you currently feel regarding the usage of the campus space.

Personal information

Gender: □Male □Female Age: ______

Race: □ UAE National ______ □ Non-UAE National □ Specify (optional):

Activity (right now): □ Sitting □ Standing

Clothing: (tick all the items closest to what you are wearing at this moment)

Shirts/Blouses: □Sleeveless □Short sleeve □Long-sleeve □Others___
Trousers: Shorts (□Short □Knee) Pants (□Knee □Ankle) Jeans (□Knee □Ankle) □Others
Dress /Skirts: □Short □Knee □Ankle □Long-sleeve dress □Others____
Footwear: □Slippers / Sandals □Leather shoe □Sports shoes □Boots □Others

(put "√" in box that best reflects your current sensation)

1) How do you feel at this moment?

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

2) Would you like the current environment to be?

Cooler	No Change	Warmer

3) How do you feel about air humidity at this moment?

Too dry	Dry	Ok	Humid	Very humid

4) Would you like the humidity to be ?

Less Humid	No Change	More humid

5) How do you feel about the air flow at this moment?

Stale	Little wind	Ok	Windy	Too much wind

6) Would you like the air flow to be ?

Less	No Change	Greater

7) How do you feel about the sun at this moment?

Too weak	Little weak	Ok	Little strong	Too strong

8) Would you like the sun to be?

Weaker	No Change	Stronger

9) Do you think the thermal environment?

Acceptable	Not acceptable

<u>Thermal adaptation and use of urban space</u>

Put "√" in box that best reflects your current situation	
Why do you come to this place?	
• Rest	
• Social or cultural activity (meeting friends, taking photos, painting	
• Studying	

Passage to another place	
How long have you been in this place?	
• 10-20 min	
• 20-30 min	
• 30 min to 1 hour>1hour	

Which environment were you in 15 mins prior to the survey now?	
• Naturally ventilated (exterior)	
• Air conditioned (interior)	

How often do you come to the campus?	
Once per week	
Twice per week	
Thrice per week	
Every day	
Others……………………	

How often do you use the place you are currently in?	
Once per week	
Twice per week	
Thrice per week	
Every day	

Please mention the place you are currently in (ex: Beside the student center, library, etc) **……………………..**	

If you feel it is too hot in this place, what measures do you prefer to take in response?	
Move to shaded trees/shelters	
Open umbrella/ wear hat	
Get more drink	
Reduce clothing	
Nothing/go away	

Appendix 2 – Interview Guide

This appendix contains the questions and interview guide that was established for the staff users of the campus, specifically the academics and professors of the university, to obtain a different point of view regarding the research topic.

Interview Questions

AUS is designed as an adaptation of the French Versailles architecture, which layout of large open spaces and buildings places far apart does not really suit the climate conditions of the UAE.

However, in our opinion, do you think:

1. The open spaces in AUS are/were designed to be thermally contented?
2. What is the environmental circumstance that would define a proper comfortable outdoor space?
3. In your opinion, what design approaches can be used in AUS to improve outdoor thermal conditions in order to increase thermal comfort?
4. If you feel it is too hot in this place, what measures do you prefer to take in response?
5. What is the main outdoor thermal condition that leads you to rest in this place?
6. What outdoor thermal condition inspires you to spend your time in this area the weekdays?
7. What ideal outdoor thermal condition would you prefer at this moment?
8. What would you recommend to ensure that this area has the best ideal outdoor thermal condition?

Appendix 3 – Sample Answers of Questionnaire for Field Survey

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This appendix shows a sample of the survey results obtained from the users of the AUS campus. It contains the tabularized results for survey questionnaire.

Section 1: Overall tabularized results for Demographic factors

Characteristics	Number	Percentage
Gender		
Male:		
Winter	7	15%
Summer	8	17%
Female:		
Winter	17	37%
Summer	14	31%
Age		
18	5	11%
19	8	17%
20	21	46%
21	10	22%
22	1	2%
24	1	2%
Race		
UAE national	2	4%
Non-UAE national	44	96%
Current Activity		
Standing		
Winter	2	4%
Summer	4	9%
Sitting		
Winter	22	48%
Summer	18	39%

Section 2: Overall tabularized results for Clothing

	Sleeveless	Short sleeve	Long Sleeve	Other
Shirt/Blouses				
Winter	0	7	14	3
Summer	0	10	11	1

	Shorts (Short /Knee)		Pants (Knee/Ankle)		Jeans (Knee/Ankle)		Other
Trousers							
Winter	0	0	1	7	0	15	1
Summer	1	1	0	3	0	12	0

	Short	Knee	Ankle	Long-sleeve dress	Others
Dress/Skirts					
Winter	0	0	0	0	0
Summer	0	0	2	2	1

	Slippers/Sandals	Leather Shoes	Sports shoes	Boots	Others
Footwear					
Winter	2	3	8	0	10
Summer	1	4	9	2	8

Section 3: Overall tabularized results for current sensation

	Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot

How do you feel at the moment Winter Summer	0	4	6	9	5	0	0
	0	0	0	3	7	5	7

	Cooler	No Change	Warmer
What you like the current environment to be Winter	8	12	4
Summer	20	2	0

	Too Dry	Dry	Ok	Humid	Very Humid
How do you feel about air humidity at the moment Winter	0	2	21	1	0
Summer	0	1	7	9	5

	Less Humid	No Change	More Humid
Would you like the humidity to be Winter	13	11	0
Summer	20	2	0

	Stale	Little Wind	Ok	Windy	Too Much Wind
How do you feel about air flow at this moment Winter	5	4	13	2	0
Summer	11	3	8	0	0

	Less	No change	Greater
Would you like the air flow to be			
Winter	3	12	8
Summer	1	4	17

	Too weak	Little weak	Ok	Little strong	Too Strong
How do you feel about the sun at this moment					
Winter	0	2	13	8	1
Summer	0	2	5	7	8

	Weaker	No change	Stronger
Would you like the sun to be			
Winter	10	13	1
Summer	20	2	0

	Acceptable	Not Acceptable
Do you think the thermal environment		
Winter	12	12
Summer	5	17

Section 4: Overall tabularized results for thermal adaptation and use of urban spaces

	Rest	Social or cultural activity (meeting friends, taking photos, painting)	Studying

Why do you come this place			
Winter	2	9	13
Summer	2	11	8

	10 – 20 min	20 – 30 min	30 min to 1 hr>1hr
How long have you been in this place			
Winter	5	7	12
Summer	12	5	5

	Naturally ventilated (exterior)	Air conditioned (interior)
Which environment were you in 15 mins prior to the survey		
Winter	3	21
Summer	2	20

	Once per week	Twice per week	Thrice per week	Everyday	Others
How often do you come to the campus					
Winter	0	0	0	22	2
Summer	0	0	0	22	

	Once per week	Twice per week	Thrice per week	Everyday	Others
How often do you use the place you are currently in					
Winter	0	0	3	21	0
Summer	2	4	4	12	0

	Move to shaded trees/shelter	Open umbrella/ wear hat	Get more drink	Reduce clothing	Nothing/ go away
If you feel it is too hot in this place, what measures do you prefer to take in response Winter	8	2	4	5	5
Summer	8	0	8	2	4